

EXCURSION GUIDE

for the areas of

TEGELEN/REUVER

and BRUNSSUM

*For Ann. Field Meeting in 1982
to Amsterdam?*

Author: W.H. Zagwijn
Rijks Geologische Dienst
Haarlem
The Netherlands

August 1971
revised: September 1977

TEGELEN-REUVER area

The pits are partly on Dutch territory, partly on the German side of the frontier (fig. 1). They are often dug in the escarpment of the Main Terrace on the eastern flank of the river Meuse valley.

From north to south one proceeds by a series of faults from the Venlo Graben to the Peel-Horst (= Horst of Brüggen-Erkelenz) (fig. 2). In all pits we will meet the fluvial gravels and coarse sands of the "Weert-zone" of the Sterksel Formation (so-called Younger Main Terrace Gravels of German authors), which unconformably top Lower Pleistocene and Pliocene beds, some of which are well-known from their fossil molluscs, wood, fruits and seeds; Reuver Clay: fruits and seeds, leaves, wood, molluscs.

Since Cl. and E.M. Reid's memoir of 1915 the Tegelen flora (now: Lower Pleistocene) and the Reuver flora (now: Upper Pliocene) form landmarks in the stratigraphy of the Upper Neogene non-marine beds of Europe.

In the Reuver flora many forms are still found (e.g. Sequoia, Taxodium, Nyssa, Aesculus, Liquidambar, Fagus and many others) which are lacking in Tegelen. Here only some relics of the Tertiary flora element survive (Tsuga, Pterocarya, Carya, Eucommia, Phellodendron, Actinidia). The eradication of so many of the warmth-loving elements was assumed to have been caused by the first cold phase at the onset of the Pleistocene (Pretiglian). Some years ago it has been possible to prove this assumption in more detail by means of pollen-analyses by which it could be shown that two temperate forest phases, the lower of Reuver type, the upper of Tegelen type, were separated by a cold-subarctic phase of open landscape (Zagwijn, 1960).

At present exposures are not by far as good as they used to be, mainly because of change in way of exploitation. Especially at Tegelen conditions are bad and only one good exposure remains (Pit Laumans), though it will disappear also within a few years. Unfortunately no beds rich in fossils are exposed at the time neither.

In the Tegelen area beds of Upper Lower Pleistocene and Upper Tiglian age are found below the Sterksel Formation (fig. 6). In the transitional area towards the Horst at Oebel and near Belfeld (both on German territory) we find Lower Tiglian and Upper Pliocene beds, whereas on the Horst proper the Sterksel Formation caps the Upper Pliocene Reuver Clay and in some places even older beds (Miocene and Oligocene glauconiferous sands).

1. Pit Peter van Eijck (fig. 3)

At the base a Pliocene (Upper Reuverian) clay bed is found (pollen-diagram fig. 4). Lately W. Boenigk (1970) found that the heavy mineral composition of this clay and underlying sand was a garnet-epidote-saussurite association (fig. 3). Therefore he assumed a Pleistocene age, as this association up till now was assumed to be of Pleistocene age exclusively. In fact, however, the combination of the pollen-data and the mineralogical data now clearly proves, that the big change in heavy mineral composition in the sediments of the river Rhine (from stable to instable assemblages) was already in the uppermost Pliocene.

Follows the Belfeld Gravel and some clay beds which are of Tiglian age. In the pollen-assemblage of the clay bed found in the adjoining

pit Janssen-Dings, at this level, which is called the Belfeld Clay, *Fagus* is still present (fig. 11), therefore this clay is placed in the Lower Tiglian. This tree later in the Tiglian disappeared for a long time from this part of Europe, to return only in the Holocene. It should be noted, that the Tiglian is not a simple interglacial but a complex of alternating temperate and cool phases, none of the latter of which is at the present state of knowledge cold and long enough to use the term "glacial".

It is, however, well possible that increased knowledge in future will change this situation and that one or perhaps some of the "cool phases" will turn out to represent longer and colder stages, which would induce a splitting up of the Tiglian into some glacials and interglacials.

In pit Peter van Eijck several clay beds of Middle to Upper Tiglian age and referred to as Tegelen Clay, are present. The pollen assemblages vary in their composition, but *Fagus* is absent in all of them.

2. Oebel (fig. 5)

The lowermost clay member has the characteristic features of the Reuver Clay at the type-area. Especially the blue clay sandwiched between peat-horizons in the upper part is highly characteristic from the lithostratigraphic point of view (compare fig. 9).

In this part of the Reuver Clay begins, according to W. Boenigk (1970), for the first time a heavy mineral assemblage dominated by garnet-epidote-hornblende-saussurite. It seems likely that this part of the Reuver Clay correlates with the basal clay and sand in the Peter van Eijck pit.

The remainder of the section is similar to that in the Peter van Eijck pit. In a gully of the Tegelen Clay a very humic clay filling of Upper Tiglian age (pollen-zone TC3) occurs (fig. 12). The Sterksel Formation caps the underlying beds unconformably.

Literature

- Boenigk, W. (1970) - Zur Kenntnis des Altquartärs bei Brüggen. Sonderveröff. Geol. Inst. Univ. Köln, 17.
- Vlerk, I.M. van der & F. Florschütz (1953) - The Palaeontological Base of the Subdivision of the Pleistocene in the Netherlands. Verh. Kon. Ned. Ak. Wet., ser. 1, part 20, No. 2.
- Zagwijn, W.H. (1960) - Aspects of the Pliocene and Early Pleistocene vegetation in the Netherlands. Med. Geol. St., ser. C-III-1, No. 5.
- Zagwijn, W.H. (1963) - Pollen-analytic investigations in the Tiglian of the Netherlands. Med. Geol. St., Nw. ser., No. 16.

3. Pit Russel-Tiglian Egypte (fig. 13)

This pit has been abandoned now, after having been in exploitation for about 20 years. In the last decennium excavation was done by drag-lines, this resulting in bad exposures. Lately an excavation was undertaken by the State Museum of Geology and Mineralogy (Leiden) for the purpose of washing small mammal remains.

The pit is directly adjacent to the former pit of Canoy-Herfkens,

Table 2. Comparison between the fossil wood-flora of Tegelen and related taxa in some Recent floras.

3.

| | European flood- plain forest | Manchurian deciduous forest | Hokkaido deciduous forest | mixed mesophytic forest of eastern Asia | eastern North American flood- plain-forest and upland forest | Pontic forest | number of samples | percentage of samples |
|--|---------------------------------|--------------------------------|------------------------------|---|---|---------------|----------------------|--------------------------|
| <i>Pinus</i> spp. | — | + | + | — | + | — | 4 | 3.1 |
| <i>Picea</i> spp. | — | — | — | + | + | + | 15 | 11.5 |
| <i>Abies alba</i> | — | — | — | + | + | + | 1 | 0.8 |
| <i>Chamaecyparis</i> cf. <i>thyoides</i> | — | — | — | — | — | — | 2 | 1.5 |
| <i>Magnolia</i> sp. | — | + | + | + | + | — | 4 | 3.1 |
| <i>Ulmus</i> sp. | + | + | + | + | + | + | 3 | 2.3 |
| <i>Celtis</i> sp. | — | + | + | — | — | + | 5 | 3.8 |
| <i>Tilia</i> sp. | + | + | + | + | + | + | 1 | 0.8 |
| <i>Phellodendron</i> sp. | — | — | + | + | + | — | 1 | 0.8 |
| <i>Acer campestre</i> | + | + | + | + | + | + | 8 | 6.2 |
| <i>Vitis sylvestris</i> | + | + | + | + | + | + | 1 | 0.8 |
| <i>Cornus mas</i> | + | + | + | — | + | + | 2 | 1.5 |
| <i>Crataegus</i> sp. | + | — | + | + | + | + | 2 | 1.5 |
| <i>Sorbus aucuparia</i> | — | — | + | + | + | + | 3 | 2.3 |
| <i>Prunus</i> sp. | + | + | + | + | + | + | 7 | 5.5 |
| cf. <i>Cytisus</i> sp. | — | — | — | — | — | — | 1 | 0.8 |
| <i>Fraxinus excelsior</i> | + | + | + | + | + | + | 37 | 28.3 |
| <i>Populus nigra</i> | + | + | + | — | — | — | 2 | 1.5 |
| <i>Carya</i> sp. | — | + | + | — | — | — | 2 | 1.5 |
| <i>Pterocarya</i> sp. | — | — | + | + | — | + | 28 | 21.6 |
| Indet. | — | — | — | — | — | — | 1 | 0.8 |
| Percentage of taxa | 45 | 60 | 80 | 75 | 75 | 70 | | |
| Percentage of samples | 48 | 60 | 85 | 89 | 70 | 88 | | |

Table 3. Smaller mammals from the clay-pit Egypte.

- Insectivora
 - Talpa fossilis* Petenyi, 1864
 - Desmana tegelensis* Schreuder, 1939
 - * *Desmana* sp. (small species)
 - * *Sorex* sp.
 - * *Sorex* cf. *praeearaneus* Kormos, 1934
 - * *Petenya* cf. *hungarica* Kormos, 1934
 - * *Beremendia fissidens* (Petenyi, 1864)
- Lagomorpha
 - Hypolagus* sp.
- Rodentia
 - * *Sciurus* cf. *vulgaris* Linnaeus, 1758
 - * *Muscardinus* cf. *avellanarius* (Linnaeus, 1758)
 - * *Ungaromys* nov. sp.
 - * *Clethrionomys* ? sp.
 - Mimomys pliocaenicus* (Major, 1889)
 - * *Mimomys reidi* Hinton, 1910
 - Mimomys newtoni* Major, 1902
 - * *Apodemus* cf. *sylvaticus* (Linnaeus, 1758)
 - * *Micromys* sp.

(the species marked with an * are new for the assemblage from Tegelen).

Table 4 Mollusks from the Dutch Tiglian.

| | pit Egypte | | | previous records for Dutch Tiglian |
|--|------------|----------------|------|--|
| | clay | gully basis | sand | |
| <i>Cochlostoma (Obscurella) sp.</i> | — | — | x | — |
| <i>Viviparus viviparus</i> (L., 1758) | x | — | x | — |
| <i>Viviparus contectus</i> (Millet, 1813) | x | — | — | — |
| <i>Viviparus diluvianus</i> (Kunth, 1865) | x | — | x | x |
| <i>Viviparus glacialis</i> (Wood, 1872) | x | — | — | x |
| <i>Valvata piscinalis</i> (Müller, 1774) | x | — | x | x |
| <i>Valvata goldfussiana</i> Wüst, 1900 | x | — | — | x |
| <i>Neumayria crassitesta</i> (Brömme, 1885) | x | x | — | x |
| <i>Bithynia tentaculata</i> (L., 1758) | — | x | — | x |
| <i>Bithynia leachi troscheli</i> (Paasch, 1842) | — | x | x | — |
| <i>Lithoglyphus naticoides</i> (Pfeiffer, 1828) | x | — | — | x |
| <i>Tanousia stenostoma</i> (Nordmann, 1901) | x | — | — | x |
| <i>Carychium sp.</i> | — | — | x | — |
| <i>Lymnaea palustris</i> (Müller, 1774) | ? | — | x | x |
| <i>Lymnaea peregra</i> (Müller, 1774) | ? | — | x | x |
| <i>Planorbis planorbis</i> (L., 1758) | — | — | x | x |
| <i>Planorbis corneus</i> (L., 1758) | ? | — | x | x |
| <i>Acroloxus lacustris</i> (L., 1758) | — | — | x | — |
| <i>Succinea elegans</i> Risso, 1826 | — | — | x | x |
| <i>Succinea oblonga</i> Draparnaud, 1801 | — | — | x | x |
| <i>Cochlicopa sp.</i> | — | — | x | ? |
| <i>Vertigo cf. alpestris</i> (Alder, 1838) | — | — | x | — |
| Chondrinidae | — | — | x | — |
| <i>Pupilla muscorum</i> (L., 1758) | — | — | x | x |
| <i>Pupilla cf. sterri</i> (Voith, 1838) | — | — | x | — |
| <i>Vallonia pulchella</i> (Müller, 1774) | — | — | x | x |
| <i>Vallonia costata</i> (Müller, 1774) | — | — | x | x |
| <i>Ena montana</i> (Draparnaud, 1801) | — | — | x | — |
| <i>Discus rudatus</i> (Studer, 1820) | — | — | x | — |
| <i>Discus perspectivus</i> (Megerle von Mühlfeldt, 1816) | — | — | x | — |
| (?) <i>Aegopinella sp.</i> | ? | ? | x | x |
| <i>Aegopinella cf. nitidula</i> (Draparnaud, 1805) | — | — | x | — |
| <i>Retinella (Riedeliella) sp.</i> | — | — | x | — |
| <i>Vitrea crystallina</i> (Müller, 1774) | — | — | x | — |
| <i>Vitrinobrachium breve</i> (Férussac, 1821) | — | — | x | x |
| <i>Eucobresia diaphana</i> (Draparnaud, 1805) | — | — | x | — |
| <i>Limax sp.</i> | — | x | — | — |
| Limacidae | — | x | x | — |
| Clausiliidae | — | — | x | ? |
| <i>Perforatella sp.</i> | ? | ? | x | x |
| <i>Perforatella dibothryon</i> (von Kimakowicz, 1884) | — | — | x | — |
| <i>Steklovia cf. koehnei</i> Schlickum & Strauch, 1972 | — | — | x | — |
| <i>Trichia hispida</i> (L., 1758) | — | — | x | x |
| <i>Trichia cf. striolata</i> (Pfeiffer, 1828) | — | — | x | — |
| <i>Soosia sp.</i> | — | — | x | — |
| <i>Helicigona sp.</i> | — | — | x | — |
| <i>Arianta arbustorum</i> (L., 1758) | x | — | x | x |
| Helicidae | — | — | x | — |
| <i>Unio tumidus</i> Philipsson, 1788 | x | — | — | — |
| <i>Anodonta cf. cygnea</i> (L., 1758) | x | — | — | — |
| <i>Sphaerium corneum</i> (L., 1758) | x | — | x | x |
| <i>Pisidium amnicum</i> (Müller, 1774) | x | — | x | x |
| <i>Pisidium clessini</i> Neumayr, 1875 | x | — | x | x |
| <i>Pisidium moitessierianum</i> Paladilhe, 1866 | x | — | x | x |
| <i>Pisidium henslowanum</i> (Sheppard, 1823) | x | — | x | x |
| <i>Pisidium supinum</i> Schmidt, 1850 | x | — | x | x |
| <i>Pisidium subtruncatum</i> Malm, 1855 | x | — | x | x |

from which Dubois and Cl. and E.M. Reid collected many fossils in the beginning of this century. This pit showed about the same succession as the pit of Egypte. Therefore this latter can serve as a substitute for the stratotype of the Tiglian as well as of the Tegelen Clay. Two sedimentary cycles are present. Cycle I consists of lake-clay filling an ancient oxbow of about 200 metres broad. Cycle II consists of a narrow gully incised in the top beds of the lake-clay with levees at each side, and further away backswamp clay. This latter bed in most other pits of the Tegelen area forms the Tegelen Clay *sensu stricto*. The lower clay of cycle I has been found only in the direct vicinity of pit Egypte. A block-diagram may give an impression of the conditions in this pit as they were about 10 years ago. In the filling of the gully at the base of cycle II many fossils have been collected. It contains fossil wood, fruits, seeds, mammal remains. Among the latter *Elephas meridionalis* deserves to be mentioned. Since 1970 a large amount of material has been washed by Dr. Freudenthal of the Rijksmuseum van Geologie en Mineralogie in Leiden, in order to collect remains of small mammals. A list of the plant remains found in this level, follows below. A pollen-diagram from the Russel-Tiglian Egypte pit is also given (fig. 10). It shows the fossil rich gully sand to date from pollen-zone TC 5. The wood remains have been studied by van der Burgh (1974) (table 2). Furthermore lists of the smaller mammals and molluscs found are presented (tables 3 and 4) according to Freudenthal et al. (1976).

Fossil fruits and seeds etc., collected from the Tegelen Clay in pit Russel-Tiglian Egypte at Tegelen

SAMPLE: Sandy and clayey filling of gully at the base of the cycle IIa. Pollen-zone TC 5.

f = fruit; s = seed; + = new for Tegelen

| | |
|---|---------|
| + <i>Rossenilites areolatus</i> (Fres.) MEY | 1 |
| <i>Picea Florschützii</i> VAN DER HAMMEN | 2 cones |
| <i>Potamogeton acutifolius</i> LINK | 1 f |
| + <i>Sparganium minimum</i> FR. | 1 f |
| <i>Scirpus</i> sp. | 1 f |
| <i>Carex</i> sp. | 18 f |
| <i>Pterocarya limburgensis</i> REID | 1022 f |
| <i>Carpinus betulus</i> L. | 21 f |
| + <i>Corylus avellana</i> L. | 1 f |
| <i>Rumex maritimus</i> L. | 1 f |
| <i>Pilea pumila</i> A. GR. | 1 s |
| + <i>Nuphar luteum</i> SMITH | 17 s |
| <i>Euryale limburgensis</i> REID | 1 s |
| <i>Magnolia kobus</i> DC | 60 s |
| <i>Ranunculus sceleratus</i> L. | 98 f |
| <i>Eucommia europaea</i> MÄDLER | 69 f |
| + <i>Rosa</i> sp. | 1 thorn |
| <i>Dendrobenthamia tegelensis</i> MAI | 129 f |
| <i>Prinus maximoviczii</i> RUPR. | 35 f |
| <i>Prunus</i> sp. | 1 f |
| + <i>Mercurialis</i> cf. <i>annua</i> L. | 4 s |
| <i>Phellodendron elegans</i> REID | 38 s |
| <i>Staphylea pinnata</i> L. | 63 s |

| | |
|--|------------|
| <i>Acer campestre</i> L. | f |
| <i>Acer limburgensis</i> REID | f |
| <i>Acer</i> cf. <i>opulifolium</i> VILL. | f |
| <i>Acer</i> sp. div. (total) | 96 f |
| <i>Vitis</i> cf. <i>silvestris</i> GMEL. | 318 s |
| <i>Vitis</i> sp. | tendrils |
| + <i>Parthenocissus</i> sp. | 4 tendrils |
| <i>Menispermum crassicaipum</i> (REID) | |
| nov. comb. | 3 s |
| <i>Actinidia faveolata</i> REID | 2 s |
| + <i>Actinidia</i> sp. | 1 s |
| <i>Viola</i> sp. div. | 64 s |
| <i>Trapa natans</i> L. | 1 f |
| Araliaceae/Cornaceae (REID 1910) | 1 f |
| <i>Cornus mas</i> L. | 3 f |
| + <i>Ajuga reptans</i> L. | 4 s |
| + <i>Viburnum opulus</i> L. | 1 s |
| + <i>Sambucus pulchella</i> REID | 2 s |

Literature

- Boenigk, W. (1970) - Zur Kenntnis des Altquartärs bei Brüggen. Sonderveröff. Geol. Inst. Univ. Köln, 17.
- Burgh, J. van der (1974) - Wood-remains from the Lower Pleistocene of Tegelen (The Netherlands). Scripta Geol., 25.
- Freudenthal, M., T. Meijer & A.J. van der Meulen (1976) - Preliminary report on a field campaign in the continental Pleistocene of Tegelen (The Netherlands). Scripta Geol., 34.
- Vlerk, I.M. van der & F. Florschütz (1953) - The Palaeontological Base of the Subdivision of the Pleistocene in the Netherlands. Verh. Kon. Ned. Ak. Wet., ser. 1, part 20, No. 2.
- Zagwijn, W.H. (1960) - Aspects of the Pliocene and Early Pleistocene vegetation in the Netherlands. Med. Geol. St., ser. C-III-1, No. 5.
- Zagwijn, W.H. (1963) - Pollen-analytic investigations in the Tiglian of the Netherlands. Med. Geol. St., Nw. ser., No. 16.

4. Pit Laumans (Tegelen)

A survey of the stratigraphy and lithology will be found in fig. 14. Here we see only the topmost beds of the Tegelen Clay; more complete sections of which have been found in the Russel-Tiglian Egypte pit (fig. 13). A simplified pollen-diagram from the latter pit is shown in fig. 10, showing the transition of the temperate conditions of the main part of the Tegelen beds to cool and even cold-subarctic conditions when the top part of the Tegelen Clay was formed. Cold conditions persisted during formation of the fine sands of the Kedichem Formation on top (locally called "pap-zand" = porridge-sand, because of its quickening habit) as witnessed by small frost-wedge casts in the middle of the beds. All these cold deposits are placed in the Eburonian glacial. Some soils on top (partly with peat-horizons from which pollen-data have been obtained) point to temperate conditions again (probably during the Waalian interglacial). The soils are overlain by fine sands showing very clearly frostwedges and involutions. They are considered to date from the Menapian glacial.

An unconformity comprising the top of the Lower Pleistocene and the lower part of the Middle Pleistocene separates the Kedichem Formation and the overlying uppermost zone ("Weert-zone") of the Sterksel Formation. Higher in the Sterksel Formation some large intra-formational frost-wedge casts have been observed. Therefore this part of the Sterksel Formation dates from a Glacial Stage, yet unnamed, which is part of the so-called "Cromerian" complex. The presence of (ice-rafted) large blocks likewise indicates cold conditions.

5. Pit Maalbeek

In this now abandoned pit below the Sterksel Formation part of the Kedichem Formation is found (the latter with a heavy mineral assemblage predominantly consisting of stable minerals), which overlies the Tegelen Clay (with a garnet-epidote-saussurite-hornblende assemblage). The pollen-diagram of the latter (fig. 15) indicates a cold climate, during its deposition. The deposit dates from the Eburonian and lithostratigraphically it represents the top of the Tegelen Clay (fig. 7).

The site is remarkable for the find of a molar of *Anancus* (*Mastodon*) *arvernensis*.

6. Pit east of Canoy-Herfkens

In this pit the fine sands of the Kedichem Formation display some fine cryoturbations of Eburonian and Menapian age very similar to those described here sub. 4. Furthermore, a clay seam, filling a shallow gully in the basal part of the gravelly sands of the "Weert-zone" (Sterksel Formation) has yielded a pollen-diagram. This pollen-diagram shows spectra with a fair amount of N.A.P., much *Pinus*, and little thermophilous trees. It indicates cool to cold conditions at the onset of the formation of this part of the Sterksel Formation.

Palaeomagnetism

According to van Montfrans (1971) the top beds of the Tegelen Clay, which date from the transition of the Tiglian to the Eburonian, probably date within the Olduvai event, 1,600,000 years ago. The results obtained from various pits to be visited during this excursion, are given below.

- | | |
|---------------|---|
| Pit Laumans: | normal polarity for the upper part of the section, reversed polarity for the lowermost part. |
| Pit Maalbeek: | reversed polarity. |
| Pit Egypte: | normal polarity. |

Literature

- Montfrans, H.M. van (1971) - Palaeomagnetic dating in the North Sea Basin. Thesis, Amsterdam, 113 pp.

TEGELEN

MAALBEEK

BELFELD

REUVER

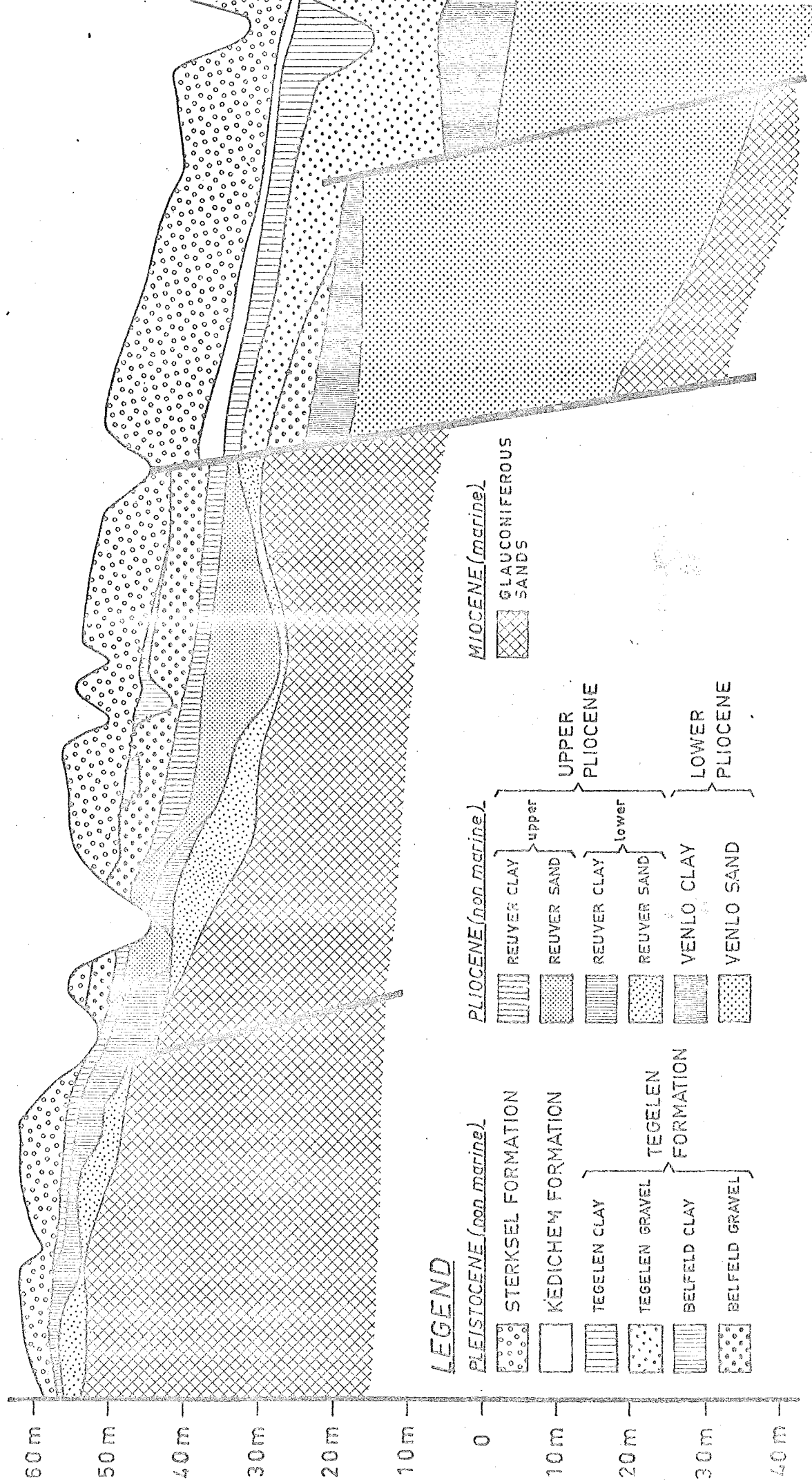










fig. 2

BELFELD-Pit "Peter van Eyck"

LEGEND

| | | | |
|---|------------|---|-----------------|
|  | GARNET |  | OTHER MINERALS |
|  | EPIDOTE |  | STAUROLITE |
|  | ALTERITE |  | METAMORFIC MIN. |
|  | HORNBLende |  | TOURMALINE |

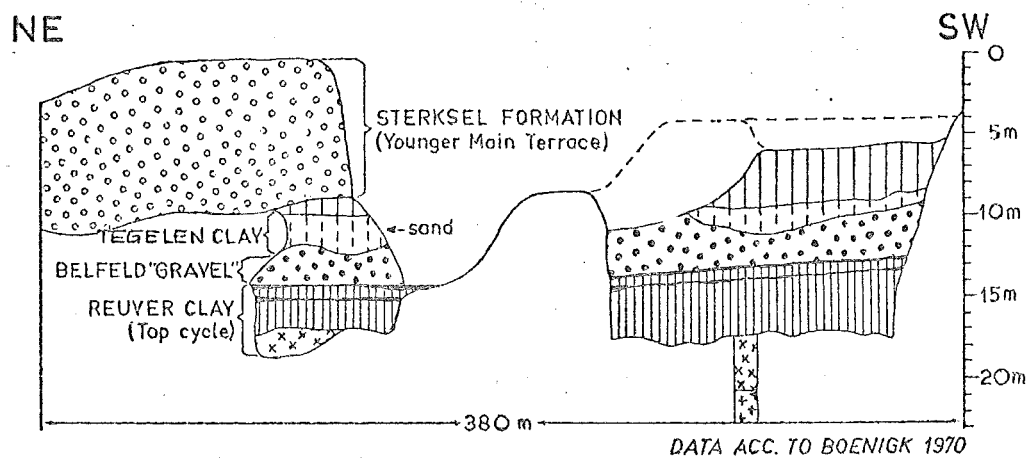
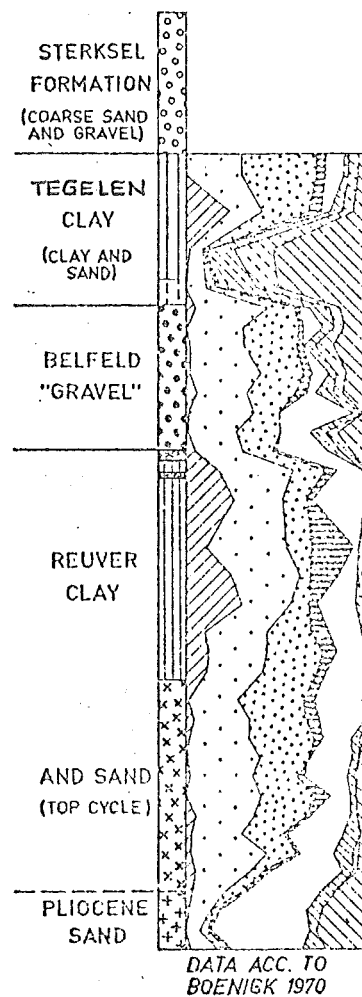


Fig. 3

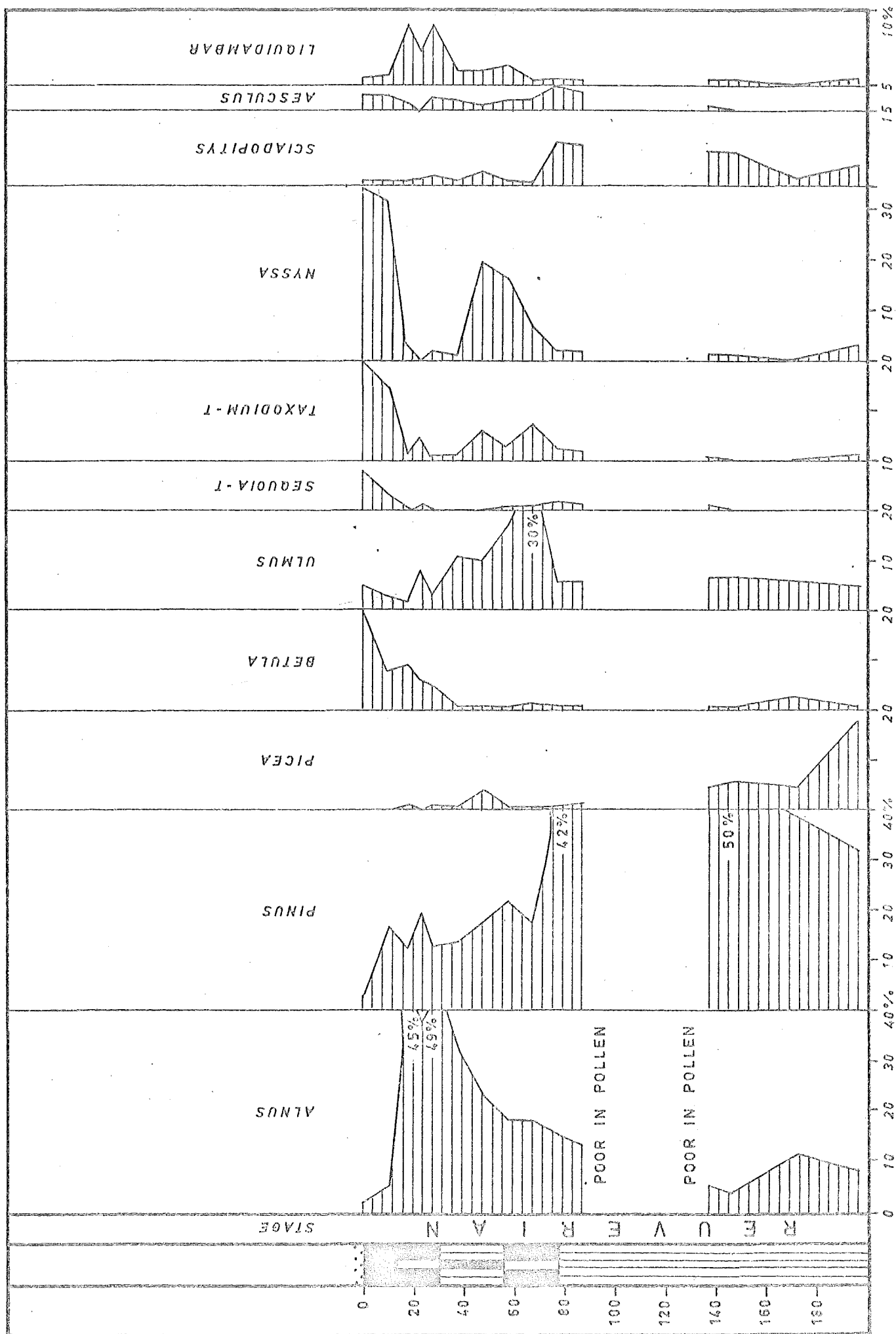










fig. 4

ÖBEL

LEGEND

| | | | |
|---|------------|---|-----------------|
|  | GARNET |  | OTHER MINERALS |
|  | EPIDOTE |  | STAUROLITE |
|  | ALTERITE |  | METAMORFIC MIN. |
|  | HORNBLENDE |  | TOURMALINE |

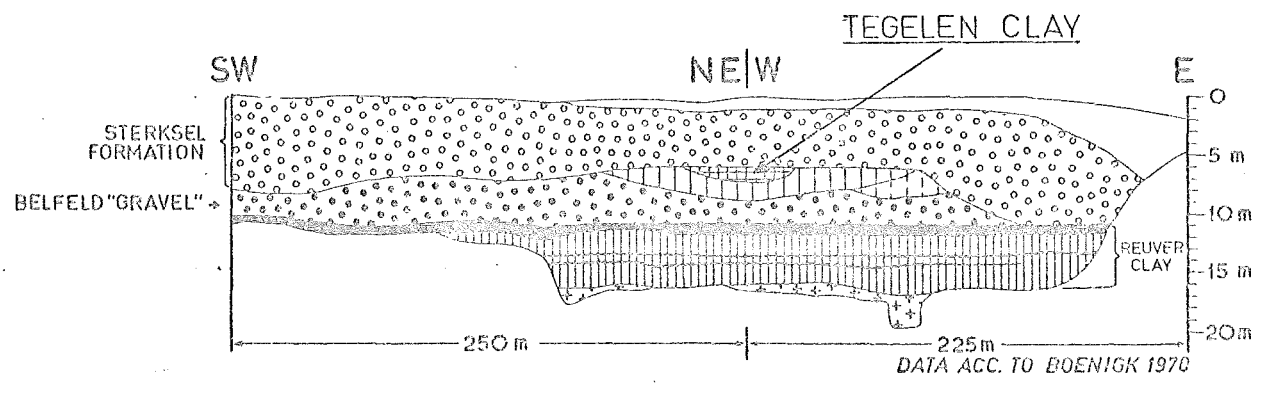
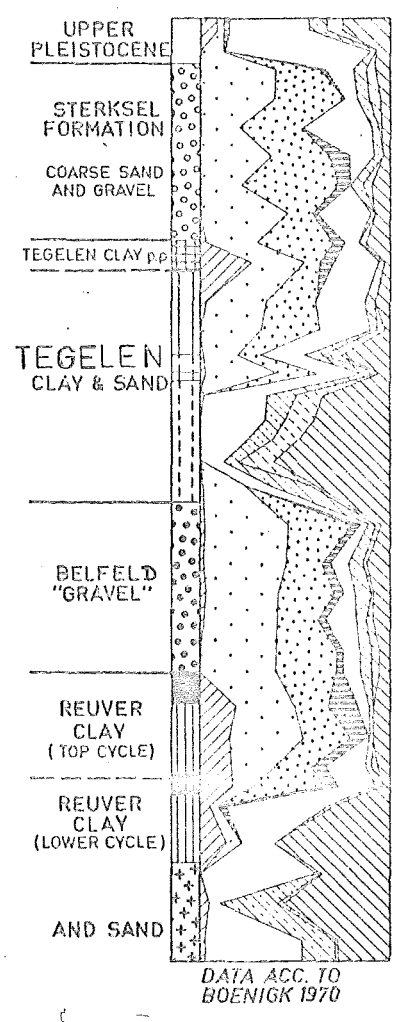
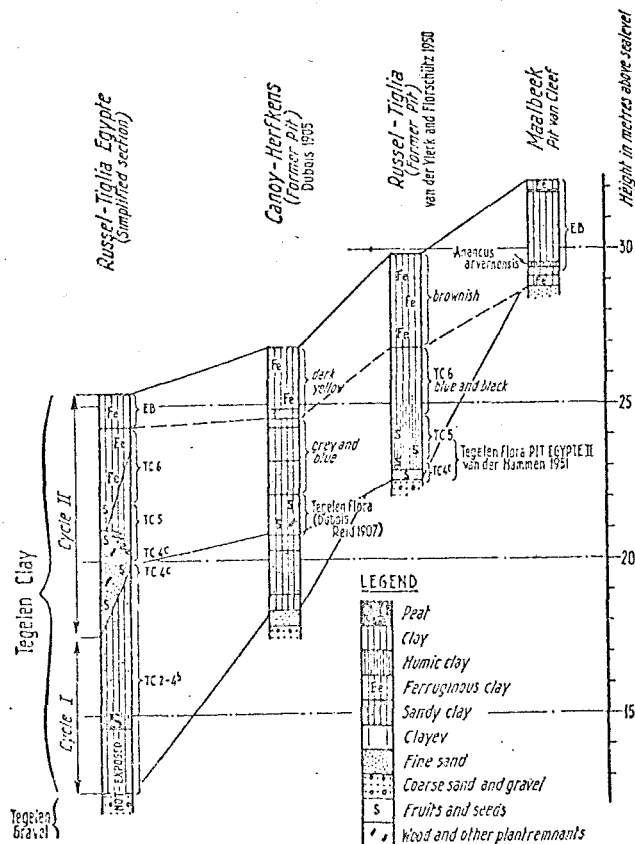


fig. 5

| | | Stage | Pollenzones | Estimate of mean temperature in July 10° 20°C | Range of Azolla | Venlo Graben and Peel Horst | | Central Graben | | W and Central Netherlands (area of marine lower Pleistocene) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|-------------------|-------------|--------|-------------|---|-----------------|-----------------------------|---------------------|--|-----------|--|---|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|
| | | | | | | Tegelen-area | Belfeld-Reuver area | Meinweg-herkenbosch | Eindhoven | Rosmalen | W. Netherlands | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| MIDDLE PLEIST. | "CROMERIAN" | | | | | Sterksel Formation | | Sterksel Formation ^{Westerhaven Clay} | | Sterksel Formation | Various deposits not considered in this table | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| EARLY PLEISTOCENE | MENAPIAN | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | WAALIAN | C | W-C | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | B | W-B | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | A | W-A | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | EBURONIAN | ED VII | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | ED VI | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | ED V | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | ED IV | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | EB III | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | TIGLIAN | ED II | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | ED I | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | YC 6 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | TC 5 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| TC 4 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| TC 3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| TC 2 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| TC 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| PRAETIGLIAN | B | TB | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | A | TA | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| REUVERIAN | C | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | B | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| LATE PLEISTOCENE | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| REUVERIAN | C | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | B | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| REUVERIAN | C | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | B | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| REUVERIAN | C | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | B | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| REUVERIAN | C | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | B | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| REUVERIAN | C | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | B | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| REUVERIAN | C | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | B | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| REUVERIAN | C | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | B | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| REUVERIAN | C | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | B | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| REUVERIAN | C | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | B | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| REUVERIAN | C | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | B | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| REUVERIAN | C | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | B | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| REUVERIAN | C | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | B | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| REUVERIAN | C | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | B | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| REUVERIAN | C | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | B | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| REUVERIAN | C | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | B | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| REUVERIAN | C | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | B | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| REUVERIAN | C | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | B | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| REUVERIAN | C | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | B | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| REUVERIAN | C | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | B | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| REUVERIAN | C | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | B | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| REUVERIAN | C | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | B | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| REUVERIAN | C | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | B | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| REUVERIAN | C | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | B | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| REUVERIAN | C | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | B | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| REUVERIAN | C | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | B | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| REUVERIAN | C | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | B | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| REUVERIAN | C | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | B | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| REUVERIAN | C | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | B | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| REUVERIAN | C | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | B | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| REUVERIAN | C | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

Table comparing pollen-zonation, climatic curve and lithostratigraphy of the Lower Pleistocene in the Netherlands.

fig. 6



Comparison between some sections of Tegelen Clay in the area of Tegelen. TC 2-6: pollen-zones of Tiglian C; EB: pollen-zones of Eburonian Glacial Stage. Locations fig. 2.

fig. 7

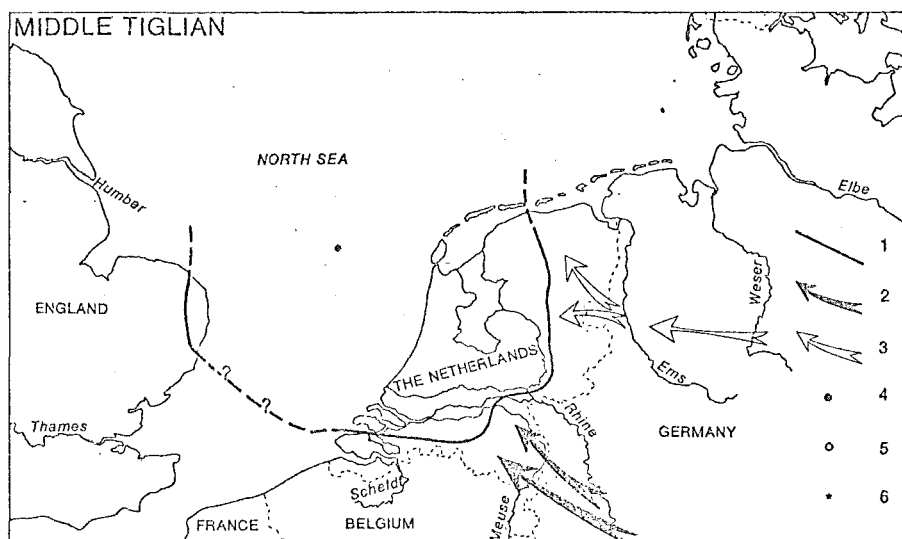
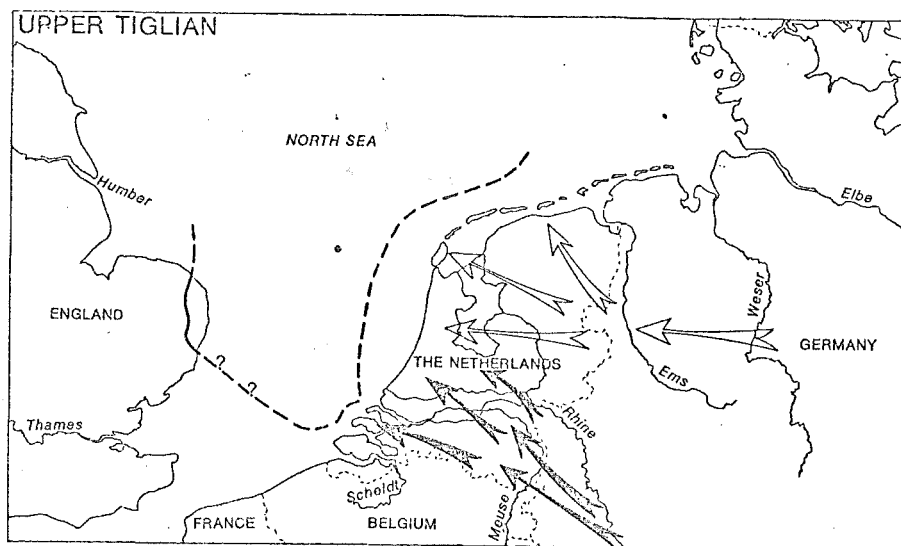


Fig. 8. Legend: 1 coastline
 2 main flow direction of River Rhine
 3 main flow direction of NW German rivers
 4-6 borings in the North Sea

LITHOLOGY AND CORRELATION OF THE REUVERCLAY AND OF THE MEINWEGCLAY

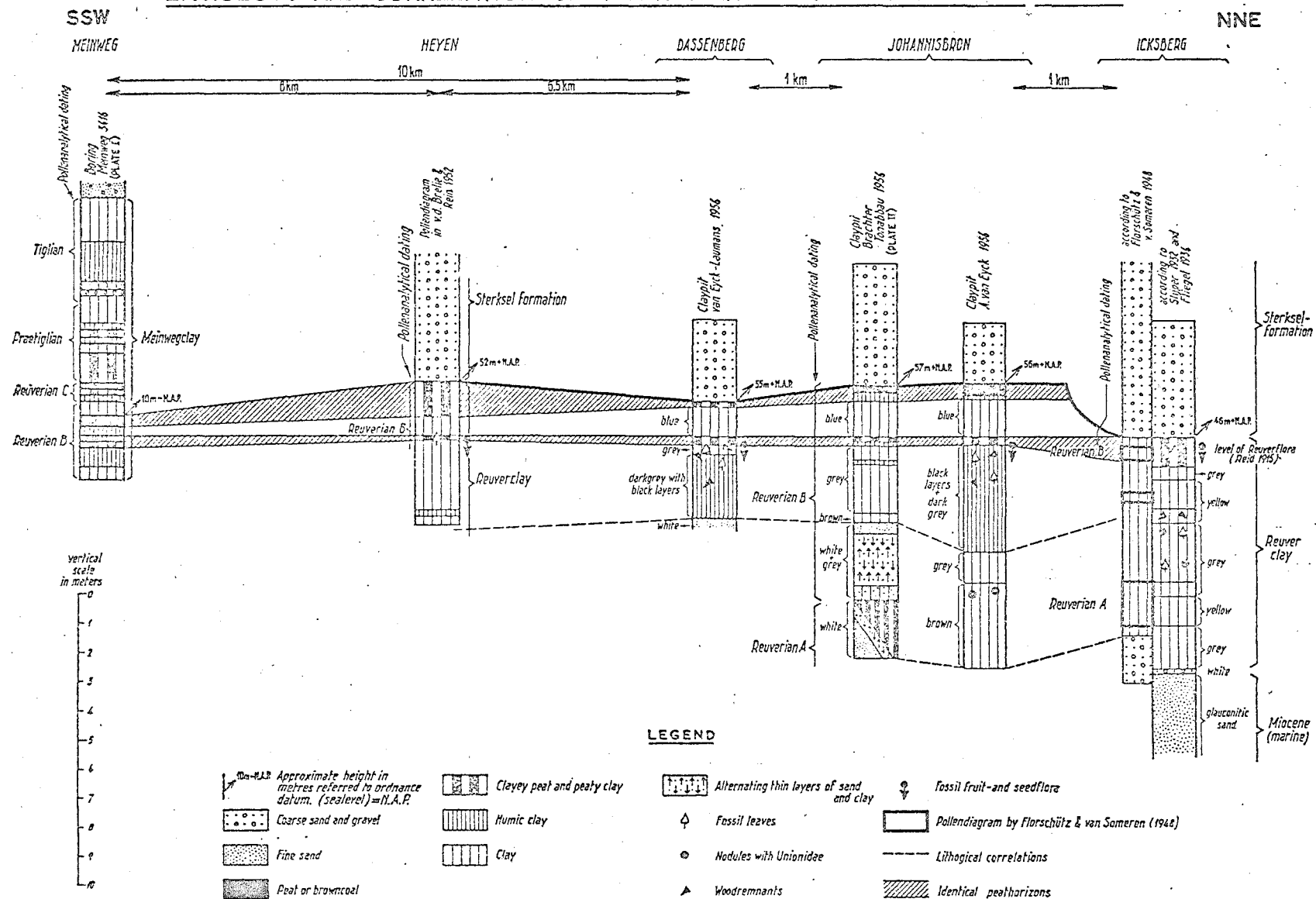


fig. 6

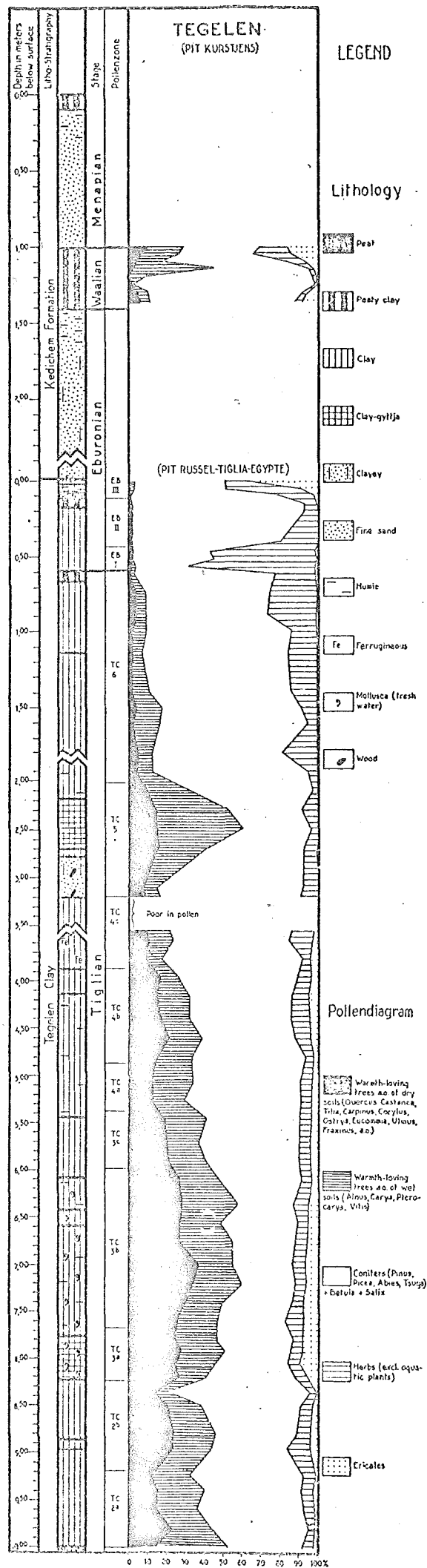


fig. 10

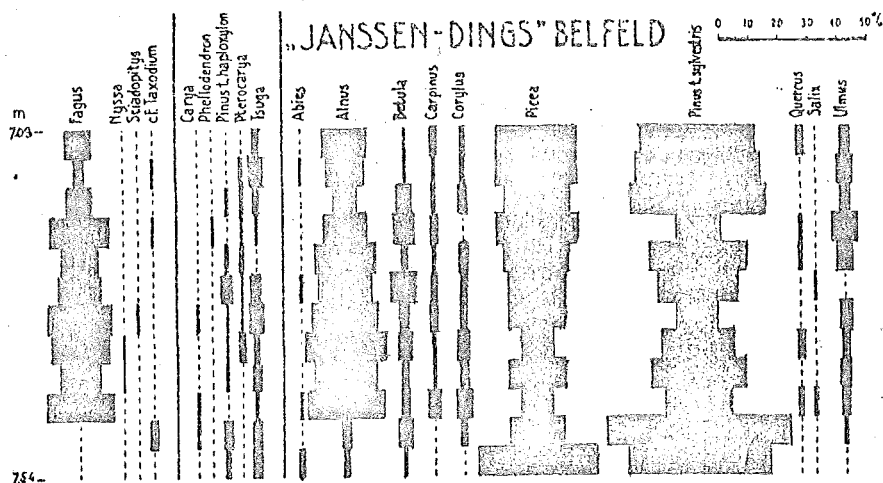


Fig. 11. (pollendiagram from Belfeld Clay acc. to Florschütz 1953)

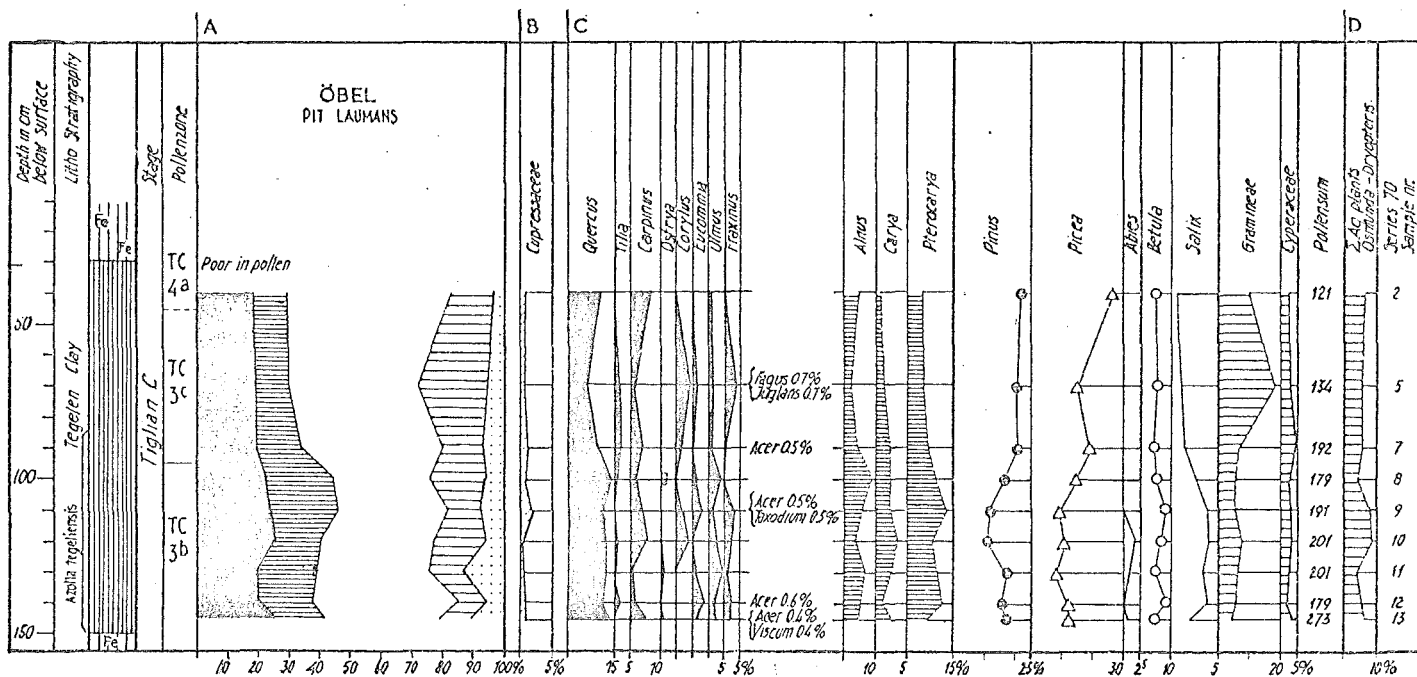
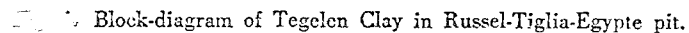


Fig. 12

Pollendiagram from the Tegelen Clay in pit Oebel.

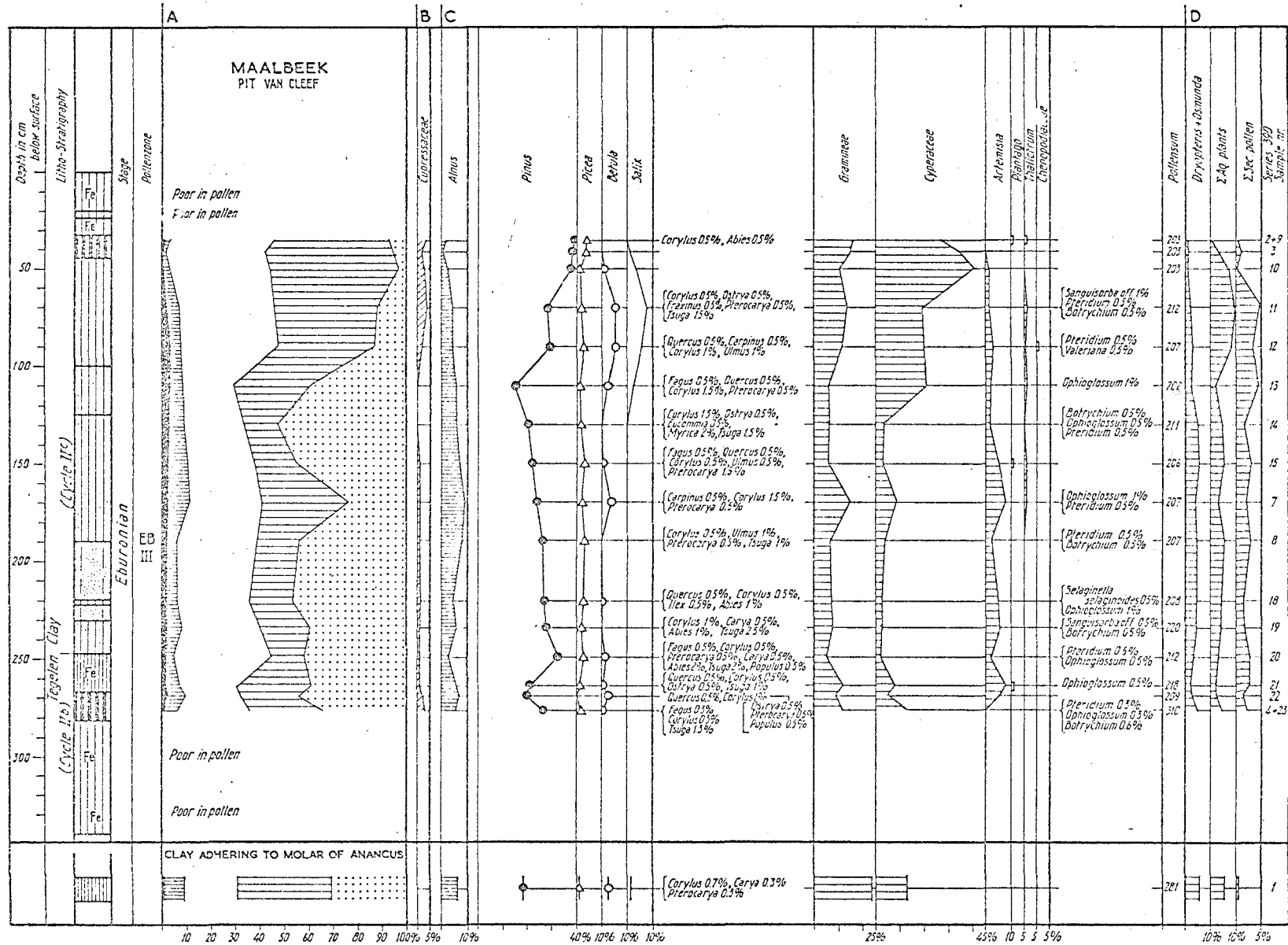


10

STRATIGRAPHY OF PIT LAUMANS (TEGELEN)

| | | FORMATION | climate | LITHOLOGY/SEDIMENTOLOGY | cryoturbations | MINERAL ZONE AND PROVENANCE | HEAVY MINERALS |
|-----------------------|---------------|-----------------------|----------------|---|--|--------------------------------|--|
| UPPER PLEISTOCENE | WEICHSELIAN | TWENTE FORMATION | cold | COVERSAND (ABOUT 1m) | | | |
| MIDDLE PLEISTOCENE | | STERKSEL FORMATION | cold | ABOUT 15 m OF COARSE SAND AND GRAVEL SOME LARGER BLOCKS MEANDERING RIVERS p.p. | frostwedge casts | "WEERT ZONE" (RHINE) | EPIDOTE HORNBLende SAUSSURITE |
| LOWER PLEISTOCENE | MENAPIAN | KEDICHEM FORMATION | cold | FINE SANDS | (large) frostwedges and involutions | "LOWER FINE ZONE" (LOCAL) | TOURMALINE STAUROLITE ZIRKONE METAMORFIC MIN. |
| | WAALIAN (pp.) | | | SOILS | | | |
| | EBURONIAN | | cold | FINE SANDS PARTLY FLUVIATILE PARTLY PERIGLACIAL-EOLIAN (ABOUT 3m) | small frostwedge casts (in other pits) | | |
| | TIGLIAN (tcp) | TEGELEN FORMATION | cool- temp. | CLAY FLUVIAL (MEANDERING RIVERS) (ABOUT 2-3m) | in other pits: involutions | "TEGELEN ZONE" (RHINE) | GARNET EPIDOTE HORNBLende SAUSSURITE |

File. 15



Pollen-diagram of Tegelen Clay exposed in pit Van Cleef, Maalbeek.

BRUNSSUM area

In this area (fig. 16) an important fault, the Feldbiss, is encountered, which is the southern boundary fault of the Central Graben system of the southern Netherlands. South of this fault Lower to Middle Miocene continental deposits, including browncoal, are near the surface. North of the Feldbiss these deposits are covered by a thick series of continental beds of Upper Miocene and Pliocene age.

These beds are included in the Kieseloölite Formation, with the following members:

| | |
|---------------------------------------|--|
| Schinveld Sands (with clay lenses) | age: Upper Pliocene (Reuverian) and Lowermost Pleistocene (Praetiglian) |
| Brunssum Clay | age: Lower Pliocene (Brunssumian) and Upper Miocene pp. (Susterian) |
| Waubach Gravel | age: Upper Miocene (Susterian and older). |

The general dip of these deposits is towards the northwest. In the extreme southeast Waubach Gravel is at the surface, towards the NW follows Brunssum clay and still further in that direction Schinveld Sands.

Pit "Ora et Labora"

The original pit as figured on the map (fig. 16) has been very much extended in depth and size and has shifted to the north and west, north of the borings 759/411 and 759/138 (profile Ia).

Below several metres of white sands (Schinveld Sands) an approximately 10 metres thick series of alternating clay and humic clay with browncoal seams is seen (Brunssum Clay) (fig. 17).

The organic beds are concentrated in two different litho-zones: an upper (litho-zone 2) and a lower (litho-zone 4) (fig. 17). Overlying, in between, and underlying are clays of light colour, relative poor in organic components (litho-zones 1, 3, and 5) (fig. 18).

At the base of the excavation a thick series of gravelly white sands is exposed. These form a lens or gully filling within the Brunssum Clay member (litho-zone 6). As shown by borings at still greater depth more clay beds are found (not exposed) which in turn overly the Waubach Gravel. This latter member attains in this locality a thickness of some 80 metres.

Palynology and Palaeobotany of pit "Ora et Labora"

The light coloured clays of litho-zones 1, 3, and 5 in this particular pit are frequently poor in pollen, or show assemblages dominated by *Pinus*. The spectra from the browncoals of litho-zones 2 and 3 are frequently dominated by pollen of *Sequoia*. Such high frequencies of *Sequoia* are among the characteristics of the Brunssumian stage. From the younger Reuverian it can be separated by the presence of *Symplocos* and *Tricolporites edmundi*, *Meliaceae* (*Cedrela*) and some other exotic plants. The macroflora (fruits and seeds) is distinctly richer in Eastern Asiatic and North American species than the macroflora in the Reuverian beds.

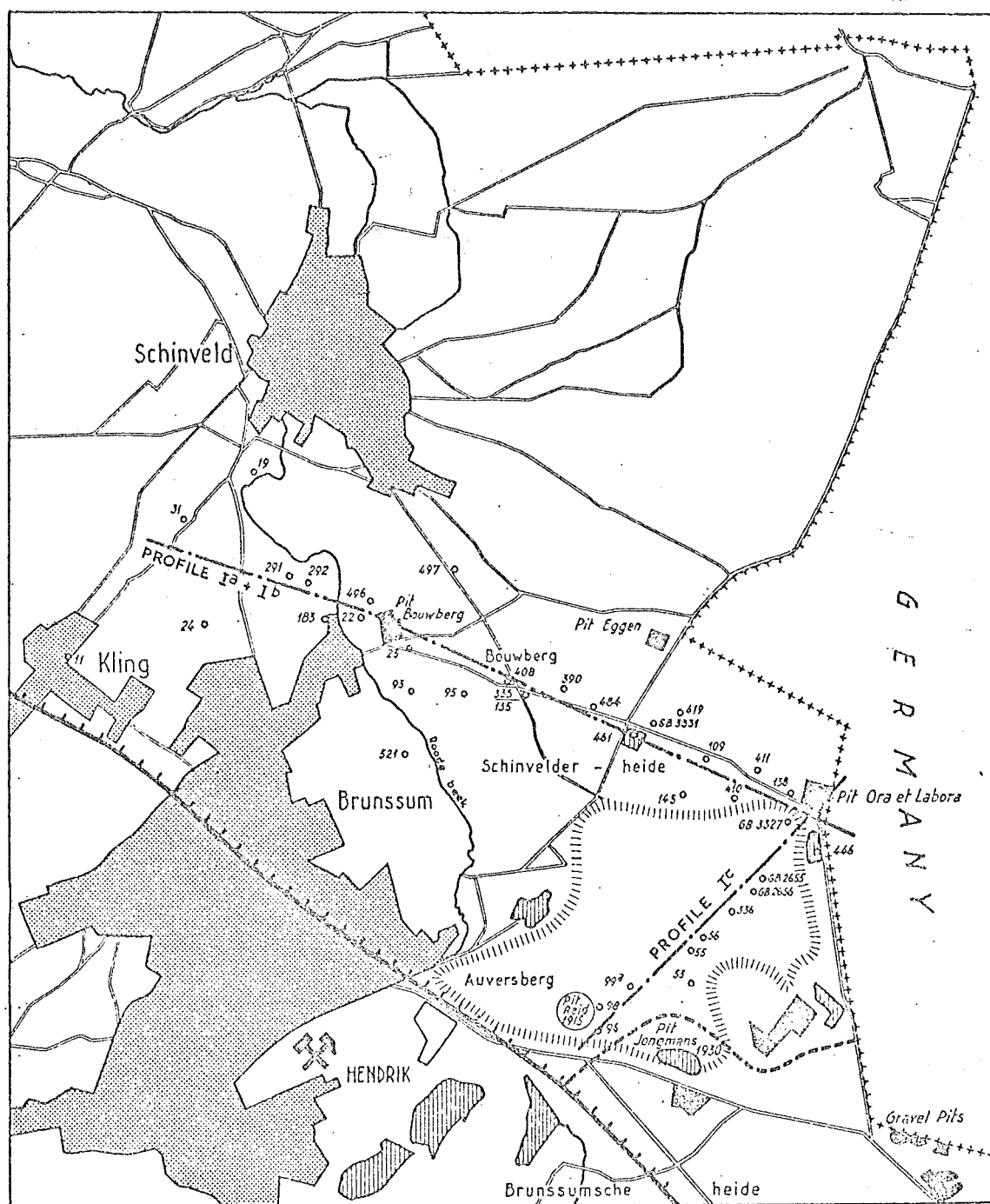
Some distinctive plants are: Glyptostrobus europaeus, Cunninghamia, Cyclocarya, Spiromatospermum wetzleri, Martyia naviculaeformis (= Toddalia naviculiformis), and many others which are not known from the Reuver Clay.

In this particular pit it is now known where the Brunssumian-Susterian boundary (the latter stage is among other characteristics dominated by Pinus) should be drawn. Comparison with more complete diagrams from other localities makes it likely that the boundary is at or near the base of litho-zone 5.

Note: In the original description of the Susterian (Zagwijn 1960) this stage was thought to be Lower Pliocene in age. Later correlation has shown however, that the continental beds of Susterian stage age correlate with marine Upper Miocene beds as testified by the foraminiferal and molluscan assemblages.

Literature

Zagwijn, W.H. (1960) - Aspects of the Pliocene and Early Pleistocene vegetation in the Netherlands. Med. Geol. St., ser. C-III-1, No. 5.



LEGEND:

- | | | | |
|--|-----------------------------|--|---|
| | Village | | Former pit |
| | Road | | Pit in exploitation (1952/58) |
| | Brook | | Boring (number: Geological Survey sheet 759, or number indicated by GB: Geologisch Bureau in Heerlen) |
| | Frontier | | Approximate situation of Feldbiss-fault at the surface |
| | Tip of the colliery Hendrik | | Approximate line of outcrop of the base of the Brunssum-clay |
| | Profile | | |

Map of the Brunssum-area.

fig. 16

fig. 17

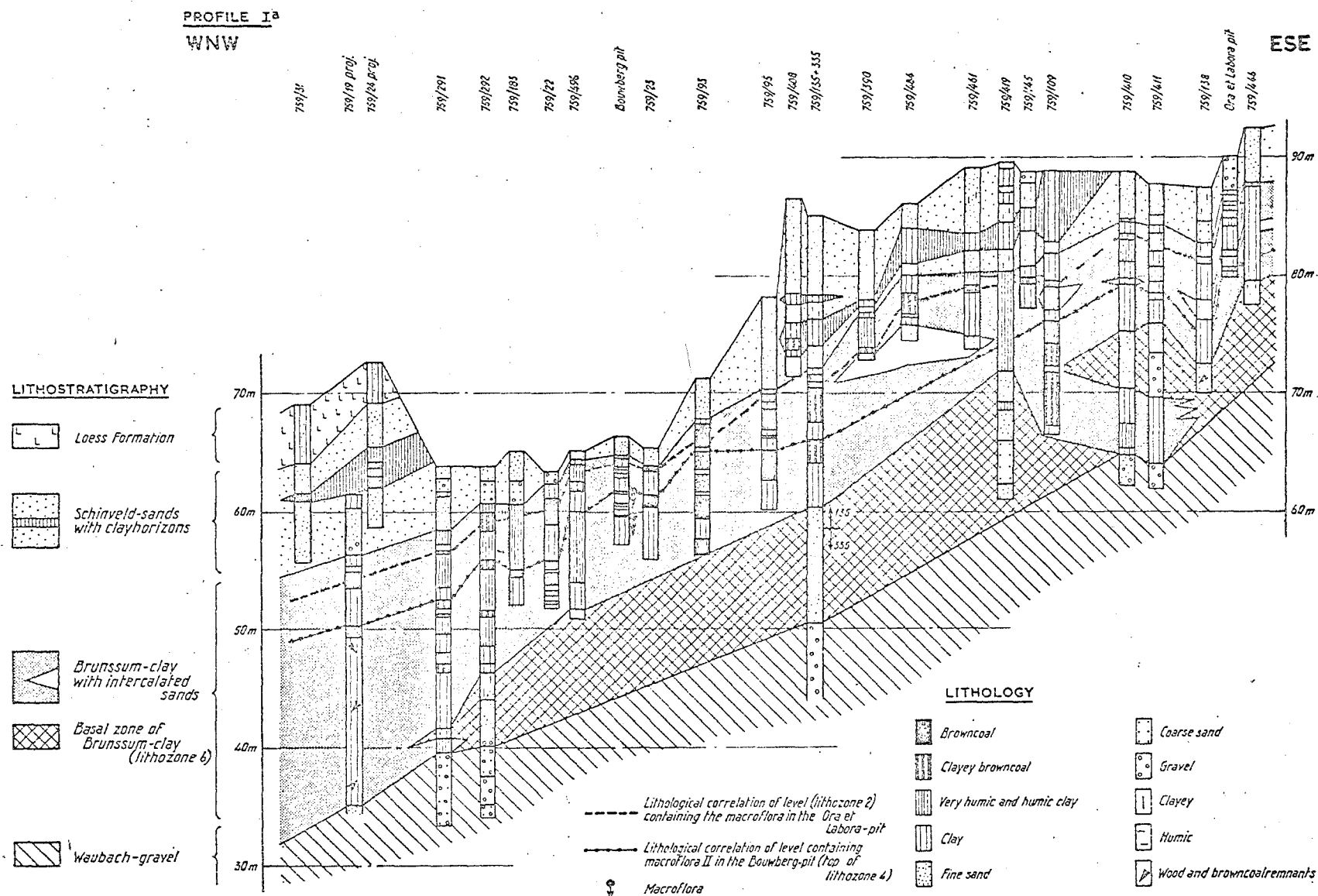
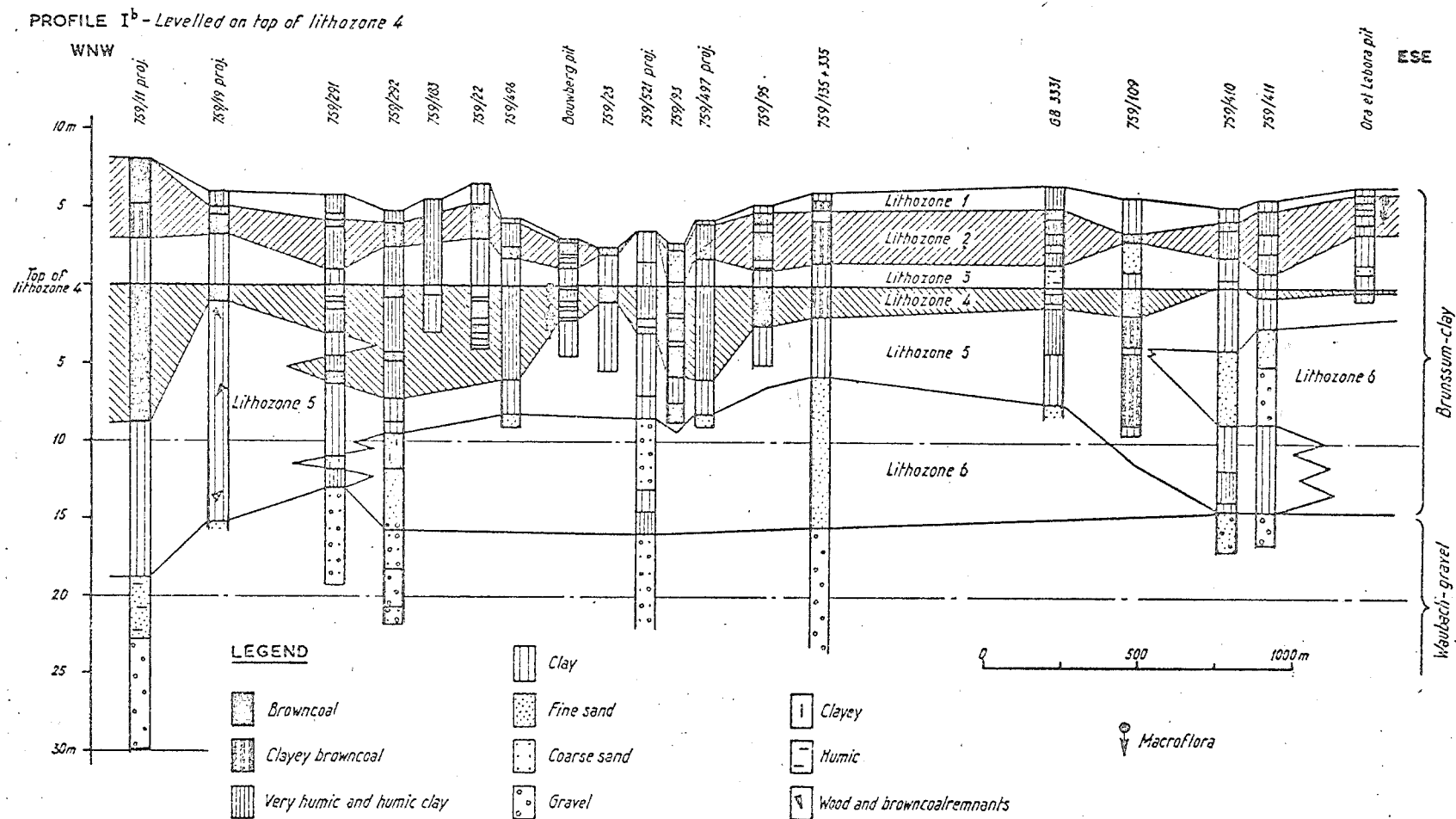


fig. 18



Profile I^b.
Detailed profile of the Brunssum-clay at Brunssum, leveled on the top of lithozone 4.

BIBLIOGRAPHY.

- ANDERSEN, S. T. (1960): Silicone Oil as a Mounting Medium for Pollen Grains. — *Danm. geol. Unders.*, IV Rke, Vol. 4, no. 1, p. 1.
- (1961): Vegetation and its Environment in Denmark in the Early Weichselian Glacial (Last Glacial). — *Danm. geol. Unders.*, II Rke, nr. 75, p. 1.
- BRELIE, G. VON DER, K. KILPPER and R. TEICHMÜLLER (1959): Das Pleistozän-Profil von Frimmersdorf an der Erft. — *Beitr. Geol. Rheinl. Westf.*, Vol. 4, p. 179.
- DOKTOROWICZ-HREBNICKA, J. (1957): Wzorce spektra pylkowe pliocenkich osadów węglonośnych. — *Inst. Geol. prace*, Tom XV, p. 87.
- DOPPERT, J. W. CHR. and ZONNEVELD, J. I. S. (1955): Over de stratigrafie van het fluviatiele Pleistoceen in West-Nederland en Noordbrabant. — *Med. Geol. Sticht.*, N.S. 8, p. 13.
- GREGUSS, P. and R. VAN HOORNE (1961): Etude Paléobotanique des Argiles de la Campine à Saint-Leonard (Belgique). — *Inst. roy. Sc. nat. Belg. Bull.* t. XXXVII, nr. 33, p. 1.
- HACQAERT, N. (1961): Palynologisch onderzoek van de cenozoïsche mariene zanden (Scaldisien en Merxemien) van het Hansadok te Antwerpen. — *Natuurw. Tijdschr.* 42, p. 65.
- HAMMEN, T. VAN DER (1951): A contribution to the Palaeobotany of the Tiglian. — *Geol. en Mijnb.*, N.S. 13, p. 242.
- HEGI, G. (1925): Illustrierte Flora von Mitteleuropa. — Vol. V, p. 261.
- IVERSEN, JOH. (1941): Landnam i Danmarks Stenalder; en pollenanalytisk undersøgelse over det første landbrugs indvirkning paa Vegetationsudviklingen. — *Danm. geol. Unders.*, Rke II, nr. 66.
- (1944): *Viscum, Hedera and Ilex* as climate indicators. — *Geol. Fören. Förh.*, Vol. 66, p. 774.
- (1960): Problems of the Early Post-Glacial Forest Development in Denmark. — *Danm. geol. Unders.*, Ser. IV, Vol. 4, p. 1.
- KORTENBOUT VAN DER SLUIJS, G. and W. H. ZACWIJN (1962): An Introduction to the Stratigraphy and Geology of the Tegelen clay-pits. — *Med. Geol. Sticht.*, N.S. 15, p. 31.
- LOOSE, H. (1960): *Dicerorhinus kirchbergensis* in the Tiglian? — *Proc. Kon. Ak. Wet.*, Ser. B 63, 3, p. 380.
- MONREAL, W. (1959): Die sedimentpetrographische Gliederung der Terrassen im Venloer Graben und am Viersener Höhenrücken. — *Fortschr. Geol. Rheinl. Westf.*, Vol. 4, p. 171.
- NOTA, D. J. G. (1956): Sedimentpetrologische Untersuchungen altpleistozäner Ablagerungen im Gebiet von Tegelen, Niederlande. — *Geol. en Mijnb.*, N.S. 18, p. 402.
- PANNEKOEK, A. J. (1956): Geological History of the Netherlands. — The Hague, p. 1.
- POLAK, B., G. C. MAARLEVELD and D. J. G. NOTA (1962): Palynological and Sedimentary Petrological data of a section in ice-pushed deposits (Southern Veluwe, Netherlands). — *Geol. en Mijnb.* 41, p. 333.
- REID, E. M. (1920): Recherches sur quelques grânes pliocènes du Pont-de-Gail (Cantal). — *Bull. Soc. Géol. France*, 4^e Sér., 20, p. 48.
- REID, CL. and E. M. REID (1907): The fossil flora of Tegelen-sur-Meuse, near Venloo in the Province of Limburg. — *Verh. Kon. Ak. v. Wetensch.* (2e sectie), Vol. 13, nr. 6, p. 1.
- (1910): A further investigation of the pliocene flora of Tegelen. — *Proc. Kon. Ak. v. Wet.* 19, p. 192.
- (1915): The Pliocene Floras of the Dutch-Prussian border. — *Med. v. d. Rijksopsp. van Delfst.* 6, p. 1.
- DUBOIS, E. (1905): Over een equivalent van het Cromer-forestbed in Nederland. — *Versl. en Med. Kon. Ak. v. Wet.* 13, p. 243, 453.
- ERDTMAN, G. (1952): Pollen Morphology and Plant Taxonomy. — *Angiosperms* (An Introduction to Palynology I), p. 1.
- FAEGRI, K. and JOH. IVERSEN (1950): Textbook of modern Pollen Analysis. — Copenhagen, p. 1.
- FLORSCHÜTZ, F. (1933): Die beiden Azolla-Arten des Niederländischen Pleistozäns. — *Rec. Trav. Bot. Néerl.* 35, p. 932.
- FLORSCHÜTZ, F. and A. M. H. VAN SOMEREN (1948): Microbotanische verschillen tussen de klei van Reuver en de klei van Tegelen. — *Geol. en Mijnb.*, N.S. 10, p. 68.
- (1950): The Palaeobotanical Boundary Pliocene-Pleistocene in the Netherlands. — Reprinted from *Internat. Geol. Congress „Report of the Eighteenth Session Great Britain 1948”*, Part IX, p. 40.
- TESCH, P. (1934): De opeenvolging van de oud-pleistocene lagen in Nederland. — *Tijdschr. Kon. Ned. Aardr. Gen.* 51, p. 649.
- TRALAU, H. (1962): *Najas tenuissima* (A. Br.) Magnus during the Late Cenozoic period in Europe. — *Bot. Not.* 115, p. 4.
- TROELS-SMITH, J. (1960): Ivy, Misteloe and Elm. Climate indicators, Fodder Plants. — *Danm. geol. Unders.*, Ser. IV, Vol. 4, no. 4, p. 1.
- VLERK, I. M. VAN DER and F. FLORSCHÜTZ (1950): Nederland in het ijsstijdvak (De geschiedenis van flora, fauna en klimaat toen aap en mammoet ons land bewoonden), Zeist, p. 1.
- (1953): The Palaeontological base of the sub-division of the Pleistocene in the Netherlands. — *Proc. Kon. Ak. Wet.*, Ser. 1, t. 20, nr. 2, p. 1.
- VOORTHUYSEN, J. H. VAN (1957): The Pliocene boundary in the North Sea Basin. — *Geol. en Mijnb.*, N.S. 19, p. 263.
- (1962): De Geologische Dienst als gastheer van het Colloque européen de Micropaléontologie. — *Jaarverslag Geol. Stichting*, 1961, p. 66.
- WANG, C. W. (1961): The Forests of China with a Survey of Grassland and Desert Vegetation. — *Maria Moors Cabot Foundation*, publ. no. 5, p. 1.
- WATTS, W. A. (1959): Interglacial Deposits at Kilbeg and Newtown Co. Waterford. — *Proc. Roy. Irish Ac.*, Vol. 60, sect. B, no. 2, p. 79.
- WEST, R. G. (1961): The Glacial and Interglacial Deposits of Norfolk. — *Trans. Norfolk and Norwich Naturalists' Soc.*, Vol. 19, part 6, p. 365.
- WOLDSIEDT, P. (1919): Das Vereisungsgebiet der Britischen Inseln und seine Beziehungen zum festländischen Pleistozän. — *Geol. Jahrb.*, Vol. 65, p. 621.
- ZACWIJN, W. H. (1957): Vegetation, Climate and Time-correlations in the Early Pleistocene of Europe. — *Geol. en Mijnb.*, N.S. 19, p. 233.
- (1959): Zur stratigraphischen und pollenanalytischen Gliederung der Pliozänen Ablagerungen im Roertal-Graben und Venloer-Graben der Niederlande. — *Fortschr. geol. Rheinl. u. Westf.*, Vol. 4, p. 5.
- (1960): Aspects of the Pliocene and Early Pleistocene Vegetation in the Netherlands. — *Med. Geol. Sticht.*, Serie C-III-1, no. 5, p. 1.
- (1961): Vegetation, Climate and Radiocarbon Datings in the Late Pleistocene of the Netherlands. — Part I: Eemian and Early Weichselian. — *Med. Geol. Sticht.*, N.S. 14, p. 15.
- (in the press): Pleistocene stratigraphy in the Netherlands, based on changes in vegetation and climate. — *Proc. Kon. Ned. Geol. Mijnb. Gen.*
- ZACWIJN, W. H. and J. I. S. ZONNEVELD (1956): The interglacial of Westerhoven. — *Geol. en Mijnb.*, N.S. 18, p. 37.
- BOENIGK, W.: Zur Kenntnis der Altquartärs bei Brüggen (westlicher Niederrhein). — *Sonderveröff. Geol. Inst. Univ. Köln*, 17, 141 S., Köln 1970.
- , KOWALCZYK, G. & BRUNNACKER, K.: Zur Geologie der Ältestpleistozäns der Niederrheinischen Bucht. — *Z. Deutsch. Geol. Ges.*, 123, S. 119—161, Hannover 1972.