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Genesis of the cliff-face near Bergen op Zoom in the southwest of the Netherlands

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Abstract

A cliff-face stretching north-south in the southwest part of the Netherlands, (from Halsteren to near the Belgium border) separates Holocene marine sediments from tidal and aeolian Pleistocene deposits. There is a difference of opinion regarding the age of the formation of this cliff-face. The main objective of this study was to verify the origin of this feature. To this end auger drilling and pollen analysis on peat was carried out. The cliff-face proved to have been formed by marine erosion during the Eemian.

Introduction

In the southwest part of the Netherlands, Holocene marine clay polders of the Scheldt estuary are separated from gently undulating Late Pleistocene cover sands by a distinct steep slope (25°–30°). This steep slope strikes north-south between Halsteren and Ossendrecht. At Ossendrecht it reaches a maximum altitude of approximately 20 m. At this point, it changes abruptly from a north-south to a northwest-southeast direction and becomes less steep. The steep slope between Halsteren and Ossendrecht, will be referred to as cliff-face in this paper (Fig. 1). Small, mostly dry transverse valleys cut the cliff-face in many places (Fig. 2).

The cliff-face has been formed by erosion of Lower Pleistocene tidal deposits (Kasse, 1986) of the Tegelen Formation (Table 1). East of the cliff-face the Tegelen Formation unconformably underlies Weichselian cover sand of the Twente Formation (Van Oosten, 1967; Zagwijn & Van Staalduinen, 1975).

So far there are different theories regarding the

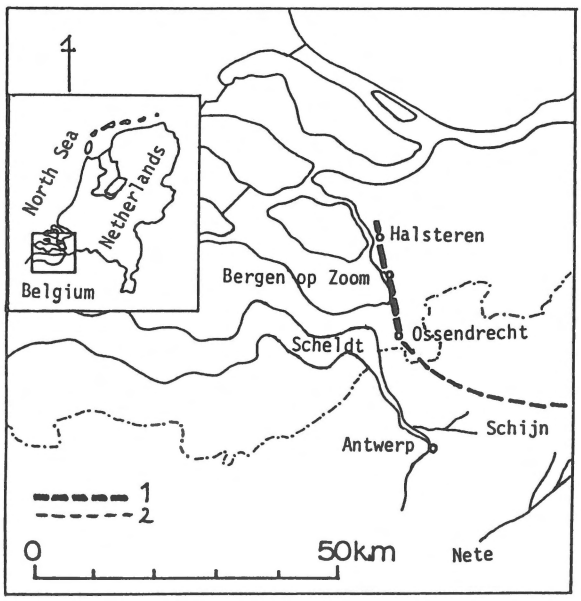

Fig. 1. Location map. 1. cliff-face; 2. northwest-southeast striking slope.

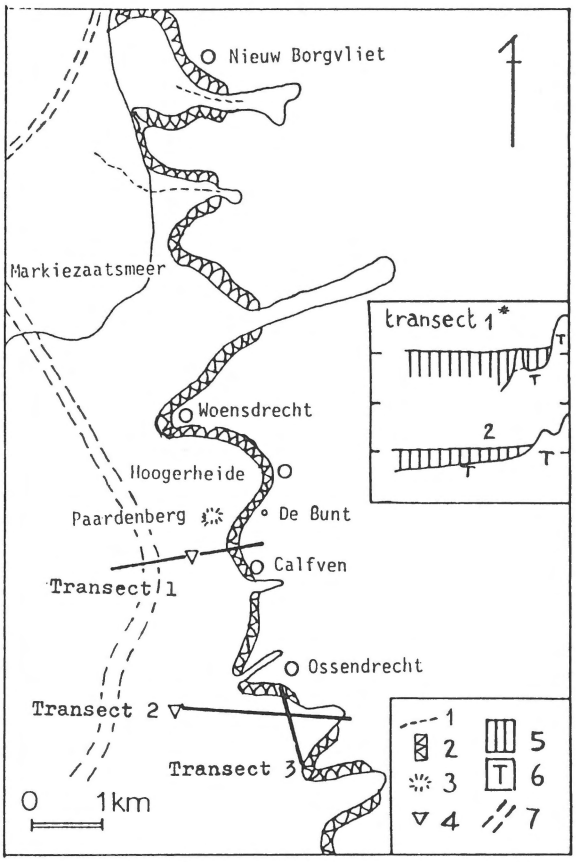

Fig. 2. The studied area. 1. creek; 2. cliff-face; 3. erosional remnant; 4. location of peat sample; 5. Westland Formation; 6. Tegelen Formation; 7. former course of the Scheldt.
* We were unable to determine whether in transect 1 we are dealing with an erosional remnant or with a fluvial dune, due to insufficient data.

age and the formation of this phenomenon. Some authors have suggested that the cliff-face has been formed by Holocene marine erosion (Van Dorsser, 1956; De Ploey, 1961). Ovaa (1966), however, maintains that the cliff-face is older than Holocene. Therefore, this investigation made a detailed study of the geology and geomorphology in order to elucidate the development of this cliff-face and to determine the period in which it was formed.

Investigation methods

In the field use was made of a hand auger (Edelman) and a gouge. 110 bore holes were made down to a maximum of 10 m depth along three transects. Two peat samples were collected with the gouge for pollen analysis in the laboratory (see Fig. 2).

Geology

Our own data and data given by Buysrogge et al. (1982) and Ovaa (1966) have been used to produce a model of the transects (Fig. 3).

The lowermost deposits in our transects belong to the Tegelen Formation (Table 1) which consists of micaceous tidal sands alternating with clay layers. It shows locally frequent cross-bedding and flaser structures. The Tegelen Formation is exposed only in a few sand pits along the cliff-face and in occasional remnants which protrude slightly through the marine clays to the west of the cliff-face. The Paardenberg, west of De Bunt (Fig. 2), is such a remnant.

The cliff-face in the Tegelen Formation is veneered with a well sorted aeolian sand cover, (the median of the diameter is 180 μm), without visible stratification. Well developed humic podzols are usually present in the sand cover. The podzols have often been destroyed by tillage. In accordance with Ovaa (1966) and Damoiseaux (1982) we ascribe this aeolian cover to the Upper Pleistocene cover sand of the Twente Formation (Table 1).

Ovaa (1966) and Leenders (1984) reported fluvial dunes of Weichselian age (Twente Formation) west of the cliff-face.

The marine Holocene deposits west of the cliff-face belong to the Westland Formation (Table 1). The clastic deposits comprise the lower Calais Deposits and the upper Dunkirk Deposits. The intercalated peat belongs to the Holland Peat Member (Buysrogge et al., 1982).

If we ignore the erosional remnant (Figs. 2, 3) for the time being, the data indicate that the Tegelen Formation on the westside of the cliff-face dips slightly to the west until, abruptly it deepens to 10 m and more below O.D. to form a channel. The

width of the higher level varies from 175 m to about 2500 m (Buysrogge et al., 1982).

The study of Buysrogge and co-workers also showed that this dipping surface has been dissected. Leenders (1984) states that the incisions partly are an extension of valleys with creeks (as shown in Fig. 2). The dry valley in which transect 3 is located (Fig. 4) also shows an incision in the Pleistocene surface in the southern part of the valley.

Pollen diagrams

Pollen diagrams 1 and 2 (Fig. 5) have been derived from two peat samples from −7.70 m O.D. and −8.30 to −7.80 m O.D. respectively (Fig. 2). The diagrams are characterised by high percentages of Alnus (up to 49%) and Quercetum mixtum (up to 46%), while Pinus is less important (maximum 19%). The increase of aquatic plants in the upper part of both diagrams indicates wetter conditions.

If we compare these results with the pollen zonation of the Holocene according to Zagwijn (1975),

Table 1. Local stratigraphy

Chronostratigraphy		Lithostratigraphy			
		Marine deposits	Tidal deposits	Marsh deposits	Eolian deposits
Holocene	Subatlantic	Westland Fm. — Dunkirk Dep. II-III			Kootwijk Fm. Y.D.
	Subboreal			Holland Peat	
	Atlantic	Calais Deposits			
	Boreal			Basal Peat	Kootwijk Fm. O.D.
	Preboreal				
Pleistocene	Weichselian				Twente Fm.
	Eemian	Eem Fm. (Schouwen Dep.)			
	Saalian				
	Holsteinian				
	Elsterian				
	Cromerian				
	Bavelian				
	Menapian				
	Waalian				
	Eburonian				
	Tiglian		Tegelen Fm.		
	Pretiglian	Maassluis Fm.			
Pliocene	Reuverian				

Eolian deposits: Kootwijk Formation Y.D. - Young Drift sand
Kootwijk Formation O.D. - Old Drift sand
Twente Formation - Cover sand

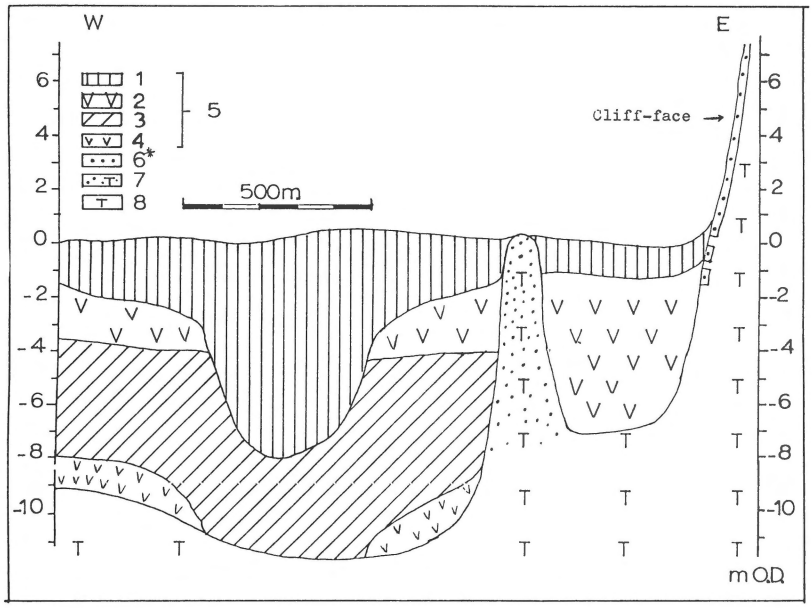

Fig. 3. Schematic east-west transect. 1. Dunkirk Deposits; 2. Holland Peat; 3. Calais Deposits; 4. Basal Peat; 5. Westland Formation; 6. Twente Formation* (cover sand); 7. Tegelen Formation (erosional remnant) or Twente Formation (fluvial dune); 8. Tegelen Formation.

our diagrams indicate an Atlantic age. This agrees with the time-depth graph reported by Jelgersma (1979) and the age of a peat sample in the study area reported by Ovaa (1966).

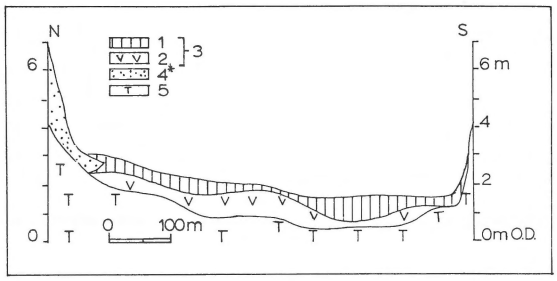

Fig. 4. Flat bottomed transverse valley: transect 3. 1. Dunkirk Deposits; 2. Holland Peat; 3. Westland Formation; 4. Twente Formation* (cover sand); 5. Tegelen Formation.
* We were unable to determine whether the sand present under the Westland Formation belongs to the Twente Formation or to an older Formation, due to insufficient data. Therefore the cover sand is not shown underneath the Westland Formation.

Age of the cliff-face (cf. Fig. 3)

(Fig. 3): Firstly, the Dunkirk II/III transgressions did not affect the Tegelen Formation. Therefore the Dunkirk transgressions could not have formed the cliff-face. Secondly, the Atlantic peat adjacent to the cliff-face indicates that the cliff-face is older than the peat. Thirdly, the Calais Deposits do not reach the cliff-face. Therefore the Calais transgressions could not have formed the cliff-face. In conclusion (see Table 1); the cliff-face is older than Atlantic. Furthermore, the lower Early Holocene sea level and the veneer of cover sand indicate that the cliff-face is even older than Holocene.

Formation of the cliff-face

The presence of a gently westward sloping surface and erosional remnants developed in the Tegelen Formation, west of the cliff-face, point to wave action and the development of an abrasion plat-

Diagram 1

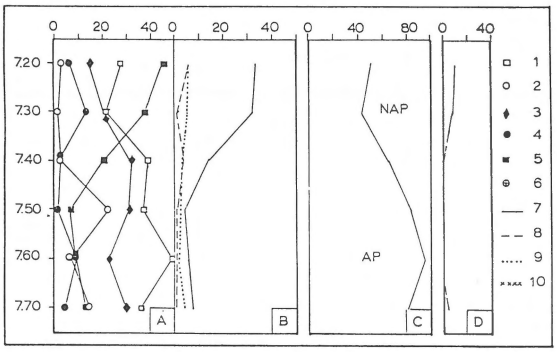

Diagram 2

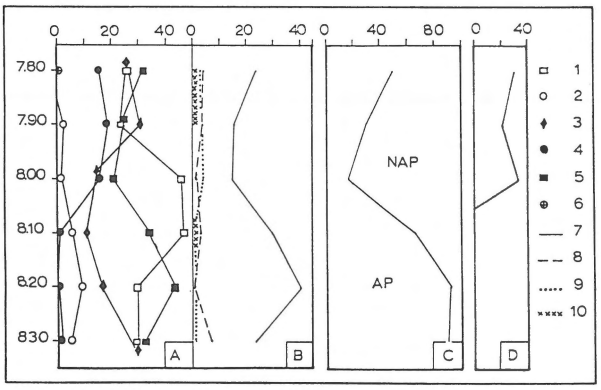

Fig. 5. Pollen diagrams 1 and 2.
A. Arboreal Pollen;
B. Quercetum mixtum; } Σ Arboreal Pollen = 100%
C. Arboreal Pollen/Non Arboreal Pollen;
D. Aquatic Plants } Σ Arboreal Pollen + Non Arboreal Pollen = 100%
1. Alnus; 2. Betula; 3. Corylus; 4. Pinus, 5. Quercetum mixtum; 6. Salix; 7. Quercus; 8. Tilia; 9. Ulmus; 10. Fraxinus.

form. This platform extends into several transverse valleys as can be seen in Fig. 2. These valleys are very wide in the west but taper off strongly to the east. The paleomorphology of an abrasion platform in front of a cliff-face with wide, flat-bottomed valleys in between, typically resembles a bay-cliff coast. The abrasion platform and the cliff-face have not been formed by the Holocene sea and extreme low sea levels occurred during the Weichselian. However, the Eemian sea level stood sufficiently high for the development of the coastal features mentioned above (Van de Plassche, 1981; Zagwijn, 1983). This hypothesis fits well into the development of the Scheldt estuary as summarized below.

Development of the Scheldt estuary and its relation to the cliff-face

The early history of the Scheldt estuary in the Quarternary has been summarized by Goossens (1984). During the Middle Pleistocene the northern part of the Brabant Massif in Belgium and the Campine were drained by the Flemish Valley (Fig. 6), a deeply eroded valley with many branches.

A northern branch was occupied by the Middle Pleistocene Schijn river, forming a catchment area between the cuestas of the Oligocene Rupelian clay and the Lower Pleistocene Campine clay (Fig. 6). This valley may have had several transverse valleys.

At the beginning of the Holsteinian (cf. Table 1) the Flemish Valley had been scoured to such an extent that the rising sea was able to enter, forming an estuary. According to Goossens (1984), subsequent severe Saalian erosion under periglacial conditions deepened and widened the Flemish Valley.

During the Eemian the sea transgressed the Flemish Valley further than during the Holsteinian. An estuary developed north of Ghent, due to the Saalian deepening of the Flemish Valley and the high level of the Eemian sea. In large areas of the south-west Netherlands marine and estuarine deposits developed: Eemian Formation, Schouwen Deposits (Van Rummelen, 1978).

The north slope of the Eemian Schijn Valley was formed by a protective layer of Tiglian clay beds overlaying easily erodible sandy deposits. The cliff-

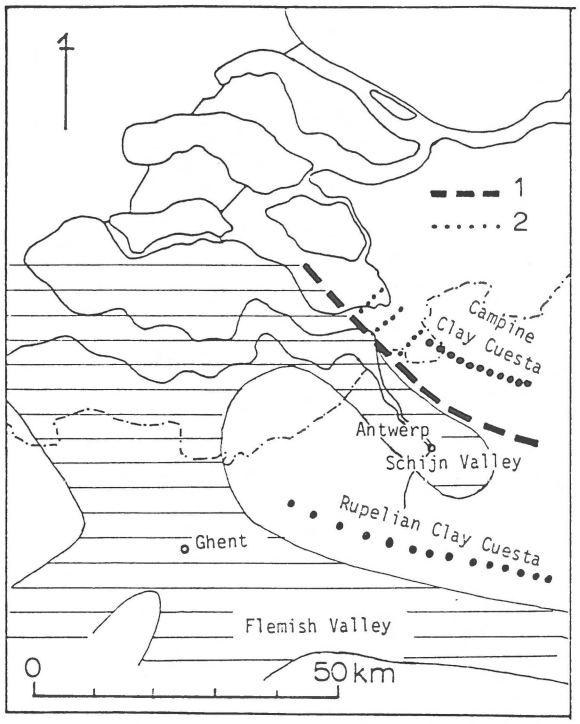

Fig. 6. Middle Pleistocene. Flemish Valley with the Schijn Valley. 1. North slope of the Schijn Valley; 2. transverse valleys.

face and an abrupt change in strike of the slope was formed when this slope was cut back by the Eemian sea (Fig. 7).

The already existing transverse valleys were shortened, widened and flattened and a typical bay-cliff coast was formed, with a wave cut platform in front. On top of this erosional platform, hilly remnants of the Tegelen Formation are found.

During the Weichselian with its low sea levels terrestrial erosion again dominated and headward erosion and renewed incision probably extended and deepened the wide, flat and short transverse valleys. This resulted in young narrow valleys within the wide, flat transverse valleys: the development of a new terrace.

The valleys north of Woensdrecht and south of Ossendrecht (Figs. 2, 4) have such a typical morphology. New valleys also formed, which in contrast to the older valleys are not widened. Examples of these narrow valleys can be found between Calfven and Ossendrecht (Fig. 2).

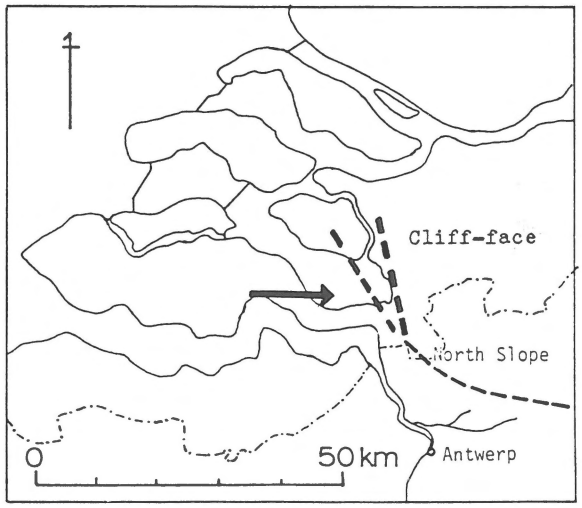

Fig. 7. Eemian. Eastward retreat of the north slope of the Schijn Valley due to marine erosion.

During the Late Glacial, cover sand was deposited on the cliff-face and the surrounding area and an important change took place. Large amounts of sediment were deposited in the Flemish valley due to the high sediment load of the rivers. Consequently the Scheldt found a new outlet through a small valley in the Rupelian clay cuesta (Goossens 1984). North of Antwerp the river flowed in between the Eemian cliff coast in the east and a Late Glacial cover sand ridge in the west, reported by Van Rummelen (1965). See Fig. 8.

At some distance from the cliff coast the Scheldt cut itself into the cover sand and the abrasion platform and thus the channel west of the cliff-face was formed. This channel was not found in transect 2 (Fig. 2) because at this point the Scheldt flowed further westward (Ovaa, 1966). The dunes which in places rest upon the wave-cut platform are probably formed from sand of the braided Late Glacial Scheldt by prevailing westerly winds.

Relatively small changes occurred during the Holocene. In this period the rise in sea level continued resulting in higher groundwater levels along the transgressing sea. Both the higher groundwater levels and the improved climate favoured peat growth (Hageman, 1969). Close to the cliff-face peat could grow unhampered from the Atlantic

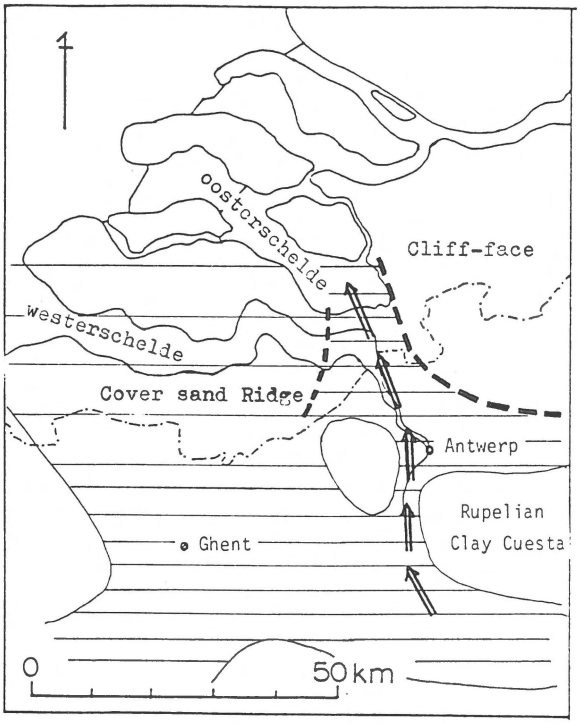

Fig. 8. Late Weichselian: The Scheldt finds a new outlet through the Rupelian clay cuesta into the Schijn Valley.

until the Dunkirk II transgressional phase.

The Dunkirk Deposits mainly consist of clay sheets cut by a dendritic system of sand-filled gullies of which the branches originate from the sector were the sea broke in (Hageman, 1969). These transgressions probably caused no erosion of the cliff-face in the investigated area. However, Leenders (1984) reports some erosion of the cliff-face along the Markiezaatsmeer (Fig. 2) due to the Dunkirk III transgression.

During the Middle Ages a branch of the Scheldt flowing through the Westerschelde became more important to the disadvantage of the more northern branch through the Oosterschelde (Fig. 8). In 1867 the Oosterschelde was definitively closed for the Scheldt by the construction of a railway dam. From then onwards, the Scheldt flows only through the Westerschelde.

Discussion

We realize, looking at our data, that there are still some problems. For instance, in the literature no marine Eemian deposits have been reported from the study area. Possibly they have not been recognized, or they have largely been removed by later erosion.

Also, we are not able to give an extensive view of the Pleistocene surface west of the cliff-face. However, our results do fit in with the more complete data given by Buysrogge et al. (1982) for the Markiezaatsmeer (Fig. 2).

Conclusions

So far there has been a disagreement on whether the cliff-face has been formed during the Holocene or is older. In this investigation we have made an attempt to determine the period of formation of this feature. It is obvious, looking at the results from our palynological analysis and borings, that the cliff-face is older than Holocene and that it has been formed by the sea.

We may conclude that only the Eemian sea level stood sufficiently high to form a bay-cliff coast at the present location. This hypothesis agrees with the theory regarding the development of the Scheldt fluvial system.

Acknowledgments

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References

Buysrogge, R.A., D.J. de Jong, P.J. Ente & J. Visser 1982 Landschaps-ecologisch onderzoek Markiezaatsmeer – Flevobericht 192: 54 pp

Damoiseaux, J.H. 1982 Toelichting by kaartblad 49 Oost Bergen op Zoom – Stiboka, Wageningen: 137 pp

De Ploey, J. 1961 Morfologie en Kwartair-stratigrafie van de

Antwerpse Noorderkempen – Acta Geogr. Lovaniensia 1: 130 pp

Goossens, D. 1984 Inleiding tot de geologie en geomorfologie van België. 2nd. pr. – V.d. Berg/Witkam, Enschede: 228 pp

Hageman, B.P. 1969 Development of the Western Part of The Netherlands during the Holocene – Geol. Mijnbouw, 48: 373–388

Jelgersma, S. 1979 Sea level changes in the North Sea Basin. In: E. Oele, R.T.E. Schüttenhelm & A.J. Wiggers (eds): The Quaternary History of the North Sea. Acta Univ. Ups, Symp. Univ. Ups. Annum Quingestesimum Celebrantis: 2, Uppsala: 233–248

Kasse, C. 1986 The tidal character of the Formation of Tegelen in northern Belgium – Geol. Mijnbouw, 65: 41–46

Leenders, K.A.H.W. 1984 Hildernisse – KNAG Geogr. Tijdschr. 18: 146–149

Ovaa, J. 1966 De bodemgesteldheid van het ruilverkavelingsgebied Scheldezoom – Stiboka Rept. Wageningen 675: 95 pp

Van Dorsser, H.J. 1956 Het landschap van Westelijk Noord-Brabant: bijdrage tot het inzicht in de ontstaanswijze – Ph. D. Thesis University of Utrecht: 133 pp

Van Oosten, M.F. 1967 Bijdrage tot de kwartair-geologie van westelijk Noord-Brabant – Geol. Mijnbouw, 46: 131–146

Van de Plassche, O. 1981 Sea level, groundwater, and basal peat growth – a reassesment of data from the Netherlands – Geol. Mijnbouw, 60: 401–408

Van Rummelen, F.F.F.E. 1965 Toelichtingen bij de geologische kaart van Nederland 1:50.000. Bladen Zeeuws Vlaanderen West en Oost – Rijks Geol. Dienst, Haarlem: 79 pp

Van Rummelen, F.F.F.E. 1978 Toelichtingen bij de geologische kaart van Nederland 1:50.000. Blad Beveland – Rijks Geol. Dienst, Haarlem 138 pp

Zagwijn, W.H. & C.J. van Staalduinen 1975 Toelichting bij de geologische overzichtskaarten van Nederland – Rijks Geol. Dienst, Haarlem: 134 pp

Zagwijn, W.H. 1983 Sea-level changes in the Netherlands during the Eemian – Geol. Mijnbouw, 62: 437–450