

Historical overview of lithostratigraphic research on the Upper Cretaceous of southern Limburg, the Netherlands *

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Key words: lithostratigraphy, history, type Maastrichtian

Abstract

A historical overview is presented of the (litho)stratigraphic studies into the Upper Cretaceous deposits in southern Limburg (the Netherlands), the type area of the Maastrichtian. From 1860 onward, a workable lithostratigraphy has been available for these deposits. At present, a division including four formations and 23 members is being used.

Introduction

Upper Cretaceous sediments in southern Limburg (the Netherlands) have long attracted the attention of inhabitants of the region. Already in Palaeolithic times, flint was quarried from these deposits for the manufacture of tools. During the Neolithic, underground galleries were excavated in order to extract the flints. Possibly, the farmers of those days had also discovered the use of chalk as a fertiliser. With the arrival of the Romans, the flints, but especially the chinks, were being used for building purposes. All these people must have had knowledge of mining techniques as well as geology.

The interest in the Upper Cretaceous deposits grew with time. In southern Limburg this is explained by the abundance of fossils as well as by the extensive underground galleries which were the result of quarrying near Maastricht and Valkenburg. Fossils from these galleries and from opencast quarries were sought-after collector's items. In fact, the collector-palaeontologists were the first to put forward views on the stratigraphy of these deposits. Until the end of the 18th century, stratigraphic research in southern Limburg remained limited, and the stratigraphic nomenclature that was used is often difficult to interpret nowadays.

Historical overview

Hausmann (1808) was one of the first to discuss explicitly the stratigraphic position of the limestones found between Maastricht and Aachen, assigning them to the 'Formation des jüngsten Flözkalksteins, des s.g. Muschelkalksteins, und zwar ohne Zweifel zu den jüngsten seiner Suite.' When considering this age assignment we should of course keep in mind that the nomenclature of most of the geological units of Hausmann's days differed considerably from current interpretations. That the 'Muschelkalkstein' as a stratigraphic unit was different from our modern definition, becomes apparent when Hausmann writes 'Das Vorkommen des Feuersteins und Hornsteins ist charakteristisch für die Muschelkalksteinformation, ganz besonders aber für die neuesten zu Ihr gehörige Erzeugnisse des Kalkmergel und die Kreide' (The occurrence of flint and chert is characteristic of the Muschelkalkstein formation, in particular so for the newest products of marl and chalk, which belong to this formation). In the same year, 1808, d'Omalius d'Halloy used the names 'Formation de la Craie' and 'Terrain de craie' for the first time, when writing about the geology of northern France.

During the years that followed, northwest European geologists attempted to formulate local subdivisions and to incorporate these into an international stratigraphic scheme. With this in mind, Belgian, German,

* Staring Memorial Lecture of the Royal Geological and Mining Society of the Netherlands, Heerlen, October 28, 1994, translated version.

Table 1. Lithostratigraphic subdivision of the Upper Cretaceous and the Danian chalk in South Limburg (the Netherlands) and neighbouring regions. After W.M. Felder & H.J. Albers (1979). Approximate geological ages are as follows: Aken (= Aachen) Fm - middle or late Santonian to early Campanian; Vaals Fm - early Campanian; Gulpen Fm - late Campanian to late Maastrichtian; Maastricht Fm - late Maastrichtian; Houthem Fm - Danian to ? Thanetian.

| Lithostratigraphic subdivision of the Upper Cretaceous and the Danian chalk in South Limburg (the Netherlands) and neighbouring regions | | | | | | | | | | |
|---|-------------------|-------------------------|---------------------|----|-------|-----------------------|------------------------|-----|------|----|
| W.M. Felder and H.J. Albers, 1979 update: W. M. Felder, 1995 | | | | | | | | | | |
| East West of the river Maas | | | | | | | | | | |
| Uhlenbroek 1912 | | | | | | | | | | |
| Hofer 1866 | | | | | | | | | | |
| PALEOCENE | Danian | HOUTHEM FORMATION | Geleen Chalk | | Vc | | Lutterade Horizon | | | |
| | | | Bunde Chalk | | Vb | | Geleen Horizon | | | R |
| | | | Geulhem Chalk | | Va | Xlw | Bunde Horizon | | Md | Q |
| UPPER - CRETACEOUS | Maastrichtian | MAASTRICHT FORMATION | Meerssen Chalk | | IVf | Xw | Vroenhoven Horizon | | | N |
| | | | Nekum Chalk | | IVe | IXw | Caster Horizon | | | L |
| | | | Emael Chalk | | IVd | | Laumont Horizon | | Mc | K |
| | | | Schiepersberg Chalk | | IVc | | Romontbos Horizon | | | I |
| | | | Gronsveld Chalk | | IVb | vllw | Schiepersberg Horizon | | Mb | J |
| | | | Valkenburg Chalk | | IVa | | St. Pieter Horizon | | Ma | H |
| | | | Lanaye Chalk | | IIIg | Vllw | Lichtenberg Horizon | | Cr4 | G |
| | | | Lixhe 3 Chalk | | IIIf | Vlw | Nivelle Horizon | | | F |
| | | | Lixhe 2 Chalk | | IIIe | Vw | Boirs Horizon | | Cr3c | E |
| | | | Lixhe 1 Chalk | | III d | IVw | Halembaye 1 Horizon | | Cr3y | |
| | Campanian | GULPEN FORMATION | Vylen Chalk | | IIIc | IIIw | Wahlwiller Horizon | | Cr3b | D |
| | | | Beutenaken Chalk | | IIIb | | Bovenste Bosch Horizon | | | C |
| | | | Zeven Wegen Chalk | | IIIa | IIw | Slenaken Horizon | | | B |
| | | | Benzenrade Sand | | IIg | | Zeven Wegen Horizon | | Cr3a | A |
| | | | Terstraten Sand | | II f | | Benzenrade Horizon | | | |
| | | | Beusdal Sand | | IIe | | Terstraten Horizon | | | |
| | | | Vaalsbroek Sand | | II d | Iw | Beusdal Horizon | | Cr2 | A' |
| | | | Gemmenich Sand | | IIc | | Overgeul Horizon | | | |
| | | | Cottessen Sand | | IIb | | Gemmenich Horizon | | | |
| | | | Raren Sand | | IIa | | Cottessen Horizon | | | |
| Santonian | AKEN FORMATION | Hauset Sand | | Ic | | Raren Horizon | | | | |
| | | Aken Sand | | Ib | | Flög Horizon | | Cr1 | | |
| | | Hergenrath Clay | | Ia | | Schampelheide Horizon | | | | |
| Hergenrath Horizon | | | | | | | | | | |

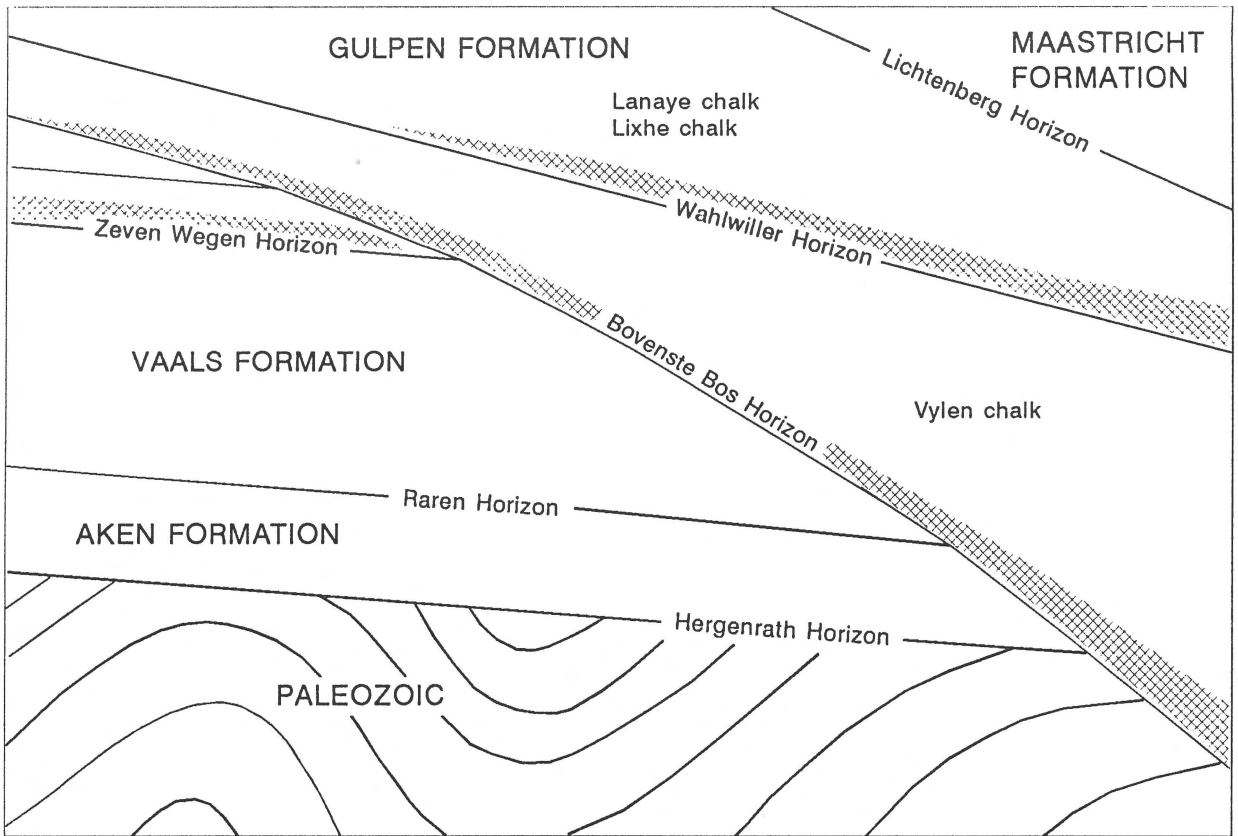


Figure 1. Schematic representation of the disconformable character of the Upper Cretaceous deposits in the type area of the Maastrichtian Stage; for details see text. Cross hatching indicates glauconite-rich beds. Base of Gulpen Fm is at Zeven Wegen Horizon. Aken and Vaals Formations are siliciclastics, Gulpen and Maastricht Formations are carbonates. Thickness of sequence shown varies and reaches locally 500m.

French and English geologists visited the Upper Cretaceous of southern Limburg, where much work was also done by several local geologists. Based at Liège, André Dumont carried out detailed investigations and in particular attempted to tie these in with studies in France. It was he who, in 1849, assigned the upper part of the Sénonien of d'Orbigny (1842) as exposed near Maastricht to an independent unit, the 'Système Maestrichtien'.

For the Aachen area, M.H. Debey published an excellent local subdivision in 1849. In the Netherlands, J.T. Binkhorst van den Binkhorst, who lived in Maastricht, introduced useful local stratigraphic units in 1859, in his extensive description of the Cretaceous in southern Limburg. At the same time, W.C.H. Staring assembled data for his geological map of the Netherlands and for his two-volume work 'De Bodem van Nederland'. Simultaneously, local workers other than those already mentioned, were active in southern Limburg. In fact they were a mixed

lot, including mining engineers such as Van Swieten (1857) and Labry (1858), in the search for minerals, and fossil collectors, interested in geology to varying degrees, amongst whom Müller (1847–1859) and Ubaghs (1879). Data collected by these people were published and/or exchanged between them in unpublished form.

In this way, Staring (1860) was able to include in the chapter 'Krijt van Zuid-Limburg' (Cretaceous of southern Limburg) an extensive and clear overview of the contemporary knowledge of lithostratigraphic subdivisions. Staring distinguished, just as we do to this day, four main units:

Maastrichtsche Krijt,
Gulpenische Krijt,
Zand van Herve,
Akenische Zand.

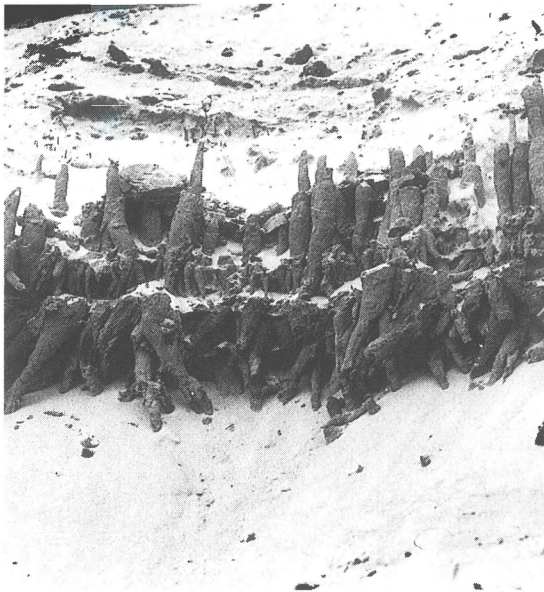


Figure 2. Bioturbations in Hauset Sand Mbr of the Aachen Fm in the Bingeberg quarry, Hauset (Belgium). Each burrow is approximately 30 cm in length.

He subdivided these into 19 lithostratigraphic units, five each for the three upper units and four for the 'Akensche Zand' (= Aachen Sand).

Staring also paid attention to lateral facies changes, such as the pronounced difference between the Maasricht and Kunrade limestones. Dumont (1838) had previously ascribed this difference to the influence of hot springs near Aachen. Staring suggested that different loam contents suffice to explain the difference between these limestones. His work was a solid basis for the subsequent lithostratigraphic research on the Upper Cretaceous in southern Limburg. Studies continued in subsequent years, but contributed little to the lithostratigraphic knowledge. Most conspicuous was the ever-returning discussion on the correlation of the Maastricht and Kunrade limestones. Going through C. Ubaghs's 1879 paper, it soon becomes clear that geologists of the period were unable to solve this problem.

As part of the activities during 1903–1923 of the 'Dienst der Rijksopsporing van Delfstoffen', the predecessor of today's Geological Survey, G.D. Uhlenbroek was instructed to describe the Upper Cretaceous deposits in southern Limburg; in 1905 he received his PhD on geological research in this region. The subdivision he published (1912; Figure 1) did not appreciably differ from that of Staring (1860).

In the years that followed nothing changed from the lithostratigraphic point of view but quarries for the cement industry were opened from c. 1875 onwards. When W.J. Jongmans & F.H. van Rummelen (1937) published the 'Bodem van Zuid-Limburg', no progress had been made. During the war (1940–1945), the Geological Bureau at Heerlen employed students in its investigations of southern Limburg geology. A few of these students focused on the numerous outcrops of Cretaceous strata. Unfortunately, there were no supervisors to properly process all collected data. Following Francken's thesis (1947), silence returned, which however does not imply that no research on the Cretaceous took place. Subsequent to Staring, much work has been done which would prove to be indispensable in later years.

In 1954, the character of Cretaceous studies changed with the establishment of the 'Maastrichtien Werkgroep'. Two years later, this working group comprised 29 prominent members, of whom Jan Hofker was asked to study the smaller foraminifera. Already between 1926 and 1932, Hofker had published extensively on foraminifera from the Upper Cretaceous of southern Limburg. Thirteen contributions appeared, all in the 'Natuurhistorisch Maandblad', a monthly journal issued by the Natuurhistorisch Genootschap in Limburg. The results of a study based on the collections of the Institut royal des Sciences naturelles at Brussels, appeared in print in 1949. In February 1955, Hofker's first paper in a new series of descriptions of foraminifera came out in the *Natuurhistorisch Maandblad*. In 1966, the 85th and last part in this series appeared. Hofker's enthusiasm, combined with the support from Bart Romein, secretary to the 'Maastrichtien Werkgroep', resulted in the 1966 monograph, which appeared as a supplement of the journal 'Palaeontographica'. Romein prepared the numerous lithological sections of that paper, illustrating all localities where samples had been collected. It was Hofker who revived the discussion on the Cretaceous–Tertiary boundary in southern Limburg. This discussion first appeared in print with the publication of lists of fossils by Binkhorst van den Binkhorst (1859, 1861). I consider myself fortunate to have been able to witness the progress of Hofker's, and especially Romein's work. Of course, Hofker and Romein were not alone: Dutch colleagues as well as those abroad studied various aspects of the Upper Cretaceous in southern Limburg.

During 1966–1975, I was responsible for the elaboration of a lithostratigraphic scheme for the Upper

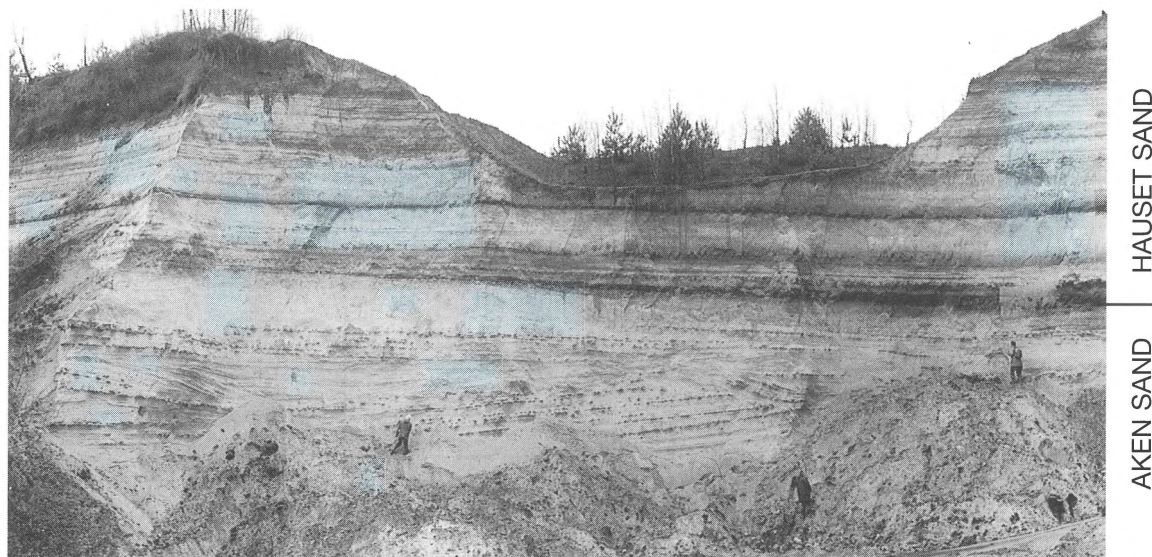


Figure 3. Large-scale channels in the Aken (= Aachen) Sand Mbr of the Aachen Fm, and regular succession of sedimentation cycles in the Hauset Sand Mbr. Bingeberg quarry, Hauset (Belgium). Persons for scale.

Cretaceous and Lower Tertiary in southern Limburg, in order to facilitate geological mapping. Earlier, I had started work on the well-exposed Cretaceous of the west bank of the River Maas (= Meuse). The first results appeared in 1975 (Table 1). The new subdivision incorporated the outcome of previous studies, but was more formal and met internationally agreed standards (Felder 1975a, b). The larger lithostratigraphic units were referred to as formations, named after towns and villages in the area. These formations were then subdivided into mappable members, which in turn were broken down into sets of beds sharing more or less characteristic features. Names for the surfaces between successive units were newly added (Table 1, Figure 1). These are the so-called lithostratigraphic horizons. This was done so as to be able to illustrate the effect of depositional interruptions. For instance, the bioturbation zone directly below the Bovenste Bos Horizon is linked primarily to the base of the overlying Vylen Member and not to any feature of the underlying sediments (Figure 1).

Lithostratigraphic overview

All Upper Cretaceous deposits in southern Limburg consist of fining-upward cycles, and a number of mega- and minicycles may be distinguished. It is my view that deposition in both cycle types started off under relatively high-energy conditions, and ended in low-energy settings.

In stratigraphic order, I shall now briefly discuss the various formations, and some of their members. For a complete overview reference is made to Albers & Felder (1979).

Aachen Formation

At the base of the Aachen Formation, lie the unmistakably terrestrial deposits of the so-called Hergenrath Clay Member, which comprises an alternation of clays, sands and intermediate sediment types. Locally, this member contains rootlet beds, of which some are covered by thin lignite layers.

Resting on these terrestrial strata, are the marine sands of the Aachen Member. These sands are characterised by many bioturbation structures (Figure 2). In the lower part, decametre-scale channel structures occur (Figure 3). From the base of the overlying Hauset

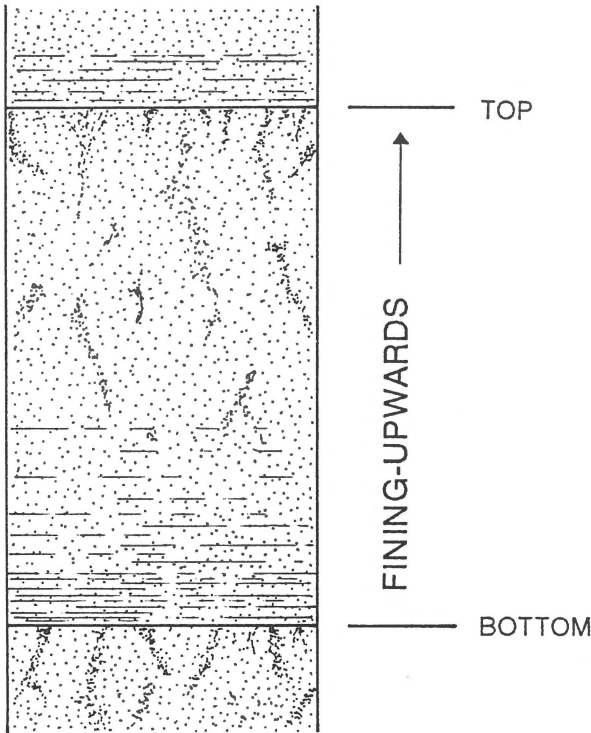


Figure 4. Example of a sedimentation cycle in the Hausset Sand Mbr of the Aachen Fm. Legend in Figure 5. Cycle thickness varies from 0.3 to 1 m.

Sand Member upward, these structures disappear and are replaced by horizontally bedded cycles, which are more or less distinctly characterised by the same rhythmic structure (Figures 3, 4). Locally, these cycles are cut by shallow and small channels.

Vaals Formation

Recent geological mapping has shown that the Vaals Formation rests disconformably upon the Aachen Formation. At the base of the Vaals Formation, occurs a conglomerate, consisting mainly of more or less strongly rounded quartz pebbles. A few clay-rich sandy sedimentation cycles rest on top of this conglomerate in the type area of this formation. They change upwards fairly rapidly into silty, fine-sandy, glauconite-rich cycles, of which the stratification is identical to that in the sands of the Aachen Formation (Figure 6). The structure is well visible on account of the glauconite abundance (Figure 7). In general, the thickness of the cycles exceeds that of the Aachen Formation cycles; it varies from 0.5 to 2 m.

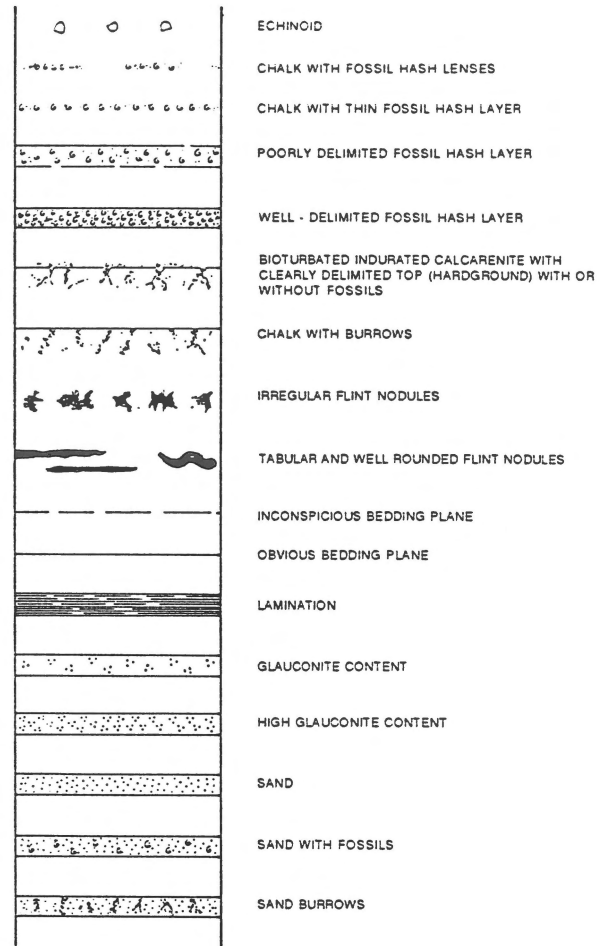


Figure 5. Lithological legend used in Figures 4, 6, 8, 10, 11, 15 and 17.

H.J. Albers (1970, 1974), who studied the Vaals Formation in detail, was able to distinguish six sand members (Table 1). In general, detailed research of the Vaals Formation is difficult: not being economically interesting, these deposits are rarely well exposed.

Gulpen Formation

Just as between the Aachen and Vaals formations, a hiatus occurs between the Vaals and Gulpen formations. In most of southern Limburg, the Gulpen Formation rests more or less unconformably on the Vaals Formation. The Gulpen Formation may be subdivided into seven chalk members of varying thickness (Table 1), comprising several sediment types. Our current knowledge of these deposits is limited. A few remarks must suffice.

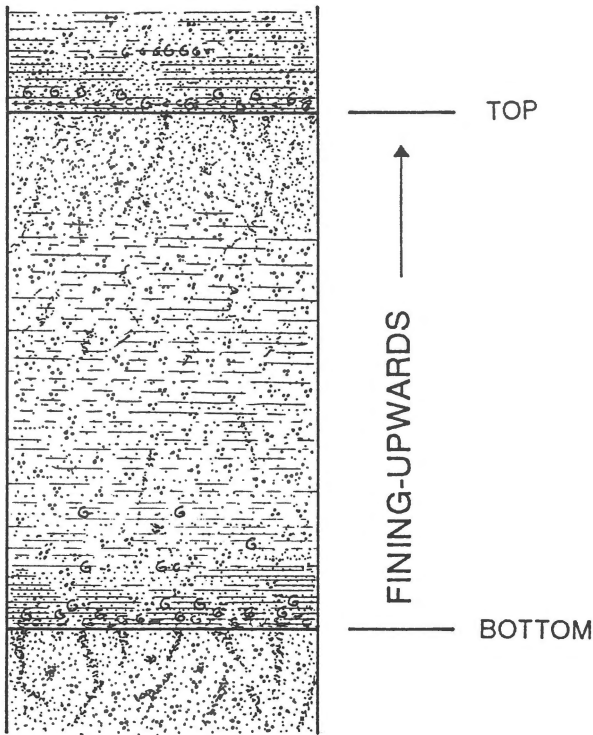


Figure 6. Example of a sedimentation cycle in the Vaals Fm, Eschberg- Vaals. Legend in Figure 5. Cycle thickness varies from 0.5 to 2 m.

With the deposition of the Gulpen Formation began the sedimentation of more or less pure chalks in southern Limburg.

Zeven Wegen Member

This member, the basal one of the formation, consists entirely of so-called 'white chalk'. The stratification of this member has not yet been studied in detail. On (macro)fossil evidence it has become apparent that a rhythmic structure occurs in this member. This, however, is difficult to see on account of the uniform character of the very fine-grained sediment.

Beutenaken Member

The Beutenaken Member is only found in a few places, resting on the Zeven Wegen Member. It consists of fine-grained sandy and glauconitic calcisiltites.

Vylen Member

Prior to and during deposition of the Vylen Member, large-scale tectonic movements must have occurred. At a number of places, and before the Vylen Member sedi-

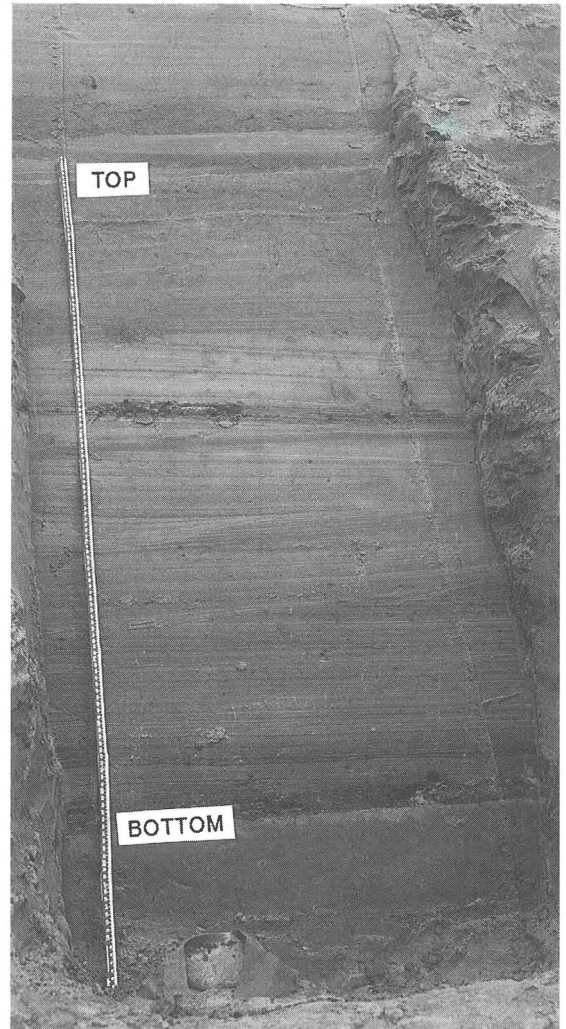


Figure 7. Sedimentation cycle in the Vaals Fm, Eschberg-Vaals. Measuring rule is 1.5 m.

mentation, erosion must have removed the entire previously deposited Upper Cretaceous (Figure 1). Studies of outcrops, and especially of borehole cores, show that this member is characterised by sedimentation cycles which closely resemble those of the Vaals Formation (Figure 8). The difference is that a silty to fine-grained, calcareous and glauconitic sand is involved in the latter formation, while the Vylen Member consists of fine-grained glauconitic chalk (calcisiltite to pure calcilutite). In the upper part of this member the glauconite content is almost nil.

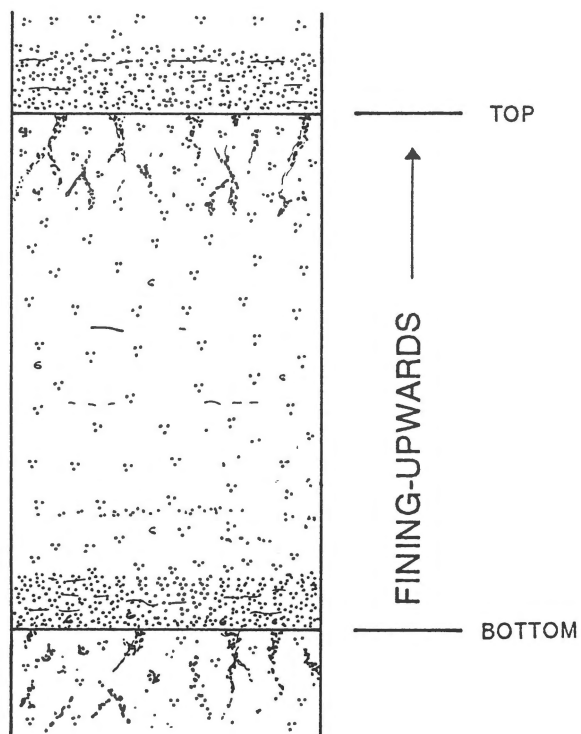


Figure 8. Example of a sedimentation cycle in the Vylen Mbr of the Gulpen Fm. Legend in Figure 5. Cycle thickness varies from 0.5 to 4 m.

Lixhe Members

The three Lixhe members are well exposed in the southwest of southern Limburg, and less well exposed in the east, where a well-developed conglomerate occurs at their base. This conglomerate decreases in thickness to the west, where the base of the members is formed by the first layer of black-grey flints. The members consist of uniform calcilutite with beds of extremely irregularly shaped black-grey flint concretions (Figure 9).

In the lower part, these flint-bearing beds are 10 to 15 cm thick. Towards the top this thickness increases to 15 to 30 cm. All flint-bearing layers may be ascribed to bioturbation. A detailed study of these cycles reveals a rhythmic succession (Figure 10). This is especially apparent in the Lixhe 3 Member (Figure 11), which is divisible into five subunits, separated by 30 to 40-cm-thick chalk beds without flints. Within these subunits, four to six cycles, each with a more or less clearly developed flint layer, occur. Zijlstra (1994) assumed the subunits to have comprised ideally five small-scale layers, as is the case in subunit 4.

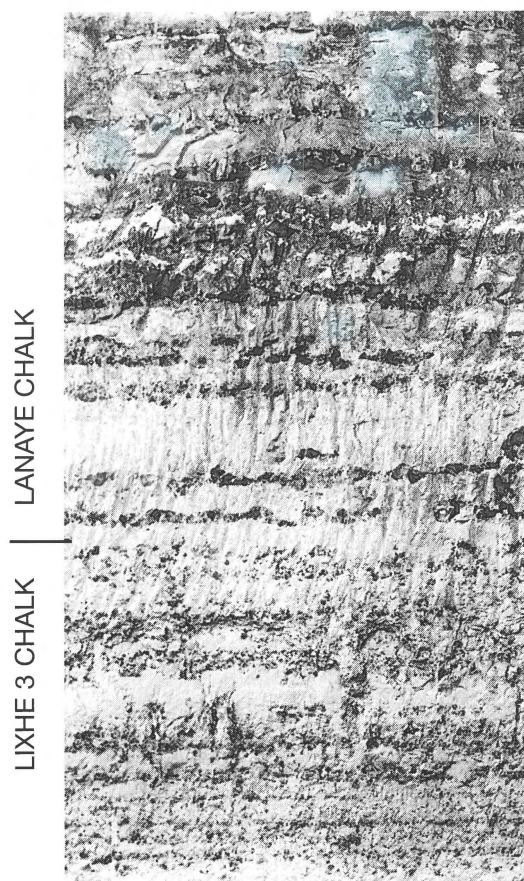


Figure 9. Flint beds in the Lixhe 3 and Lanaye members of the Gulpen Fm as exposed at the ENCI quarry (Maastricht). Height of photographed part of exposure is c. 10 m.

Lanaye Member

In the uppermost part of the Lixhe 3 Member, a change in sediment becomes apparent. The overlying Lanaye Member is clearly different: not only are the flint and the chalk layers thicker, but the latter are also entirely flint-free (Figure 9).

Especially in this member and in the lower part of the overlying Maastricht Formation, the separate sedimentation cycles are easily seen under favourable outcrop conditions. Figure 12 shows the lateral development of such cycles. In the southwest, only sequence types 1 to 4 occur, in the northeast only types 5 to 7.

In the southwest, the layering depends on grain size. There are clear indications that 'fining upwards' sequences occur and that part of the flint correlates with biogenic structures within the sediment. Towards the northeast, the sand, silt and clay content increases

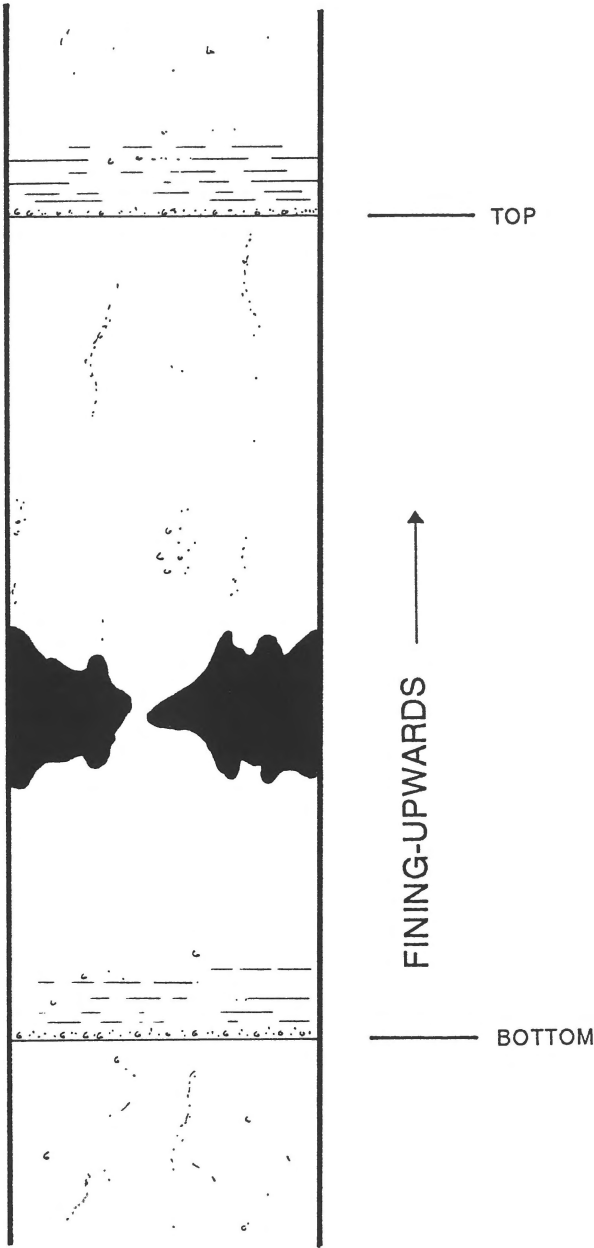


Figure 10. Idealised representation of a sedimentation cycle in the Gulpen and Maastricht formations (Lixhe and Lanaye members, and Valkenburg to Emael members). Legend in Figure 5. Cycle thickness is generally 0.2 to 2.5 m.

slightly (to c. 1.5 %), whilst flints disappear and hard-grounds develop in the uppermost parts of the cycles.

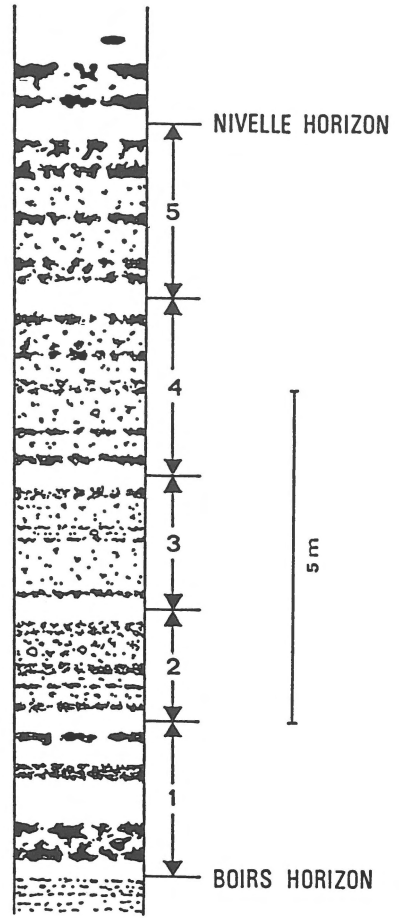


Figure 11. Development of sedimentation cycles in subunits 1 to 5 of the Lixhe 3 Mbr of the Gulpen Fm. Legend in Figure 5.

Maastricht Formation

In the southwesternmost Cretaceous outcrops in southern Limburg, the cyclic pattern which characterises the upper part of the Gulpen Formation continues in the Maastricht Formation. Towards the northeast, a hiatus occurs at the base of the Maastricht Formation (Figure 13), which near Heerlen lies directly on the Carboniferous. This base is characterised by a glauconitic layer of fossil hash. As early as the beginning of the last century, this layer attracted the attention of geologists, and it is referred to in the literature of those days as the ‘Coprolietenlaagje’ (coprolite bed) (Figure 14).

The Maastricht Formation has been subdivided into six members. I will briefly discuss two of these, the Schiepersberg and Meerssen members (Table 1).

MAASTRICHT CHALK | KUNRADE LIMESTONE

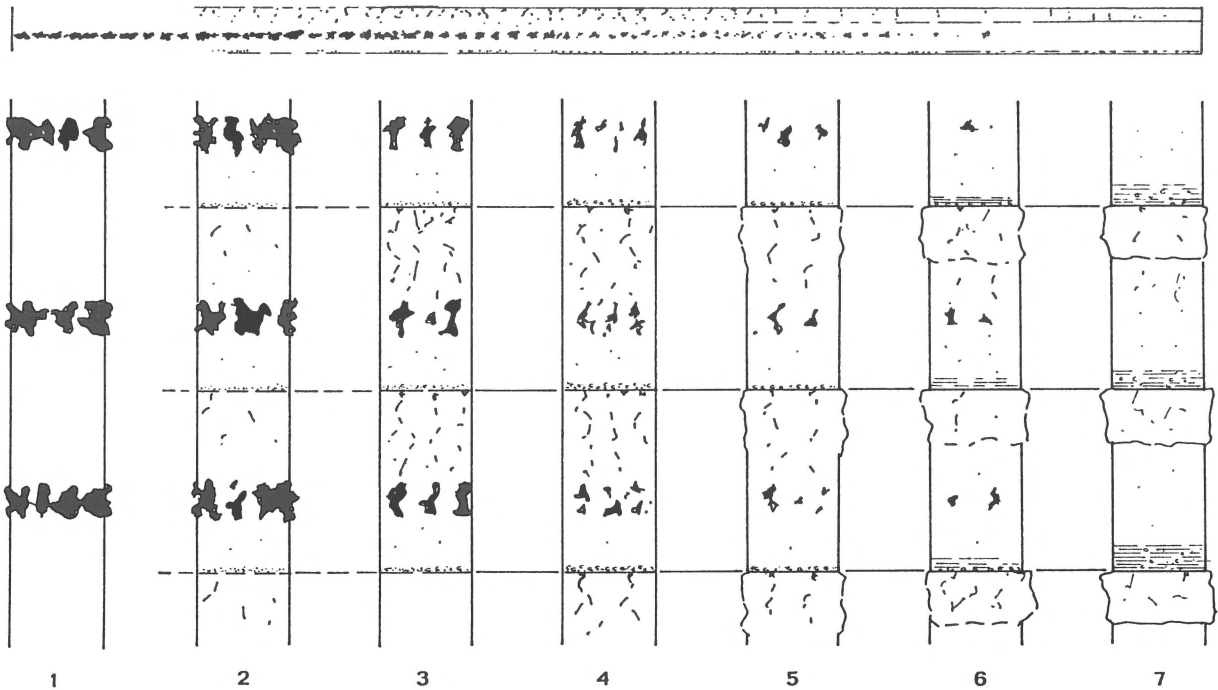


Figure 12. Schematic development of two sedimentation cycles in the lower part of the Maastricht Fm (Valkenburg to Emael members) between Maastricht (1) and Heerlen (7). Legend in Figure 5. Cycle thicknesses vary from 0.2 to 2.5 m. Continuous profile shown at the top shows lateral development of a single cycle on a different scale. Cycle boundaries are difficult to locate in the southwest, and distinct in the northeast.

Schiepersberg Member

The stratification of this member corresponds more or less to that of the underlying Gronsvelde and overlying Emael Member (Table 1). At the base, a more or less clearly recognisable thin layer of fossil hash occurs which can be traced over large distances throughout southern Limburg (Figure 15). Following upon this hash, are a number of disconformable calcarenite cycles, which incise into one or more underlying cycles. Towards the top, these incisions decrease and the cycles and associated flint layers become traceable over larger distances.

Meerssen Member

At the top of the Emael Member, a lithological change sets in which via the Nekum Member eventually results in the Meerssen Member. In the lower part of this member, more irregularities in stratification are noted than in the higher part, in which the cycles are generally thicker. The Meerssen Member rests unconformably on the Nekum Member.

The Meerssen Member comprises several cycles which contain no flint, and vary in thickness from less than one to more than 7 m. At the base of each cycle, a layer of fossil hash generally occurs, with or without pebbles, originating from the underlying hardgrounds (Figures 16, 17). Going up section, again a 'fining upwards' trend is apparent in each cycle. During breaks in sedimentation, after completion of each cycle, a bioturbation zone formed at its top, which subsequently indurated to form a more or less clearly developed hardground.

The Meerssen Member, and with it the Maastricht Formation, terminates with an extremely thick fining-upward cycle (4 to more than 10 m). This cycle is the subject of current research on the Cretaceous–Tertiary (K/T) boundary in the area. I do not wish to discuss this subject here, knowing that my colleagues will report their findings soon.¹

¹ **Editor's note:** A special issue of *Geologie en Mijnbouw*, entitled 'The Cretaceous/Tertiary boundary at Geulhemmerberg in the Maastrichtian type area, SE Netherlands', and edited by H. Brinkhuis and J. Smit will appear in 1996.

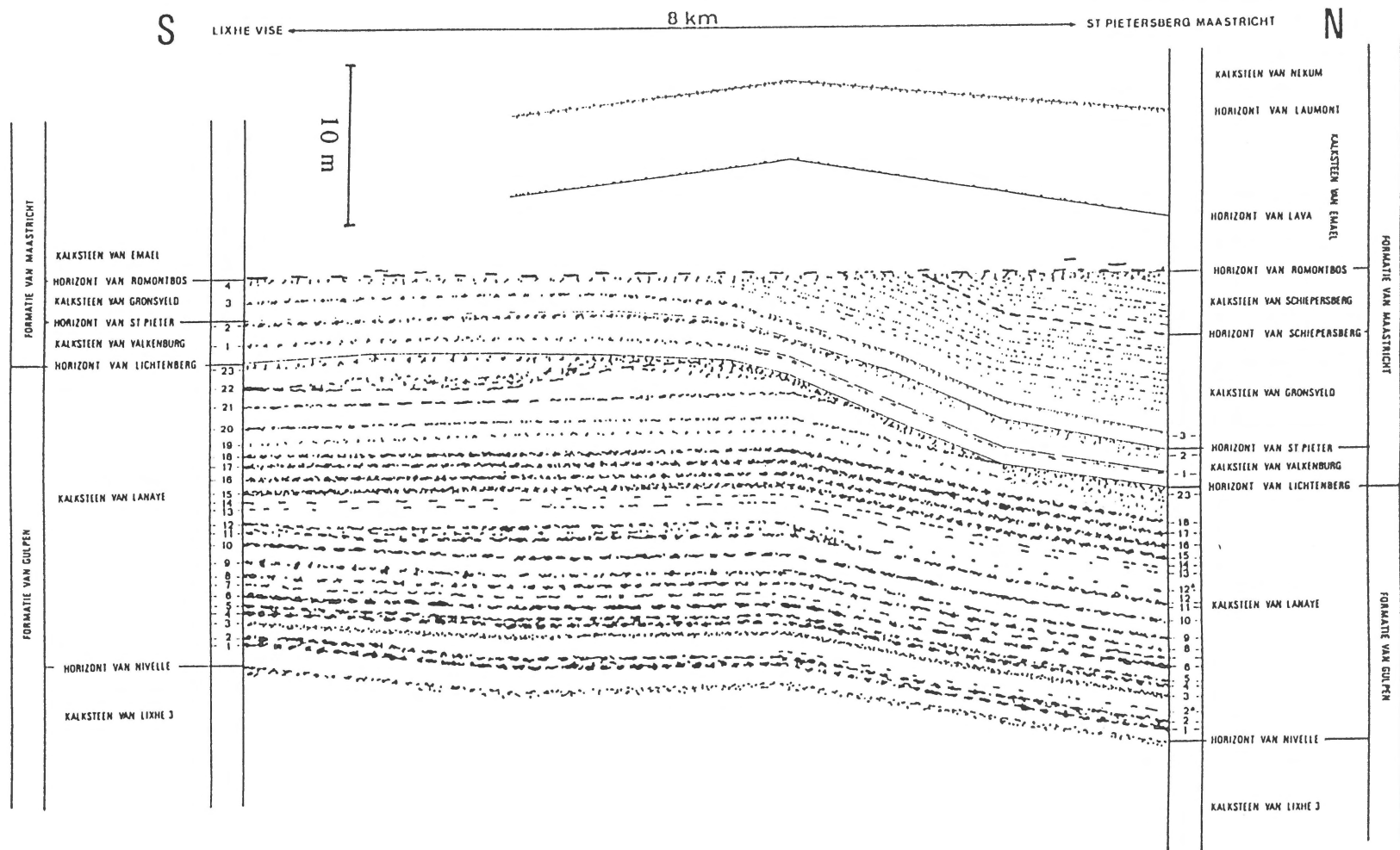


Figure 13. Schematic section showing in particular the erosional contact between the Gulpen and Maastricht formations as exposed at the ENCI (Lichtenberg section) and CBR (Lixhe) quarries. The Romontbos Horizon at the base of the Emael Mbr serves as datum line. Flint layers (black) above those at this horizon are less well exposed, and not indicated. Translations: Formatie van Maastricht = Maastricht Fm, kalksteen = limestone. Numbers in columns refer to flint layers.

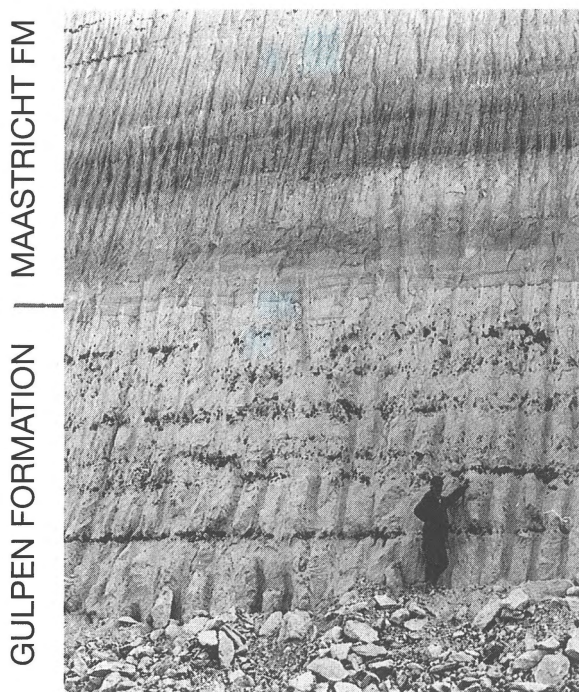


Figure 14. Boundary (Lichtenberg Horizon) between the Gulpen and Maastricht formations as exposed at the ENCI quarry (Maastricht).

The carbonate sedimentation in southern Limburg did not end at the end of the Cretaceous. It continued and resulted in a 35 m thick sequence of early Paleocene age (Table 1).

Summary

In summary, the following may be stated:

When in 1860 Staring published Part 2 of his 'Bodem van Nederland', a workable lithostratigraphic subdivision of the Upper Cretaceous in southern Limburg became available. Many of Staring's rock units are still in use today, be it under partly different names.

The micropalaeontological studies by Hofker during the years 1946–1966, supported by Romein, provided the basis for new lithostratigraphic research and also led to renewed discussions on the Cretaceous–Tertiary boundary.

During my investigations many new data have been collected on the often complex stratification of the various sediments. A detailed lithostratigraphic nomenclature has been introduced. The causes of many of the observed features still remain subjects for future studies.

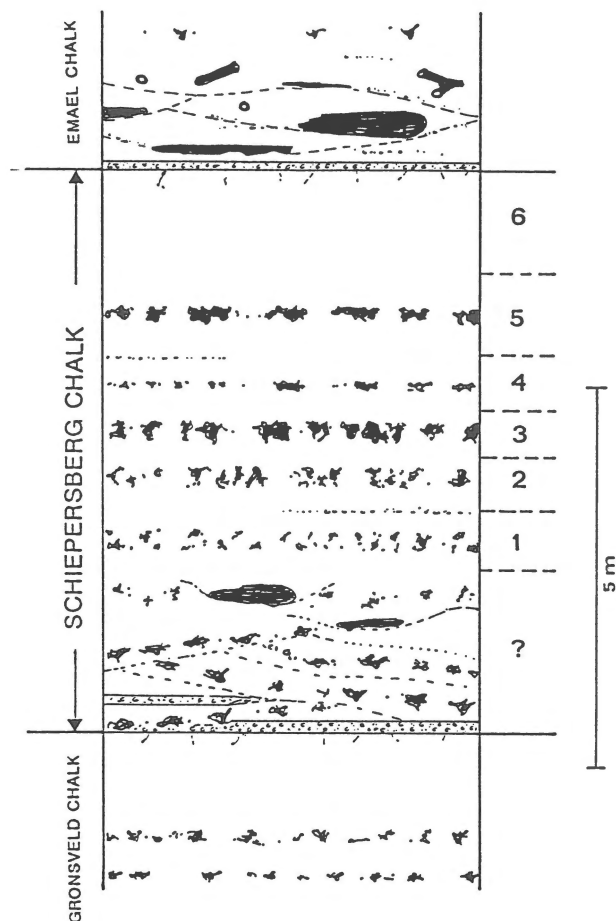


Figure 15. Sedimentation cycles (numbered 1 to 6) in the Schiepersberg Mbr of the Maastricht Fm. Legend in Figure 5.

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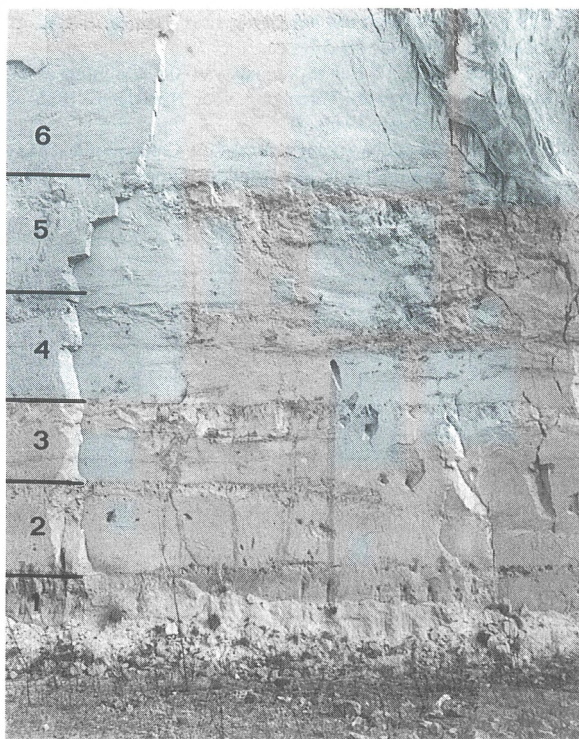


Figure 16. Sedimentation cycles in the lower part of the Meerssen Mbr; Curfs quarry near Geulhem. Height of photographed part of exposure is c. 7 m.

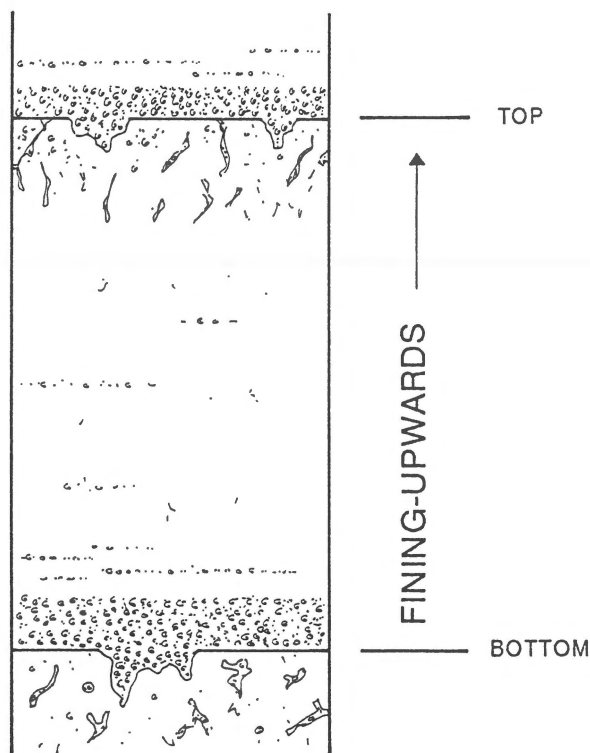


Figure 17. Sedimentation cycle in the Meerssen Mbr of the Maastricht Fm. Legend in Figure 5. Cycle thickness generally varies from 0.5 to 4 m, and reaches exceptionally 9 m.

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