

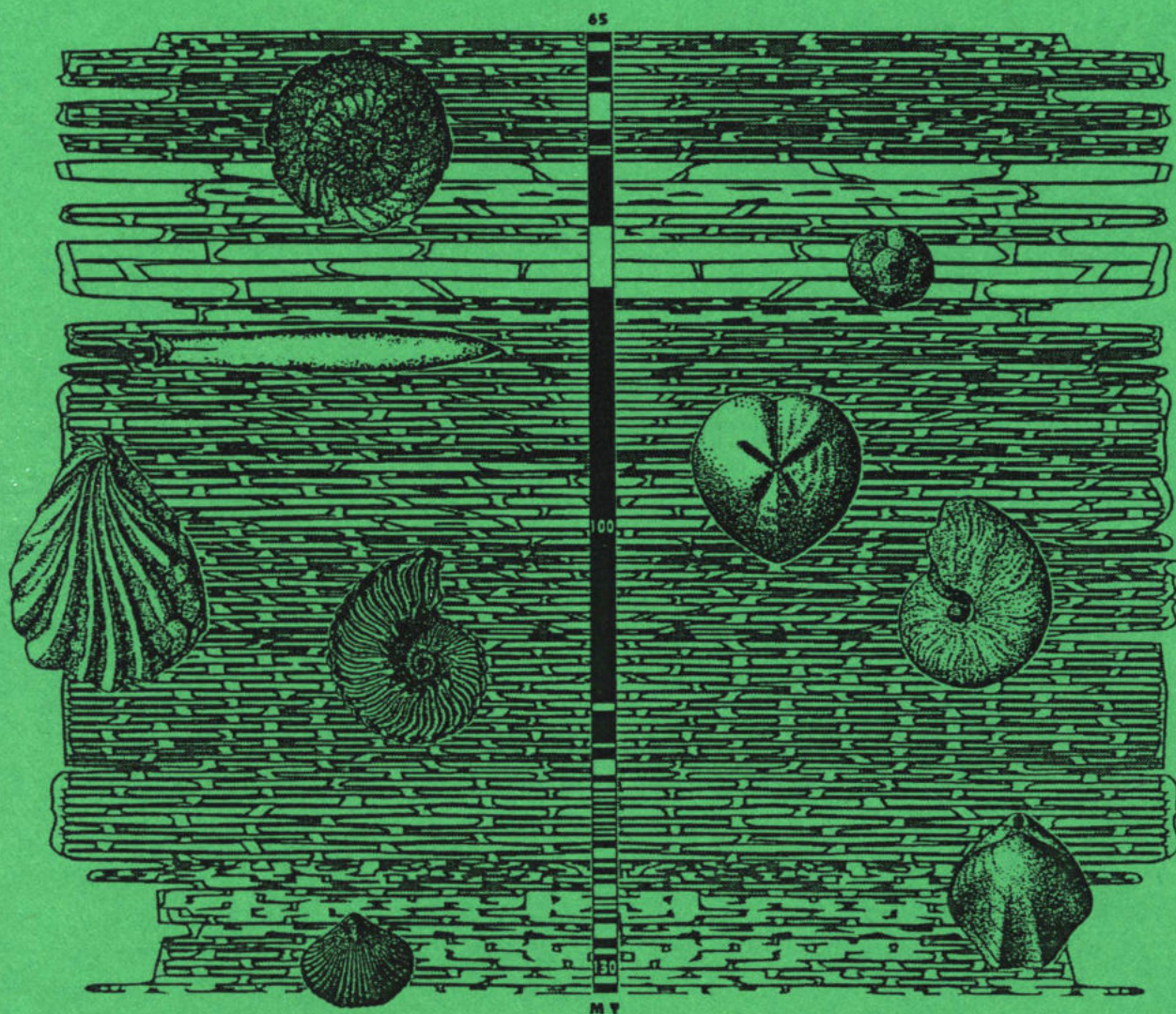
**A1**

Saturday

**9**

**Excursion to Maastricht**

Second International Symposium on  
**CRETACEOUS STAGE BOUNDARIES**



Local organiser: Annie V. Dhondt

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THE MAASTRICHTIAN OF THE  
TYPE AREA (SOUTHERN LIMBURG,  
THE NETHERLANDS):  
RECENT DEVELOPMENTS

Field excursion A1, September 9, 1995

Second International Symposium on  
Cretaceous Stage Boundaries

BRUSSELS, 8 - 16 September 1995

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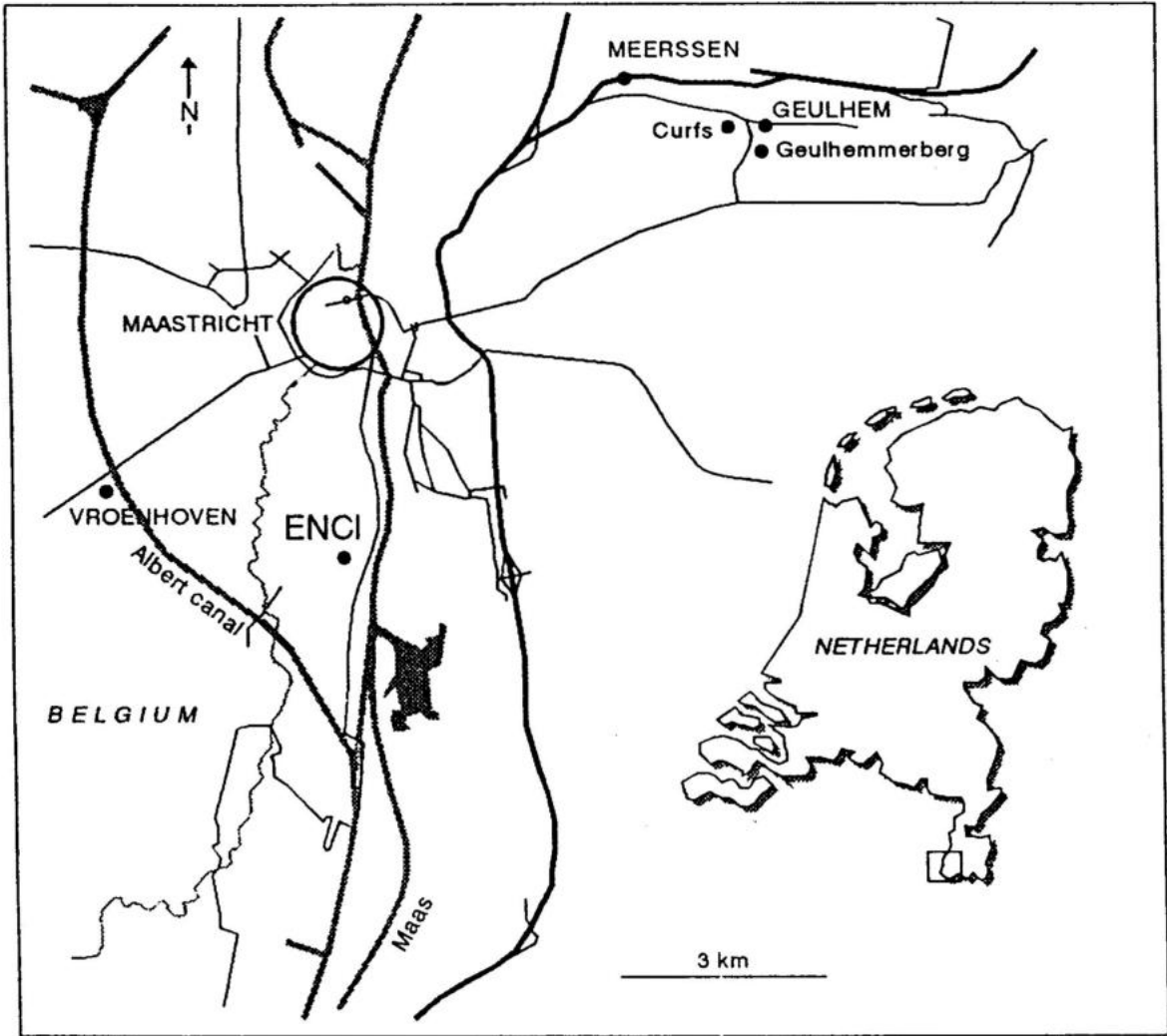


Fig. 1. Locality map of the Maastricht-Geulhem area (southern Limburg, The Netherlands), showing location of the ENCI Nederland BV quarry south of Maastricht, and of the Ankerpoort/Curfs quarry and Geulhemmerberg underground workings near Geulhem (modified from JAGT *et al.*, in press).

## Field excursion A1

### THE MAASTRICHTIAN OF THE TYPE AREA (SOUTHERN LIMBURG, THE NETHERLANDS): RECENT DEVELOPMENTS

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#### INTRODUCTION

The group of stratigraphers and palaeontologists informally referred to as the 'Maastricht Groep' comprises representatives of a number of institutions, amongst which are the Vrije Universiteit Amsterdam, the Universiteit Utrecht, the Nederlandse Aardolie Maatschappij (NAM), the Rijks Geologische Dienst, the Natuurhistorisch Museum Maastricht, the Koninklijk Belgisch Instituut voor Natuurwetenschappen and the Université d'Etat à Liège. This group currently recognises three major key sections for the Upper Cretaceous (Santonian-Maastrichtian) and Lower Palaeocene of the type area of the Maastrichtian Stage, here extended to include parts of the Belgian provinces Liège and Limburg and the Aachen area (Germany).

Two of these key sections, the ones exposed at the ENCI Nederland BV (Maastricht) and Ankerpoort/Curfs quarries (Geulhem), will be visited during this field trip. The emphasis is on the biozonation of the type Maastrichtian and on recent developments with regard to the Cretaceous-Tertiary (K/T) boundary in the area.

Santonian, Campanian and Lower Maastrichtian strata have been the subject of various recent stratigraphic and palaeontological studies (e.g. KEUTGEN & VAN DER TUUK, 1991). In particular, the intricate facies relationships of the Vijlen Member (of Early to early Late Maastrichtian age) in its type area have been unravelled using bioclasts and benthic foraminifer assemblages (P.J. FELDER & BLESS, 1994). The so-called 'Vijlen Werkgroep' is currently working out a biozonation for the Vijlen Member and correlation with the NW German white chalk standard section (SCHULZ *et al.*, 1984). Field work is concentrated on (disused) quarries and outcrops in southern Limburg and contiguous areas in Belgium and Germany (Aachen area): interim reports (see JAGT *et al.*, 1995) will be published by this working group. In addition, attempts have been made to determine the extent of the Zeven Wegen Member (Gulpen Formation) into the late Campanian (KEUTGEN, in prep.)

In view of the fact that Santonian, Campanian and Lower Maastrichtian strata are comparatively poorly exposed in the area, the emphasis of the present field trip will be on the Upper Maastrichtian and on a K/T boundary section.

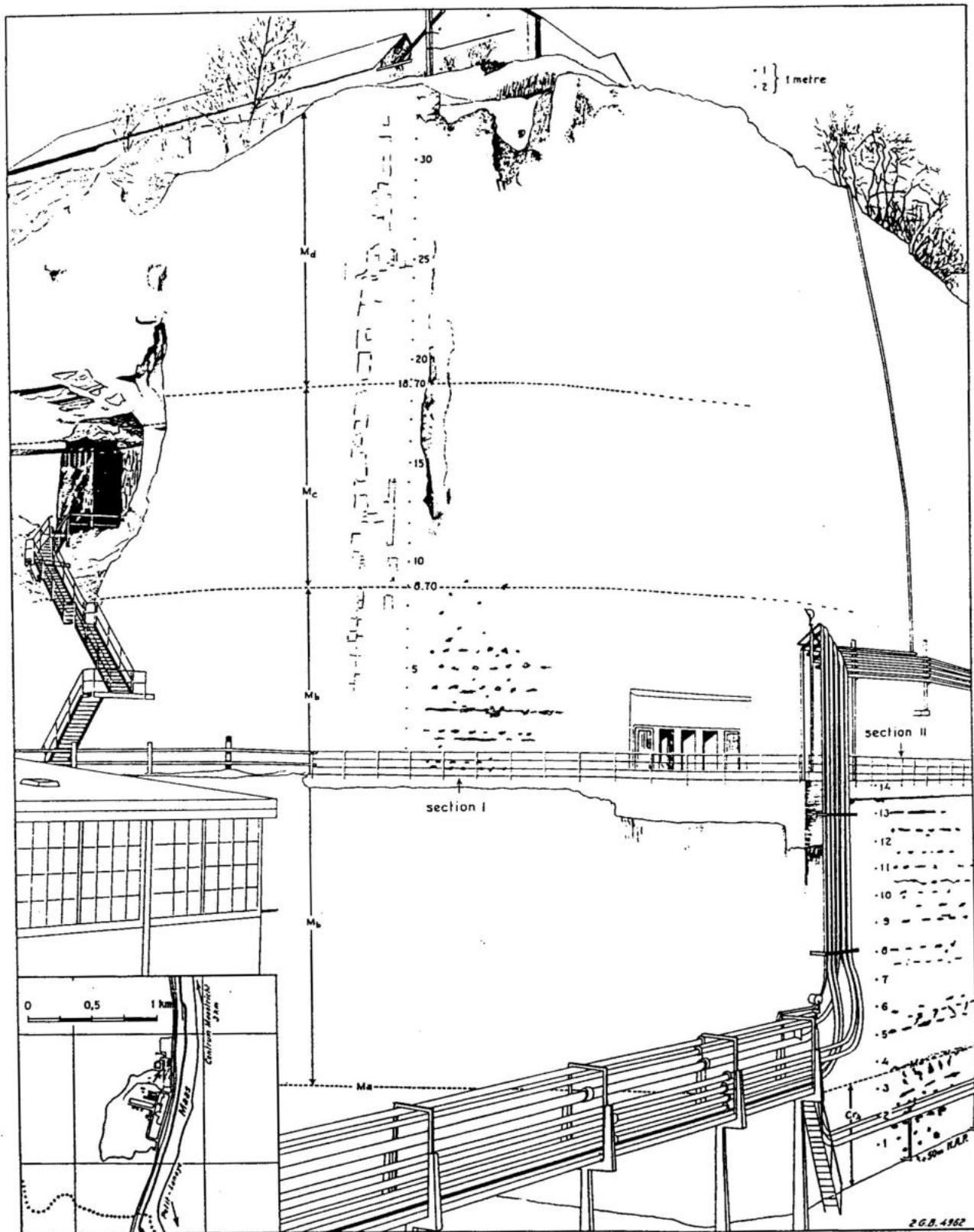


Fig. 2. Simplified lithostratigraphic log of the steep rock face exposed below Lichtenberg farm (Sint Pietersberg, Maastricht), being the type section of the Maastrichtian Stage, behind the main office building of the ENCI Nederland BV cement company (after ROMEIN, no date, excursion guide), showing UHLENBROEK'S (1912) Cr4, Ma, Mb, Mc and Md units, corresponding to the Lanaye Member (Gulpen Formation), Valkenburg/Gronsveld/Schiepersberg/Emael, Nekum and Meerssen members (Maastricht Formation), respectively.

		Oost West van de Maas		Uhlenbroek 1912	Hofker 1966		
FORM. VAN HOUTHEM		Kalksteen van Geleen	Vc	Xlw	Md	R	
		Kalksteen van Bunde	Vb			Q	
		Kalksteen van Geulhem	Va			P	
FORM. VAN MAASTRICHT	Boven	Kalksteen van Meerssen	IVf	Xw	Mc	N L M	
		Kalksteen van Nekum	IVe	IXw		K	
	Onder	Kalksteen van Emael	IVd	VIIIw	Mb	Ma	I
		Kalksteen van Schiepersberg	IVc				J
		Kalksteen van Gronsveld	IVb				H
		Kalksteen van Valkenburg	IVa				G
	FORMATIE VAN GULPEN	Boven	Kalksteen van Lanaye	IIIg	VIIw	Cr4	F
			Kalksteen van Lixhe 3	III f	VIw		
Kalksteen van Lixhe 2			III e	Vw			
Kalksteen van Lixhe 1			III d	IVw			
Onder		Kalksteen van Vylen	III c	IIIw	Cr3b	D C B	
		Kalksteen van Beutenaken	III b				
		Kalksteen van Zeven Wegen	III a	IIw			
FORMATIE VAN VAALS	Boven	Zand van Benzenrade	IIg	Iw	Cr2	A'	
		Zand van Terstraten	II f				
		Zand van Beusdal	II e				
	Onder	Zand van Vaalsbroek	II d				
		Zand van Gemmenich	II c				
		Zand van Cottessen	II b				
		Zand van Raren	II a				
FORMATIE VAN AKEN	B	Zand van Hauset	Ic		Cr1		
		Zand van Aken	Ib				
	O	Klei van Hergenrath	Ia				
						Horizont v. Hergenrath	

Fig. 3. Lithostratigraphy of the Upper Cretaceous (Santonian-Maastrichtian) and Lower Palaeocene (Danian) strata in southern Limburg (The Netherlands) and contiguous areas (ALBERS & W.M. FELDER, 1979; adapted 1995, W.M. FELDER, pers. comm.). Previous lithostratigraphic units proposed by UHLENBROEK (1912) and HOFKER's (1966) benthic foraminifer zonation are also shown in the right-hand columns.

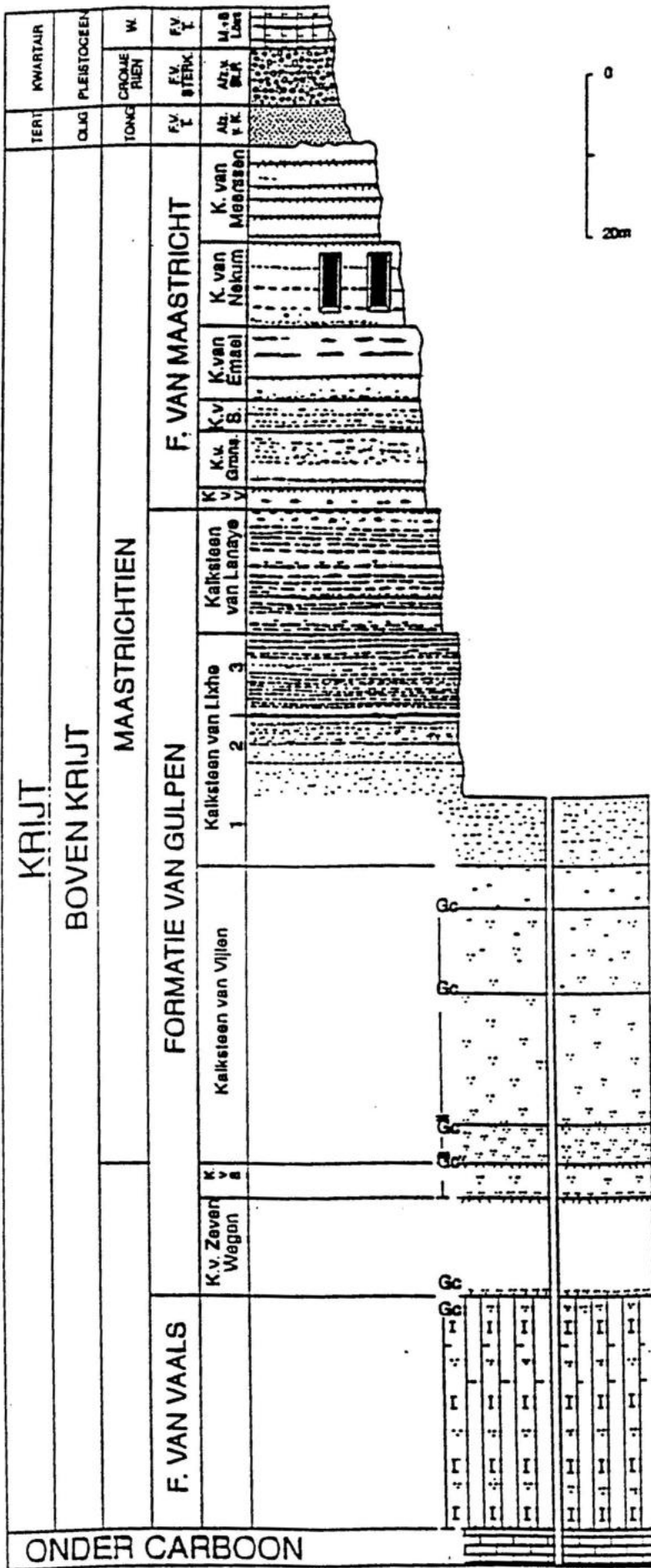
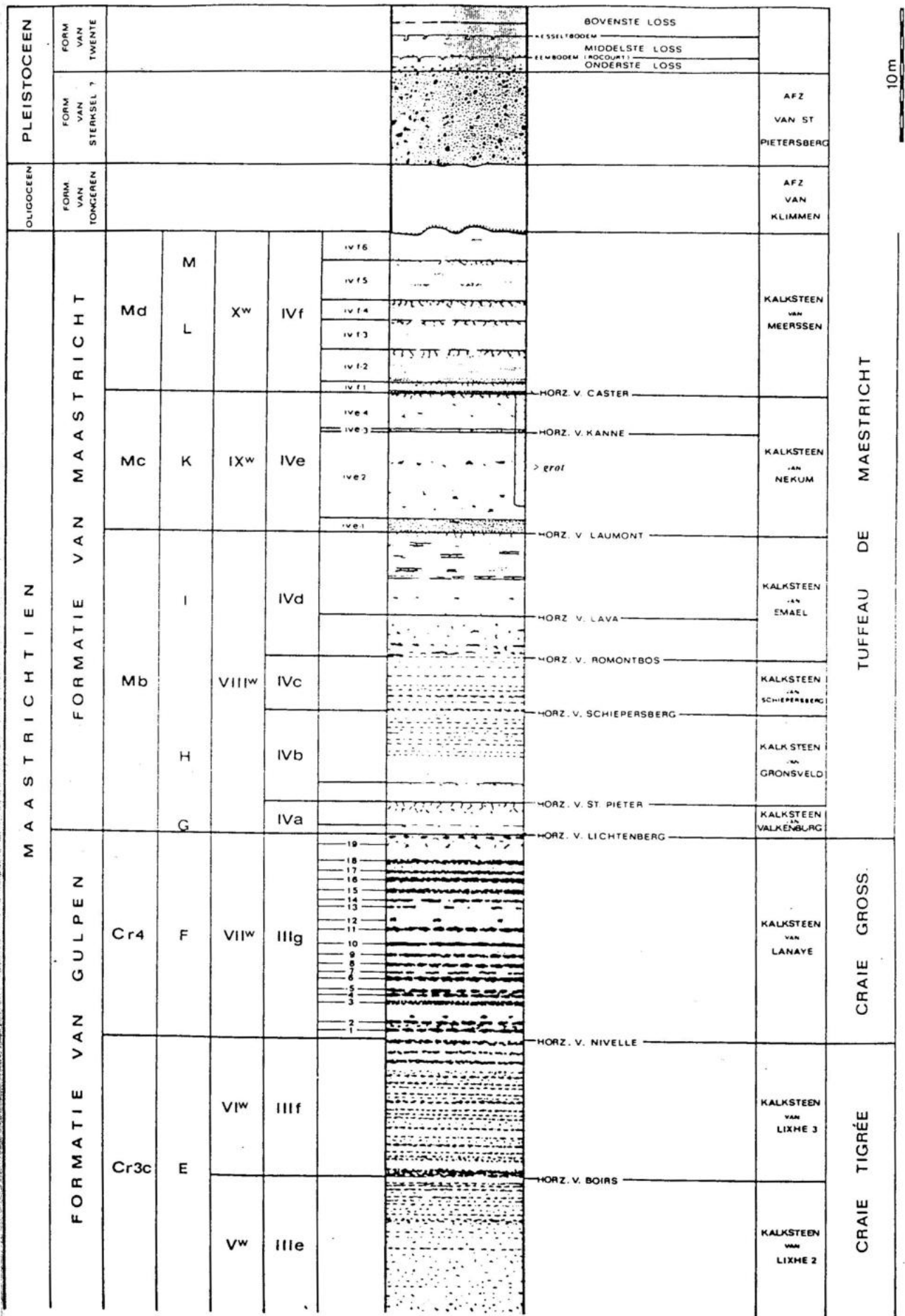


Fig. 4.

Extended lithostratigraphic log for the ENCI Nederland BV quarry, showing strata penetrated in borehole, extending into the Lower Carboniferous basement (W.M. FELDER, unpubl.).



10m

Fig. 5. Lithologic log for the section exposed at the ENCI Nederland BV quarry (Maastricht); current quarrying activities in the southeastern corner expose the upper part of the Lixhe 1 Member (Gulpen Formation).

# ENCI MAASTRICHT 61F-19

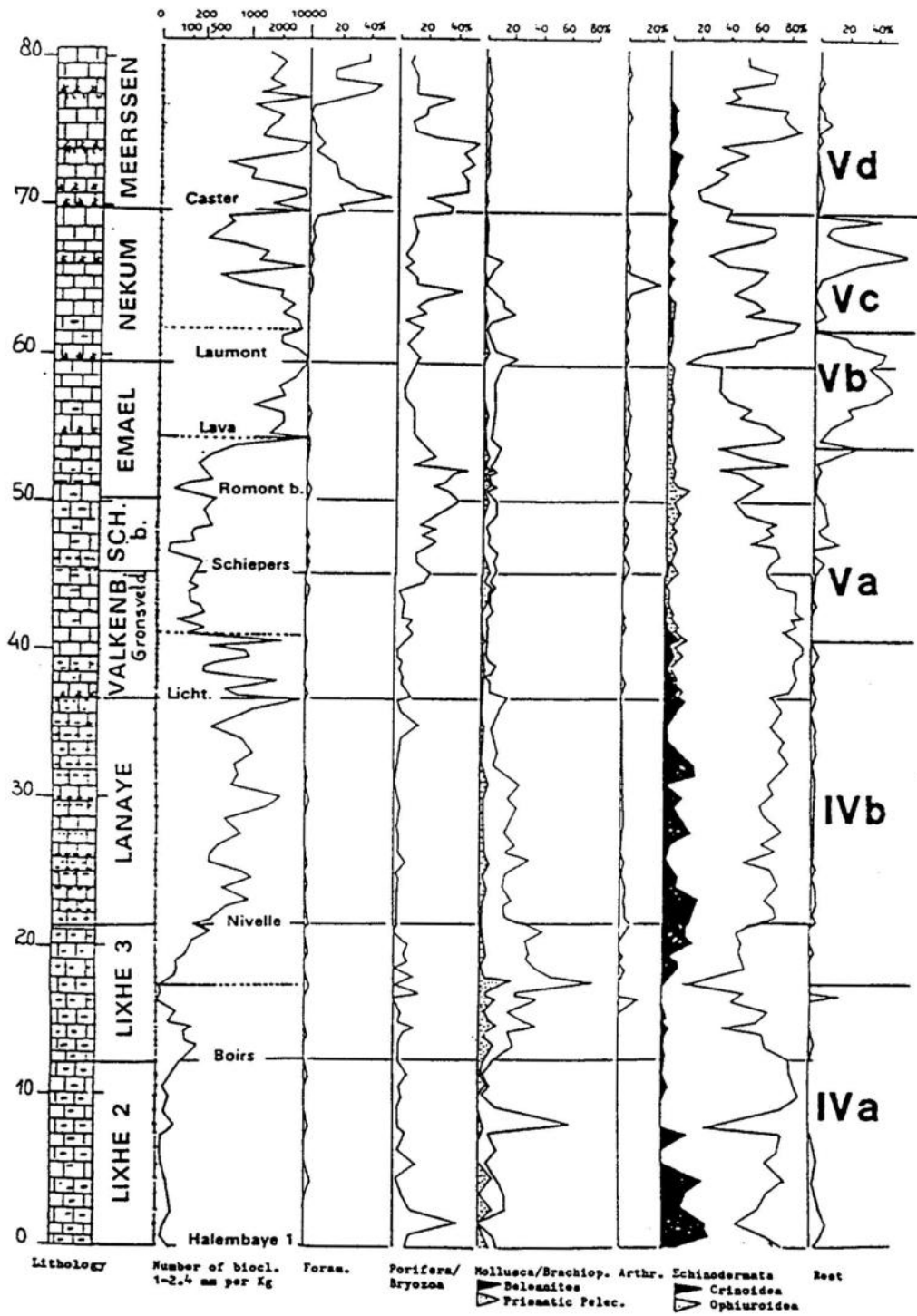


Fig. 6. Bioclast analyses and ecozonation of the section exposed at the ENCI Nederland BV quarry (after P.J. FELDER).

## Locality 1

### ENCI NEDERLAND BV QUARRY Maastricht (Limburg, The Netherlands)

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Rijks Geologische Dienst/Kartering (Geologisch Bureau Heerlen), file number 61F-19; topographical map of The Netherlands, 1:25.000, sheet 61F Maastricht, co-ordinates 176.000/315.000.

This extensive quarry of the ENCI cement company (Eerste Nederlandse Cement Industrie), south of Maastricht (Fig. 1), includes the type section of the Maastrichtian Stage (DUMONT, 1849) as currently defined, which comprises the steep rock face directly behind the main office building, below the Lichtenberg farm (Fig. 2). Collecting from all lithostratigraphic units of the Maastricht Formation as well as of the underlying Lixhe 1-3 and Lanaye members of the Gulpen Formation (in W.M. FELDER's [1975] and ALBERS & FELDER's [1979] terminology; see Fig. 3) is best done in the adjoining quarry. Conditions of exposure there change rapidly on account of quarrying activities and where virtually the entire section is easily accessible.

The deepest pit of the quarry, in the southeastern corner, currently exposes the Lixhe 1-3 and Lanaye members of the Gulpen Formation. Plans are being made to deepen the quarry even further during future years. A borehole sunk a few years ago has demonstrated the presence of the Vijlen, Beutenaken and Zeven Wegen members (Gulpen Formation), of early Maastrichtian, and late Campanian age, respectively (see Rijks Geologische Dienst, 1984; Fig. 4).

A lithologic log (with lithologic units and benthic foraminifer zones) of the section exposed at the ENCI quarry, the result of bioclast analyses with definition of ecozones and the number of (precession) cycles per interval and estimated average rate of deposition are illustrated in Figs 5 to 7.

The most detailed studies describing the section exposed at the ENCI quarry are those of VILLAIN (1977) and ZIJLSTRA (1994). With regard to sedimentology and interpretations of sedimentary environments, data presented below are taken from these two papers. Added are personal observations on macropalaeontology and biozonation.

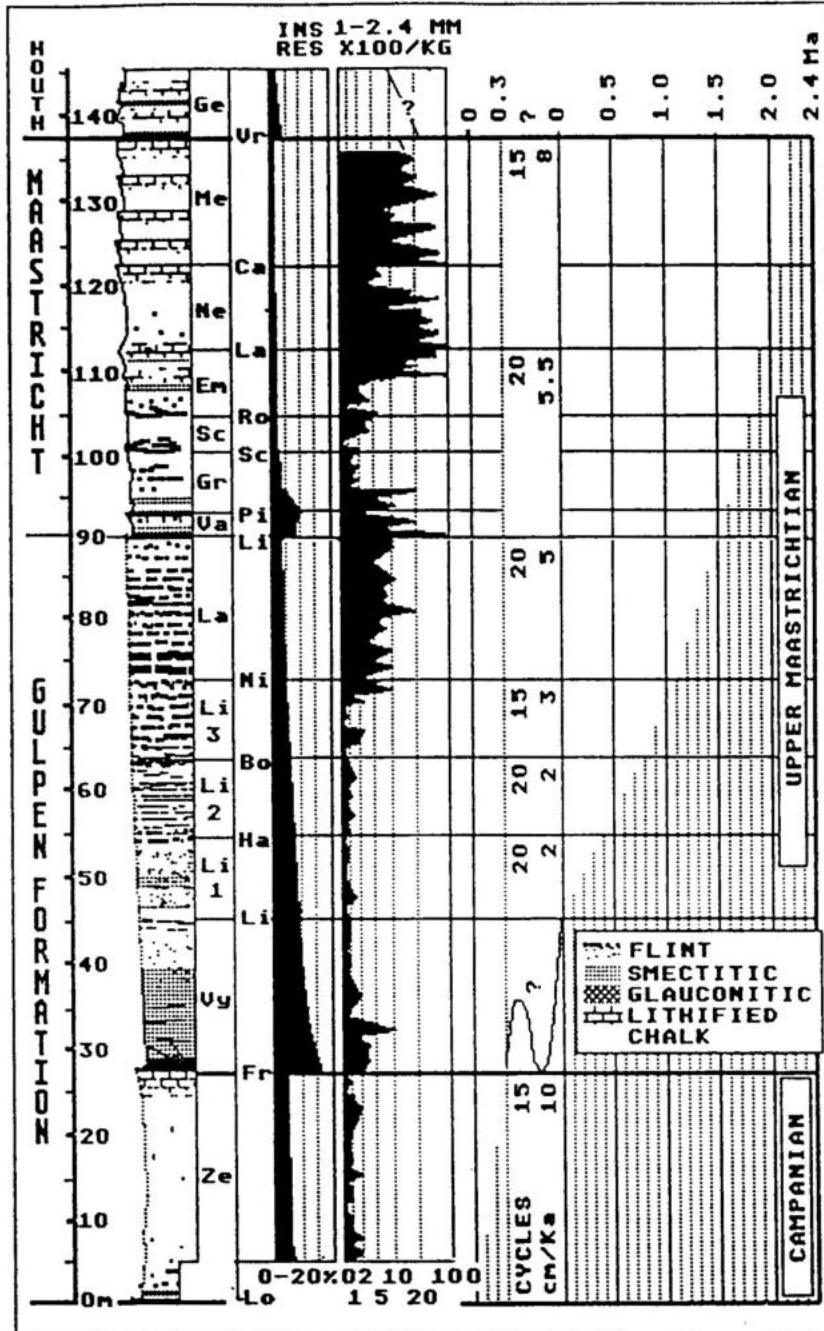
## 1 - GULPEN FORMATION

### 1a - LIXHE 1-3 MEMBERS (late Maastrichtian)

VILLAIN (1977) typified the 'Craie tigrée' (= Lixhe Members) as a biomicrite (wackestone), deposited in a setting with oceanic influence (based on the occurrence of calcareous nannofossils and planktonic foraminifers), but without transport or horizontal currents. Palaeodepth was considered to have been between 80 and 150 m.

ZIJLSTRA (1994) interpreted the Lixhe 3 Member as a pure coccolithic wackestone, with silt-sized bioclasts, horizontal flint beds, and considered it to be homogeneously bioturbated (*Planolites*, *Zoophycos*, *Chondrites*, *Bathichnus* and *Thalassinoides* type deep burrows). Since the Lixhe 3 Member occurs mostly below the present-day ground water table, it is dark grey in colour and still contains reduced iron (pyrite, smectite and glauconite).

The genesis of flint was studied in detail by ZIJLSTRA (1987, 1994) in the upper part of the Gulpen Formation (Lixhe and Lanaye members), which shows a regular succession of c. 75 thickening-upwards, continuous flint layers (Fig. 5). These nodule layers are



(from ZIJLSTRA, 1994)

Fig. 7. Composite lithostratigraphic column of the Gulpen Formation (Late Campanian and Middle to Late Maastrichtian, quarry North), Maastricht Formation (Late Maastrichtian, quarry ENCI) and Houthem Formation (Danian, quarry ENCI and quarry Curfs). The Maastrichtian s.s. of Dumont (1849) is equivalent with the Maastricht and Houthem Formations. Left of the 150 m thick sequence is depicted the lithification (theoretical weathering profile). Further to the right are depicted: the lithology (see box); Members and Horizons (Felder, 1975a,b); insoluble residue (Villain, 1977); number of 1-2.4 mm large bioclasts (times 100=0-10,000) per kilogram sample (Felder, 1988); number of (precession) cycles counted per interval and estimated mean deposition rate [interval thickness (cm) / (number of cycles x 20 ka)] and; the accretion of the sediment surface during 0.3 and 2.4 million years.

considered to have formed when detrital skeletal opal dissolved during late diagenesis and concentrated in sites of relatively high early diagenetic authigenic silica polymorph concentration. These silica polymorphs precipitated in the anoxic redox zones of bacterial sulphate and/or carbon dioxide reduction, situated below and parallel to the sediment surface. The highest concentrations of authigenic silica occurred during periods when deposition rate was low, and when sediment resided for a relatively long period in the anoxic redox zone. The rhythmic vertical variation of the flint nodule concentration is held to reflect the influence of the periodic variation of the earth's orbital parameters (precession index) on climate, oceanography and periodically varying deposition rates.

ZIJLSTRA (1994) also attempted to relate the flint-rich sequence of the Lixhe and Lanaye members to the Milankovitch rhythmicity. His conclusion: the chalk with flint contains 75 flint layers, with individual members containing 20, 15, 20 and 20 flint layers, respectively, and with flint layers forming bundles of 5, suggests that this sequence may be interpreted as E4 (1,300 ka), E3 (413 ka), E2 and E1 (98 and 126 ka) eccentricity cycles and P (20 ka) precession cycles (see Fig. 7).

The Gulpen Formation as exposed south of Maastricht reaches a total thickness of some 40 m and contains about 75 precession induced sedimentary cycles. ZIJLSTRA (1994) assumed these cycles to have been deposited during approximately  $75 \times 20 = 1.5$  million years. The increase of the mean cycle thickness from 4 dm at the base to 1 m at the top of the Gulpen Formation sequence would then reflect an increase in mean deposition rate from 2 to 5 cm/ka.

To ZIJLSTRA (1994) this fine-grained chalk with a high flint concentration and symmetrical thin-bedded eccentricity cycles reflects a low-energy environment with a low deposition rate. The coarser-grained (tuffaceous) chalk, on the other hand, with a lower flint concentration and asymmetrical thick-bedded eccentricity cycles reflects a high-energy environment with high erosion/deposition rate.

The Lixhe 1-3 members yield very few macrofossils, with the exception of holasterid echinoids, coleoid cephalopods and various bivalves. Of note amongst the echinoids is the apparently sudden replacement in the Lixhe 3/Lanaye members of the genus *Echinocorys* (gr. *conoidea*) by *Hemipneustes* (*striatoradiatus* and *oculatus*). It appears that there is no overlap in their ranges, and that there is even a part of section which does not yield representatives of either genus. Coleoids are all assignable to the *Belemnitella junior* group, by definition (JELETZKY, 1951) the index taxon of the temperate/boreal Late Maastrichtian. Ammonites have not yet been recorded from these units.

The Lixhe 2 Member shows a peak in crinoid distribution (Fig. 6), which finds a match in the peaks characterising the overlying Lanaye Member.

Nannofossil assemblages in these members and in the Lanaye Member are held to be indicative of the *Lithraphidites quadratus* Zone (CEPEK & MOORKENS, 1979), while planktonic foraminifera include taxa of the *Globotruncana contusa* Zone.

#### 1b - LANAYE MEMBER (late Maastrichtian)

VILLAIN (1977) interpreted the 'craie grossière' (Cr 4 = Lanaye Member) as a compact biomicrite (with biomicrosparitic patches), deposited in a setting with oceanic influence still, with horizontal transport of sediment particles by episodic currents, and a palaeodepth of 40 to 80 m. LIEBAU (1978) described the depositional setting as a platform environment with minor open ocean influences (middle sublittoral) and subtropical temperatures.

ZIJLSTRA (1994) considered this unit to represent a pure (97%) coccolithic bioclastic silty, homogeneously bioturbated packstone, with large-scale wavy lamination preserved in

MAASTRICHT FORMATION

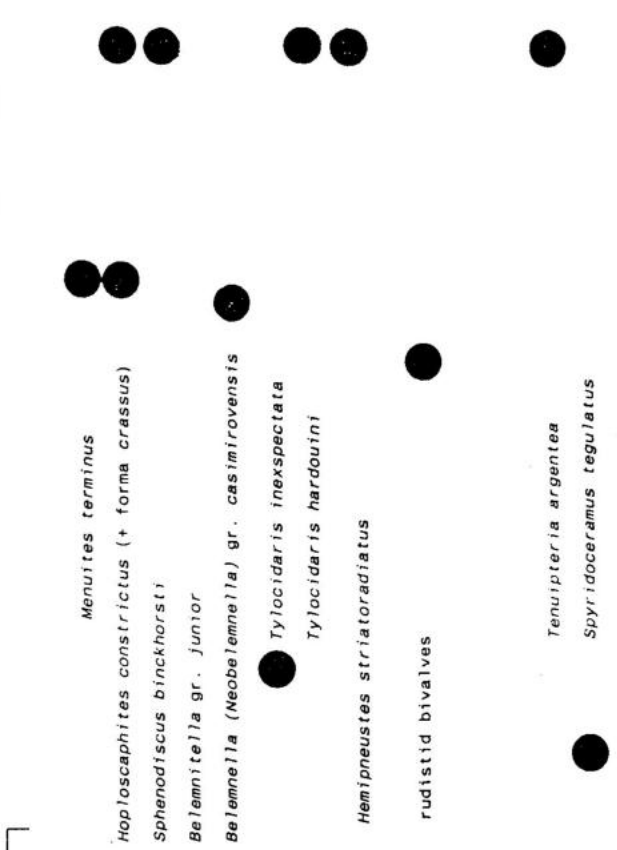
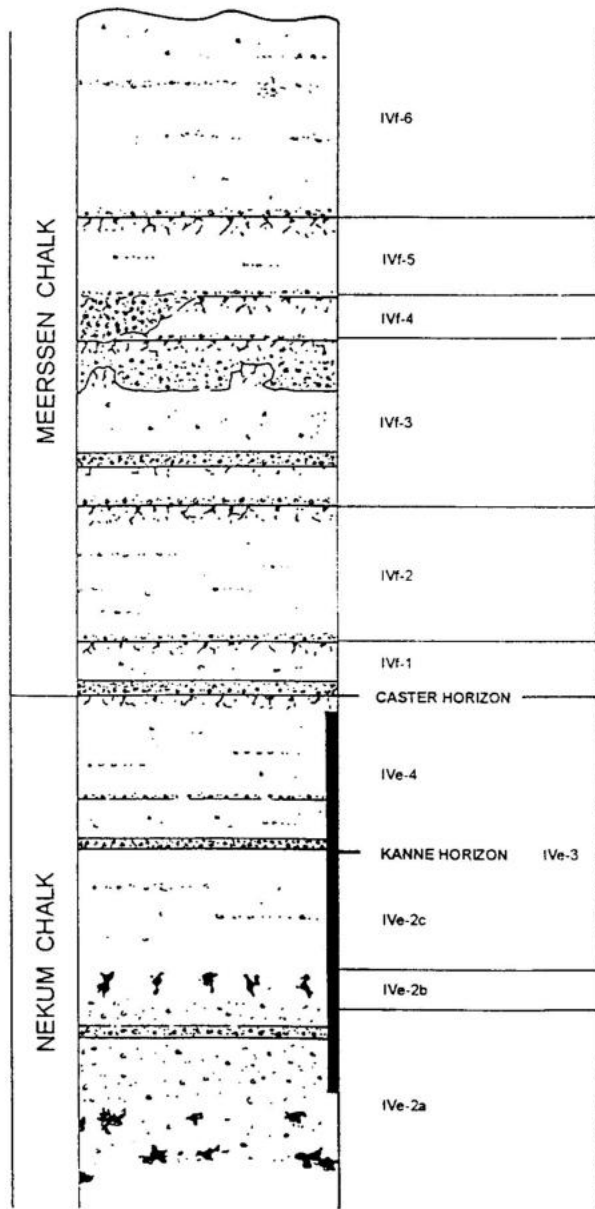


Fig. 8. Lithologic log for the upper part of the Maastricht Formation (Nekum and Meerssen members) as exposed at the ENCI Nederland BV quarry (Maastricht). In the southwestern corner ammonites, especially *Hoploscaphites constrictus* forma *crassus* opuski, 1911 and *Sphenodiscus binckhorsti* J. Böhm, 1898 are known from indurated portions/discontinuous hardgrounds at the top of unit IVf-6, which suggests local extension of the ENCI section to the Berg en Terblijt Horizon as exposed at the Ankerpoort-Curfs quarry (see Fig. 10). The FAD (first appearance datum) of representatives of the *Belemnella casimirovensis* (sensu Jeletzky, 1951) group occur at the base of section IVf-4, and the matrix of the sole specimen of *Menuites terminus* (Ward & Kennedy, 1993) suggests provenance from section IVf-5 (or IVf-6). The last *in situ* rudistid bivalves [in particular *Hippurites lapeirousii* (Goldfuss, 1840)] appear to occur at the top of section IVf-3. Locally unit IVe-4 (Nekum Member) has yielded coquina-like concentrations of the inoceramid *Spyridoceramus tegulatus* (von Hagenow, 1842), which testifies to the fact that *Tenuipteria argentea* (Conrad, 1858) seems to be restricted to the overlying Meerssen Member.

places. Well-developed planar-parallel flint nodule layers occur at 0.5-1.5 m interspaces. Nodules are either tubular (formed around crustacean burrows) or platy, and traces of shallow burrowing and sediment mixing are common but poorly preserved. The activity of deep burrowers is preserved as ghost structures in flint.

In this member is found a flint maximum (Figs 5, 7), which SCHULZ & SCHMID (1983) considered to correspond with a similar maximum at Hemmoor (NW Germany). The FAD (first appearance datum) of the index nannofossil taxon *Nephrolithus frequens* seems to follow immediately upon this flint maximum at both localities (VAN HECK, 1979; CEPEK & MOORKENS, 1979).

Amongst macrofossils of correlative value are mainly coleoid cephalopods, all assignable to the *Belemnitella junior* group, ammonites comprising only ill-preserved, phosphatised baculitids.

*Hemipneustes* is not the only 'southerly' echinoid genus to appear first in this member (see above); it is accompanied by e.g. *Oolopygus* and *Nucleopygus*. The crinoid fauna does not comprise any isocrinids (which abound in white chalk facies elsewhere in NW Europe), but is composed almost exclusively of bourgueticrinids/bathycrinids which are closely related to and congeneric with the otherwise exclusively North American genus *Dunnicrinus*. Distribution in time of these crinoids fluctuates considerably and analyses of 5 cm samples have lately revealed a rhythmic (seasonal ?) pattern (P.J. FELDER, in prep.).

Inoceramid bivalves comprise only the 'teglated' types, but poor preservation precludes definite specific assignment (see below). Other bivalve species do not appear to include stratigraphically important taxa, but pectinids, bachevellids, plicatulids and ostreids are common.

Additional evidence amongst micro- and macrofauna for an increasing Tethyan/Mediterranean influence during this interval is furnished by ostracods (BLESS, 1989) and mosasaurs and cheloniid turtles (JAGT *et al.*, 1995).

## 2 - MAASTRICHT FORMATION

### 2a - VALKENBURG MEMBER (late Maastrichtian)

The base of W.M. FELDER's (1975) Maastricht Formation corresponds to the original definition of the 'système maestrichtien' by DUMONT (1849) (see VAN DER HEIDE, 1954; ROMEIN, 1962). The boundary (= Lichtenberg Horizon) between this formation and the underlying Gulpen Formation is an irregular, slightly undulating erosion surface. ZIJLSTRA (1994) noted the occurrence of several tens of metres wide and decimetre deep depressions at the top of Lanaye Member, filled with coarse-grained phosphatic/glaucconitic and pyritic bioclastic sand, representing the base of a fining-upward cycle. Depositional lamination was shown to be virtually entirely destroyed by bioturbation, and the sand to contain skeletal remains, reworked chalk and low concentrations of sand-sized extrabasinal quartz and heavy mineral grains.

The Valkenburg Member is 2.5 m thick, shows a fining-upwards trend, with an upper cycle of 1.5 m thickness, having a rather fine-grained, slightly lithified (proto-hardground), pure carbonate top with poorly developed flint nodules around spreiten and *Thalassinoides* type burrows (ZIJLSTRA, 1994).

The macrofauna comprises numerous crinoid ossicles, echinoids, craniid and thecideid brachiopods, cirripedes, coleoids, nautilid jaw elements, octocorals, faecal pellets (hence DUMONT's name 'couche à coprolithes') and vertebrate remains. All of these taxa have also been recorded from the underlying Lanaye Member.



## 2b - GRONSVELD MEMBER (late Maastrichtian)

According to ZIJLSTRA (1994) the lower part of this unit also consists of fining-upward cycles with a phosphatic, glauconitic/pyritic bioclastic sand at the base, the sand of the lowermost cycle being characterised by well-developed wavy lamination. Wavy laminated sediment at the base of these cycles changes upwards via (sub)horizontally laminated sediment towards lithified homogeneously bioturbated, fine-grained, purer carbonate sediment at the top.

The upper part of the Gronsveld Member consists of well-sorted bioclastic fine sand with low-angle, large-scale wavy lamination (hummocky stratification), with flint nodules forming laterally restricted curvi-planar layers (ZIJLSTRA, 1994).

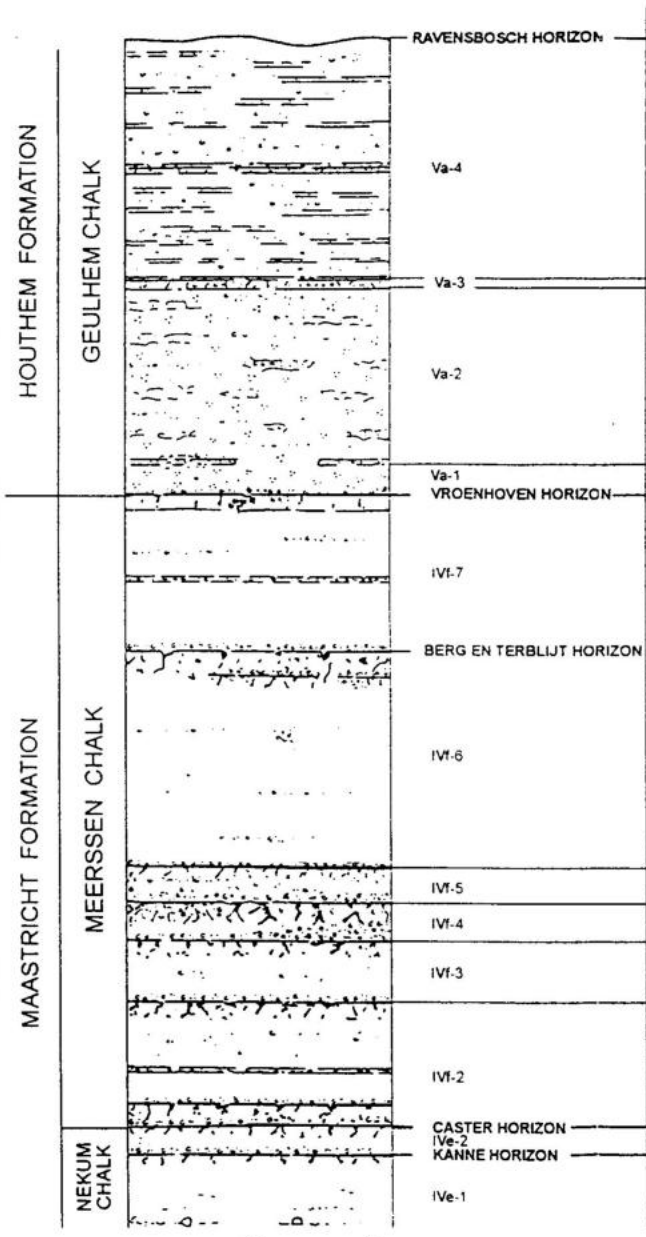
Of particular note is ZIJLSTRA's (1994) observation that the glauconitic cycles of the Valkenburg Member at ENCI change laterally towards the south into cycles with flint nodule layers very similar to those of the Lanaye Member. This correlation is corroborated by analyses of bioclast contents (P.J. FELDER, in prep.). The same holds true for the St. Pieter and ENCI Horizons (*sensu* W.M. FELDER, 1975), which have recently yielded entire specimens of bourgueticrinid crinoids, and of ophiolopidine and ophiacanthid ophiuroids. This occurrence testifies to a sudden burial (obtrusion) by a clastic input (from the northeast ?) and subsequent (near)absence of bioturbation. A detailed taphonomic analysis of this occurrence is under way (JAGT, DECKERS, DORTANGS & KUYPERS, in prep.).

Prior to 1975, W.M. FELDER's (1975) Valkenburg, Gronsveld, Schiepersberg and Emael members (Maastricht Formation) were referred to as unit Mb (*sensu* UHLENBROEK, 1912). VILLAIN (1977) considered the interval Ma/Mb to represent a gravelly intrabiomicrosparite, with regional currents constant enough to horizontally displace sediment particles over the entire platform, at shallow depths of 20 to 40 m, and free from oceanic influences (see also BLESS, 1991). Sediment reworking resulted in homogenisation of sediments over a depth of some decimetres, resulting in a relatively solid sea floor and clear waters. LIEBAU (1978) typified the setting as middle sublittoral, with subtropical temperatures and characterised by the occurrence of seagrass communities.

## 2c - NEKUM MEMBER (late Maastrichtian)

This member comprises medium- to coarse-grained biocalcarenes (mainly packstones and grainstones; gravelly intrabiomicrosparite according to VILLAIN, 1977), with resting upon the Laumont Horizon an indurated calcarenite. ZIJLSTRA (1988) described the flint nodules occurring in the lower part of this member (the highest stratigraphic *in situ* occurrence of flints in the type Maastrichtian) as having a crypto/microcrystalline texture. Often nodules are associated with concentrations of large skeletal grains, and nodules are tubular when related to bioturbation. The upper part of the Nekum Member consists of porous, fine carbonate sands, with undulating erosion surfaces. Sand lenticles resting on such erosion surfaces may show tangential cross-bedding; the Kanne Horizon representing an undulating erosion surface overlain by very coarse bioclastic sand (ZIJLSTRA, 1988). The lowermost part of the section has yielded the first representatives of the ammonoid *Sphenodiscus binckhorsti* and the endemic scaphitid *Hoploscaphites felderi*. Amongst the enormous number of serpulids, the occurrence of numerous bivalves (ostreids, gryphaeids, pectinids, limopsids, nuculids, nuculanids, arcids, crassatellids and trigonids) and gastropods should be noted.

Throughout the remainder of this interval occur numerous echinoderm breccias (composed mainly of shattered tests of the echinoid *Hemipneustes striatoradiatus*), with a wealth of



- Menuites fræsvillensis*
- Baculites* aff. *anceps*
- Hoploscaphites constrictus* (+ forma *crassus*)
- Sphenodiscus binckhorsti*
- Belemnella* gr. *junior*
- Belemnella* (*Neobelemnella*) gr. *casimirovensis*
- Diplodetus* sp.
- Hemipneustes striatoradiatus*
- Tenuipteria argentea*
- rudistid bivalves
- Danocrania geulhemensis*
- Tylocidaris hardouini*
- Tylocidaris* gr. *bruennichi*
- Metopaster spenceri*
- Metopaster kagstrupensis*
- Hyposalenia heliophora*
- Ditrupe schiotheimi*
- Ranilliformis baltica*

Fig. 10. Lithologic log for the upper part of the Maastricht Formation (Meerssen Member), and lower part of the Houthem Formation (Geulhem Member) as exposed at the Ankerpoort-Curfs quarry (Geulhem). The uppermost part of section IVf-6 has yielded the last *in situ* ammonites, including amongst other species *Sphenodiscus binckhorsti* J. Böhm, 1898 and *Hoploscaphites constrictus* forma *crassus* Opuski, 1911. Reworked guards of the *Belemnella casimirovensis* group (*sensu* Jeletzky, 1951) occur sporadically at the base of section IVf-7, being accompanied by many fragments of characteristic latest Cretaceous echinoids and bivalves. Locally a thin clay film covers this basal fossil hash, with another, but laterally continuous clay film being found in the middle of this unit. From the 'chalkstone' underlying the Vroenhoven Horizon, traditionally interpreted as the K/T boundary (Fig. 9), a number of well-preserved baculitid ammonites have lately been collected. Locally also concentrations of specimens of the echinoid *Hemipneustes striatoradiatus* are known from the same bed: recently collected macrofaunules are also shown in section. Based on palynological evidence the K/T boundary in this section is suggested to correspond to the Berg en Terblijt Horizon, matching the section at the Geulhemmerberg underground workings.

comatulid crinoids, astropectinid and goniasterid asteroids and ophiuroids. The upper third is characterised by the mass occurrence of chelae of the thalassinid shrimp *Protocallianassa faujasi*, and a number of associated brachyuran crabs.

Coleoids are all referable to the *Belemnitella junior* group, and include the best-preserved and largest specimens seen from the area.

The upper third of this member has recently yielded a coquina of tegulated, equivalved inoceramid bivalves (Natuurhistorisch Museum Maastricht Collections), corresponding to the current concept of *Spyridoceramus tegulatus* (ABDEL-GAWAD, 1986; DHONDT, 1983, 1992). This suggests that the poorly preserved tegulated inoceramids in e.g. the Lanaye Member (at CBR-Romontbos quarry, for instance) should also be assigned to this taxon, which in the NW German white chalk standard section does not extend beyond the earliest Late Maastrichtian (*tegulatus/junior* Zone; see SCHULZ & SCHMID, 1983; SCHULZ *et al.*, 1984). Alternatively, this species and the other tegulated inoceramid *Tenuipteria argentea* may be considered to have co-occurred locally/regionally for longer periods than previously assumed. Or: the ENCI situation corresponds to that in central Poland, where *T. argentea* is confined to the *Belemnella casimirovensis* Zone, and has been suggested as alternative index taxon for this zone (ABDEL-GAWAD, 1986).

## 2d - MEERSSEN MEMBER (late/latest Maastrichtian)

ZIJLSTRA (1994) observed that the upward coarsening of grain size and the increase of average bed thickness indicated a gradual increase of average hydrodynamic energy and deposition rates. The most strongly silicified/lithified layers formed when deposition rate was zero, thus when hydrodynamic energy increased and the consequent increase of erosion was equal to the relative sea level rise. During a further increase of the hydrodynamic energy, previously lithified sediment was eroded during storms and wavy beds formed. A hardground, a bored, encrusted and mineralised rocky sea bottom, formed when the sediment that was eroded during a storm was not redeposited after the storm, so that the previously lithified layer was continuously exposed.

VILLAIN (1977) described this unit as a gravelly intrabiomicrosparite, deposited in a shallow setting (2-15 m), with agitation having been able to displace larger sediment particles, deposited in oblique stratification under maximum energy conditions during the lower portion of this unit. LIEBAU (1978) typified these sediments as high-energy deposits, with a high production of carbonate detritus leading to the establishment of a broad, shallow, well-lit, warm carbonate platform with rich phytal association. Water temperatures are held to have risen to 20-25°, allowing the growth of solitary corals, especially in the lower/middle portions of this member.

Traces of bioturbation include burrows which acted as fossil traps and from which exquisitely preserved bryozoan (VOIGT; 1959, 1981, 1987) and other faunas are known. On top of hardgrounds and indurated beds occur concentrations of macro- and mesofossils (bioclasts), which comprise brachiopods, bivalves, corals, echinoids, crinoids, asteroids and ophiuroids, bryozoans etc. Reef-like structures (biohermal structures) occur at places, are of a lenticular structure, and yield many corals and rudistid bivalves.

Biostromes in this member occasionally yield interesting macrofaunal assemblages, e.g. exuviae of decapod crustaceans (COLLINS *et al.*, 1995), diverse ophiuroid faunules as well as near-perfectly preserved astropectinid star fish.

In an attempt to provide detailed correlations between the Meerssen Member as exposed at the Ankerpoort/Curfs, Blom (Berg en Terblijt) and ENCI quarries, the section exposed at the last-named locality has recently been re-measured (Fig. 8; see also JAGT *et al.*, in press). It appears that the Meerssen Member at the ENCI quarry in places (SW corner) extends to (just below) the Berg en Terblijt Horizon as recognised at the Ankerpoort/Curfs quarry (see Fig. 9). This means that subunit IVf-7 of this member (Fig. 9) is not

represented at the ENCI quarry, and that, as a consequence, this section cannot furnish any details in the discussion on the K/T boundary in the Maastrichtian type area. However, it should be noted that locally lenticular structures of fossil hash have yielded abraded primary spines of psychocidarine echinoids of early Danian age.

Recent macropalaeontological studies have focused on determining the FAD of the coleoid index *Belemnella (Neobelemnella) gr. casimirovensis*, the LAD of rudistid bivalves and the range of ammonoid species. Of particular note is the recent discovery (in collections of the Natuurhistorisch Museum Maastricht) of the index pachydiscid *Menuites terminus*, a short-ranging species characterising the *terminus* Zone in the Bay of Biscay sections (WARD & KENNEDY, 1993) and the latest Maastrichtian brachiopod zone 10 in Denmark (BIRKELUND, 1993).

## Locality 2

### ANKERPOORT/CURFS QUARRY Geulhem (Valkenburg aan de Geul, Limburg, The Netherlands)

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Rijks Geologische Dienst/Kartering (Geologisch Bureau Heerlen), file number 62A-13; topographical map of The Netherlands, 1:25.000, sheet 62A Valkenburg, co-ordinates 182.000/320.000.

In the autumn of 1992, the section exposed at this quarry (Fig. 9) was sampled for calcareous nannofossil, foraminiferal and dinoflagellate contents, across the Berg en Terblijt Horizon and into the lower portion of the Geulhem Member (across the Vroenhoven Horizon). Traditionally, the boundary (= Vroenhoven Horizon) between the Meerssen and Geulhem members was considered to represent the K/T boundary, or rather, the hiatus characterising this boundary (W.M. FELDER, 1975). However, on dinoflagellate evidence (BRINKHUIS & SMIT, in press) the K/T boundary is now drawn at the base of subunit IVf-7, with the last coleoids occurring in the fossil hash at the base, and the top of the underlying subunit yielding the last *in situ* ammonites. In places, resting on the fossil hash is a thin clay film, and another clay film occurs in the middle of subunit IVf-7. These clay layers have been correlated with better developed clay occurrences in the underground workings of the Geulhemmerberg. The reader is referred to BRINKHUIS & SMIT (in press) for detailed discussions of sedimentological and micro-/macrofaunal analyses of the latest Maastrichtian and early Danian transition.

## 1 - MAASTRICHT FORMATION

### 1a - MEERSSSEN MEMBER (late/latest Maastrichtian)

In comparison with the section exposed at the ENCI quarry, the Meerssen Member at the present locality is better developed, but a still thicker sequence is known from a borehole at Valkenburg aan de Geul, a few kilometres to the east. Sedimentological and (macro)palaeontological interpretations of the ENCI section generally correspond with those of the present section.

The indurated portion underlying the Berg en Terblijt Horizon (Figs 9, 10) has yielded the last *in situ* ammonites in the Maastrichtian type area, comprising mainly *Sphenodiscus binckhorsti*, *Hoploscaphites constrictus* (including forma *crassus*), *Baculites vertebralis* and a single specimen of *Menuites fresvillensis*. Its congener, *M. terminus*, known from the ENCI quarry (see above) and the nearby Blom quarry (Berg en Terblijt), has not yet been recorded from the Curfs section. Associated coleoids are all assignable to the *Belemnella casimirovensis* group, which is in need of a modern revision.

Recent field work (JAGT & FRAAYE, poster abstract IGCP 362 Meeting) at this quarry has focused on collecting macrofossils from subunit IVf-7, following the discovery of well-preserved baculitid ammonites in the chalkstone-like (*sensu* BROMLEY & GALE, 1982) indurated portions immediately below the Vroenhoven Horizon. At 2.8-3.0 m above the Berg en Terblijt Horizon (= K/T boundary on dinoflagellate evidence), diverse macrofaunules consisting of echinoids (*Hemipneustes striatoradiatus*, *Diplodetus* sp.), bivalves (*Entolium membranaceum*, *Tenuipteria argentea*: articulated specimens, the largest-sized individuals so far recorded from the area !) have been collected. Initially, the specimens of the brissid echinoid *Diplodetus* sp. (JAGT, in press) were considered to be

of Danian age, but their association with the typically late Maastrichtian *H. striatoradiatus* appears to contradict such an interpretation.

Two well-developed crustacean burrows, piping down for at least a metre, from the base of subunit Va-1 (Fig. 10), have been noted in the NE corner of the quarry. Such burrows, and others less easily recognised in the field, may account for the occurrence of Danian marker species amongst nanno- and microfaunas lower in the section (basal part of subunit IVf-7). In such a case, the Vroenhoven Horizon would have to be considered representing the K/T boundary at this locality.

## 2 - HOUTHEM FORMATION

### 2a - GEULHEM MEMBER (early/middle Danian)

Macrofaunal studies (see JAGT, in press for details) have provided arguments for an early and middle Danian age for the Geulhem Member as exposed at the present locality (Fig. 10). The lower portion (subunits Va-1 and Va-2) may correlate with the *oedumi* Zone of the Danian type area (Sjælland, Denmark), with subunit Va-3 representing a sedimentary break (possibly of *abildgaardi* Zone age), and subunit Va-4 having been deposited during the second Danian transgression, of middle Danian, *bruennichi* Zone, age.

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