The depositional environments of the Maastricht and Kunrade Chalks (Maastrichtian) from the type area of Limburg, Netherlands

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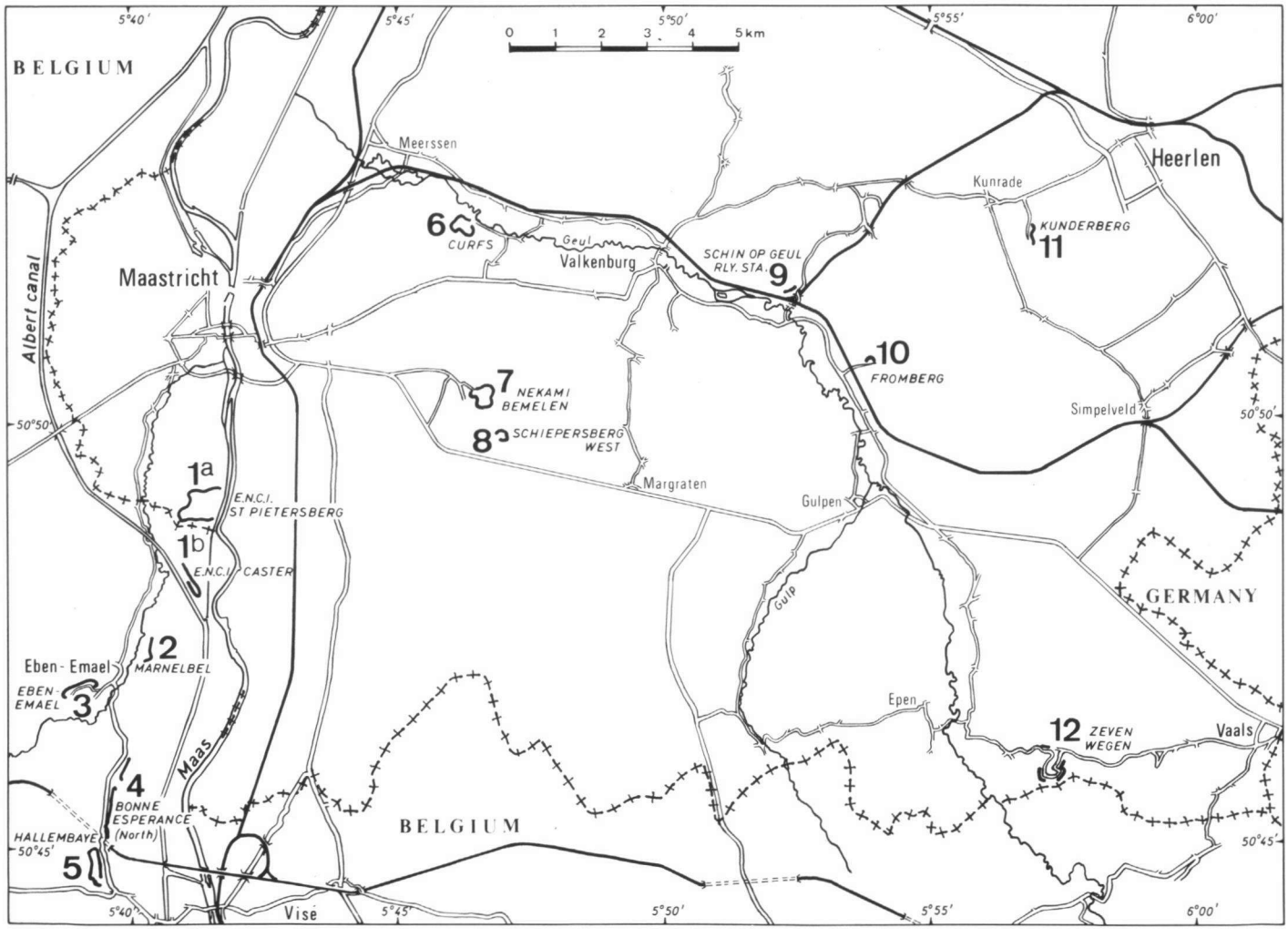
ABSTRACT:
Following the deposition of the Gulpen Chalk (Campanian-Maastrichtian), the Maastricht and Kunrade Chalks exhibit typical feateres of high energy shallow water carbonate deposition. There is a progressive shallowing through the deposition of the Maastricht Chalk as typified by the changes from calcilutite (chalk) deposition in the lower Maastricht Chalk to medium and coarse grained calcarenities with occasional calcirudites in the higher levels. This trend is paralleled in the faunal characteristics, exhibiting an increase in abundance and diversity of the benthos.

Introduction:
Following the widespread trangression during the Upper Cretaceous with its peak in the late Campanian and early Maastrichtian, there followed over most of Northwest Europe a regional regression with the deposition of the late Maastrichtian and Danian 'chalks'.
Locally, here in South Limburg, the Upper Maastrichtian shows the characteristics of a transgressive sequence resulting from local downwarping along the major fault block area to the northwest. I wish to describe the features of this sequence as seen in the deposition of the Maastricht Chalk and Kunrade Chalk.
The Maastricht Chalk outcrops in the western half of South Limburg from the vicinity of Valkenburg in the west, across into Belgium, dipping northwards towards the Upper Cretaceous depocentre in the North Sea (Hancock & Scholle, 1975). The major outcrop area being around Maastricht and the type locality at St. Pietersberg. In contrast the Kunrade Chalk occupies a smaller outcrop area in the northeast corner of South Limburg between Valkenburg and Heerlen - extending also into West Germany.

Lithofacies:
The Maastricht and Kunrade Chalks are essentially calcareous, with a varying amount of terrigenous clastic content which is more evident in the Kunrade Chalk. We can split up the two 'chalks' on, firstly their outcrop pattern, on their lithology, and finally on their depositional environments.
The contemporaneity of these two deposits has in the past been in dispute but it is fairly well documented that the Kunrade Chalk is a lateral equivalent of the Maastricht Chalk (Romein, 1963). In the area between Valkenburg and Kunrade the Maastricht and Kunrade Chalks can be seen to interfinger (Kruit, 1949).
The lithologies of these chalks range from calcisiltites and calcarenites containing subordinate terrigenous clastic horizons in the Kunrade Chalk to medium to coarse calcarenites and calcirudites in the Maastricht Chalk. The limestones are generally soft and friable, with irregularly comented hard horizons, more prominent in the Kunrade Chalk, characterised by an alternation of well cemented and friable horizons of calcisiltite and calcarenite. These well cemented horizons in the Kunrade have an irregular aspect and although they extend laterally cannot be followed for great distances and often run into each other. As stated before, the Kunrade Chalk has a high clastic content, this is seen best in the basal part of the section where prominent horizons of quartz and glauconite, with minor amounts of calcarenite, are intercalated with glauconite calcisiltites. Higher in the succession, as seen at Kunderberg, the calcisiltites and calcarenites have a very

Fig. 1. Locality Map of South Limburg, Netherlands.



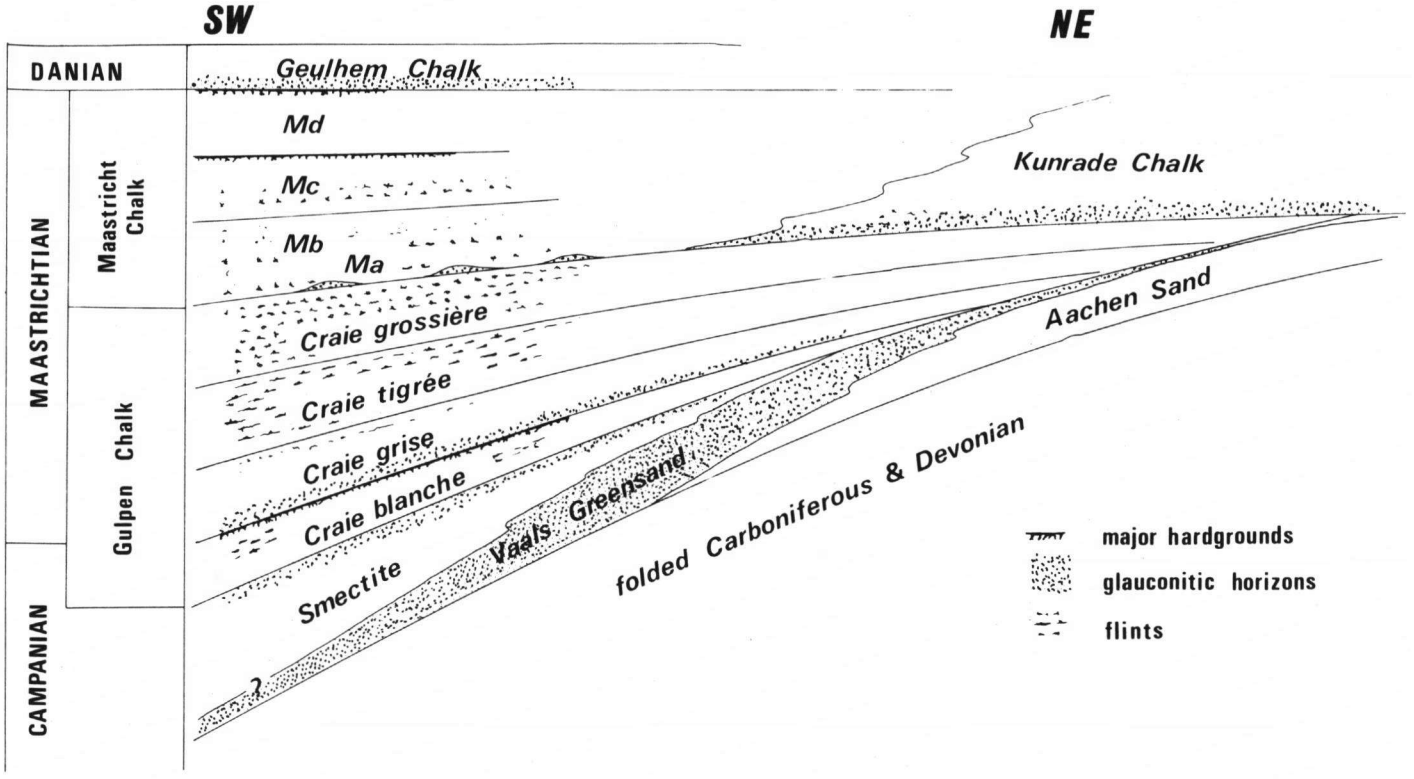


Fig. 2. Diagrammatic section across South Limburg form NE to SW.

high argillaceous content and often contain clasts of quartz and quartzite pebbles, grey clay laths and angular fragments of high rank coal, presumably derived from a Carboniferous source (Pollock, 1974).

The Maastricht Chalk, in contrast, is a very pure limestone with a minimal terrigenous content. The overall grain size of the Maastricht Chalk increases up the section from the Mb into Md, apart from irregular shelly calcirudite horizons. The break between the underlying white calcilutites of the Gulpen Chalk and the yellow calcarenites of the Maastricht Chalk is marked by a minor hardground or conglomeratic horizon.

The constituents of the calcarenite are shell debris, intraclasts, rare quartz, pellets and micrite. They have a high primary porosity unlike the Kunrade Chalk. Sedimentary structures are normally obcured by usually intense bioturbation, but low angle cross stratification can sometimes be seen in the quartz-glauconite horizons of the Kunrade Chalk. Larger scale cross stratification is sometimes present within the Md unit of the Maastricht Chalk but notmally the bedding is subhorizontal throughout both chalks. Southwards from St. Pietersberg into Belgium the grain size of the Maastricht tends to remain constant with medium calcarenites being the predominant lithology. The coarse calcirudites are normally absent although thin coarse shelly horizons do occur in minor amounts. The Maastricht Chalk is generally soft and friable, but contains, commonly within the Md unit well cemented 'hardground' horizons, formed during periods of non-sedimentation. The cementation extends in depth for up to 30 or 40 cms, returning to soft friable calcarenites with depth. The hardgrounds extend laterally over considerable dis tance as mappable horizons, predominating in the St. Pietersberg area and becoming less apparent to the east also southwards into Belgium.

Flints occur through both the Maastricht and Kunrade Chalks with a concentration in the Mb unit of the Maastricht Chalk. At St. Pietersberg, they occur as irregular nodules and often follow the shape and form of burrow systems. They also occur sporadically through the lower levels of the Mc unit. These irregular nodules seen in St. Pietersberg tend to coalesce into larger flint nodules and often become large sheet-like concretions in the exposures in Belgium. In most cases the silification of these sheet like concretions has not obscured the original bedding and burrow systems of the original chalk. Flints do not occur within the Kunrade Chalk at Kunderberg. Nevertheless, thin section analysis of these limestones show the presence of small amounts of length-show chalcedony (lutecite), normally associated with sulphate minerals and evaporate sequences in general (Fok & Pitman, 1972).

Biofacies:

These limestones yield a very interesting and varied fauna, contrasting with each other and also with the underlying Gulpen Chalk. Faunal evidence shows a marked change in the climatic conditions between the two formations.

The fauna of the Gulpen Chalk has affinities with the Boreal zoogeographical region and although the climatic conditions prevalent during Gulpen Chalk times were not truly Boreal, (using the term 'Boreal' here in the geographic sense), the conditions existing were somewhat subtropical to warm temperate followed by tropical to subtropical or Tethyan for the Maastricht Chalk. Faunal affinities of the Gulpen Chalk are correlated with Northwest Germany and the North Sea area in general, whilst those of the Maastricht can be correlated with the Maastrichtian (Dordonian) fauna's of the Aquitaine Basin (Voigt, 1964).

Major differences in the diversity of their fauna are apparent between the two chalks. The Kunrade Chalk has an essentially bivalve fauna, the main representatives being *Nuculana, Limatula, Cucullaea* and the ubiquitous ostreiid *Pycnodonte,* minor amounts of small gastropods also occur with rare occurrences of the echinoid, *Cardiaster granulosus* (Goldfuss), ammonites and brachiopods. Not only is the fauna dominantely bivalve, but they are mainly shallow burrowing forms which prefer muddy substrates and the associated turbid bottom conditions. An associated microfauna of bryozoa, foraminifera and ostracoda is also present. Plant remains occur commonly, especially the seagrass *Thalassocharis.* The burrow systems of *Thalas-*

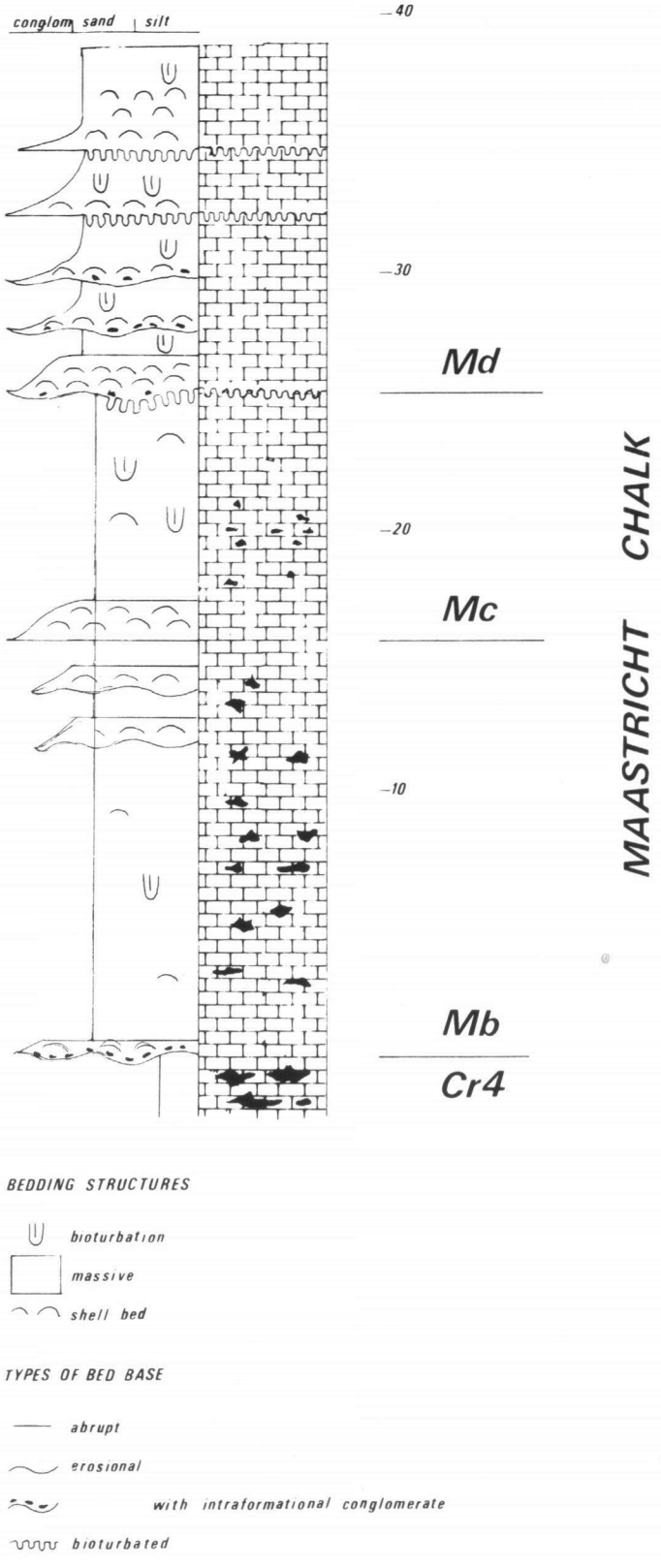


Fig. 3 Typical section of the Maastricht Chalk.

sinoides and *Ophiomorpha,* attributable to the shrimp *Callianassa* are common.
In contrast the Maastricht Chalk has a very varied and diverse fauna again dominated by bivalves, but with a higher associated percentage of echinoids, corals and brachiopods. The fauna shows an increase in diversity and abundance up the sequence reaching a peak in the Md unit, where corals and echinoids form a high percentage of the fauna. The ostreiids *Pycnodonte* and *Agerostrea* are very common. Associated with this fauna rare ammonites, crinoids, belemnites and rudistids.
The bivale fauna shows forms which are normally associated with sediments of sand size grains, but a variety of ecological niches are represented, both infaunal and epifaunal.
The Mc and Mb units contain an associated fauna of infaunal bivalves, shallow burrowing echinoids, bryozoa and occasional oysters. With the prepondence of hardgrounds within the Md unit, fauna's preferring a harder substrate predominate - cideroids, corals, thecidean brachiopods, rudistids etc. and free swimming bivalves, e.g. pectinids. With a return of sedimentation, these forms are superceded by shallow burrowing forms, more suited to unstable conditions. all the fauna's represented here are very similar to fauna's associated with or near to modern reef complexes, although no reefs, as such, have been found within the Maastricht Chalk.
An abundance of the corals and also associated algal *(Lithothamnium)* remains, show that the water depth was very shallow with high energy conditions prevalent during most of the deposition of the Maastricht Chalk.
To the south in Belgium the fauna tends to be less diverse although still as abundant, with bivalves predominating. In most cases the faunal remains, show signs of transportation - i.e. fragmentation and the deposition of these chalks are thought to be the flanks of the shoal area at St. Pietersberg.

Conclusions:
The Maastricht Chalk can be compared to the recent carbonate sheet sands as described by Imbrie and Buchanan (1965) from the Bahamas, deposited in shallow water although a superficial resemblance can be seen with the recent bryozoan carbonate sands now forming in slightly deeper water off the South Australian Coast in the Great Australian Bight (Wass, Conolly & Macintyre, 1970). It seems likely that the Kunrade Chalk was deposited in a shallow water, semi lagoonal area close to land of low relief providing a restricted supply of terrigenous clastic material. Fully marine conditions existed for both chalks. Using Irwin's (1965) classification of carbonate environments, The Kunrade Chalk corresponds with his Z zone and the Maastricht Chalk the Y zone. The Mastricht Chalk was deposited further offshore, within the deposition of clean carbonate sands. Further shallowing of the sea during the Md unit resulted in periods of non deposition, with the associated lithification of the sands forming hardgrounds, enabling colonisation on this hard substrate of a coral-echinoid fauna.

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