

BIOSTRATIGRAPHY AND EVENTS AT THE CAMPANIAN-MAASTRICHTIAN BOUNDARY¹

by

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(4 figures)

ABSTRACT.- Problems related to stages, bioevents, ecoevents and stage boundaries as well as their mutual relationships are briefly discussed. Subsequently, a review is made of the data on the Campanian-Maastrichtian boundary as currently accepted and defined in the Boreal and Tethyan realms.

RESUME.- Une discussion est d'abord présentée sur les problèmes relatifs aux étages, aux bio- et écoévénements et aux limites d'étages. Viennent ensuite des informations et des remarques sur la limite Campanien-Maastrichtien telle qu'elle est appréhendée et définie dans les domaines boréal et téthysien.

1. STAGES AND STAGE BOUNDARIES

1.1. STAGES ARE TIME UNITS

A stage represents the smallest chronostratigraphical unit in the standard hierarchy of the geological times which can be recognized throughout the world. The Cretaceous system comprises twelve stages all defined around the middle of the last century.

1.2. STAGES ARE REPRESENTED BY BODIES OF STRATA

Stages are materialized by a rock sequence. Type regions or type localities or type sections constitute the field references where stages are defined. Usually type sections consist of a sedimentary sequence and its paleobiological content.

1.3. STAGES ARE CHARACTERIZED BY ASSEMBLAGES OF FOSSIL MARKERS

As animals and plants are submitted to Evolution throughout geological times, each stage is characterized by assemblages of fossil species arranged in successive biozones. Thus, in most cases chronostratigraphy (time) is closely linked to biostratigraphy (fossils).

1.4.- A STAGE BOUNDARY IS MARKED BY A BIOEVENT

It was agreed at the symposium on Cretaceous stage boundaries held in Copenhagen in October 1983 «that stages are 'packages of zones' and that the most sensible way to define a stage is by the base of the earliest biozone at a boundary stratotype. [...] The base of the zone preferably be defined on the first appearance of a new taxon» (Birkelund *et al.*, 1984). So, it is a bioevent (the first appearance of a new species) which marks the beginning of a stage.

It should be noted that stages were created by d'Orbigny, a pupil of Cuvier known for his «catastrophist» concept about the renewal of fossil fauna. The notion of stage was founded on this catastrophist view, that is to say on «sudden» appearance of a large number of new species and concomitant extinction of older species in the preceding stage. D'Orbigny characterized stages

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on assemblages of species specific for each of them. But he did not pay much attention to the definition of boundaries with fossil markers. His definitions of stages seem to be linked to the older concept of «terrains» or formations. For example, Upper Cretaceous stages were first referred to facies : the type Albian is represented by the clays of Aube (= Gault), the type Cenomanian by glauconious sediments, the type Turonian by Craie Tuffeau of Touraine, the type Senonian by white Chalk of Sens. Fossil markers were used only for correlating areas where type facies are not identical to those of the type areas. Presumably d'Orbigny did not focus on the definition of stage boundaries because these were not exposed or not well exposed in the type areas.

Since that time, refinements of biostratigraphy needed better definition of stage boundaries. For the Cretaceous system it is accepted for historical reasons that ammonites constitute the reference for biostratigraphy and all other fossil groups are calibrated on ammonite sequences.

1.5. MAJOR BIOEVENTS ARE RELATED TO MAJOR ECOEVENTS

Important physical changes, or ecoevents, have an influence on living organisms and lead to paleontological events, or bioevents. For example, global sea level changes, anoxic events or changes in oceanic currents may have influence on extinction of certain overspecialized species. Whenever such species abandon an ecological niche this can be occupied by new ones (a question remains : as extinctions are seeming to be sudden and appearances more gradual, are extinctions or appearances the more suitable bioevents to be used for stage boundaries?).

1.6. MAJOR ECOEVENTS ARE RELATED TO EUSTASY (in part, at least)

Eustasy gives a formal explanation of worldwide sea level fluctuations producing large forward and backward movements of the seas on continental platforms. A rise of several kilometers in mid-oceanic ridges has a considerable effect on sea level : «Uplift of oceanic ridge would cause eustatic rise in sea-level... In general, this mechanism explains transgressions and regressions of worldwide incidence» Bott (1965).

As transgressions and regressions deeply modify marine biotope by changing physical characteristics of water masses on continental platforms, they provoke biological crises which are immediately printed in sedimentary sequences and can be read as bioevents. For example, an eustatic sea level rise can move the oxygen minimum zone upwards relative to the sea floor

(Hart, 1985). Therefore bioevents matching stage boundaries frequently reflect rise or fall of the sea level. But since these sea level variations are not instantaneous and take some time to be stabilized, bioevents linked to the same will be marked by some diachronism.

1.7. ECOEVENTS AND KEELED PLANKTONIC FORAMINIFERA EXTINCTIONS

As shown by Bé (1977), many species of recent keeled planktonic foraminifera «spend their earlier stages in the epipelagic zone» and their adult life in meso- to bathypelagic depths. In the Cretaceous, a water-depth control for the evolution of planktonic foraminifera was then recognized by several authors (Hart & Bailey, 1979; Hart, 1980; Caron, 1983; Caron & Homewood, 1983). Strongly keeled forms spend the adult stage of their life cycle in deep waters. When there is a sea level rise, the oxygen minimum zone (in modern waters at about 500 to 700 m below the surface (Hart, 1985) encroaches the continental shelf and prevents the development of adult forms. This leads to the extinction first of the stronger keeled species.

This means that significant global sea level rises (transgressions) would be marked first by extinctions of thick-walled or keeled planktonic foraminifera which during the adult stage of their life cycle are sensitive to variations in the oxygen content of the sea water. Such events are well known and widely used for biostratigraphical purposes when studying core samples on land or offshore (for example in DSDP cores).

Figure 1 shows the most important extinctions of keeled planktonic foraminifera from Albian to Maastrichtian. (Robaszynski, Caron & E.W.G.P.F., 1979; Robaszynski, Caron, Gonzalez Donoso, Wonders & E.W.G.P.F., 1984). On the left side is reported the transgression-regression graph as proposed by Hancock & Kauffman (1979). An other schematic graph presented recently for Tunisia by Marie *et al.*, (1984) closely matches this one. It seems that there is some coincidence between most of extinctions and the beginning of a sea-level rise.

The cases of *Helvetoglobotruncana helvetica*, *Dicarinella asymetrica* and *Globotruncanita calcarata* are different since these may have become extinct during a sea level fall. This feature may be explained in two ways : 1) various phenomena may cause extinctions, 2) the graph is based on too few points and is not sufficiently accurate. A current investigation on a continuous section in the Tethyan realm will yield new data which should give an answer to this problem.

It is to note that all the extinctions shown in

figure 1 are sudden, whereas the appearances of new species are slow and progressive : it is much easier to locate the extinction level of any one of the species mentioned in the figure than to put a boundary line for a species appearance.

2. THE EXAMPLE OF THE CAMPANIAN-MAASTRICHTIAN BOUNDARY

2.1. PALEOGEOGRAPHY

The map of figure 2 shows the geography during Campanian time (after Smith & Briden, 1977). In the Boreal and Tethyan realms,

sediments near the Campanian-Maastrichtian boundary are different : mainly chalks in the Boreal sea, marls or limestones in the Tethyan ocean. Differences in the environmental conditions are reflected by differences in the biological content of the sediments in the two realms. Therefore, the Campanian-Maastrichtian boundary is defined by different bioevents; for example with the group of belemnites in the Boreal realm and with the group of globotruncanids in the Tethyan realm (fig. 3). This creates a problem as far as the isochronism of the boundary in these realms is concerned. Four areas will be considered : Northern Germany and Maastricht area for the Boreal realm, Charentes (France) and Northern Tunisia for the Tethyan realm (fig. 4).

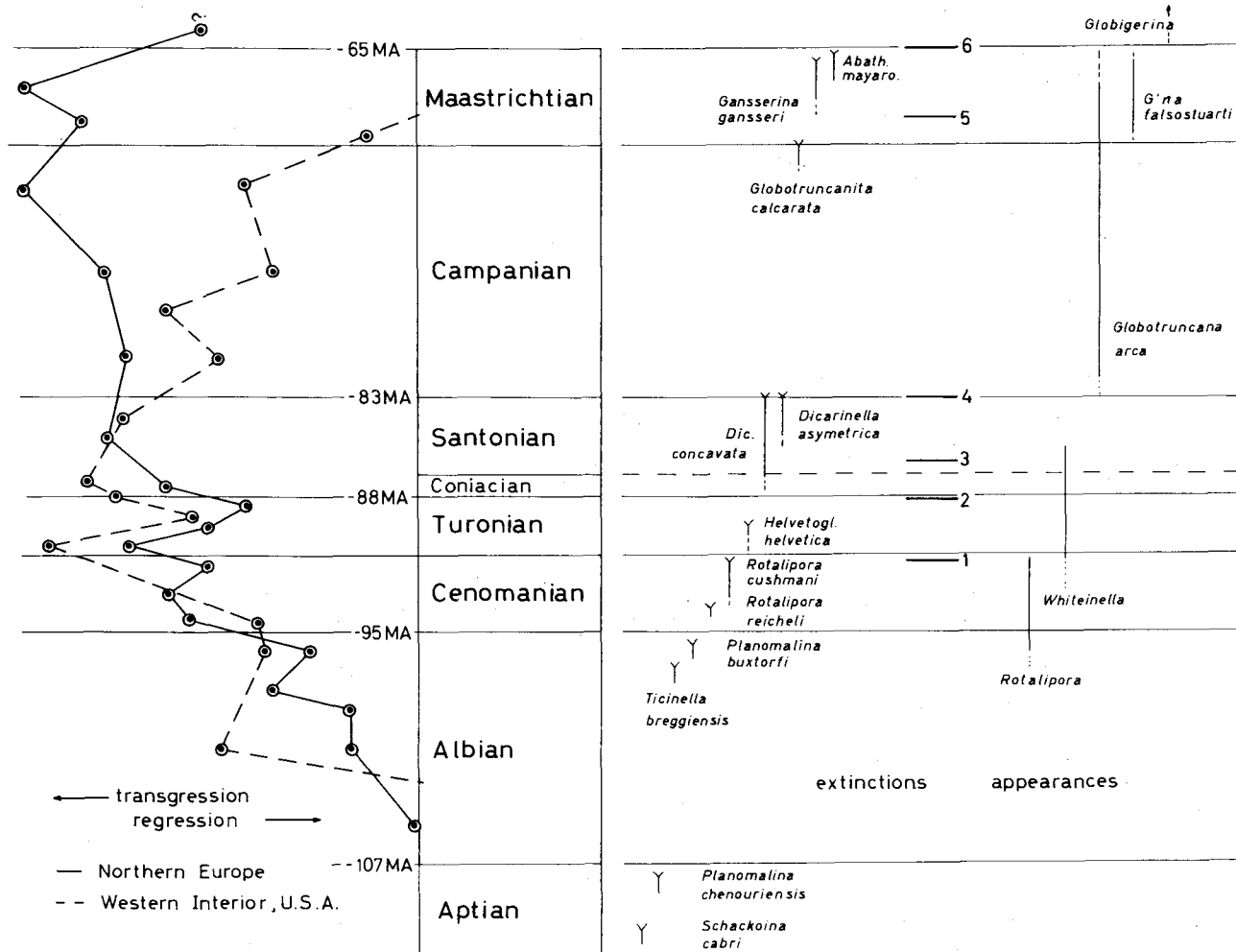


Fig. 1.- Range and position of extinction levels of index planktonic foraminifer species from Aptian to Maastrichtian (graph from Hancock & Kauffman, 1979; numerical ages from Odin, 1983; main extinctions 1 : of *Rotalipora* spp., 2 : of several species of *Praeglobotruncana*, *Dicarinella* and some *Marginotruncana*, 3 : of other species of *Dicarinella* and *Marginotruncana*, 4 : of the rest of *Dicarinella* and *Marginotruncana*, 5 : of several *Globotruncana* and *Globotruncanita* species, 6 : of all Globotruncanids).



Fig. 2.- Paleogeography at the Campanian times (after Smith & Briden, 1977). 1 to 4 : see fig. 4.

2.2. THE BOUNDARY IN THE BOREAL SEA

In Northern Germany, quarries at Kronsmoor and Hemmoor show a continuous succession of white chalk without any apparent hiatus or lack of sedimentation (Schulz *et al.*, 1984). The chalk contains many belemnites belonging to three groups :

- at the base, the *Belemnitella mucronata* group;
- in the middle, the *Belemnella lanceolata* group;
- at the top, the *Belemnitella junior* group.

Since 1951, according to the studies of Jeletzky on belemnites, it is accepted that the Maastrichtian stage begins with the appearance of *Belemnella lanceolata* (Birkelund *et al.*, 1984).

Two other fossil groups are important, although their representatives are rare. These are in the first place the ammonites with *Bostrychoceras polyplacum* (index of Late Campanian) and

Hoploscaphites constrictus (appearing a little bit above the Campanian-Maastrichtian boundary) and secondly small benthic foraminifera with *Bolivinooides australis* seeming to appear around the boundary (in England : Swiecicki, 1980).

So, in Northern Germany, the Campanian-Maastrichtian boundary is well defined and placed at the appearance of *Belemnella lanceolata*.

In the type-Maastrichtian area, the succession of chalks is different because there are some lacks in the sedimentation (probably due to regional tectonic events).

But, *Belemnella* of the *lanceolata* group was recorded in the vicinity of Maastricht, at Beutenaken, and is associated with *Bolivinooides australis*. Thus, the Lower Maastrichtian, at least a part of it, is represented in the type-Maastrichtian area (Robaszynski *et al.*, 1985).

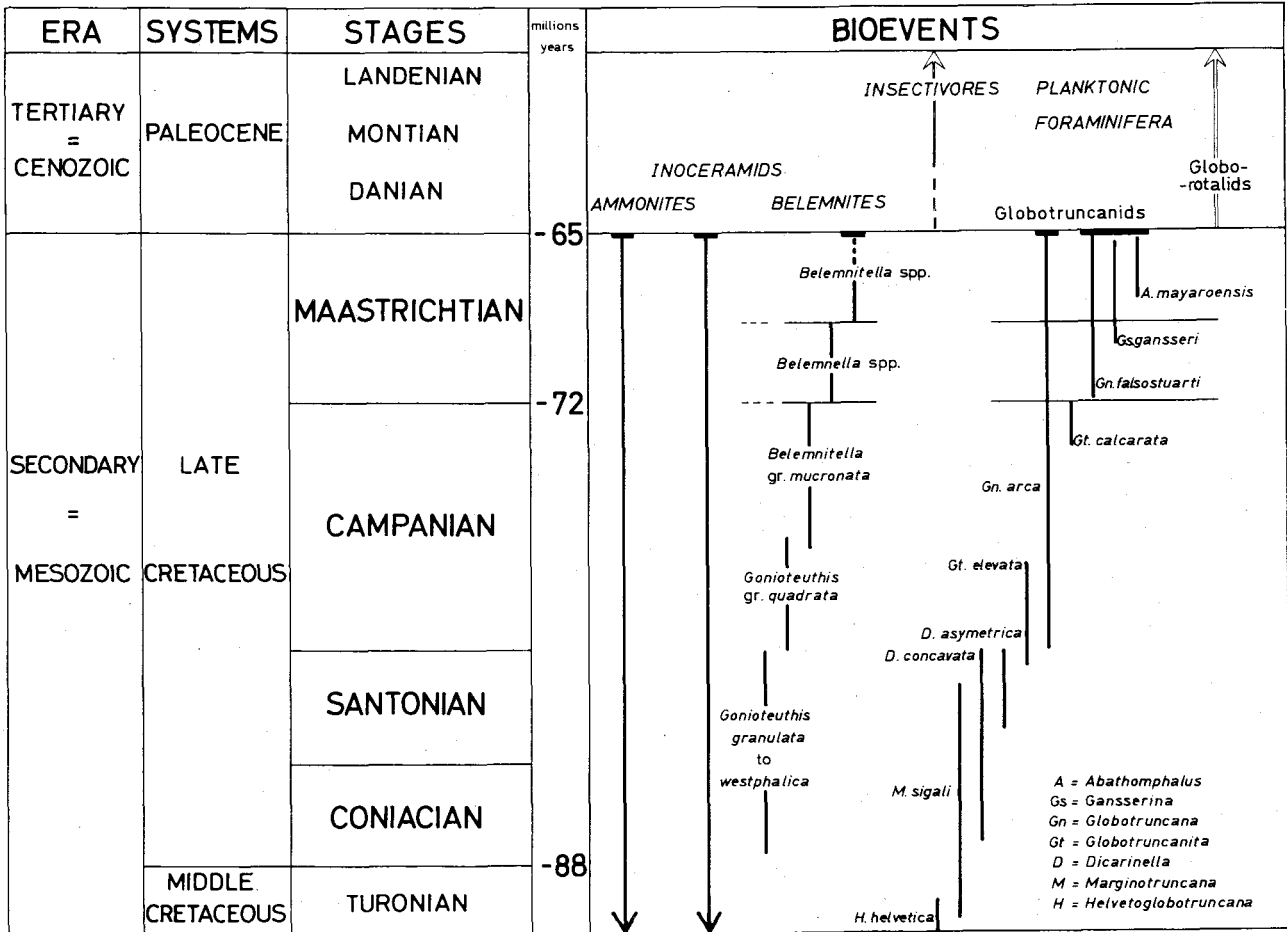


Fig. 3.- Situation of the Campanian-Maastrichtian boundary in the Late Cretaceous time scale (Belemnites from Schulz *et al.*, 1984; numerical ages from Odin, 1983).

2.3. THE BOUNDARY IN THE TETHYAN REALM

In the type-Campanian area (Charentes, France) there is a succession of limestones with a reef-level of rudists. Other macrofossils are rare. Only several specimens of *Bostrychoceras polyplacum* and belemnites of the *mucronata* group were recorded. These characterize the Late Campanian (Neumann & Platel, 1985). It is generally accepted that the appearance of the rudist *Hippurites radiosus* (Philip & Bilotte, 1985) and of the benthic foraminifer *Siderolites praecal-citrapoides* marks the base of the Maastrichtian (Neumann & Robaszynski, 1985).

In Northern Tunisia, there is a continuous succession of marls with interbedded marly limestones. No belemnites are present. Only several beds with *Bostrychoceras polyplacum* indicate the Late Campanian (Burollet & Sainfeld, 1956). But there, planktonic foraminifera belonging to the Globotruncanid family abound and several groups are represented: *arca*, *stuartiformis* and *minuta*.

The extinction of *Globotruncanita calcarata*, a form evolved from *Globotruncanita stuartiformis*, indicates the very Late Campanian. And, for the majority of Tethyan geologists, the extinction of *G. calcarata* marks the top of the Campanian, or rather the boundary between Campanian and Maastrichtian (Bartenstein, 1948; Dalbiez, 1955; Herm, 1962; Sigal, 1967; Pessagno, 1967; Van Hinte, 1969; Linares, 1977; Masters, 1977; Wonders, 1979; Bellier, 1983; Bellier *et al.*, 1983; Marks, 1984; Lamolda, 1984; Robaszynski *et al.*, 1984; Caron, 1985; etc.).

2.4. COMPARISON OF THE BOUNDARY IN THE TWO REALMS

As presented above and in figure 4, there are very few evidences for using ammonites to draw an accurate boundary between the Campanian and Maastrichtian stages in the two realms. The best biological tools are belemnites and small benthic foraminifera in the Boreal sea, and planktonic foraminifera, large benthic foraminifera and rudists in the Tethyan realm. In the Boreal sea, the boundary is marked by the first

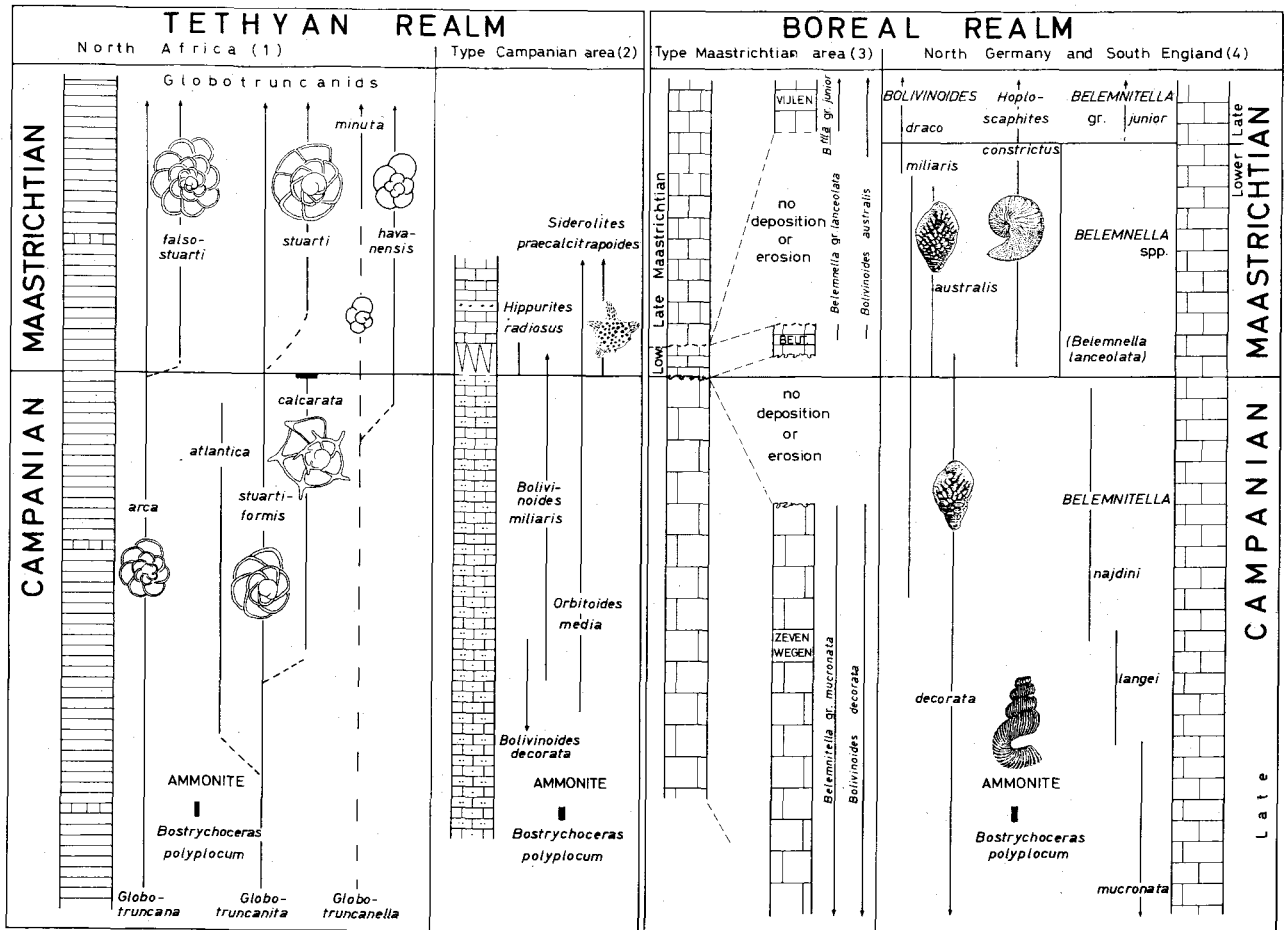


Fig. 4.- Comparison of bioevents actually used for defining the Campanian-Maastrichtian boundary in the Boreal and Tethyan realms.

Data 1 : from Buroillet & Sainfeld, 1956; Robaszynski *et al.*, 1984; Bellier, 1983; and personal observations;

2 : from Philip & Bilotte, 1985; Neumann & Platel, 1985; Neumann & Robaszynski, 1985; 3 : from Robaszynski *et al.*, 1985; BEUT. = Beutenaken Chalk;

4 : from Schulz *et al.*, 1984; Swiecicki, 1980. Lithological logs not to scale.

appearance of two taxa while in the Tethyan it is defined by the extinction of one species of planktonic foraminifera.

As yet however nobody really knows if these events are isochronic. The homogeneity of the lithology in type Boreal deposits (chalk) and in type Tethyan deposits (marls) suggests that the bioevents discussed here are not related to a major global eoevent.

Unfortunately, the type regions of the Campanian and Maastrichtian stages have been selected in former shelf areas characterized by platform carbonates and (in the Maastricht area) submitted to local tectonic influences which disturbed the sedimentary record.

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