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Aspects of the Late Jurassic and Cretaceous history of The Netherlands

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Abstract

Three depth structure maps, two subcrop maps, two isopach maps and two structural cross-sections are enclosed. They illustrate the results of uplift and erosion and of subsequent subsidence and sedimentation that occurred in The Netherlands area during the Jurassic and Cretaceous.

Near the end of the Middle Jurassic, rapid sedimentation began in narrow and restricted basins after a period of uplift and erosion, known as the Mid Kimmerian tectonic phase. This sedimentation was followed by another period of uplift and erosion, known as the Late Kimmerian tectonic phase, near the beginning of the Cretaceous. Subsequent Cretaceous sedimentation started in the centres of the Upper Jurassic basins and gradually spread towards the Mid to Late Kimmerian highs. These highs were the last areas covered with sediments near the end of the Cretaceous.

The Mid Kimmerian Unconformity, which can be mapped in the centres of the Upper Jurassic basins, was itself eroded in the areas of the Mid to late Kimmerian highs during the Late Kimmerian phase.

Sedimentation during the Cretaceous, particularly the Late Cretaceous, was more widespread than during the Late Jurassic.

Near the end of the Cretaceous, inversion and erosion took place. This erosion was strongest near the centres of the Upper Jurassic basins, where a substantial package of Cretaceous, Jurassic and locally Triassic or older sediments was eroded. This explains the present decreasing thickness of the Upper Jurassic and Lower Cretaceous sequence and of the Upper Cretaceous sediments towards the centres of the former Upper Jurassic and Lower Cretaceous basins.

Introduction

The maps presented are a compilation of local and regional interpretations by the staff of Mobil Producing Netherlands Inc and of published material. They cover the entire Dutch on- and offshore. The geological concepts used in this paper are not new but are based on publications listed in the references.

Three depth structure maps, two subcrop maps, two isopach maps and two cross-sections are discussed to illustrate aspects of the Late Jurassic and Cretaceous geological history of The Netherlands. The depth structure maps are of the Mid to Late Kimmerian Unconformity (Encl. 1)*, of Base Up-

* 8 enclosures have been inserted in the back of the issue.

per Cretaceous (Encl. 5) and of Base Tertiary / Quaternary (Encl. 6). Isopach maps are prepared for the Upper Jurassic through Lower Cretaceous (Encl. 3) and for the Upper Cretaceous (Encl. 4) intervals. The results of the Mid to Late Kimmerian erosional phases are illustrated on the subcrop map of the Mid to Late Kimmerian Unconformity (Encl. 2). This map shows the formations underlying the Base Tertiary in areas where the entire Upper Jurassic and Cretaceous sequence is eroded. Erosion caused by the Late Cretaceous to Early Tertiary inversion is evident on the subcrop map of the Base Tertiary / Quaternary (Encl. 7).

Stratigraphic revisions are not considered the objective of this paper. However, the term Mid to Late Kimmerian Uncorformity needs some explanation. The Kimmerian movements can be divided into three distinct phases (Ziegler 1975):

- The Early Kimmerian movements which occurred near the end of the Triassic were only minor in the subject area and are outside the scope of this paper.
- Mid Kimmerian movements occurred at Bajocian-Callovian times and resulted in the Mid Kimmerian Unconformity.
- Late Kimmerian movements occurred during the Jurassic-Cretaceous transition and resulted in the Late Kimmerian Unconformity. Towards the so-called Mid to Late Kimmerian highs the Mid Kimmerian Unconformity is truncated by the Late Kimmerian Unconformity.

The effects of the Mid and Late Kimmerian uplift and erosion are graphically displayed in Fig. 1. This cartoon essentially shows a diachronous surface at the base of the Late Jurassic and Cretaceous deposits. This surface will in this paper be referred to as the Mid to Late Kimmerian Unconformity.

Mapping procedures

Data base

Mobil's seismic and well database and published information have served as input for the maps and cross-sections presented here. The input data varies considerably in quality and density depending on the area. Generally, the database is better in the offshore than in the onshore (Fig. 2). Published information has been used for a major part of the onshore. In particular, reference is made to the publication 'Explanation to tectonic maps of The Netherlands' by P. Heybroek (1974).

The maps and cross-sections are simplified compilations from local and regional seismic interpretations. Results of these interpretations were digitized, gridded on a 1.15 km grid and recontoured by computer with a 100-metre contour interval. Because of the proprietary nature of the detailed interpretations, these maps have been recontoured at a 500 or 1000-metre contour interval for publication purposes. For display and computer mapping purposes, faults are represented by dense contouring.

Chronostratigraphic terminology has been used as much as possible. Where lithostratigraphic terminology was used it refers to the 'Stratigraphic Nomenclature of The Netherlands' by Nederlandse Aardolie Maatschappij & Rijks Geologische Dienst (1980) and to the revised Late Jurassic stratigraphy of Herngreen & Wong (1989).

Map description

Enclosure 1 illustrates the depth-structure of the Mid to Late Kimmerian Unconformity. The sediments overlying this erosional surface are of Callovian or younger age.

Enclosure 2 shows the subcrop of the Mid to Late Kimmerian Unconformity. In areas where this unconformity has been eroded it shows the subcrop at base Tertiary. The Late Kimmerian erosion was limited in the centres of the Upper Jurassic and Lower Cretaceous basins but has cut deeply into the sequence on the Mid to Late Kimmerian highs (Fig. 3).

Enclosure 3 is an isopach map of the Upper Jurassic and Lower Cretaceous sequence. The thickness of the sequence is the result of basin fill during the corresponding period and of subsequent erosion during Late Cretaceous and Early Tertiary inversion and uplift. The sequence is thin or absent in the inverted basin centres. Towards the platform

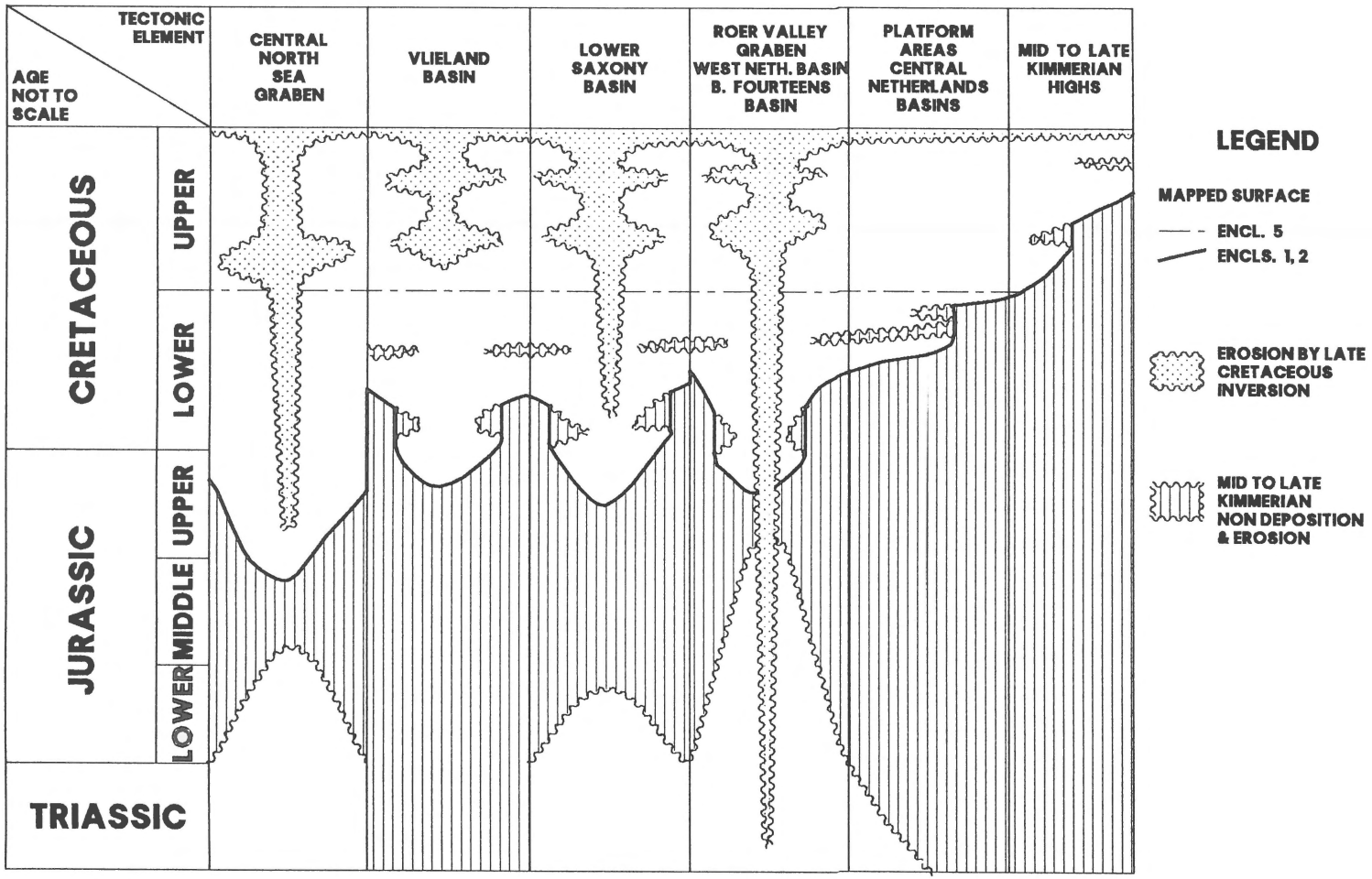

Fig. 1. Schematic diagram showing extent of Mid to Late Kimmerian non-depostion & erosion.

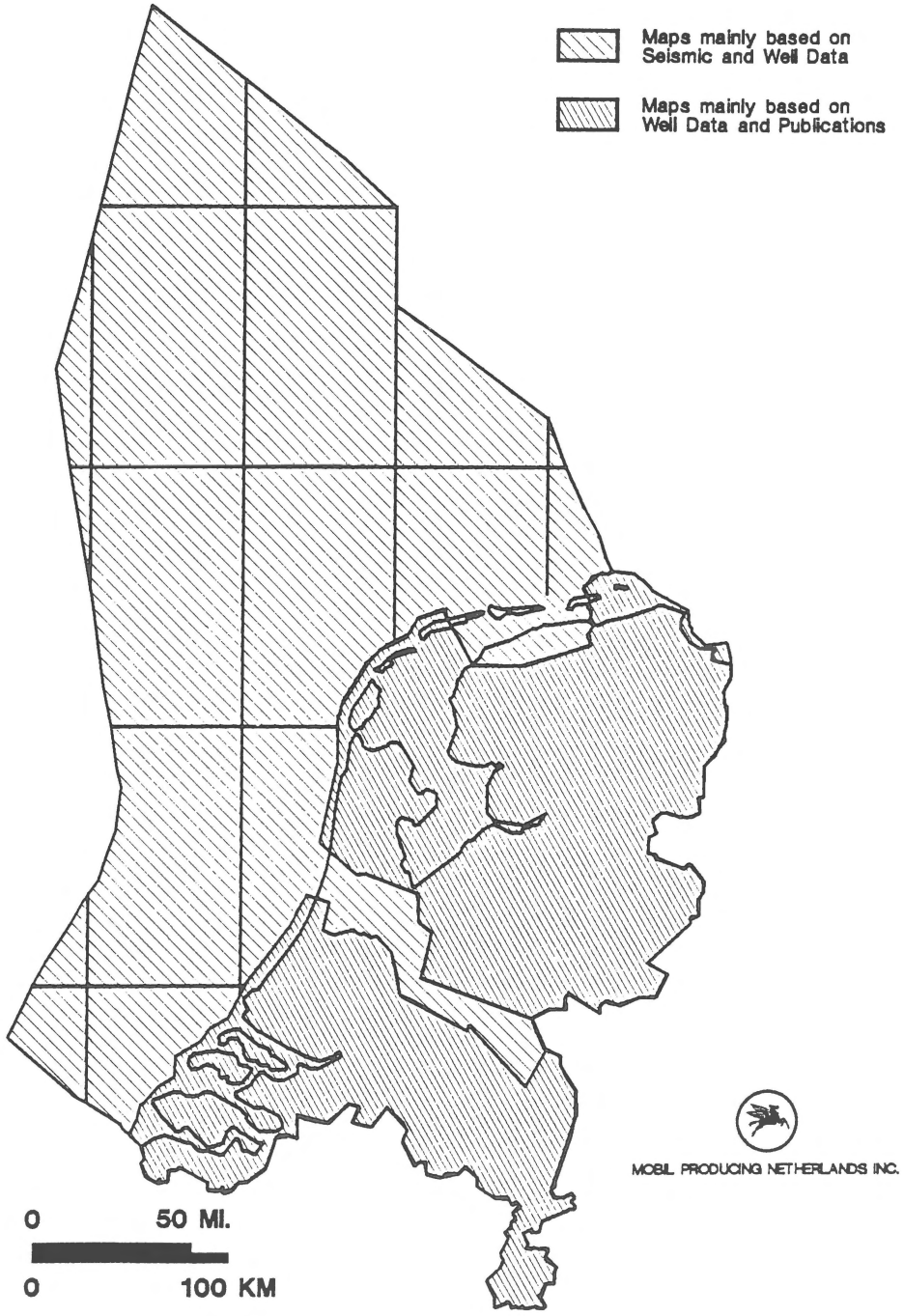

Fig. 2. Map showing distribution of data base regions as used in this compilation.

areas the interval thickens rapidly. On the platform areas and Mid to Late Kimmerian highs the sequence becomes thin to absent.

The Upper Cretaceous isopach map (Encl. 4) shows the combined results of Late Cretaceous subsidence and sedimentation and of subsequent inversion and erosion. Comparing the Upper Cretaceous isopach map (Encl. 4) with the Upper Ju-

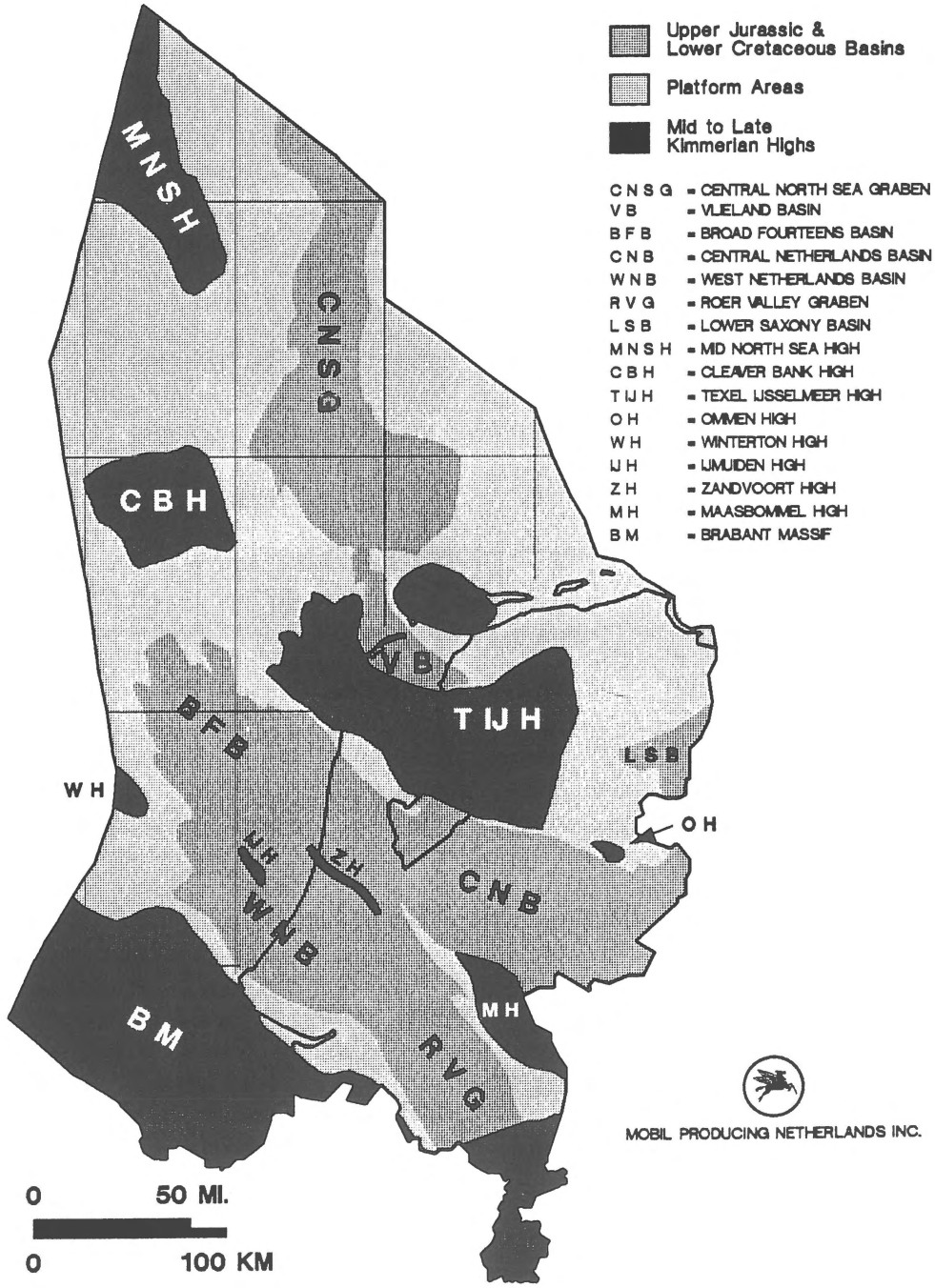

Fig. 3. Map of the Netherlands area showing distribution of Upper Jurassic & Lower Cretaceous basins and highs.

rassic and Lower Cretaceous isopach map (Encl. 3) shows the more widespread extent of Upper Cretaceous sedimentation.

The Base Upper Cretaceous depth map and the subcrop map at the Base Tertiary and Quaternary (Encls. 5, 7) illustrate the results of the Late Cretaceous and Early Tertiary inversion. This inversion was most pronounced in the centres of the former

Upper Jurassic and Lower Cretaceous basins. In these centres most of the Cretaceous and Upper Jurassic sequence is eroded.

The Base Tertiary / Quaternary depth map (Encl. 6) shows how deeply the older sediments became buried when sedimentation resumed during the Tertiary and Quaternary.

The two cross-sections (Encl. 8) illustrate the structure of the Mid North Sea High and of the inverted Broad Fourteens and West Netherlands basins together with that of the adjacent platform areas.

Discussion

Regional setting

The Dutch onshore and offshore form part of the Southern North Sea Basin which contains a thick fill of Carboniferous, Permian, Triassic, Jurassic, Cretaceous, Tertiary and Quaternary sediments. During the Carboniferous and Permian, the trend of basin development was generally east – west (Ziegler 1975). However, this trend was overprinted during the Triassic, Jurassic and Cretaceous with the formation of relatively narrow north-south and northwest-southeast trending basins. During the latter periods old Paleozoic fault trends were reactivated (Van Wijhe 1987).

Pre Mid Kimmerian

Active rifting in the Southern North Sea area started during the Triassic. In The Netherlands area, rifting commenced in the Central North Sea Graben, where it led to a thick Triassic section (Ziegler 1982). During this rifting, halokinesis started in the underlying Permian Zechstein evaporites. This halokinesis continues today and has resulted in large scale salt swells and diapirs. It has significantly affected and modified the burial history of the sediments and has led to strong localized erosion down to the Zechstein. This is illustrated on the northern parts of the depth and subcrop maps of the Mid to Late Kimmerian unconformity (Encls. 1, 2) and on cross-section B-B′ (Encl. 8), located in the northern part of the mapped area.

Rifting and related trans-tensional wrench tectonics intensified during the Jurassic (Van Wijhe 1987). This tectonic regime led to rapid deposition of the Lower and Middle Jurassic Altena Group in a number of localized and relatively narrow basins. It is postulated that limited deposition of the Lower Jurassic Aalburg Shale Formation of the Altena Group took place in areas of the future Mid to Late Kimmerian highs. This is based on the absence of sands in the Aalburg Shale suggesting that these areas were submerged during Early Jurassic time.

Mid to Late Kimmerian

Regional uplift and erosion (Encl. 2) started in the Middle Jurassic, lasted locally until the Late Jurassic and Early Cretaceous transition and gave rise to the Mid and Late Kimmerian unconformities.

In the north, the Mid Kimmerian Unconformity is of Bajocian-Bathonian age as evidenced by the presence of Callovian Lower Graben Sands directly above the unconformity (Herngreen & Wong 1989). In the south, deposition continued into Oxfordian times as indicated by the local presence of Oisterwijk Limestone below the unconformity. The earliest deposits on top of this unconformity are of Kimmeridgian age and belong to the Delfland Group (Nederlandse Aardolie Maatschappij & Rijks Geologische Dienst 1980).

After the Mid Kimmerian uplift and erosion, a new depositional cycle started in the north in the Central North Sea Graben with the deposition of the Callovian-Oxfordian Central Graben Group. In the south and east, the deposition of the Delfland Formation in the Broad Fourteens and West Netherlands basins and of the Niedersachsen Group in the Lower Saxony Basin started in the Late Jurassic. Meanwhile the platform areas and the Mid to Late Kimmerian highs were areas of non deposition or erosion. The Late Jurassic deposition was interrupted by the Late Kimmerian rifting pulse that occurred at the Jurassic-Cretaceous transition (Van Wijhe 1987). The corresponding erosion was limited in the Upper Jurassic and Lower

Cretaceous basins and extensive on the Mid to Late Kimmerian highs.

In some areas even pre-Permian sediments were eroded (Encl. 2). The present depth to the Mid to Late Kimmerian Unconformity varies generally from 1,500 to 3,000 m. The present maximum depth of this unconformity is in the Central North Sea Graben and is 6,000 m (Encl. 1).

Post Late Kimmerian

Subsidence after the Late Kimmerian movements was followed by transgression in the Early Cretaceous and started in the areas of the Upper Jurassic basins. During Hauterivian-Barremian times this transgression reached the platform areas. The Mid to Late Kimmerian highs were finally submerged during the Late Cretaceous (Haanstra 1963). This is illustrated by thinning and onlap towards the Brabant Massif and Mid North Sea High on cross-sections A-A′ and B-B′ respectively (Encl. 8).

In contrast to the restricted deposition of the Late Jurassic, the Cretaceous deposition was the result of widespread subsidence (Encls. 3, 4). This subsidence continued during the Late Cretaceous with the deposition of the Chalk Group. It is postulated that around 1000 to 2500 m of Chalk Group were deposited in the areas of the former Upper Jurassic and Lower Cretaceous basins. The current isopachs of the Upper Cretaceous (Encl. 4) show the combined results of the Late Cretaceous subsidence and sedimentation and of subsequent inversion and erosion. Erosional remnants of locally more than 1500 m of Chalk Group are located in areas covering the edges of the former Upper Jurassic and Lower Cretaceous basins.

Inversion

Towards the end of the Cretaceous, strong transpressional wrench movements took place, leading to uplift and erosion. This generally compressive tectonic regime was caused by the collision of the African and Western European plates (Ziegler 1982). The effects of these movements were most pronounced in the centres of the Upper Jurassic and Lower Cretaceous basins. In these centres most of the Jurassic and Cretaceous sediments were eroded (Encls. 4, 5, 7). In some areas, the inversion movements were so strong that this led to local erosion of Triassic or older sediments. The Mid to Late Kimmerian highs were relatively unaffected by these movements. The relative downwarping of these highs with respect to the inverted Upper Jurassic and Lower Cretaceous basins is illustrated for the Texel IJsselmeer High on cross-section A-A′ (Encl. 8).

In summary the present configuration of the Upper Jurassic and Lower Cretaceous basins (Encl. 3) is a result of locally rapid sedimentation during the Late Jurassic and Cretaceous, and of subsequent inversion and erosion near the end of the Cretaceous.

Post inversion

Subsidence resumed during the Tertiary or Quaternary as part of the North Sea Basin formation. Subsidence was not continuous and was interrupted by periods of regression and erosion. However, the shape of the basin was not substantially modified in the area mapped (Encl. 6).

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Enclosures (in pocket)

1. Mid to Late Kimmerian Unc. Depth map
2. Mid to Late Kimmerian / Base Tertiary Unc. Subcrop map
3. Upper Jurassic and Lower Cretaceous Isopach map
4. Upper Cretaceous Isopach map
5. Base Upper Cretaceous Depth map
6. Base Tertiary / Quaternary Depth map
7. Base Tertiary / Quaternary Subcrop map
8. Cross-sections A-A′ & B-B′

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