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Late Cretaceous tectono-sedimentary events in NW Europe

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ABSTRACT

Late Cretaceous sedimentary history has been strongly influenced by both sea-level fluctuations and inversion tectonics. Evidence for tectonic movements, originally identified in German Late Cretaceous basins, is applied to the UK successions. Two periods of movement are conspicuous: a Middle Turonian episode involving huge loss of section along anticlinal axes in southern England and a Late Santonian-Early Campanian episode also involving section loss on structure and section gain off structure. This pattern is repeated where folds or blocks are underlain by inversion thrust faults (e.g. the Purbeck Fault in Dorset, the Falmer Fault in Sussex, the Portsdown Fault in Hampshire and the Bray Fault in Upper Normandy). Other episodes of inversion in the Late Turonian to Middle Coniacian and the late Early Campanian are investigated and are a probable cause of slump beds and slides. These tecto-sedimentary episodes can be applied to structures in Northern Ireland, Inner Hebrides, North Sea and Yorkshire as well as southern Britain. Beyond NW Europe the Late Santonian – Early Campanian event is widely recognised in the Carpathians, southern Europe, Africa and the Levant and coincides with the end of the Long Cretaceous Quiet Zone (Chron 34N to 33R) perhaps representing a major change in Earth dynamics related to Mid-Ocean Ridge crustal production and intra-continental crust tectonism.

1. Introduction

A primary focus of Late Cretaceous Chalk studies over the last several decades onshore in the UK and NW Europe has been on the role of sea-level fluctuations (Hancock, 1975a,b, 2000; Hancock and Kauffman, 1979; Hancock and Scholle, 1975; Haq et al. 1987, 1988; Van Wagoner et al., 1988, 1990), oceanography (Hay and DeConto, 1999 and other papers in Barrera and Johnson, 1999), sequence stratigraphy (e.g. Germany and Spain, Wiese and Kröger, 1998; Wiese and Wilmsen, 1999; Wilmsen, 2003) and climatic cycles (e.g. Gale, 1990, 1995, 1996; Thibault et al., 2016). Establishing a detailed stratigraphy for correlating events created by these broad global processes has led to an ever more refined biostratigraphy and sequence stratigraphy integrated with a geochemical and cyclostratigraphy correlation framework (Thibault et al., 2016). These studies have provided a much greater understanding of the role of oceanographic changes affecting chalk seas (Fig. 1) and chalk sea-floor environments.

In contrast, offshore in the North Sea and the N W European shelf surrounding Britain, tectono-sedimentary processes creating re-worked chalks and environments for hydrocarbon traps has been a major focus of investigation (e.g. D'Heur, 1987, 1990; Oakman and Partington, 1995). An advantage offshore is the three-dimensional view of remobilised chalks and underlying tectonic framework provided by seismic images. Onshore where high quality seismic images are rare, reworked chalks including several types of gravity driven slides and slump bedding, are more difficult to recognise and investigate given the small-scale and often two dimensional character of most geological exposures. Onshore, however, the details of the sedimentary and tectonic structures are more easily investigated at a bedding scale not generally available in the offshore environment. Interpretations from offshore core samples and geophysical logs and extrapolating these results into a broader model, benefit from onshore examples of potentially similar structures. A problem with chalk-on-chalk hiatuses is the poor resolution on seismic images due to weakly contrasting physical properties between many bedding or formation breaks, especially at great depths in the offshore.

Within the new and more precise stratigraphy the influence of tectonics on sedimentation, at a tectonic plate scale, regional scale and on a local fault or fold, can be re-assessed. The NW European platform, sandwiched between an opening Atlantic on its NW margin and Africa shearing along its southern edge, offers the chance to investigate how these combined stresses have acted on our local Cretaceous geology and its embedded structures in the UK. This requires a review of the meticulous work carried out by our European neighbours who have for long recognised such

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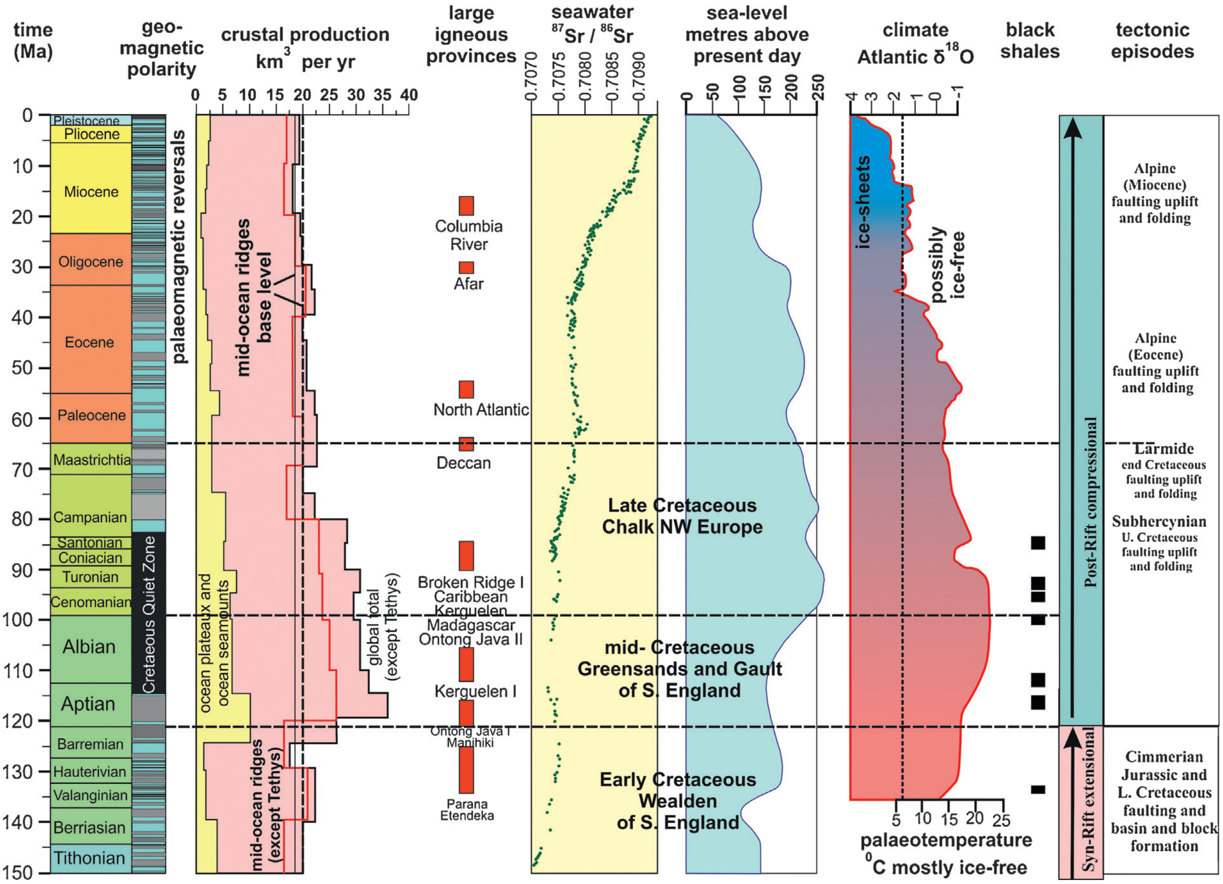

Fig. 1. Summary of global changes that influenced mid and Late Cretaceous sedimentary processes (modified from Skelton, 2003,Fig. 7.16; tectonic episodes added).

influences on the evolution of Cretaceous sedimentary basins and sea-bed highs especially in Germany, Poland, Denmark and the Netherlands.

Voigt (1963) recognised that 'compressional' tectonics probably played an important part in fault movements along the Harz and Osning thrusts. Van Wijhe (1987) used compressional intra-plate tectonism to explain inversion in the Dutch offshore. Subsequently, Ziegler (1975, 1981, 1990) provided the most comprehensive summary of the tectonic setting for Palaeozoic to Cenozoic sedimentation in Europe. Ziegler's summary includes the Late Cretaceous Subhercynian tectonic 'pulses' first described by Voigt (1929), Stille (1924) and Riedel (1940, 1942) in the Subhercynian Basin, Germany. Tectono-sedimentary structures created by the Late Cretaceous Subhercynian and end Cretaceous Laramide tectonic phases are relatively small-scale compared with later Cenozoic 'Alpine' tectonics and have, therefore, been under-emphasised in the UK (not elsewhere in Europe) as a role in the evolution of Late Cretaceous sedimentary environments and tectonic structures, especially in the Chalk.

A feature of the tectonics across NW Europe is the reactivation of older basement faults during the Mesozoic and Cenozoic recognised by many authors (Stille, 1924; Voigt, 1929, 1963) summarised by Ziegler, 1975, 1987, 1990). In Plane stresses applied by the opening of the North Atlantic Ocean and African Plate collision with the European Plate are considered to be the driving forces behind the reactivation of these faults leading to inversion (Bosworth et al., 1999; Guiraud and Bosworth, 1999; Nielsen et al. 2005, 2007). Only recently have the impacts of these tectonic fault movements on Late Cretaceous sediments been more widely investigated and demonstrated in the British Isles (Mortimore and Pomerol, 1991, 1997; Mortimore, 2011b; Mortimore, 2018b, *in prep*). The examples from the British Isles match the history of synsedimentary and penecontemporaneous tectonic movements during Late Cretaceous sedimentation in Europe, the North Sea and Africa (Niebuhr and Ernst, 1991; Niebhur, 1995; Bosworth et al., 1999; Guiraud and Bosworth, 1999; Vejbæk and Andersen, 2002; Mortimore et al., 1998; Mortimore, 2011a,b).

Potential Late Cretaceous tectonic movements are recognised by the presence of hiatuses, lateral variations in Chalk thicknesses between subsiding basins and uplifting highs, lithological changes and inter bed slides and slump bedding closely related to local basin boundary faults and/or folds in each region of the British Isles and the adjacent offshore (Mortimore, 2011a; Mortimore, 2018b, *in prep*). Several stages in the evolution of slump folding and bed shearing have also been recognised. Initial sedimentation onto a non-uniform sea floor (e.g. block faulted seabed in Northern Ireland and Outer Moray Firth (see below), and uplift along faults and folds in the North Sea basin), provided slopes for gravity driven bed sliding. Further sedimentation would have eventually blanketed the early sea-bed profile. To maintain space and slope conditions for renewed sediment accumulation, slumping and sliding, a new sea-floor profile needed to be regularly created and this occurred in areas where fault blocks, folds and tilting were active. Sea-floor erosional channels created channel-side slopes (Esmerode et al., 2007, 2008) where active downslope sliding could also occur. The tectonically controlled highs between downfaulting basins were areas where condensation of sediments, active sea-floor erosion and winnowing and hardground formation were also typical.

It was further suggested (Mortimore, 2018b, *in prep*) that sliding happened on various scales involving partly consolidated calcareous chalk muds and partly formed flints. A typical slide profile involved 10–20 m thick megablocks. Décollement basal shears

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