Proceedings of the Geologists' Association xxx (2018) xxx–xxx

Contents lists available at ScienceDirect

Proceedings of the Geologists' Association

journal homepage: www.elsevier.com/locate/pgeola

Chalk thickness trends and the role of tectonic processes in the Upper Cretaceous of southern England

Andrew J. Newell[a,*], Mark A. Woods[b], Andrew R. Farrant[b], Helen Smith[b], Richard B. Haslam[b]

[a] British Geological Survey, Maclean Building, Wallingford, Oxfordshire, OX10 8BB, United Kingdom
[b] British Geological Survey, Environmental Science Centre, Nicker Hill, Keyworth, Nottingham, NG12 5GG, United Kingdom

ARTICLE INFO

Article history:
Received 19 September 2017
Received in revised form 29 March 2018
Accepted 4 April 2018
Available online xxx

Keywords:
Chalk
Upper Cretaceous
England
Inversion

ABSTRACT

A series of six thickness maps created at a formation scale for the Chalk of the Southern and Transitional Chalk provinces of SE England reinforce the difficulty in determining the controls on Chalk deposition. However, at the broad scale, they do appear to show that thickness patterns in the Cenomanian to Turonian chalks of the West Melbury Marly Chalk, the Zig Zag Chalk and the Holywell Nodular Chalk show correspondence with the underlying Mesozoic extensional basin structure. The major exception to this is the south Dorset area which was uplifted in the Early Cretaceous as an eastern extension to the Cornubian Ridge. The younger New Pit Chalk and Lewes Nodular Chalk show a switch toward thicker successions on the London Platform and thinner, more uniform successions across the Mesozoic basins to the south. This change may indicate some initial basin inversion starting in the mid Turonian which caused a shift in the main locus of Chalk deposition toward East Anglia. The work potentially suggests multiple control-modes shaping the geometry of Chalk deposits, involving an interplay of: 1) long-lived basin-defining faults and structural blocks acting to shape large-scale thickness trends through differential compaction and interaction with relative sea level change; 2) smaller scale structures that may function to more effectively dissipate stress created by intra-Cretaceous tectonic events, producing more localised/sub-regional thickness and facies variations; 3) early basin inversion reflecting the broader basin-scale response to intra-Cretaceous tectonics, potentially responsible for regional shifts in patterns of sedimentation.

1. Introduction

The Chalk Group is a fine-grained biogenic carbonate generated primarily by coccolithophores in marine waters that covered much of NW Europe during a phase of high eustatic sea-level in the Late Cretaceous (Hancock and Kauffman, 1979; Hancock, 1989; Jeans and Rawson, 1980; Wray and Gale, 2006; Cope, 2006). The Chalk forms the bulk of what has been termed by Underhill and Stoneley, (1998) the 'Upper Cretaceous Megasequence' which, in southern Britain, is bounded below by the Late Cimmerian Unconformity and above by the Eo-Alpine or Laramide Unconformity (Fig. 1). In southern England, the Upper Cretaceous Megasequence is pre-dated by a thick (up to 3 km) Permian-Lower Cretaceous sequence that was deposited during multiple phases of crustal extension and normal faulting related to the breakup of the Pangaean Supercontinent (Chadwick, 1986; Coward et al., 2003). By contrast, the Chalk is post-dated by Tertiary strata that were deposited under complex, and currently much debated, interactions between epeirogenic uplift associated with the Iceland mantle plume, crustal compression related to Alpine orogenesis and/or ridge push associated with the production of new oceanic crust in the North Atlantic Ocean (Cogné et al., 2016; Coward et al., 2003). The Late Cretaceous Chalk is thus bracketed by two contrasting tectonic episodes, and possibly as a result, there has always been some uncertainty over whether its deposition was influenced by the closing stages of Mesozoic extension, the beginning of Cenozoic compression, or indeed a prolonged period when there was very little tectonic activity at all (Coward et al., 2003). For example, Hancock (1989) and Mortimore (1986b) described patterns of thickness and facies change that appear to be related to active tectonics and/or patterns of sea-level change. Other studies have shown that basin-margin faults frequently cut the Chalk Group, and in places extend upward into Tertiary strata (Hopson et al., 2007; Booth et al., 2011; Newell and Evans, 2011; Hopson and

* Corresponding author.
E-mail address: ajn@bgs.ac.uk (A.J. Newell).

https://doi.org/10.1016/j.pgeola.2018.04.002
0016-7878/

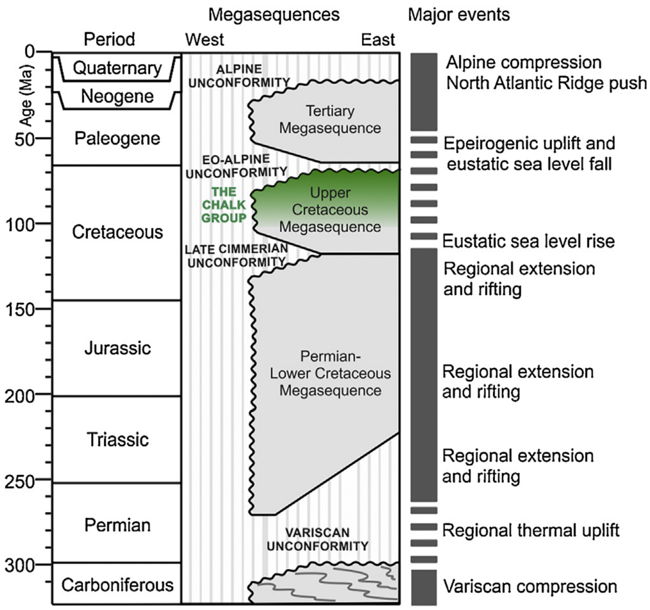

Fig. 1. Simplified chronostratigraphy of southern Britain showing depositional megasequences, major unconformities and selected major tectonic and eustatic events. Modified from Underhill and Stoneley, (1998).

Farrant, 2015). In contrast, Chadwick (1985b) concluded that most thickness changes in the Chalk could be accounted for by differential compaction of the underlying basin fill, without the need for active synsedimentary tectonics. Hibsch et al. (1993) similarly concluded that the great majority of normal faults observed in the Chalk result from heterogeneous compaction processes and that, relative to areas in the east such as the Sole Pit Trough and West Netherlands Basin, Late Cretaceous compressional structures in southern England were weakly developed.

Understanding the tectonic context of Chalk deposition has been further complicated in recent years by the recognition of large-scale sedimentary features in the Chalk such as moats, drifts, mounds and channels (Surlyk and Lykke-Andersen, 2007). Many of these features have amplitudes of more than a hundred metres and can extend laterally for kilometres and in the past may have been misinterpreted as having a tectonic origin rather than having a causal link to bottom currents in Chalk marine environments (Gale et al., 2013; Lykke-Andersen and Surlyk, 2004).

To date, the majority of studies investigating the possible relationship between tectonics and Chalk deposition in the onshore Chalk Group of southern England have been highly targeted on short stratigraphic intervals and restricted geographic areas (Mortimore, 2011). Such studies carefully trace and correlate individual marker beds such as marls, flints and hardgrounds across geological structures that may have had a control on their development (Robinson, 1986). While such studies are highly valuable, their scale has however raised the issue of whether the primary control on features such as bed truncations, hardgrounds and thickness changes was tectonic or sedimentary in origin (Gale et al., 2013). In this paper we adopt a different approach by examining the Chalk at a formation scale across the whole of SE England. By creating a series of six thickness maps for the Cenomanian to early Santonian Chalk and relating these to the well-constrained subsurface structure of southern England, we attempt to determine the relative importance of extensional faulting, basin inversion, tectonic quiescence or indeed large-scale sedimentary processes on the Chalk Group of southern England.

2. Methods

2.1. Area of interest

The thickness maps presented below extend across the Chalk of SE England in the area to the south of The Wash (Fig. 2): these are the chalks of what are termed the Southern and Transitional provinces (Mortimore, 2011). In contrast to the Chalk of the Northern Province in Lincolnshire and Yorkshire which are omitted from this study, the Chalk of the Transitional and Southern provinces are largely free of significant diagenetic alteration. Across SE England, the western erosional edge of the Chalk trends SW to NE from south Dorset to The Wash. South of the Berkshire Downs and Thames Estuary the Chalk is deformed into a series of W-E trending folds and monoclines (Fig. 3) produced by the inversion of basins and faults by northward-directed compression, primarily during the Cenozoic (Newell and Evans, 2011). In the major synclinal 'basins' of London and Hampshire the Chalk is overlain by a partial cover of Tertiary deposits (Fig. 2) while across many of the major anticlines such as the Pewsey, Mere and Weald inversions the Chalk has been partially or entirely eroded. Within the area of interest, the preserved distribution of Chalk is thus considerably reduced from its original depositional limits. Moreover, the erosion of Chalk from major anticlinal crests such as the Weald has destroyed critical evidence, such as onlap and thinning trends, that is required to determine whether these were active growth structures in the Late Cretaceous.

2.2. Stratigraphic interval

The historical evolution of Chalk lithostratigraphy has seen it move from a simple three-fold classification of Lower, Middle and Upper Chalk (e.g. Jukes-Browne and Hill, 1903, 1904), through a transitional phase of regionally distinct lithostratigraphical schemes (Mortimore, 1986a; Robinson, 1986; Jarvis and Woodroof, 1984; Wood and Smith, 1978), to integrated national schemes for northern and southern England (Rawson et al., 2001) (Fig. 4). The increase in stratigraphical resolution has revealed the extent of major faulting and facies variations within the Chalk succession and the likelihood of complex depositional processes.

The study considers the lowermost six formations of the Chalk Group extending from the West Melbury Marly Chalk Formation at the base to the Seaford Chalk Formation (Fig. 4). Santonian and Campanian chalks of the Newhaven, Culver and Portsdown Chalk formations are omitted from the study because of their relatively restricted geographic distribution. The preservation of younger Chalk formations across SE England is significantly reduced, not only by late Cenozoic erosion, but also by Palaeocene erosion beneath the Tertiary unconformity (Newell, 2001). Thickness maps constructed for the purposes of determining relative deposition rate should ideally be constructed from stratigraphic slices which everywhere represent an equal duration of time. Although we consider lithostratigraphical units here, within the relatively uniformly layered Chalk Group, these closely approximate to chronostratigraphic time slices.

2.3. Thickness data

The thickness of formations was determined from 375 boreholes supplemented with outcrop data from around the eroded margins of the Chalk and key coastal and quarry sections, including published logs available in the literature (e.g. Mortimore et al., 2001). Across much of southern England the Chalk is peppered with boreholes, of variable depth and quality, many drilled in connection with water supply. These are supplemented by released data for hydrocarbons boreholes, which invariably provide