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The Paleocene stratigraphic records in the Central Netherlands and close surrounding basins: Highlighting the different responses to a late Danian change in stress regime within the Central European Basin System

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ABSTRACT

Despite their similar structural style of inversion under Late Cretaceous compressional stress, basins in the Central European Basin System showed different kinematic responses to a late Danian change in the European intra-plate stress-field.

The Late Cretaceous phase was recognized throughout the Central European Basin System by compressional inversion of the Mesozoic rifts, and the simultaneous formation of marginal troughs. The late Danian change in stress regime resulted in a Middle Paleocene phase which excited longer wavelength of vertical surface movements. In several basins in Central Europe, this Middle Paleocene phase was characterized by domal uplift of the Late Cretaceous inversion zones and their proximal areas, which was interpreted to result from a sudden relaxation of the in-plane tectonic stress (a so-called relaxation inversion).

Based on the Paleocene stratigraphic records, this study shows that some basins in the south-western part of the Central European Basin System experienced subsidence of the Late Cretaceous inversion zones during the Middle Paleocene phase, or the complete opposite vertical surface movements of a relaxation inversion. Two possible mechanisms (superposition of relaxation inversions and lithospheric folding during compression) are discussed that could provide an explanation for the opposite late Danian and Selandian vertical surface movements of near-by basins in the Central European Basin System.

1. Introduction

The Central European Basin System (CEBS) in North Central Europe is a complex intra-continental sedimentary basin system that evolved through a series of Late Carboniferous to Cenozoic deformation phases (e.g. Ziegler, 1990). It covers an area extending from the southern North Sea area (UK, Belgium and the Netherlands) across Denmark and northern Germany into Poland (Fig. 1). Although the CEBS originated in Permian times above diverse crustal domains, the sub-basins on top of these domains are characterized by consistencies in their further development that unite them into one collective system (Ziegler, 1990; Van Wees et al., 2000; Scheck-Wenderoth and Lamarche, 2005). Mesozoic differentiation led to the development of NW–SE-oriented rift basins in the western part of the CEBS, such as the Broad Fourteens Basin, Central Netherlands Basin (CNB), Lower Saxony Basin, Roer Valley Graben (RVG), Sole Pit Basin and West Netherlands Basin (WNB; for locations see Fig. 1).

During the Late Cretaceous and Cenozoic, many of the Mesozoic rifts of the CEBS underwent several phases of inversion (Ziegler, 1990). The well-known Late Cretaceous compressional inversion phase was recognized throughout the CEBS and characterized by narrow uplift zones, reverse activation of faults, crustal shortening, and the formation of asymmetric marginal troughs. A late Danian fundamental change in the intra-plate stress-field of Europe triggered a subsequent Middle Paleocene phase which excited longer wavelength of vertical surface movements involved in flexural isostasy of the lithosphere underlying the CEBS (Nielsen et al., 2005, 2007). For several basins of the CEBS (such as the Sorgenfrei–Tornquist Zone (STZ), for location see Fig. 1), this phase resulted in dome-like uplift of a wide area around the Late Cretaceous inversion axis, with only mild fault movements and the formation of more distal, shallow marginal troughs (Nielsen et al., 2005). Model experiments by the latter authors explain how Middle Paleocene inversion followed inevitably from Late Cretaceous inversion after late Danian relaxation of in-plane stresses (i.e. relaxation inversion). In the RVG (for location see Figs. 1 and 2), however, the Middle Paleocene phase was not expressed by domal uplift, but flexural subsidence of a wide area around the Late Cretaceous inversion axis (Deckers and Matthijs, 2014; Deckers et al., 2014). The Middle Paleocene vertical surface movements of the RVG can therefore not be reconciled with the existing models for the other basins in the CEBS.

This study tries to establish whether the Middle Paleocene kinematics of the RVG were particular or can also be applied to other basins in the CEBS. For this purpose, the availability of sufficient stratigraphic data is essential, which is often a problem in the repeatedly inverted and

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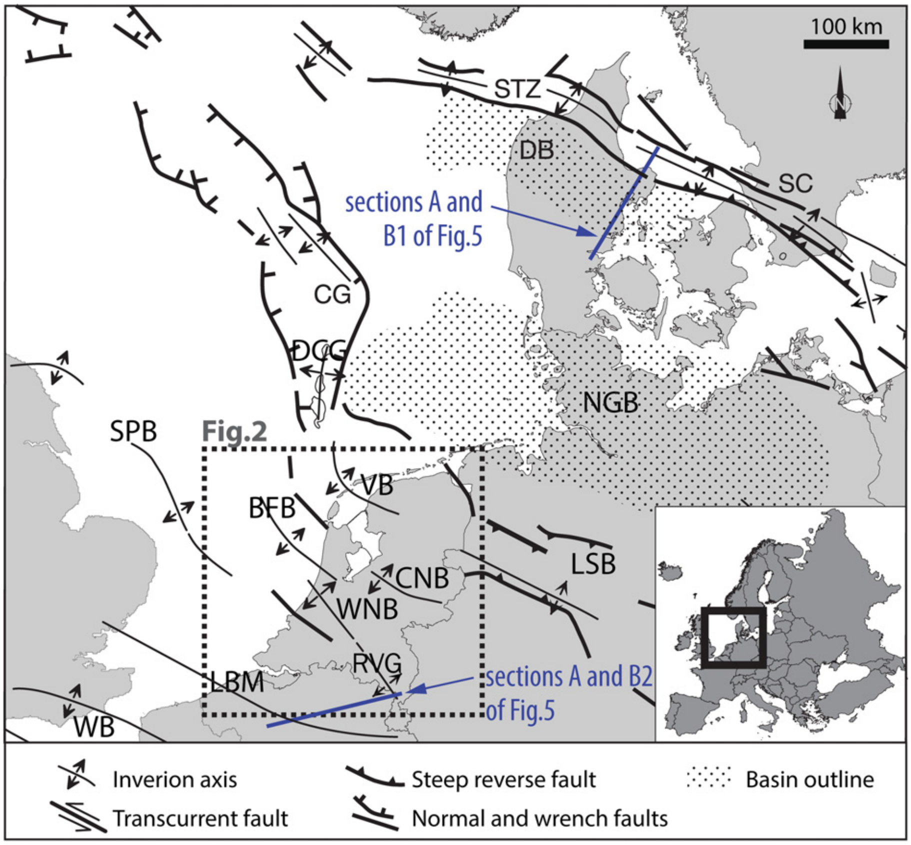

Fig. 1. Late Cretaceous structural setting in the CEBS (modified after Ziegler et al., 1990 and Nielsen et al., 2005). BFB = Broad Fourteens Basin; CNB = Central Netherlands Basin; CG = Danish Central Graben; DB = Danish Basin; DCG = Dutch Central Graben; LBM = London-Brabant Massif; LSB = Lower Saxony Basin; NGB = North German Basin; RVG = Roer Valley Graben; SC = Scania; SPB = Sole Pit Basin; STZ = Sorgenfrei–Tornquist Zone; VB = Vlieland Basin; WB = Weald–Boulonnais axis; WNB = West Netherlands Basin. The locations of Fig. 2 and sections A, B1 and B2 of Fig. 5 are indicated.

thereby strongly eroded Mesozoic rifts in the CEBS. As a result, this study focusses on the CNB (for location see Figs. 1 and 2), where the Paleocene stratigraphic records are known to be relatively complete. The stratigraphic records of the CNB will be compared to those in the RVG and another close surrounding basin (WNB) and to those in the STZ.

2. Middle Paleocene stratigraphy in the south-western part of the CEBS (onshore the Netherlands and Belgium)

In Northwest Europe, the Late Cretaceous to middle Danian stratigraphic succession is developed as a uniform cover of predominantly friable, micritic limestones that are gathered into the Chalk Group (Van Adrichem Boogaert and Kouwe, 1997). On top of the Mesozoic rifts that were inverted during the Late Cretaceous phase, the Chalk Group is thin or absent, while in their marginal troughs, the Chalk Group is relatively thick (up to >1000 m, see Fig. 2).

During the latest Danian relative sea-level low, the Chalk Group was locally overlain by the siliciclastics of the continental Opglabbeek Formation in the south-western part of the CEBS (Steurbaut and Sztrákos, 2008; Fig. 3). The Opglabbeek Formation consists of multicoloured lignitic silty claystone with intercalated sandy levels, and medium to coarse sand(stone)s (Steurbaut, 1998).

During Selandian trangression, the Heers Formation was deposited on top of the Opglabbeek Formation and older strata in the south-western part of the CEBS (Steurbaut, 1998; Fig. 3). The Heers Formation consists of a lower Orp Sand Member and an upper Gelinden Marl Member, respectively of early to middle Selandian and of middle to late Selandian age (De Bast et al., 2013). The Orp Sand Member represents a major transgression and consists of fine glauconitic marine sands, while the highstand Gelinden Marl Member consists of shallow-water marls (Steurbaut, 1998). These marls consist mainly of reworked Cretaceous nannofossils from the Chalk Group (Vandenberghe et al., 1998).

During the Thanetian, the south-western part of the CEBS became covered by the clayey deposits of the Hannut Formation (Steurbaut, 1998; Fig. 3).

3. Dataset and methodology

3.1. Dataset

The Opglabbeek and Heers Formations were not deposited throughout the south-western part of the CEBS, but only in the subsiding areas or Middle Paleocene depocenters. The thicknesses of the Opglabbeek and Heers Formations can therefore be used as a proxy for Middle Paleocene subsidence. The presence and thicknesses of these formations in the CNB were established by the use of well data. Well data was extracted from the database NLOG (www.nlog.be). Most of the wells in this database contain lithological descriptions, geophysical log data and lithostratigraphic interpretations, which enabled correlations of the Paleocene strata within the CNB (Fig. 4).

3.2. Methodology

Paleocene lithostratigraphic interpretations from the database NLOG were in some cases re-interpreted by the use of well-log data. The interpretations of log-signatures of the Paleocene strata are based on the correlation panels across the Campine Block and RVG of De Koninck et al. (2011), Deckers et al. (2014) and Deckers and Matthijs (2014; for locations see Fig. 2). Some of the main characteristics of the log-signature of the Paleocene strata are: