International Journal of Coal Geology 195 (2018) 217–237

Contents lists available at ScienceDirect

International Journal of Coal Geology

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

Temporal organic facies variations of Upper Jurassic - lowermost Cretaceous source rocks in the Danish Central Graben, North Sea

Louise Ponsaing[a,*], Jørgen A. Bojesen-Koefoed[a], Erik Thomsen[a], Lars Stemmerik[b]

[a] Geological Survey of Denmark and Greenland (GEUS), Øster Voldgade 10, Copenhagen DK-1350, Denmark
[b] Natural History Museum of Denmark (SNM), University of Copenhagen, Øster Voldgade 5-7, Copenhagen DK-1350, Denmark

ARTICLE INFO

Keywords:
Danish central graben
Upper Jurassic to lowermost cretaceous
Source rock potential
Kerogen
Maceral analysis
Oil-prone

ABSTRACT

The Upper Jurassic – lowermost Cretaceous marine mudstones of the Farsund Formation constitute the principal source rocks in the Danish North Sea sector with the uppermost Bo Member considered most prolific. However, the areal distribution of the Bo Member is limited and since it is thermally immature over large areas it is unlikely that this interval has generated sufficient quantities of petroleum to fill the reservoirs in the Danish sector. In search for additional source rocks potential we have investigated the lower part of the Farsund Formation using a sequence stratigraphic framework. Organic geochemical screening and petrographic analyses of core and cuttings samples have been performed to define the source potential and map the regional distribution of organic-rich sequences in the Upper Jurassic succession. The study outlines variations of both maturity, source rock quality, and kerogen quality at sequence level with an upward improvement from poor gas-prone Type II kerogen in the Kimm-1 and Kimm-3 sequences to highly oil-prone Type II kerogen in the Volg-1, Volg-4 and Ryaz-1 sequences. The kerogen is dominated by fluorescent AOM and liptinite and structural alginite in form of *Leiosphaerida*- and *Tasmanites*-type telalginites throughout the entire succession, with vertical- and regional variations in the amount of larger *Tasmanites*. The study shows that the shales in Volg-1 and -3 sequences are organic-rich and oil prone with TOC > 4 wt% and HI > 340 mg HC/g TOC. Particularly the Volg-1 sequence, being the thickest and laterally most widespread forms a significant supplementary source for oil in the Danish sector.

1. Introduction

Upper Jurassic – lowermost Cretaceous organic-rich marine mudstones are geographically widespread in the North Sea and the shelf areas northwards to the Arctic region. The Kimmeridge Clay Formation and its equivalents form the main source rock for hydrocarbons in this vast area. In the Danish Central Graben (DCG), the marine mudstones are included in the Farsund Formation, which constitutes the principal source rock in the Danish and southern Norwegian parts of the North Sea Central Graben (Petersen et al., 2013). The mudstones show significant lateral and stratigraphic variations in source rock quality both in the Danish sector and across the North Sea Basin (Cornford, 1998; Justwan et al., 2005; Keym et al., 2006; Petersen et al., 2010, 2013).

In the Danish sector, the uppermost part of the Farsund shales is commonly characterized as “hot” based on conspicuously high gamma-ray (GR) readings compared to the underlying part (Ineson et al., 2003). This unit forms the Bo Member (Volgian–Ryazanian) and is characterized by generally elevated Total Organic Carbon (TOC) content and Hydrocarbon Index (HI) values, and accordingly is the richest source rock interval in the DCG (Damtoft et al., 1992; Petersen et al., 2010). The areal distribution of the Bo Member is limited and the mudstones are mostly thermally immature to early mature in the Danish North Sea (Ineson et al., 2003; Petersen et al., 2010), so it is unlikely that they have generated sufficient quantities of oil to fill the fields in the DCG. Until recently, the lower part of the Farsund Formation has been largely neglected as a potential source for hydrocarbons. However, new studies indicate presence of intervals of rich, oil-prone shales, particularly in the northern DCG and southern Norwegian Central Graben (e.g. Petersen et al., 2010, 2013, 2016).

The overall aim of this study is to map the regional distribution of Upper Jurassic – Lower Cretaceous (Kimmeridgian – Ryazanian) organic-rich intervals and to investigate the source potential of the lower part of the Farsund Formation and the top part of the underlying Lola Formation to better characterize the Jurassic Petroleum System in the DCG. This is done by integrating screening data and results of petrographic analysis into a sequence stratigraphic framework so the composition and quality of the organic matter and its source potential can be assessed at high stratigraphic resolution. The study shows that

* Corresponding author.
E-mail address: lpla@geus.dk (L. Ponsaing).

https://doi.org/10.1016/j.coal.2018.06.006
Received 21 March 2018; Received in revised form 1 June 2018; Accepted 4 June 2018
0166-5162/ © 2018 Elsevier B.V. All rights reserved.

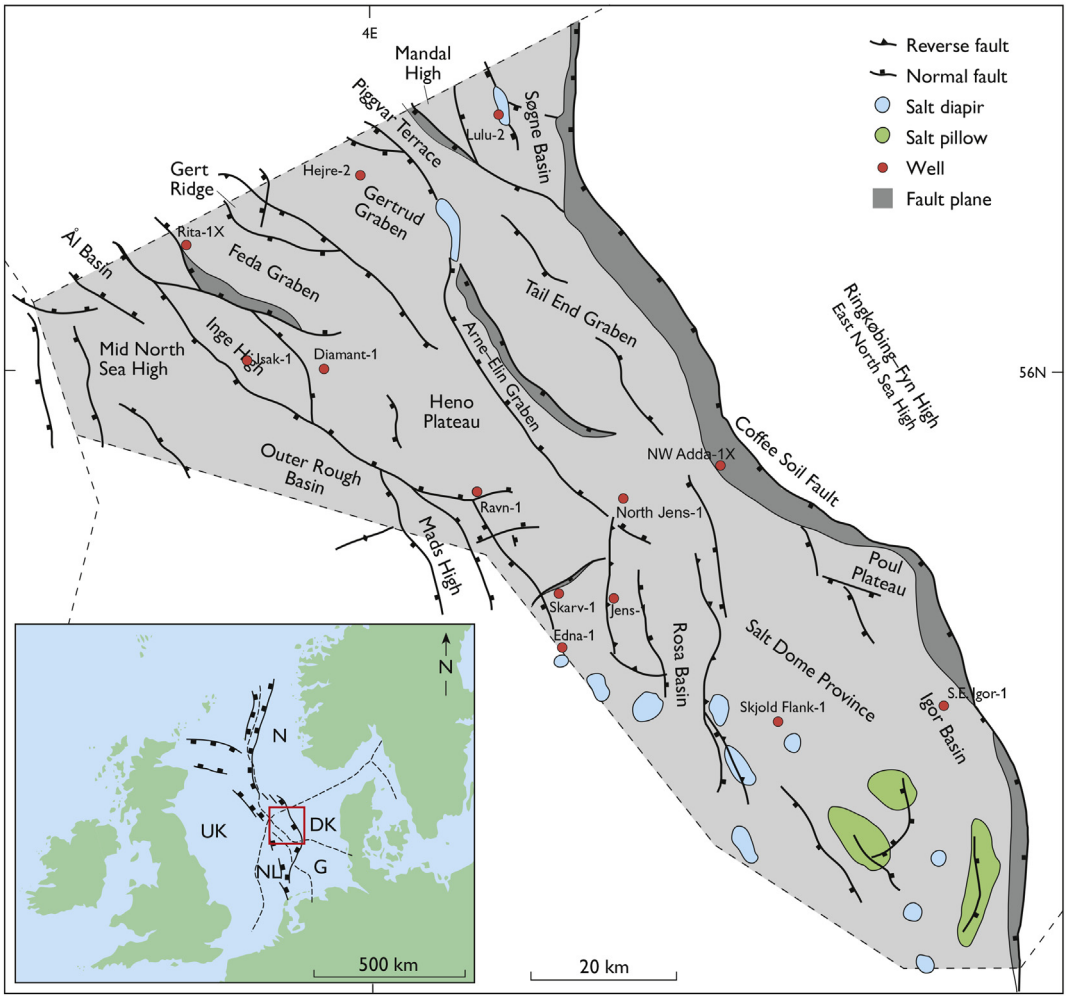

Fig. 1. Map of the selected wells and the structural elements of the Danish Central Graben (DCG). The wells cover the DCG from NW-SE. Figure adapted from Møller and Rasmussen (2003).

several of the sequences have increased source potential, with the best and laterally most widespread being the Volg-1 sequence of Andsbjerg and Dybkjær (2003).

2. Geological setting

The DCG is part of the Jurassic North Sea Central Graben rift complex. It consists of a system of generally NW–SE trending half-grabens that mainly dip eastwards (Fig. 1). The halfgrabens are separated by structural highs and bound by the major Coffee Soil Fault towards the east and the Mid North Sea High to the west (e.g., Japsen et al., 2003; Møller and Rasmussen, 2003).

The system of halfgrabens evolved by fault-controlled subsidence during the Middle Jurassic and persisted into the Early Cretaceous. Initially, fault-controlled subsidence took place in the eastern part, especially along the N–S segments of the Coffee Soil Fault. Along the fault, mid-Jurassic fluvial and deltaic sediments were deposited, representing, initial *syn*-rift deposits. During the Kimmeridgian, the tectonic trend shifted from N–S to dominantly NW-SE oriented faulting (e.g. Japsen et al., 2003; Møller and Rasmussen, 2003). At the same time subsidence rates increased significantly and sea-level was rising. Gradually, the depocentres expanded westwards and thick mudstone-dominated marine successions (Farsund Formation) were deposited over larger areas (Fig. 2). During the Early Volgian, marine deposition finally reached the flanks of Mid North Sea High. Subsidence rates decreased radically in the latter part of the Volgian, and the protracted period of extension gradually came to an end in the latest Jurassic – earliest Cretaceous as local compressional structures started to interfere with the overall extensional regime. Broadly this event coincided with deposition of the organic rich and highly radioactive Bo Member (e.g. Vollset and Doré, 1984; Andsbjerg and Dybkjær, 2003; Ineson et al., 2003; Johannessen, 2003; Michelsen et al., 2003; Johannessen et al., 2010). Petersen et al. (2010) noted that the upper part of the Farsund Formation may contain highly oil-prone shales similar to Bo Member, but the shales are not showing increased GR response.

The Jurassic succession in the DCG is subdivided into 20 sequences based on biostratigraphic and well log data supplemented with core facies analysis (Andsbjerg and Dybkjær, 2003). Subsequently, the age of some of the sequences has been slightly adjusted as part of an in-house project at the Geological Survey of Denmark and Greenland (GEUS) (Fig. 3). This paper focusses on the upper part of the Lola Formation and the Farsund Formation, corresponding to sequences Kimm-1 to Ryaz-1 (Table 1, Fig. 3). This succession attains a maximum thickness of > 2000 m in the main depocentres. The organic-rich "hot" Bo Member corresponds to the two topmost sequences, Volg-4 and Ryaz-1. It is largely restricted to depocentres in the Feda and Gertrud Grabens, western Tail End Graben and the northern Salt Dome Province (Fig. 1). Elsewhere is it either poorly developed or absent. Equivalent, laterally restricted "hot" units include the Clay Deep Member in Dutch sector and the Mandal Formation in Norwegian Central Graben (NCG) (Vollset and Doré, 1984; Ineson et al., 2003; Petersen et al., 2010).

The upper Lola and Farsund Formations and their equivalents are

Download English Version:

https://daneshyari.com/en/article/8123308

Download Persian Version:

https://daneshyari.com/article/8123308

Daneshyari.com