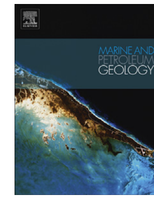
Marine and Petroleum Geology 79 (2017) 188–200

Contents lists available at ScienceDirect

Marine and Petroleum Geology

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



Research paper

The use of diagenetic signatures to distinguish marine from continental deposits in Triassic-Jurassic sandstone reservoirs from the UK Central Graben

Howri Mansurbeg

Soran University, Department of Petroleum Geosciences, Faculty of Science, Soran, The Kurdistan Region, Iraq

ARTICLE INFO

Article history:
Received 22 March 2016
Received in revised form
21 October 2016
Accepted 24 October 2016
Available online 25 October 2016

Keywords:
Diagenesis
Marine
Continental
Correlation
Central Graben
Triassic-Jurassic

ABSTRACT

Poor biostratigraphic control for some Triassic-Jurassic successions in the North Sea Basin and sub-basins necessitates the use of alternative correlation methods. This study examines the use of diagenetic signatures to distinguish continenetal from marine sandstone successions (Triassic-Jurassic) in the UK Central Graben. The key diagenetic alterations encountered in these successions include kaolinitization of the framework grains and the development of sphaerosiderite and pyrite. The $\delta\ ^{13}C_{V\text{-}PDB}$ values of siderite (−8.1 to −8.5‰) and of ankerite (−10.8 to −9.2‰), indicate a strong contribution of dissolved carbon from the decay of plant material in soil. However, marine water likely influenced diagenesis during periods of relative sea level rise by providing the dissolved sulfate (SO_4^{2-}) required for the precipitation of pyrite. The presence of diagenetic alterations such as kaolinitization of framework grains and cementation by sphaerosiderite could indicate that the sediments were deposited in an overall continental setting. However, the occurrence of pyrite and scattered grains of deep-green colored glauconite suggests occasional marine influence. Such information on the changes of the diagenetic realm provides important clues for establishing a framework for stratigraphic correlations. Caution should be exercised when interpreting petrographic data as subsequent episodes of telodiagenesis can complicate petrographic interpretations.

1. Introduction

Depositional environments have crucial control on diagenesis, reservoir quality and initial delineation of the reservoir geometry. Thus proper interpretation of depositional environment of sandstones is crucial for successful oil and gas exploration and production strategies (Selley, 1985; Morad et al., 2010).

Predicting the impact of diagenetic alterations on reservoir quality within the context of depositional environments has gained increasing recognition in recent years (Stonecipher, 2000; Morad et al., 2000, 2010; South and Talbot, 2000; Mansurbeg et al., 2008). Furthermore, it has been argued that diagenetic alterations can be linked to sequence stratigraphic framework of sandstone and carbonate reservoirs (Ketzer et al., 2003a,b; Al-Ramadan et al., 2005; Morad et al., 2012). However, using diagenesis as a tool to constrain the depositional environments is not equally well constrained in the literature.

The UK Central Graben is an area of great interest to the international oil companies as target for significant undeveloped hydrocarbon resources (Mansurbeg et al., 2008). The majority of the reservoirs in the region are sandstones deposited in a wide range of depositional environments (Evans et al., 2003; Glennie, 1998).

Overall, in the early stages of the evolution of rift basin, continental environments are prevailing. In later stages of basin development, marine depositional facies prevail. In the North Sea basin, pre-rifting Triassic fluvial channel and sheetflood sandstone reservoirs are characterized by abrupt reservoir thickness changes, elongate patterns, and poor connectivity between adjacent sand systems. Conversely, syn- and post-rifting marginal to shallow marine reservoirs of Jurassic and older formations typically form thick reservoirs with good spatial connectivity (Petroleum Prospectively, UKCS, 2009; Goldsmith et al., 2003; Husmo et al., 2002; Fraser et al., 2003; Glennie, 1998).

Thus, seismic data, biostratigraphy and subsurface facies analysis have been extensively used to constrain chronostratigraphy and depositional facies of the sands. These data were then used to predict reservoir configuration. In the North Sea, however, the

E-mail address: howri.mansurbeg@soran.edu.iq.

http://dx.doi.org/10.1016/j.marpetgeo.2016.10.026
0264-8172/

efforts to distinguish between Triassic and Jurassic successions are, in some cases, fraught with difficulty due to the lack of reliable biostratigraphic data (Goldsmith et al., 2003; Lervik, 2006).

Insufficient biostratigraphic data in the Triassic successions of the North Sea (Lervik, 2006; Goldsmith et al., 2003) have necessitated the use of alternative correlation methods (Goldsmith et al., 2003) including detrital and clay mineralogy (Glasmann and Wilkinson, 1993; Jeans, 1995), heavy-mineral analysis (Jeans et al., 1993; Mange-Rajetzky, 1995), and chemical analysis such as Sm–Nd ratios (Mearns, 1989; Mearns et al., 1989; Racey et al., 1995), magnetostratigraphy (Kent et al., 1995) and sequence stratigraphy (Steel and Ryseth, 1990; Parkinson and Hines, 1995; van Wagoner, 1995). In this study, it is proposed that diagenetic signatures can provide important insights into the depositional environments and be part of the efforts to constructing reliable stratigraphic correlations in areas with poor biostratigraphic control.

The Triassic reservoirs in the North Sea, comprise mainly continental deposits deposited in alluvial-fan, fluvial, and lacustrine environments whereas the lower to upper Jurassic formations are dominantly marginal-marine clastic sediments (Goldsmith et al., 1995,2003; Johnson and Fisher, 1998). These continental versus marine deposits are expected to have distinctive diagenetic signatures (Morad et al., 2000; Stonecipher, 2000) Therefore, eogenetic alterations should be expected to shed light on the depositional environments and, consequently, help to discriminate Triassic from Jurassic successions.

In this study, samples were collected from a succession of presumably Triassic-Jurassic sandstones in the Central Graben area (Fig. 1), for which biostratigraphy and sedimentologic core description failed to conclusively interpret the chronostratigraphy and depositional environments of the cored intervals. Detailed petrographic examinations and stable carbon ($\delta^{13}C_{V\text{-}PDB}$) and oxygen ($\delta^{18}O_{V\text{-}PDB}$) isotope analyses of carbonate cements were used to decipher the depositional environment.

Scheme of diagenetic regimes used in this paper is: (1) eodiagenesis (<70 °C; depth < 2 km), during which pore-water chemistry is controlled by surface waters (i.e. depositional and/or meteoric waters) and (2) mesodiagenesis (>70 °C; depth > 2 km), which is mediated by evolved formation water and elevated temperature (Morad et al., 2000).

2. Geological setting

Similar to other main depocenters in the North Sea, the Central Graben (Figs. 1 and 2) contains a wide range of pre-, syn- and post-rift sandstone reservoirs. The syn-rift play, which is the target of this study, contains Triassic-Jurassic fluvio-deltaic and shallow marine deposits (Brooks et al., 2002, Fig. 2). Drilling activities in the Central Graben and the surrounding area confirm that Triassic and Jurassic formations still represent viable exploration targets (Lippmann, 2012; DTI, 2003). The main Triassic reservoir in the Central Graben is the Skagerrak Formation (Fig. 3), which has been traditionally interpreted as fluvial sandstone reservoirs. The Middle-to Upper-Triassic Skagerrak Formation, is divided into the Judy, Joanne, and Josephine sandstone members, and the Julius and Jonathon mudstone members (Banham and Mountey, 2013) (Fig. 3).

However, recent studies indicate that the extent and depositional environment of the Skagerrak Formation are controversial (Jong et al., 2006). The overlying coal-bearing Middle Jurassic Pentland Formation has been interpreted to be fluvio-deltaic deposits (Wilkinson et al., 2014). There is a large unconformity (Intra-Aalenian Unconformity) separating the Triassic Skagerrak and Jurassic Pentland formations (Husmo et al., 2002). After deposition of the Pentland formation, the Central Graben was subjected to a widespread transgression, which resulted in deposition of the Upper Jurassic Oxfordian, shallow-marine sands of Fulmar Formation (Fig. 3). Deeper marine sediments of the Heather and Kimmeridge Clay formations were deposited in the central parts of the basin, transgressing its margins to form the regional top seal to the Triassic and Jurassic reservoirs (Brooks et al., 2002). A burial-history curve of the Triassic Skagerrak Formation in the nearby oilfield shows burial of up to 5 km and absence of any significant uplift (Fig. 4; Lippmann, 2012).

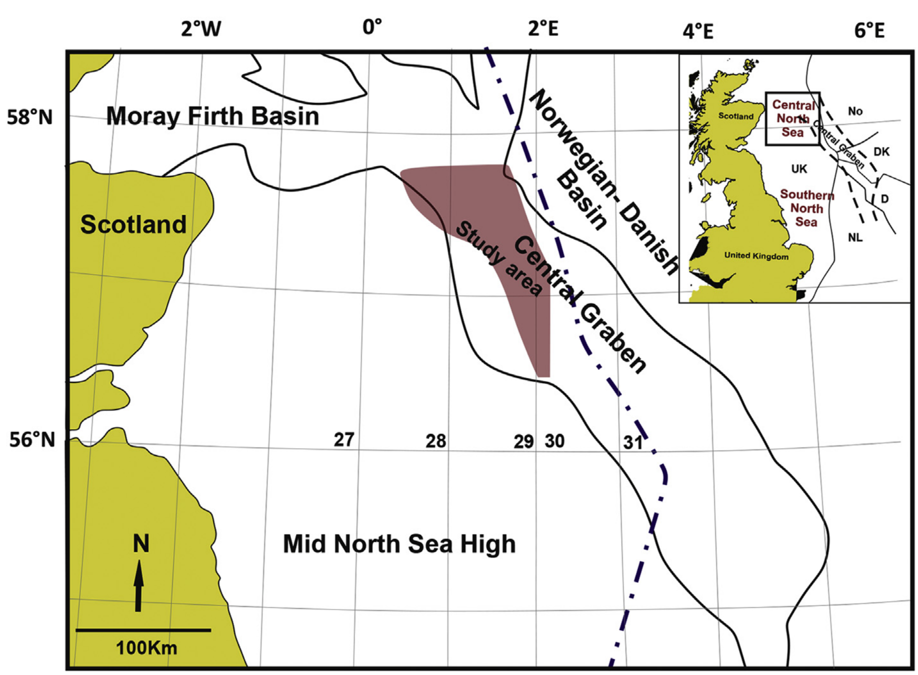


Fig. 1. Location map of the UK Central Graben and the area of the study (Modified after Faleide et al., 2002).