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Structural styles and depositional architecture in the Triassic of the Ninian and Alwyn North fields: Implications for basin development and prospectivity in the Northern North Sea

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Abstract

Interpretation of well-calibrated three-dimensional seismic volumes, sedimentological analysis and electrical well-log correlations from the Ninian and Alwyn North fields challenge the long-held view that Mid-Late Jurassic extensional faults in the East Shetland Basin represent a simple reactivation of older (Triassic) fault systems. Restoration for the effects of the younger, predominantly eastward-dipping, Mid-Late Jurassic structures clearly demonstrates that Triassic precursors had a steep, westerly dip. In contrast to the eastern flank of the Viking Graben (e.g. Troll and Oseberg areas), where the west-dipping Triassic structures are reutilised in the Mid-Late Jurassic, those of the East Shetland Basin have largely been dissected and rotated during the later event. Those west-dipping faults that did see later movement appear to have simply acted as minor antithetic structures to the throughgoing east-dipping ones.

The Triassic normal fault patterns actively controlled sediment thicknesses and facies distribution within the Lunde and Teist Formations in the basin. Use of seismic stratigraphic surfaces, calibrated by biostratigraphy and chemostratigraphic markers, provides strong evidence that the Triassic depocentres are spatially offset from their Mid-Late Jurassic counterparts. The combination of structural, stratigraphic and sedimentary effects reveal the existence of an emergent deeper Triassic play opportunity in footwall locations to the Mid-Late Jurassic normal faults, which has the potential to extend the life of what is otherwise mature acreage.

Keywords: Triassic; Basin analysis; Northern North Sea

1. Introduction

The presence of Triassic sedimentary basins in onshore and offshore areas of the UK and Norway (e.g. in the Cheshire Basin, Irish Sea, Hebrides Basin, Horda Platform, Unst Basin and Stord-Egersund Basin, etc.) has long been recognised. Furthermore, the subsequent development of major Mid-Late Jurassic syn-rift basins above the Permian to Triassic system of basins has led to the suggestion that earlier rift episodes played an important role in the development of the North Sea rift system (e.g. Steel, 1974; Steel et al., 1975; Frostick et al., 1988; Gabrielsen et al., 1990; Lervik et al., 1990; Marsden et al., 1990; Steel and Ryseth, 1990; Færseth et al., 1995; Færseth, 1996;Færseth et al., 1997;Færseth and Ravnås, 1998; Odinsen et al., 2000). However, precise definition of the architecture of Triassic basins has proven difficult, largely due to the overprinting effect of Middle to Late Jurassic rifting, with up to 15% Jurassic extension in the East Shetland Basin compared to less than 5% on the Horda Platform (Roberts et al., 1995). Although there are exceptions (e.g. Dahl and Solli, 1993; Færseth et al., 1995, 1997; Færseth and Ravnås, 1998), it has generally been assumed that the Mid-Late

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Jurassic fault configuration in the East Shetland Basin reflects the reactivation of a pre-existing, buried Triassic structural fabric that had its locus of extension either beneath the present-day North Viking Graben (e.g. Badley et al., 1988; Steel and Ryseth, 1990; Yielding, 1990; Yielding et al., 1992; Steel, 1993) or beneath the Horda Platform (Roberts et al., 1995; Færseth, 1996).

Discovery of producible hydrocarbons in Triassic reservoirs in several Northern North Sea fields (e.g. Snorre, Visund, Gulfaks, Penguin, Pelican, Cormorant, Tern, Alwyn North and Strathspey; Underhill et al., 2003) has demonstrated the viability of this stratigraphic interval as an exploration target. Furthermore, the recent discovery of a major condensate column in the Triassic beneath Alwyn North has highlighted the hydrocarbon potential that may exist beneath other fields that predominantly produce from Lower to Middle Jurassic (Brent Group) reservoirs in the East Shetland Basin (Inglis and Gerard, 1991; Van Vessem and Gan, 1991; Murray et al., 1999; Gluyas and Underhill, 2004; Harker et al., 2003).

This study utilises high-resolution three-dimensional seismic images from the East Shetland Basin to examine the structural styles at the Triassic level. When this structure is combined with sedimentological and production-based zonation from several wells in the area, an analysis of the basin-fill sedimentology can also be determined. This is used to develop a model for syn-sedimentary deposition which is compared with end-member models of continental basin fill, developed by Bridge and Leeder (1979), Frostick and Reid (1987) and Frostick et al. (1988). The aim of this paper is to reconstruct the gross tectonostratigraphic architecture of the Triassic succession beneath the Ninian and Alwyn North fields, and to consider the general implications that this has for Triassic rift basin development and reservoir distribution in this region.

2. Geological setting and database

It is generally accepted that a phase of Triassic extension in the Northern North Sea was succeeded by a phase of Early Jurassic post-rift thermal subsidence (Glennie and Underhill, 1998). Subsequent Middle Jurassic thermal doming, deflation and subsidence of the North Sea was followed by a phase of Late Jurassic rifting that led to the formation of a trilete rift system consisting of the Viking Graben, Central Graben and Moray Firth (Underhill and Partington, 1993, 1994; Underhill, 1998). The planar normal faults developed during the Mid-Late Jurassic rift episode are generally considered to have overprinted and, to varying degrees, reactivated Triassic structures. The Ninian and Alwyn North fields, situated in the East Shetland Basin on the western flank of the North Viking Graben (UK sector), consist of two westerly dipping tilted fault blocks, bounded on their eastern side by steep, easterly dipping planar normal faults; structures that are characteristic of Mid-Late Jurassic extension in this region (e.g. McLeod et al., 2002) (Figs. 1 and 3).

The Triassic succession in the UK sector is ascribed to the Cormorant Formation (Deegan and Scull, 1977), which has not been subdivided further. In the Norwegian sector, the Triassic Hegre Group is the lateral equivalent of the Cormorant Formation, and is subdivided into three major lithostratigraphic units, namely, the Teist, Lomvi and Lunde Formations (Fig. 2), which comprise a broadly aggradational alluvial/fluvial system, dominated by sheet-flood sandstones and floodplain-lacustrine mudstones (Steel, 1993). Assigning precise ages to these formations is difficult, due to the lack of radiometric dating and paucity of micro- or macroscopic fossils for biostratigraphic zonation and dating (Fisher and Mudge, 1998).

The *Teist Formation* comprises predominantly fine-grained alluvial to floodplain facies, with little internal variation. The *Lomvi Formation* is typically thin (<100 m), and characterised by fluvial–alluvial sandstones and mudstones to more lacustrine facies. Seismically, it consists

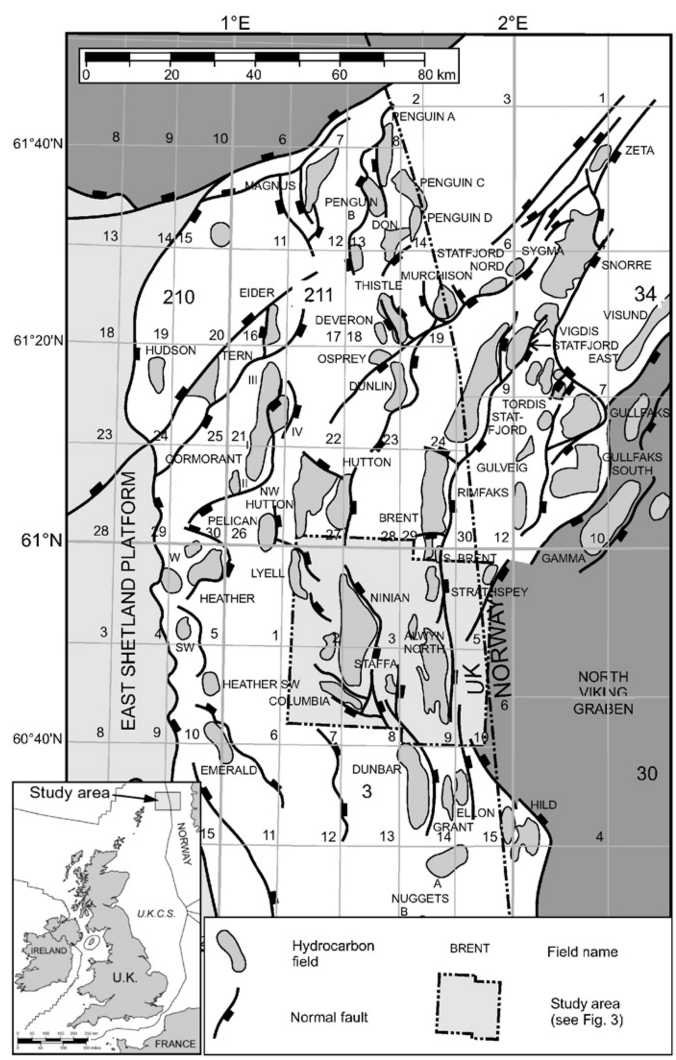

Fig. 1. Location maps of the study area in the Northern North Sea. This is enlarged in Fig. 3.