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Episodic river flooding events revealed by palynological assemblages in Jurassic deposits of the Brent Group, North Sea

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ABSTRACT

Spore and pollen (sporomorph) assemblages from Middle Jurassic marine deposits of the Brent Group in the northern North Sea are investigated to assess temporal and spatial variations in vegetation and depositional processes. Four wells were sampled for palynology from the Penguins Cluster and the Don North East fields through the Rannoch Formation shoreface succession. Hyperpycnite deposits occur throughout, but are concentrated within the lower part of the section. These are expressed by sand-prone beds displaying waxing and waning current motifs, normally graded muddy beds and structureless mudstones. Hyperpycnal/hypopycnal deposits resulting from episodic river flooding represent important sedimentary features as they may be preserved below fair weather wave base in more offshore settings and potentially be the only record of the former presence of a nearby river mouth. The hyperpycnites typically contain abundant *Botryoccocus* spp., Amorphous Organic Matter (AOM) and hinterland sporomorph taxa with relatively few marine components compared to associated marine shoreface facies. Variations in palynofacies assemblages and *Botryococcus* spp. abundances indicate frequent river mouth avulsion. Ordination of samples using non-metric multidimensional scaling (NMDS) indicates that shoreface samples of the sampled wells are relatively distinct, but hyperpycnite samples are highly similar regardless of their sampled well. This suggests that depositional processes and spore/pollen sources (i.e. catchment zones) were similar among hyperpycnite events across different wells. Abundant bisaccate pollen, *Botryococcus* spp. and AOM within interpreted hyperpycnites suggest sediment mixing along the fluvial drainage path during flooding events. The terrestrial signature of hyperpycnite sporomorph assemblages demonstrates that underflows remained coherent as they descended the shoreface profile with little turbulent mixing with ambient marine waters. Sporomorph assemblages display few large changes through time suggesting vegetation on the adjacent coastal plain was relatively static through the studied interval.

1. Introduction

Hyperpycnite deposits are increasingly recognised in the shallow marine stratigraphic record (Mulder et al., 2003; Zavala et al., 2011). Such deposits provide insights into the processes that operated on ancient shorelines, in many cases providing clues to the former presence of transient river mouths whose shallow water facies have been entirely removed by wave and tidal action. Hyperpycnal flows are negatively buoyant flows that flow along the basin floor due to their higher density, as a result of their particle load compared to the ambient density of the standing water-body (Bates, 1953; Mulder and Syvitski, 1995; Mulder et al., 2003). They form at river mouths during flooding events and can transport substantial volumes of sediment into marine basins (Mulder et al., 2003). Recognition criteria for such deposits are largely based on primary depositional structures indicative of waxing and waning flows (cf. Mulder et al., 2001), although the presence of abundant terrigenous organic matter has also been cited as a diagnostic feature (Zavala et al., 2012). These deposits differ from gravity flows resulting from episodic sediment failure in that they record the fluctuating currents associated with flood events. This contrasts with isolated waning flows resulting from sediment failure episodes. Their differentiation can be important to distinguish between deltaic systems dominated by sediment-laden seasonal flow and those capable of building unstable, failure-prone mouth-bars and delta-fronts, or subject to seismic induced failure. Here we identify the products of river flood events based on sedimentological evidence and subsequently investigate their palynomorph content to provide possible further recognition criteria for these deposits. The study area, located in the Penguins Cluster and the Don North East fields (Fig. 1) occupies the northern limit of the Middle Jurassic Brent Delta of the North Sea Viking Graben; a location which has previously been identified as turbidite-prone (Cannon et al., 1992).

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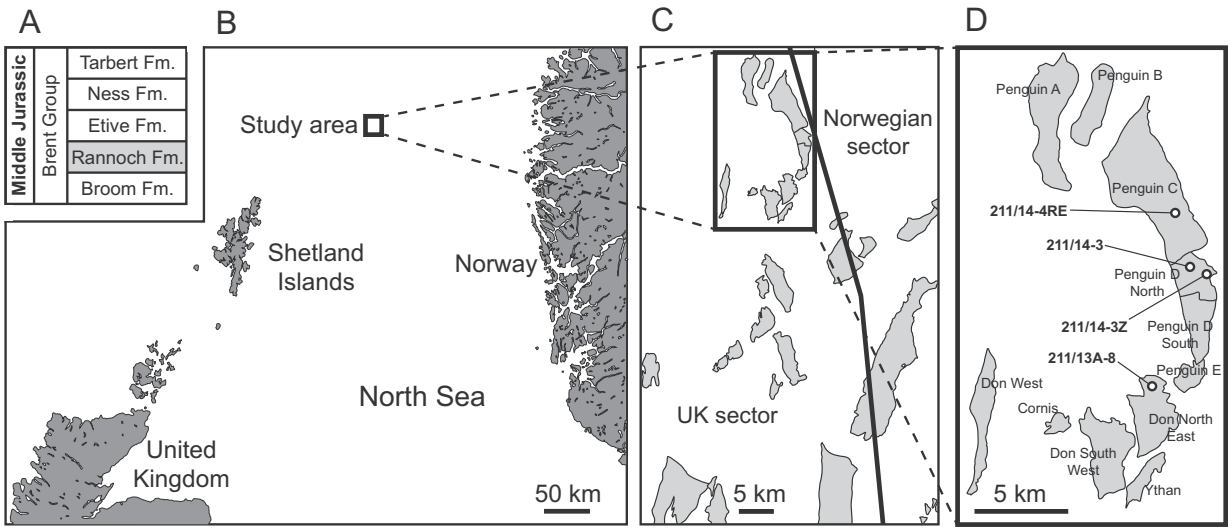

Fig. 1. Stratigraphy and maps of the study area. A, Brent Group stratigraphy (Richards et al., 1993); B, map of the North Sea with location of study area; C, regional map of study area, shaded regions represent oil/gas fields; D, well locations, shaded regions represent oil/gas fields.

We also link sporomorphs (spores and pollen) with botanical groups based on studies of spores/pollen preserved in situ within plant reproductive structures (e.g. Balme, 1995) to assess temporal and spatial variations in vegetation and sediment provenance.

2. Geological setting

The stratigraphy of the Middle Jurassic Brent Group (Fig. 1A) is largely based on fields in the East Shetland Basin (e.g. Deegan and Scull, 1977; Budding and Inglin, 1981; Cannon et al., 1992; Richards et al., 1993). The Brent Group comprises five formations (Fig. 1A): the Broom, Rannoch, Etive, Ness and Tarbert formations. The basal Broom Formation records lowstand shallow marine sedimentation, with the overlying Rannoch, Etive and Ness formations recording the progradation of an axial, basin-filling, wave-dominated delta under long-term, albeit punctuated, forced regression (Olsen and Steel, 2000; Mjøs, 2009; Went et al., 2013). In addition, Wei et al. (2016) identified a tidal signature within the Rannoch Formation c. 50 km to the south-east of the Penguin Cluster in the axial part of the basin, suggesting that the Brent delta was more tidally influenced than previously thought. The uppermost Tarbert Formation records subsequent transgression (cf. Hampson et al., 2004). The study area (Fig. 1B–D) (Domínguez, 2007), lies close to the northern limit of delta progradation (cf. Brown and Richards, 1989; Mitchener et al., 1992) and differs from the type section seen to the south-west in the Brent Field. Here the section largely lacks coastal plain Ness Formation facies (Fig. 2) and is dominated by Rannoch lower shoreface and Etive upper shoreface, inlet and beachface sandstones (Scott, 1992; Jackson et al., 2010). Ness-like facies are locally recorded in the greater Penguins area, but are poorly developed and are largely expressed by a relatively thin succession of lagoonal shales or thin coals which lack the facies

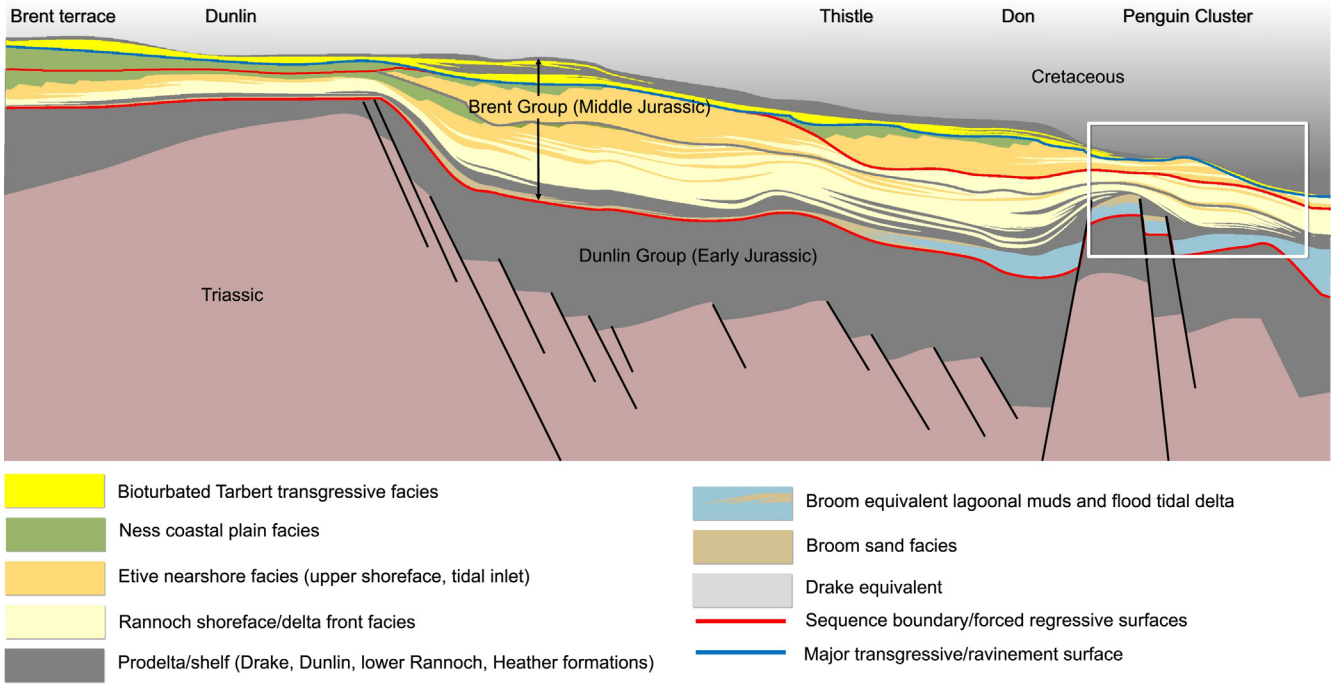

Fig. 2. Schematic facies architecture of the Brent Group extending from the area of the Brent Field north-eastwards to the area of the Penguins Cluster.

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