Late Jurassic Slumping in the “J Block” region of the UKCS Central Graben: Temporal and Spatial Relationship to Freshney Sandstone Turbidite Reservoirs*

A. D. McArthur¹, A. J. Hartley¹, D. W. Jolley¹, S. G. Archer¹, and H. M. Lawrence²

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¹Department of Geology & Petroleum Geology, University of Aberdeen (adam.mcarthur@abdn.ac.uk)
²Judy-Jade Subsurface Team Leader, ConocoPhilips

Abstract

Globally a strong relationship between mass-transport complexes (MTCs) and turbidite reservoirs is acknowledged, e.g. African and Brazilian Atlantic margins and the Gulf of Mexico. MTCs and turbidite sandstones have been recognised within the Upper Jurassic succession in the “J Block” area of the Central Graben, Quad 30 UKCS. A sedimentological and palynological study is being undertaken to determine the relationship of these MTCs to potential reservoirs.

The timing of the MTCs relative to the turbidites may have implications for production from Upper Jurassic reservoirs. Three potential scenarios for this relationship exist:

● Slumping pre-dating deposition of the turbidites may have created depositional topography, with subsequent implications for the distribution of reservoir facies.

● Simultaneous deposition, with sandstones laterally evolving from MTCs would be analogous with the Brae system. This scenario would imply connectivity between the turbidites and MTCs.

● Thirdly, the MTCs may have post-dated the turbidites. As the MTCs studied are non-erosive, they would not excise into underlying strata.

Using well log, core and seismic data, olistoliths over 100 m thick have been identified within Upper Jurassic sediments adjacent to the Jade and Judy structures. Distally debris flow horizons have been recorded. MTCs are interpreted to have originated from horsts, which developed during Late Jurassic rifting of the Central Graben.
Dinoflagellate biostratigraphy has produced a new chronostratigraphic framework, which demonstrates MTCs were not contemporaneous with Freshney deposition. Deposition of reservoir facies represented the initial rift stage, whilst MTCs occurred during rift climax.

**References**


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Adam McArthur, Adrian Hartley, David Jolley, Stuart Archer (University of Aberdeen)
Hugo Lawrence (ConocoPhillips)

11th May 2011
DEVEX
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- Background & aims of project
- Location & geological setting
- Judy structure
- Slump descriptions log & core
- Biostratigraphy
- Implications of depositional events
- Terrestrial palynology
- Freshney sources?
- Conclusions

“J Block” palynomorphs x 1000
Background of “J Block” project

- The second phase of a multidisciplinary PhD project to integrate sedimentology and palynology for reconstructing depositional systems and palaeoenvironments.
- Subsurface data from “J Block” region of the Central Graben, North Sea UK Continental Shelf (UKCS) provided by ConocoPhillips for a sedimentological and palynological examination of Upper Jurassic Mass Transport Complexes (MTCs) and Upper Jurassic turbidite reservoirs in the “J Block” area.
- Specific aim to investigate the relationship of the MTCs to turbidite system of the Upper Jurassic Freshney play, hence de-risk the Upper Jurassic stratigraphy.
Relationship of MTCs & turbidites - examples from GOM & Brazil

- Gulf of Mexico – recognised as important factor controlling reservoir distribution

Faulkenberry 2004
Hoffman et al. 2004
Figure 1. Seabed dip magnitude map of the three-dimensional seismic data. Darker toning indicates greater dip. Inset: Location of Espirito Santo Basin on the Brazilian continental margin. Locations of Figures 2, 3, 8, and 9 are also shown.

- Offshore Brazil – interaction on continental shelf controls channel distribution
What are the spatial and temporal relationships of the P1 slump block, the 7a-8 debris flows and Upper Jurassic turbidites? Do MTCs pre date, coincide or post date Freshney Sandstone?
MTCs can create topography

1. Clinoforms downlapping into slide scar
2. Systems captured in slide scar
3. Ponding on up-dip/marginal relief
4. Surface ponding - extensional faults
5. Surface ponding - contractional faults
6. Surface ponding related to folding and/or yield strength

Kneller 2010

- Removal of slump material may generate accommodation space for turbidites. Irregular surface of MTCs can also create sediment routes or surface ponding of turbidites over MTCs.
What are the spatial and temporal relationships of the P1 slump block, the 7a-8 debris flows and Upper Jurassic turbidites? Do MTCs pre date, coincide or post date Freshney Sandstone?
Contemporaneous MTCs & turbidites

Late Jurassic Brae system in South Viking Graben. Very rich sand supply to faulted margin yielded debris flow slope-apron fans that graded distally into sand rich submarine fans.

Fraser et al. 2003
Potential relationships of MTCs & turbidites

- What are the spatial and temporal relationships of the P1 slump block, the 7a-8 debris flows and Upper Jurassic turbidites? Do MTCs pre date, coincide or post date Freshney Sandstone?
Potential erosion of reservoir interval?

- MTCs are known to both create and destroy topography during their formation. E.g. Britannia Field (Central North Sea), where remobilisation of sediment has profound impact on distribution of reservoir facies, both filling and creating accommodation space for reservoir deposition. Britannia – net gain in reservoir facies due to MTCs.

Eggenhuisen *et al*. 2010
Location & Geological setting

- Located in Quad 30 of the UKCS in the centre of the Central Graben.
- Situated on the Josephine Ridge, NW-SE trending structural high.
- This study focused on Judy & Jade data.
- Fields situated on series NW plunging tilted fault blocks, bounded by high angle normal faults, with throws up to 600 m (Keller et al. 2005).
- Horsts composed of Triassic strata, with rifting believed to be Late Jurassic in age, with half grabens filling with Upper Jurassic marine sediments.
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N-S south line over southern Judy terrace.

MTCs occur on SW terrace of Judy horst, shed at main bounding fault.

P1 slump block base imaged c.100 x 100 m.
Jade olistolith vs in-situ strata

- Mid Jonathan signature observed in slump block, right way up.
- Core & biostrat analysis reveals all one block of Triassic.
Judy Core analysis

- Judy olistolith similar story to Jade.
- Distally 19 breccia and conglomerate intervals recognised from 10 – 50 cm in thickness.
- Chaotic, v. poorly sorted, matrix supported (coarse sandstone) deposits.
- Clasts sub rounded – angular, typically sub spherical, range <2 cm - >20 cm diameter.
- All events interpreted as classical submarine debris flow events originating from the Judy horst.
- Clasts largely consist of coarse sandstone and mudstone, interpreted as Triassic in origin.
Judy core analysis

- Interbedded sediments:
- Coarse grained, well sorted quartzose sandstone, with calcareous cement.
- Beds <1cm – 18cm thick, observed to fine up and have organic rich tops.
- Displays a variety of bedding structures (massive, cross-strat & thin parallel) with both prod marks & rippled bed tops – turbidite sandstone.
- Compositionally very similar to local Joanne Sandstone Triassic sediment.
- Very proximal source.
- Also fine organic rich mudstones.
Freshney Sandstone

- Massive, fine – medium grained, moderately well sorted, quartzose sandstone. Well cemented with variable siliceous & calcareous cement.
- Very sharp bases and tops to Freshney Sandstone – don't fine up. Typical of Upper Jurassic North Sea turbidites.
- Poorly resolved on seismic, beds below tuning thickness at this depth.
- Dissimilar to sandstone interbedded in with MTCs, but are minor differences due to transport?

Freshney Sandstone in 30/13-4
Sample analysis: 7a-8 - biostratigraphy

- All samples from Kimmeridgian, debris flows initiated *cymodoce* Zone.

★ First occurrence ★ Last occurrence
Sample analysis: 7a-8 - biostratigraphy

- All samples from Kimmeridgian, debris flows initiated cymodoce Zone.

**Fromea**
**Ctenidodinium**
**Kalyptea**

First occurrence ★ Last occurrence ★
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Biostratigraphic features:
- **Judy debris flows**
- **Judy olistolith**
- **Jade olistolith**
- **Freshney Sandstone - turbidite system**
Helmsdale

- First study of PhD.
- Late Jurassic fault scarp on edge of Inner Moray Firth Basin.
- Large scale MTCs shed from fault scarp into marine basin.
- Can recognise stages of rifting by nature of deposits.
Subtle alteration of topography sheds sediment captured in hinterland. Deposition of reservoir quality turbidite sandstones in the deep marine.
Once major faults broken to surface. Helmsdale & “J Block” limited sediment supply, rift climax only minor hanging-wall fans interbedded with MTCs.
• First event was deposition of Freshney reservoir units during initial rift stage, then olistolith & debris flows initiate at the same time, during rift climax but debris flows persist for c.5 Ma.
MTCs post date turbidites

- Large events (e.g. Storegga slides) which run of 1000’s km are known to erode the sea floor by 100’s of m.
- However small cohesive debris flows are, by nature non erosive.
- May exhibit loading, as with Helmsdale Boulder Beds. Hard to observe in core, but appears to load in places.
- Biostrat shows no significant sections missing, below olistoliths or within the debris flows.
- Remobilization in Britannia Field has caused removal of reservoir interval, but not anticipated in the “J Block”.

Bryn et al. 2005
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2.5 cm
Terrestrial miospores

- To determine if horsts were a source for Freshney, need to know what they were like in the Late Jurassic.
- Significant amount of “J Block” palynomorphs are terrestrially derived.
- Majority likely local and appear to decrease away from horsts.
Sample analysis: Judy miospores

- Restricted primary flora, dominated by lowland early successional affinities
Sample analysis: Judy miospores

Densiosoprites velatus

Deltoidospora sp.

Flora, dominated by lowland early successional affinities
Sample analysis: Judy miospores

Restricted primary flora, dominated by lowland early successional affinities

Deltoidospora spp.

Bisaccate pollen grains
Sample analysis: Judy miospores

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Sample analysis: Judy miospores

Spratly Islands

dominated by lowland early successional affinities
Sample analysis: Jade miospores

- Limited terrestrial palynomorphs recorded, dominated by mosses and ferns.
  - Not true ecology.
  - Material drifted in from distal land – possibly even Judy.
  - Implies Jade horst was not subaerially exposed or only for very short periods of time.
Freshney source?

- Implications of considering isolated horsts as source for Freshney Sandstone.
- Severely limited sediment yield, from very low-lying isolated islands. Multiple small hangingwall fans originating from limited horst crests. Alternatives?
- Source from UK palaeoshelf? Josephine ridge problem.
- Axial system, moving down graben, ponding against slight high where Jacqui is located?
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Fraser et al. 2003 BCU subcrop
Axial source?

- Large Ula shelf developed on Norwegian palaeo-continental margin during Late Jurassic – mirrored Fulmar Shelf. Large accumulations of shallow marine sands on either side Central Graben.
- Could Axial system have fed Freshney system? Possibly from both UK & Norwegian shelves, are all Freshney units similar?
- Mass flow into deep marine during Oxfordian lowstand (*serratum*) – classical sequence stratigraphy.
- Ula & Fulmar shorefaces regressed in Kimmeridgian with global sea level rise – explains why no turbidites in Kimmeridgian / Tithonian?

Stewart 1993
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Conclusions

- MTC complexes are known to have a profound effect on reservoir architecture.
- MTCs observed, from seismic, well logs & core data, to be originating from Judy & Jade horsts.
- Both Jade & Judy olistoliths represent singular slump events and are the correct way up.
- Breccia & conglomerate horizons represent submarine debris flows, originating from the Judy horst.
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- MTCs are not predicted to have a major impact on reservoir quality or distribution.
- The miospore assemblage suggests Judy horst was subaerially exposed, whilst Jade may have remained largely submerged.
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