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

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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.

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Late Jurassic slumping in the "J Block" region of the UKCS Central Graben: temporal and spatial relationship to Freshney Sandstone turbidite reservoirs

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Hugo Lawrence (ConocoPhillips)

11th May 2011

DEVEX

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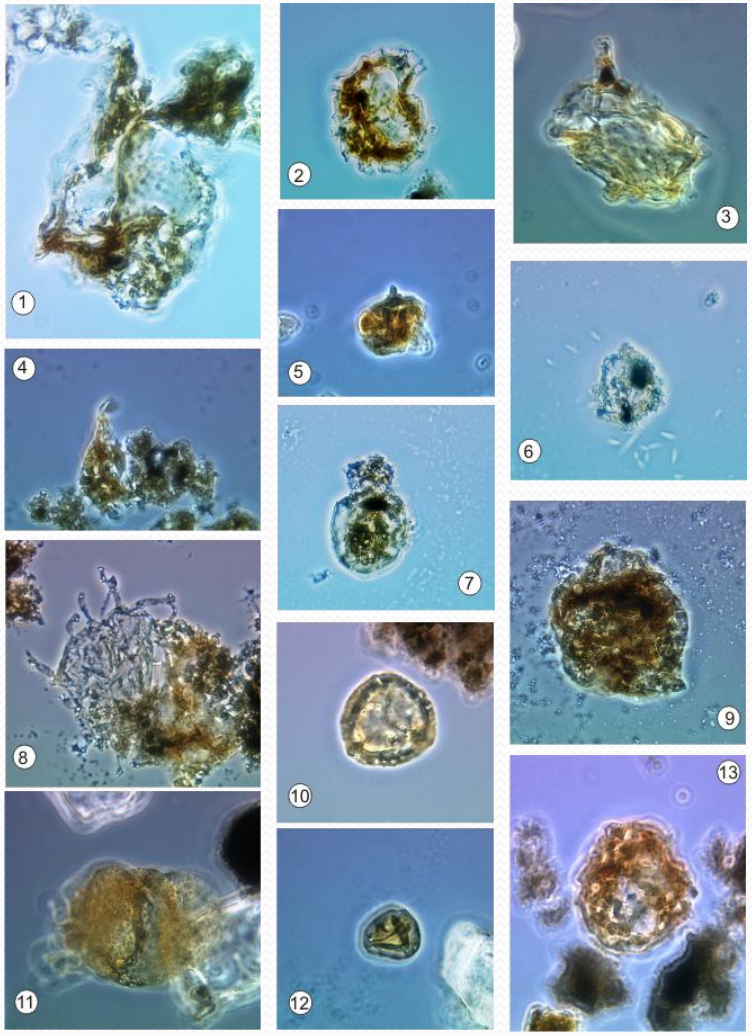
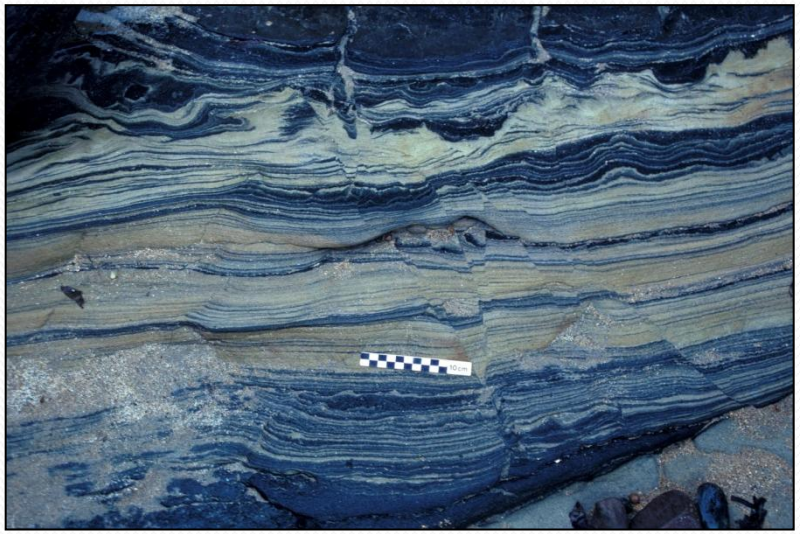
- Background & aims of project
- Location & geological setting
- Judy structure
- Slump descriptions log & core
- Biostratigraphy
- Implications of depositional events
- Terrestrial palynology
- Freshney sources?
- Conclusions

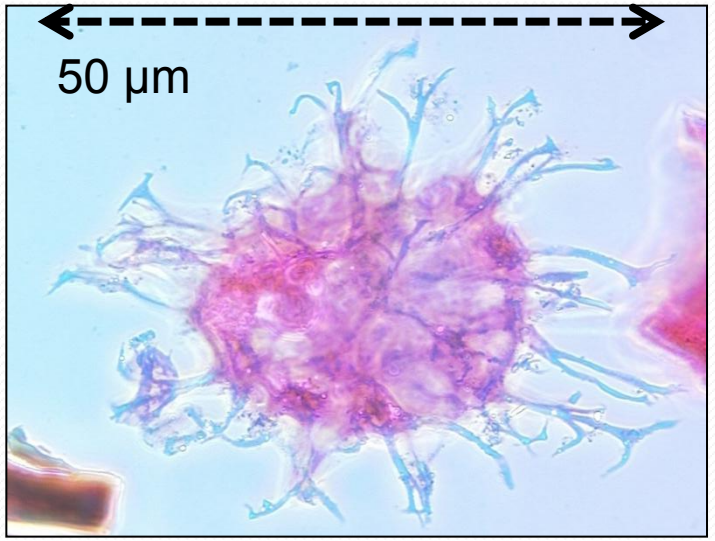


"J Block" palynomorphs x 1000

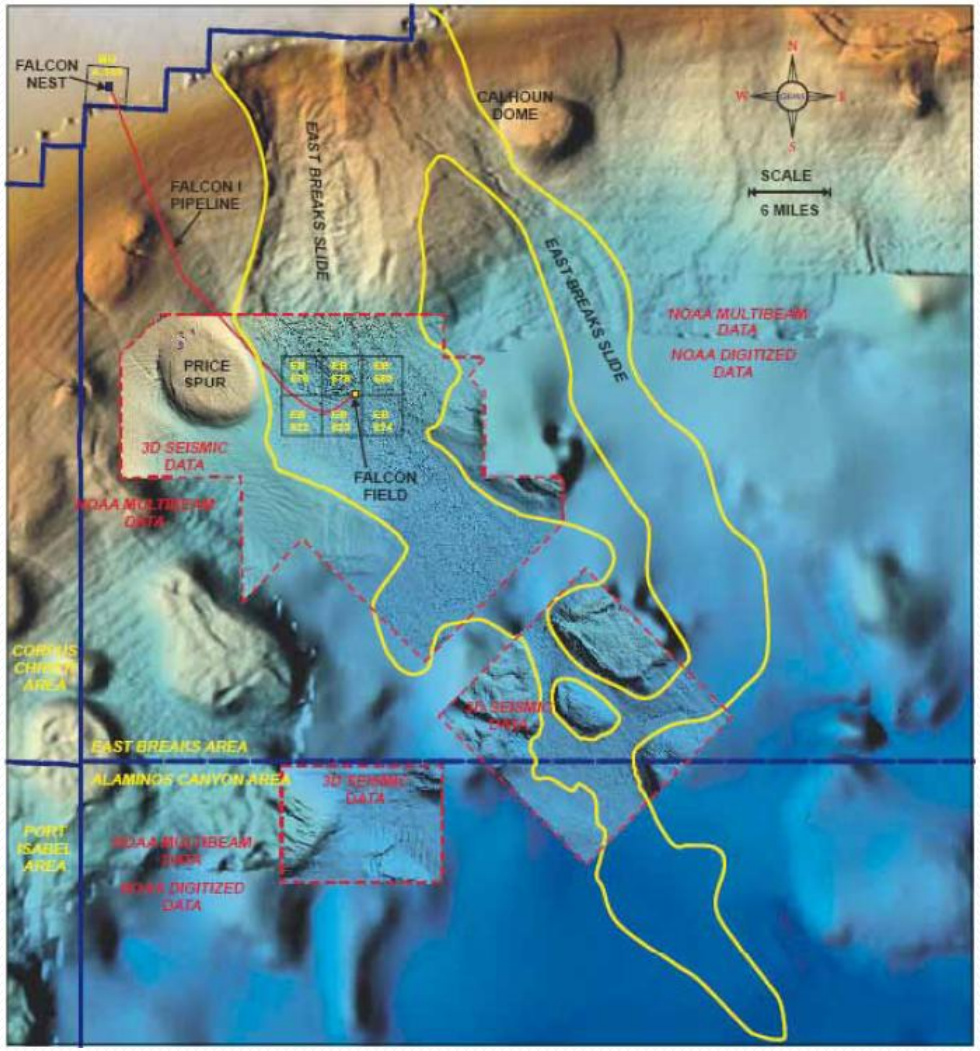
Background of “J Block” project

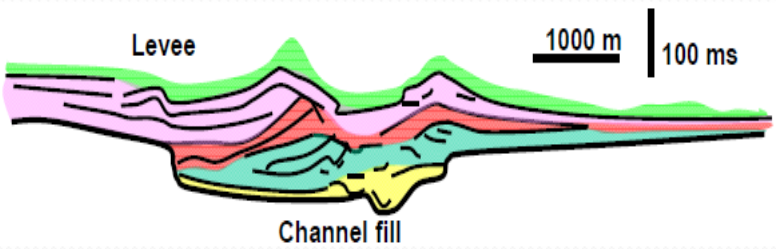
- The second phase of a multidisciplinary PhD project to integrate sedimentology and palynology for reconstructing depositional systems and palaeoenvironments.
- Subsurface data from “J Block” region of the Central Graben, North Sea UK Continental Shelf (UKCS) provided by ConocoPhillips for a sedimentological 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.

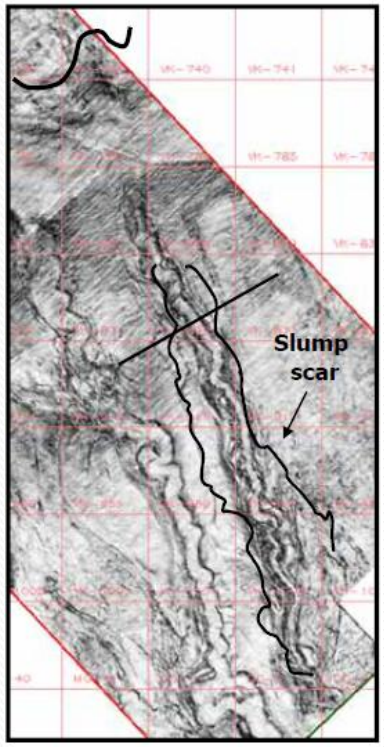




Relationship of MTCs & turbidites - examples from GOM & Brazil







Faulkenberry 2004

Hoffman *et al*. 2004

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

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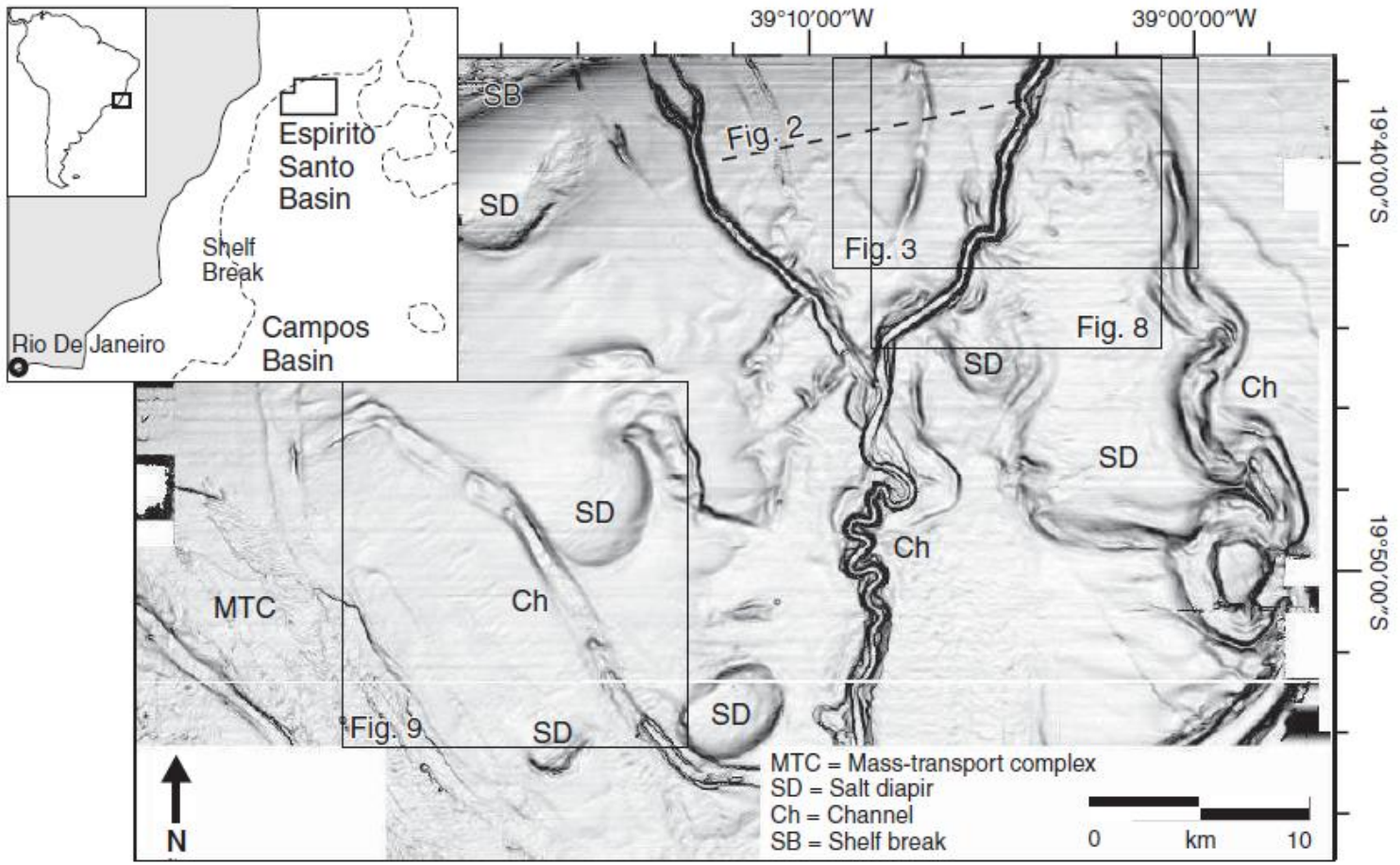
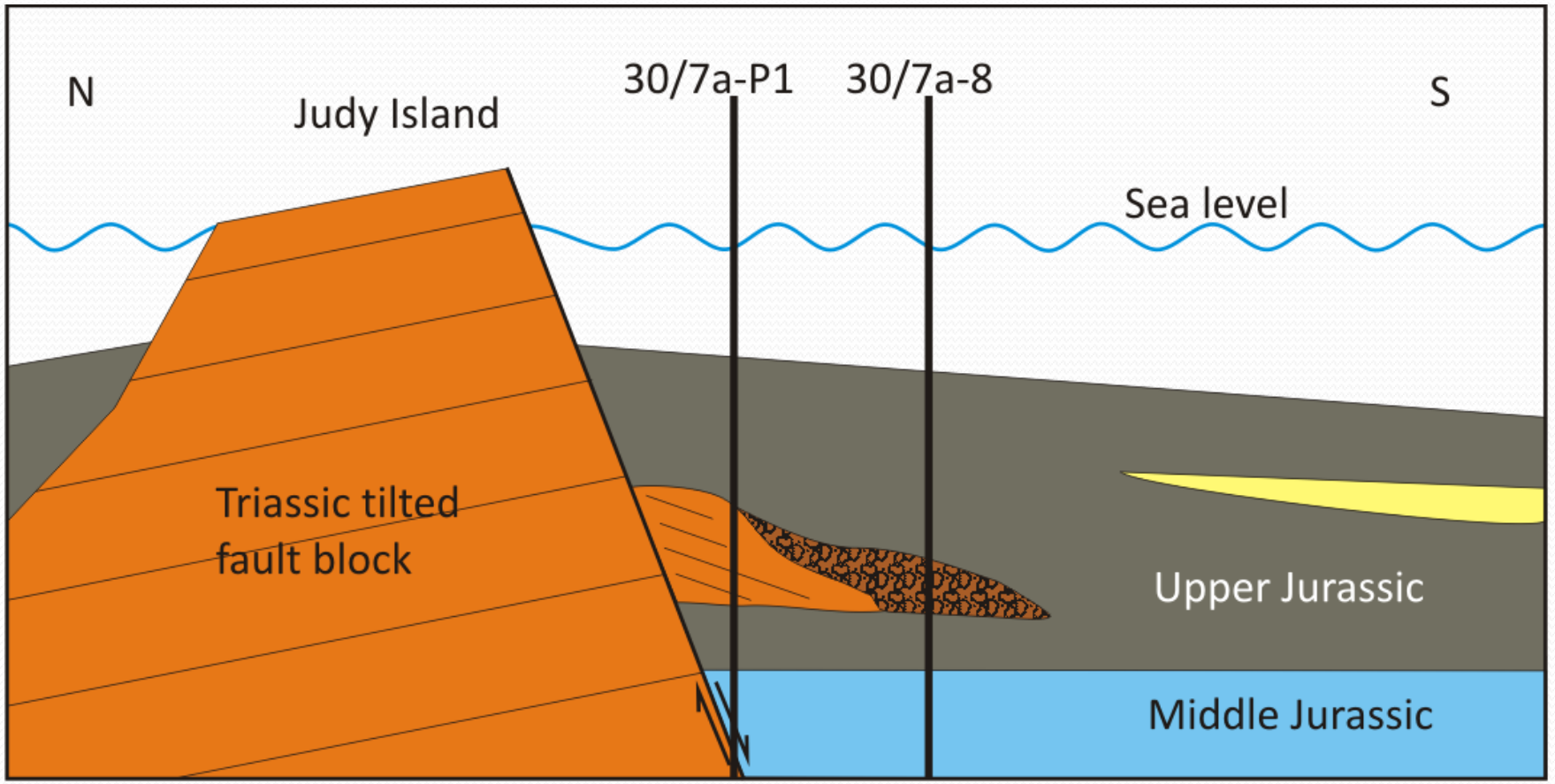


Heiniö & Davies 2009

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.

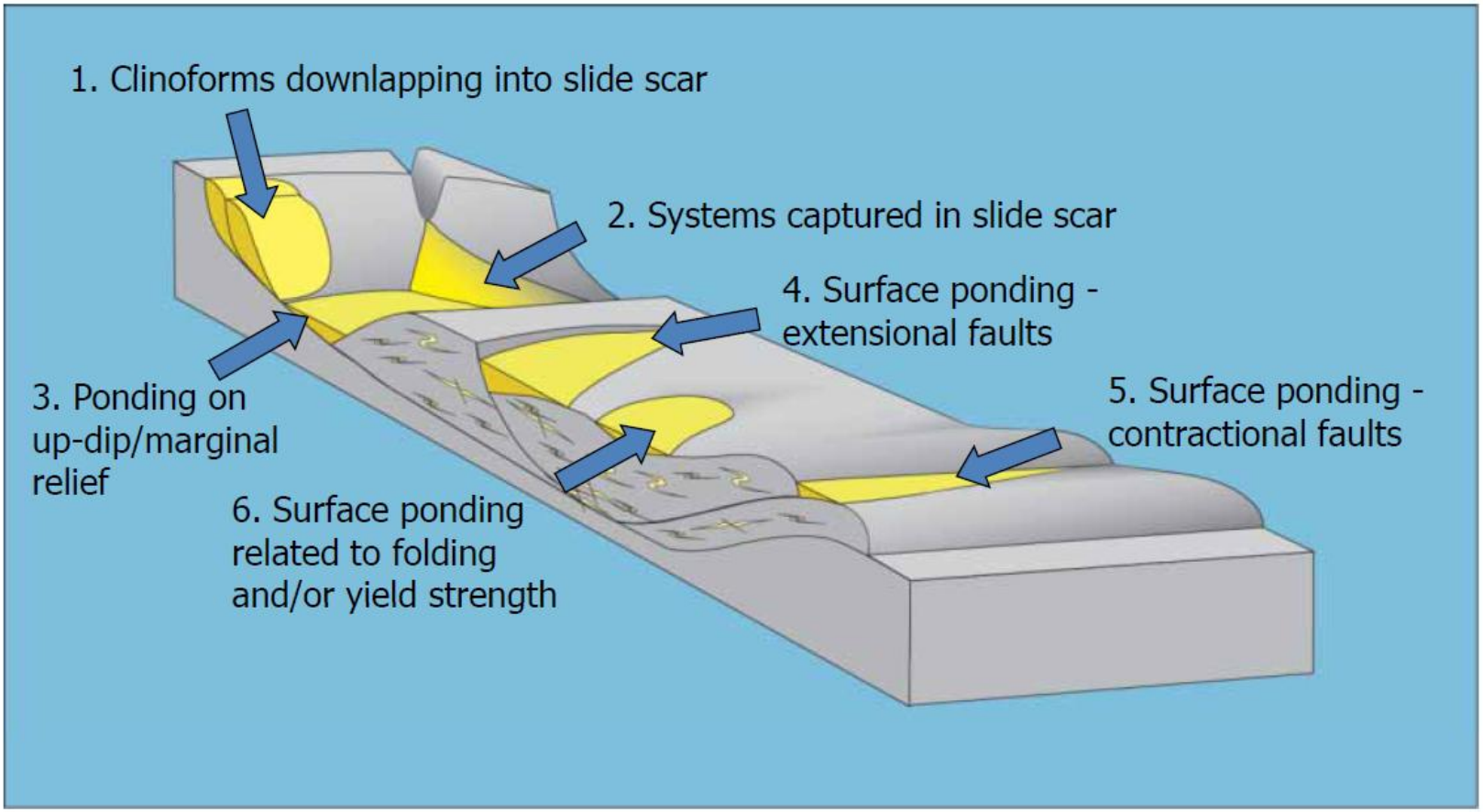
- Offshore Brazil – interaction on continental shelf controls channel distribution

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?

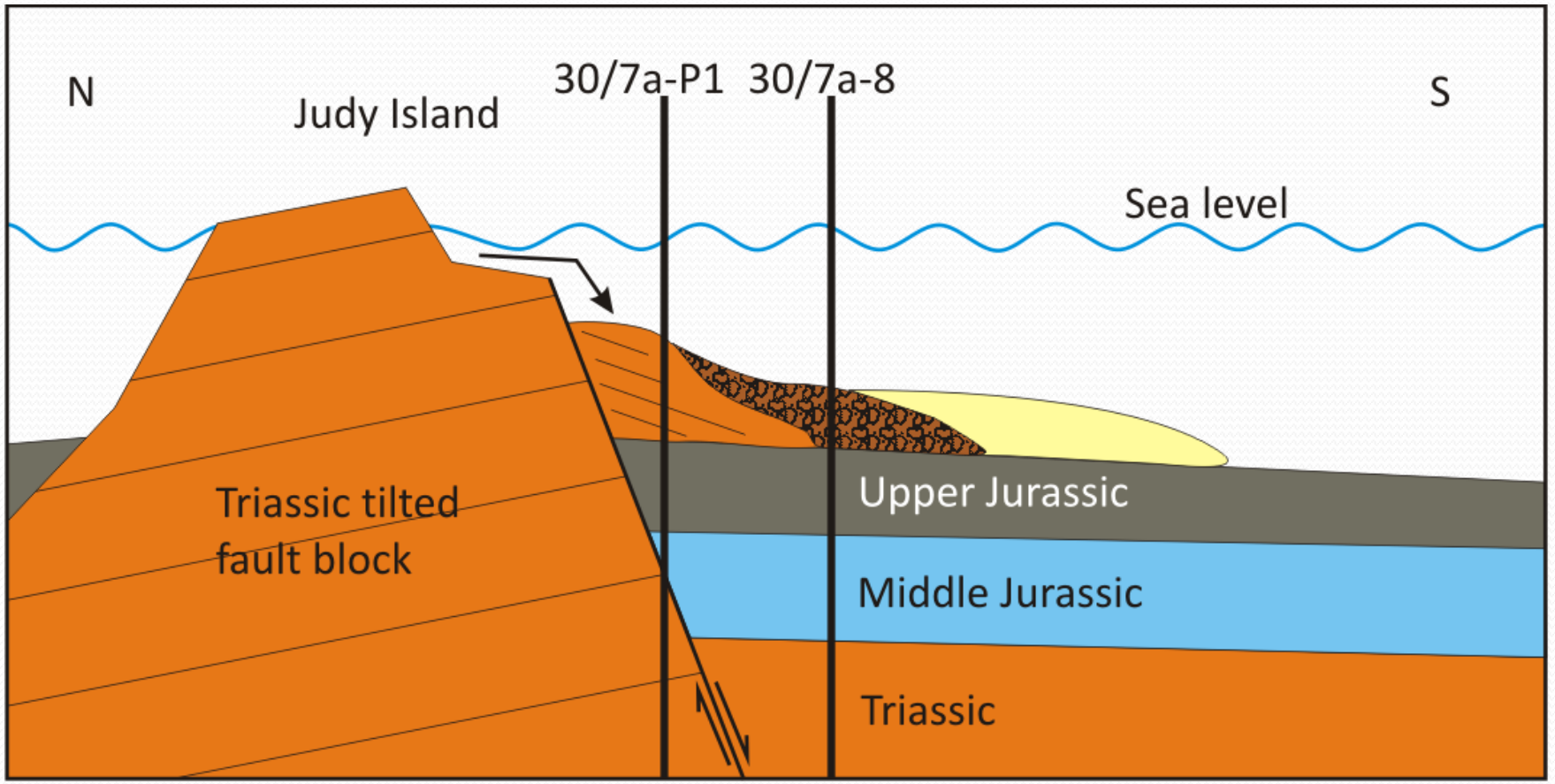
MTCs can create topography



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.

Potential relationships of MTCs & turbidites



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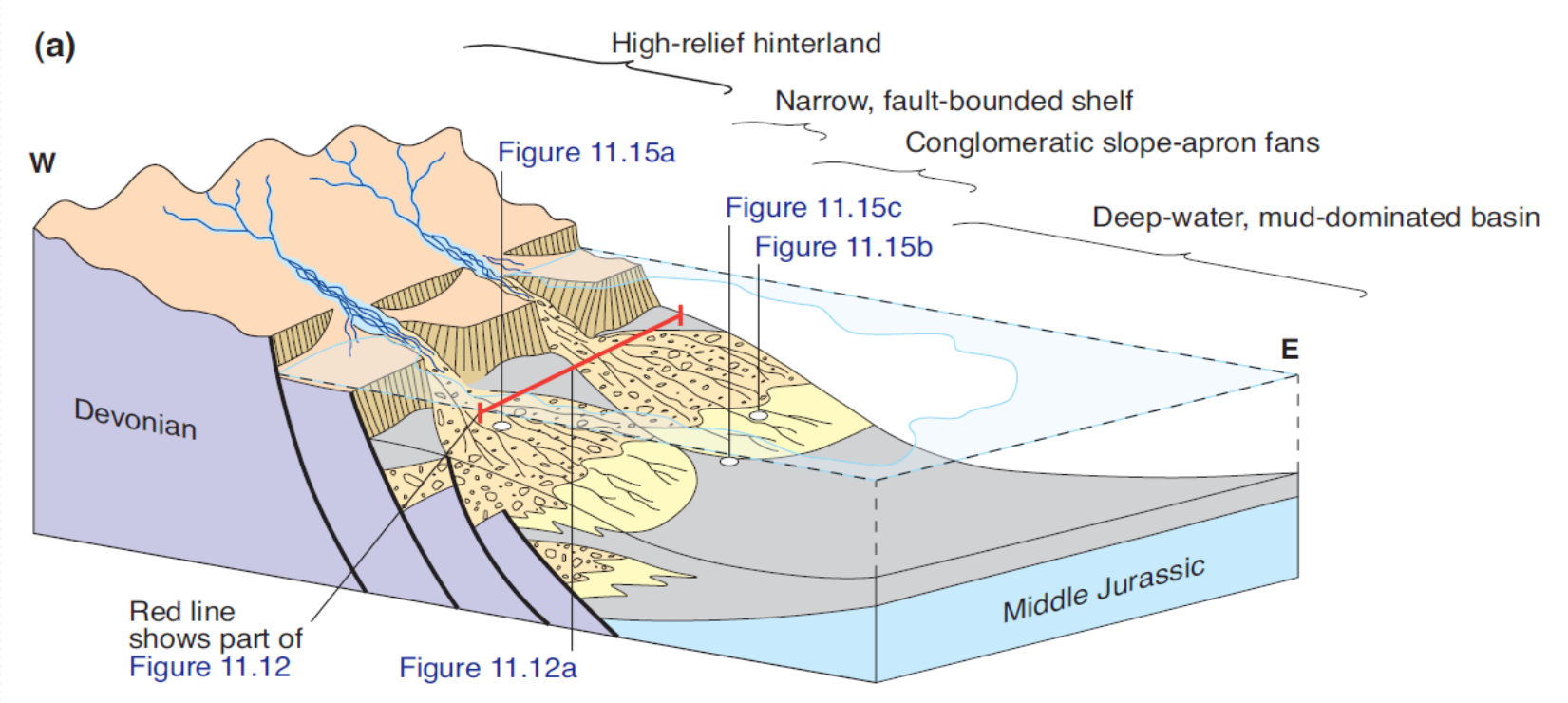
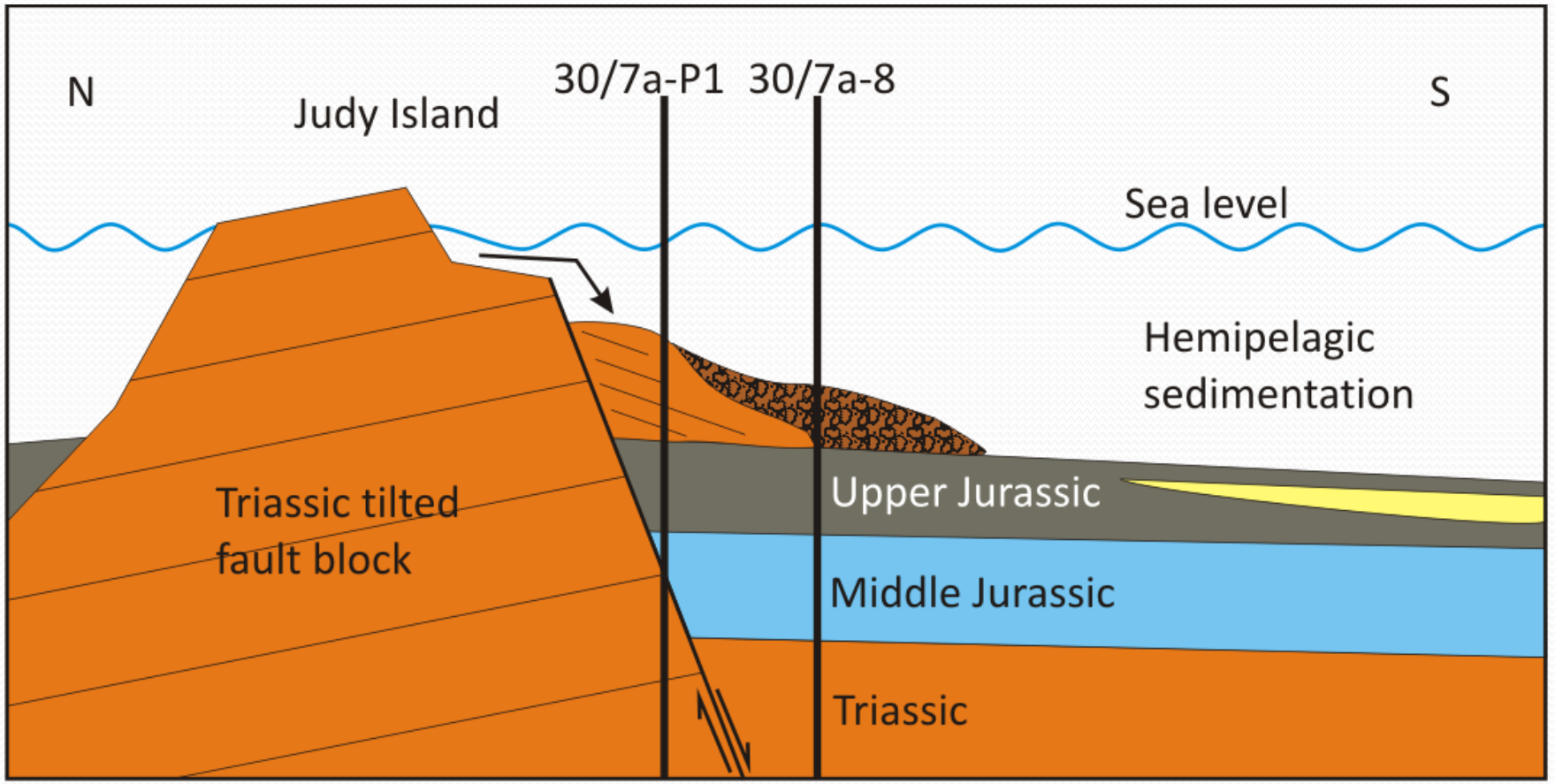
Contemporaneous MTCs & turbidites



Fraser *et al*. 2003

- 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.

Potential relationships of MTCs & turbidites



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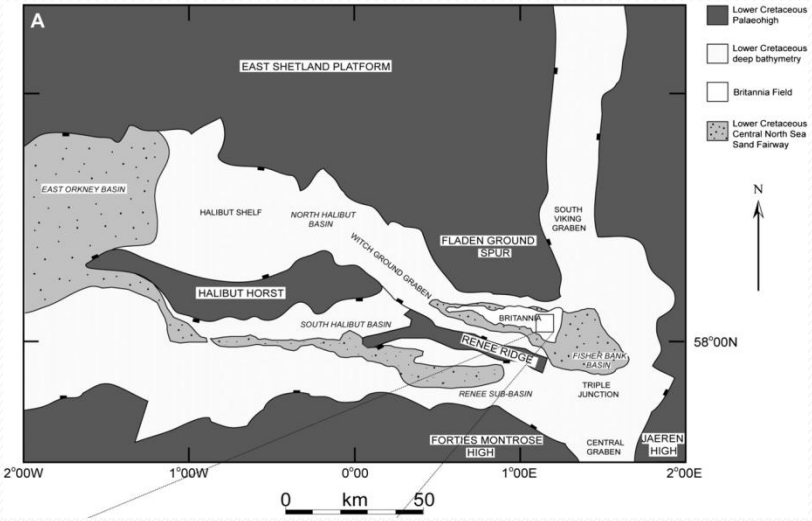
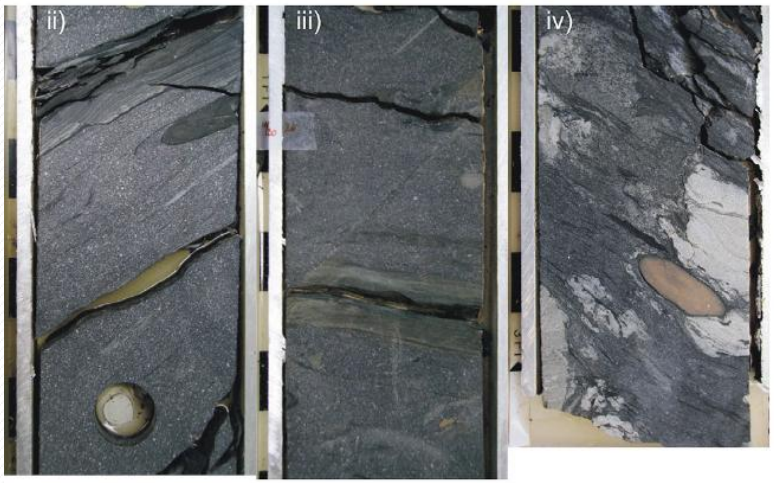
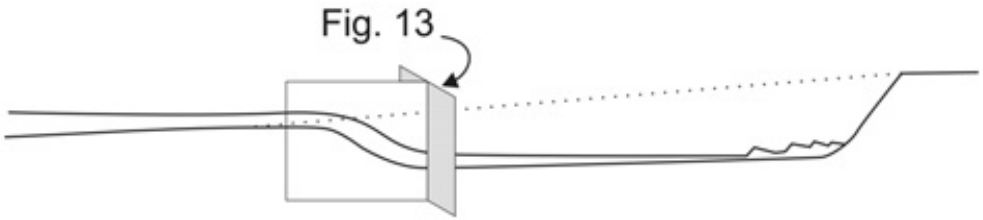
Potential erosion of reservoir interval?



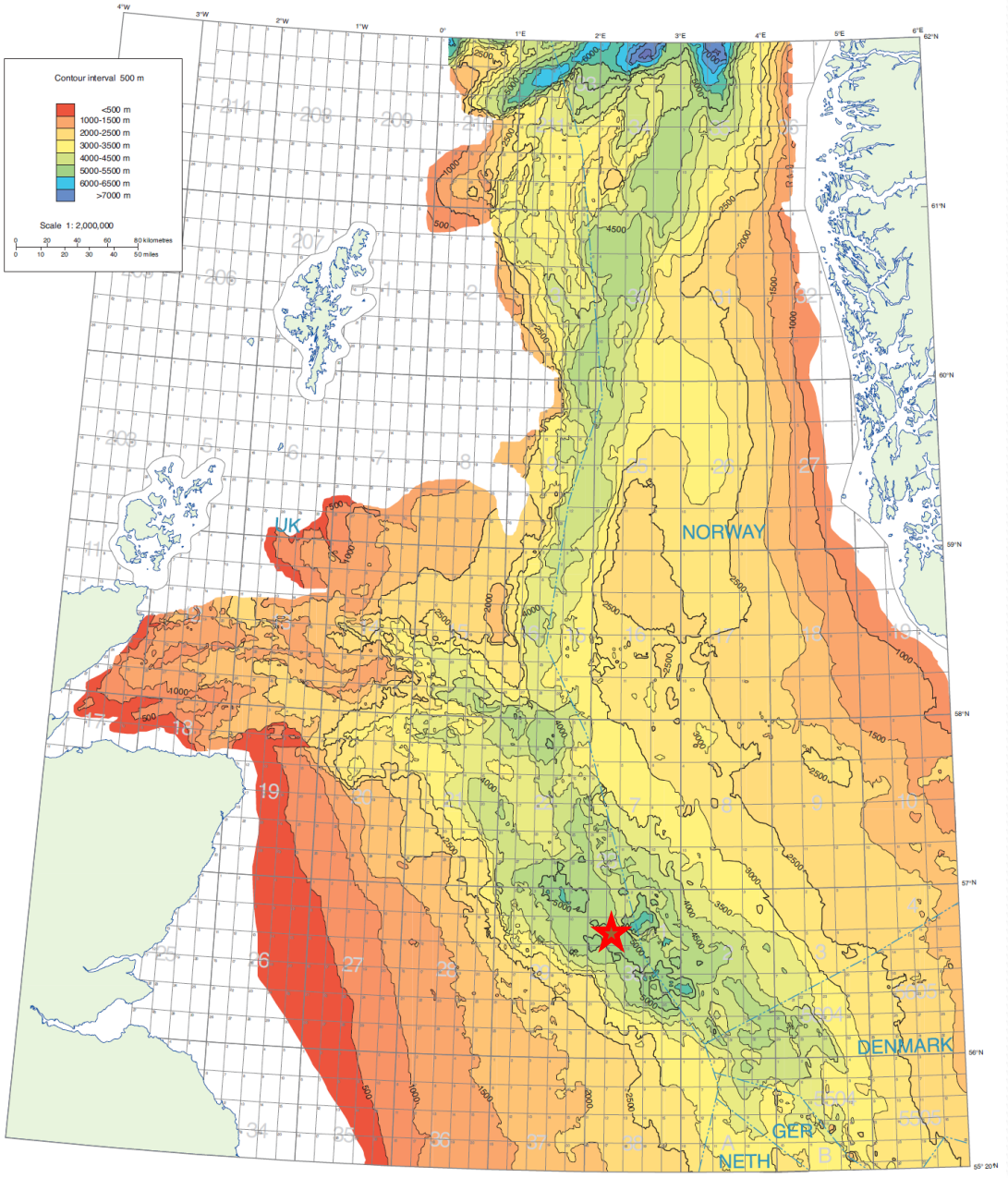




Eggenhuisen *et al*. 2010

- 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.

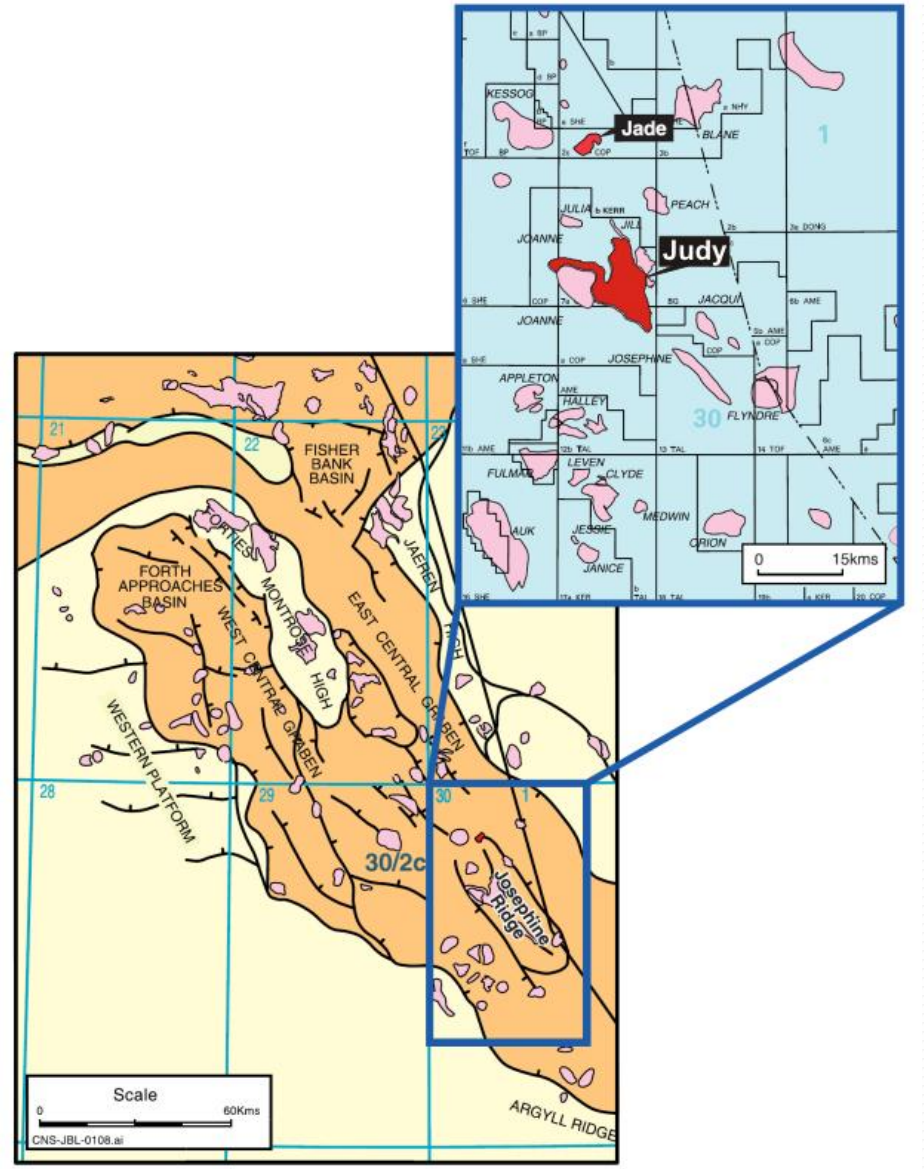
Location & Geological setting



Depth to BCU Fraser *et al*. 2003

- 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.

Location & Geological setting



After Jones et al. 2004

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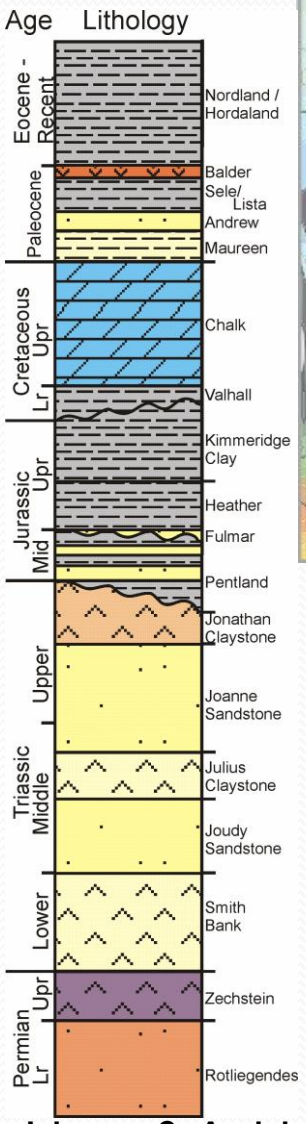
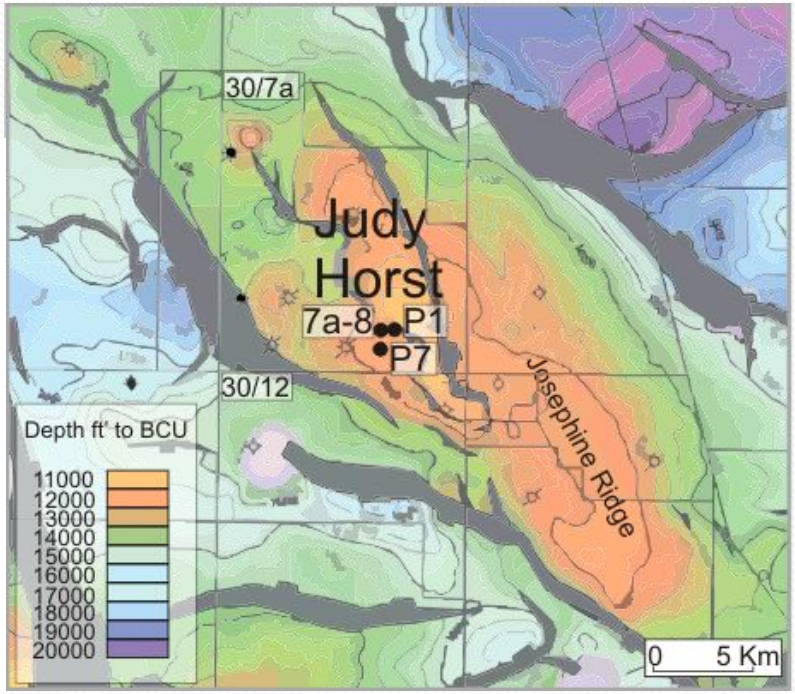
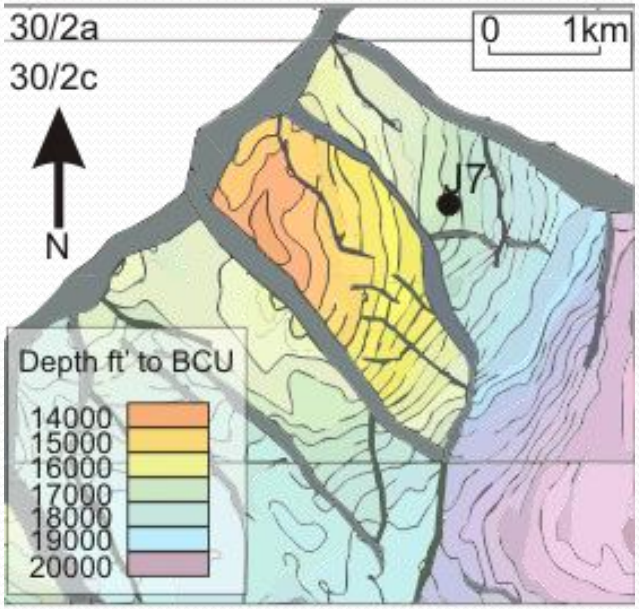


Lines & Auld 2004





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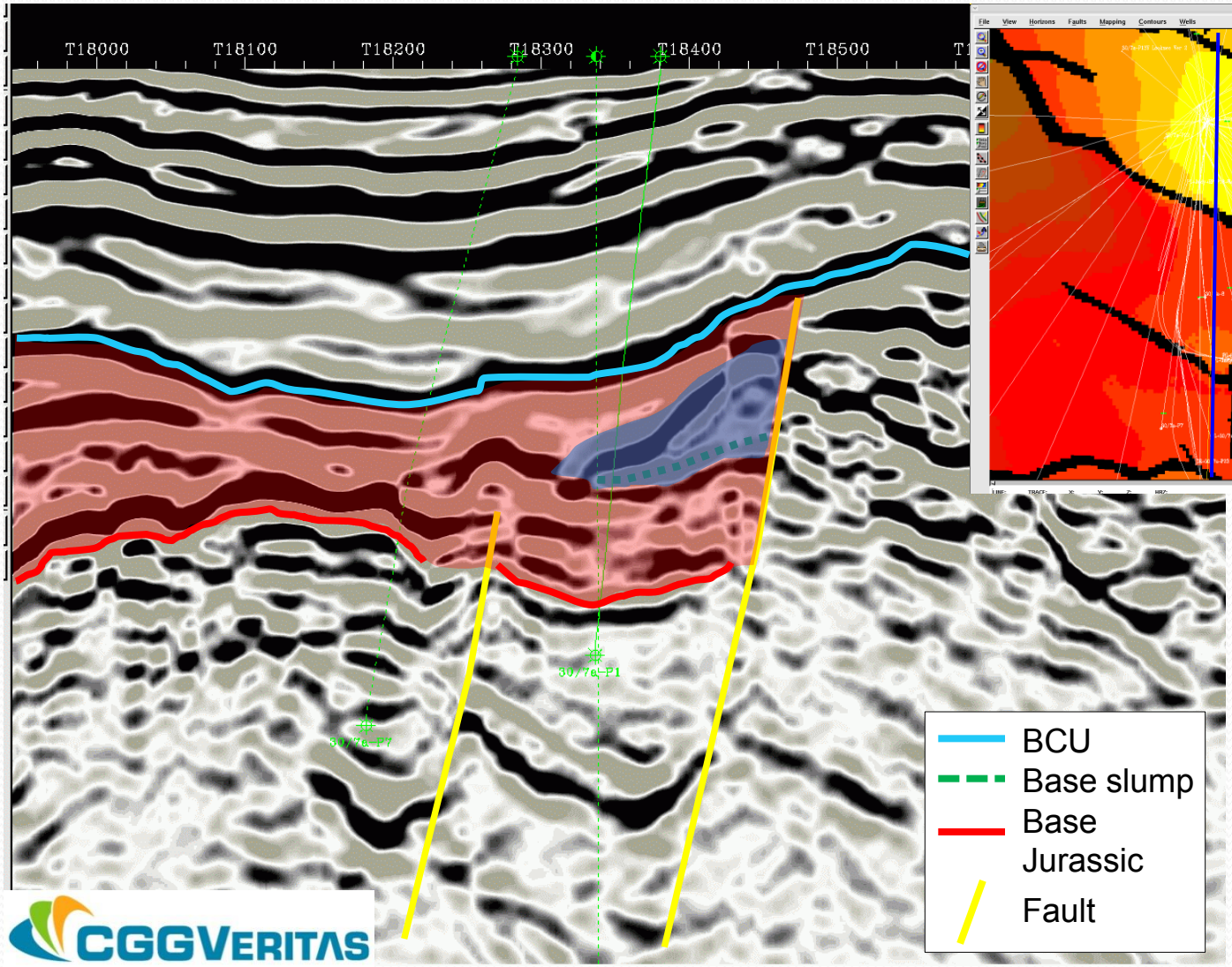
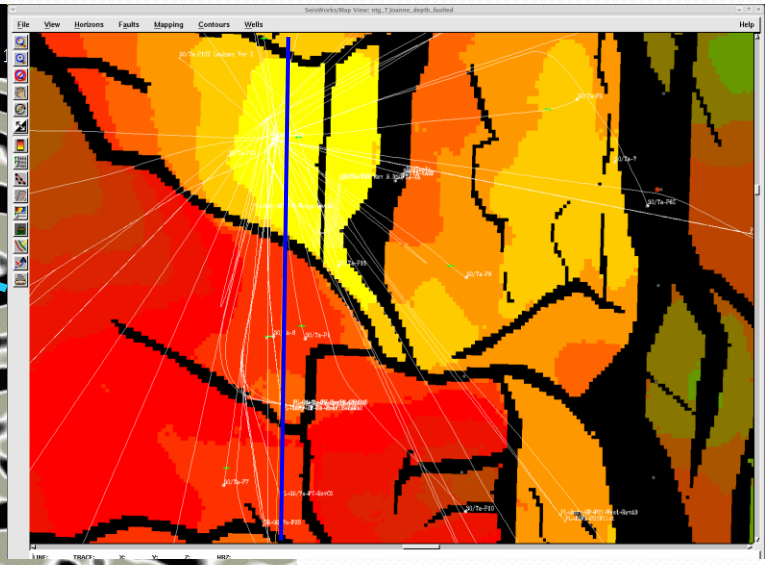
Judy Seismic

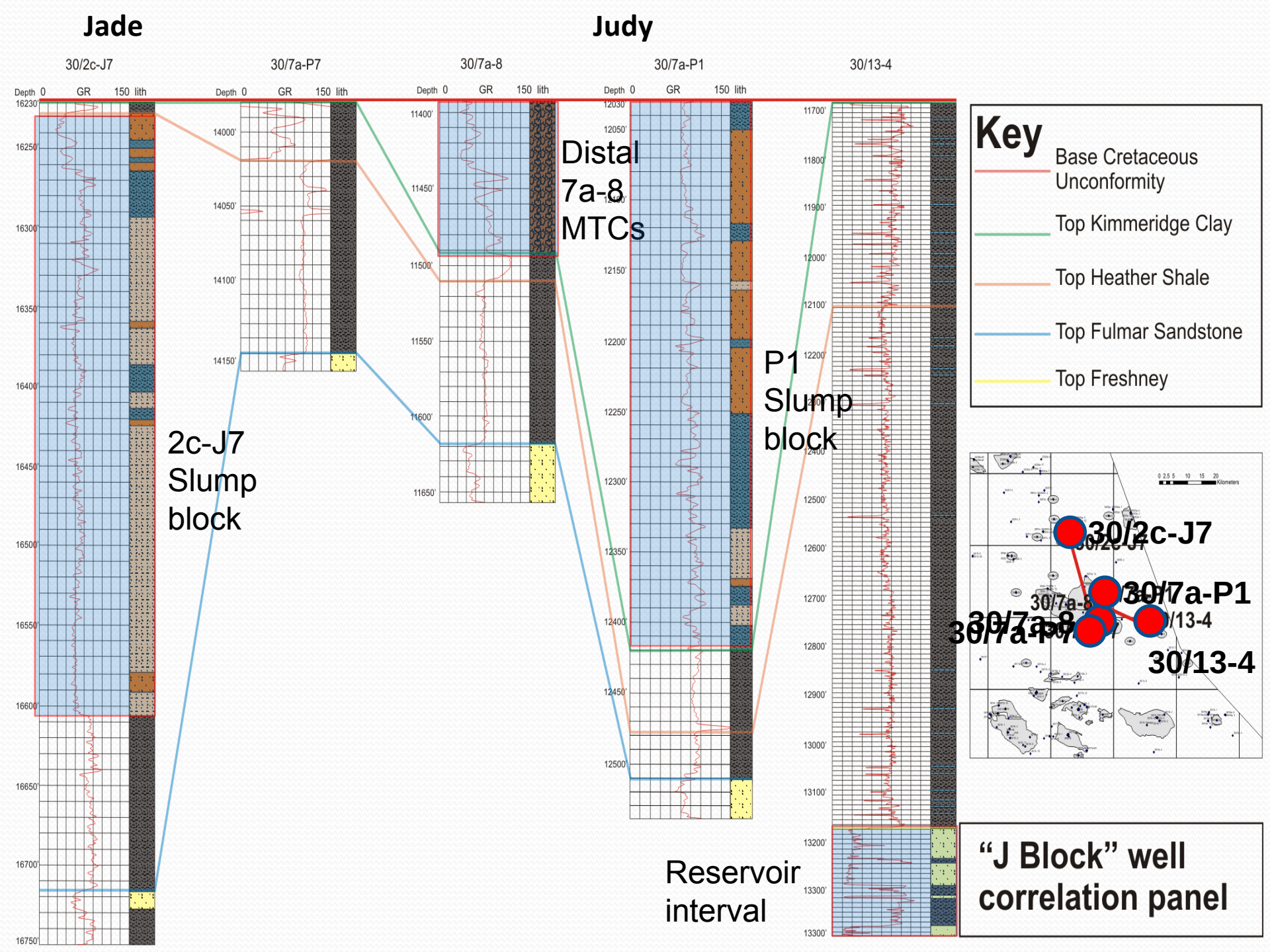




S P7 block P1 block Judy horst N

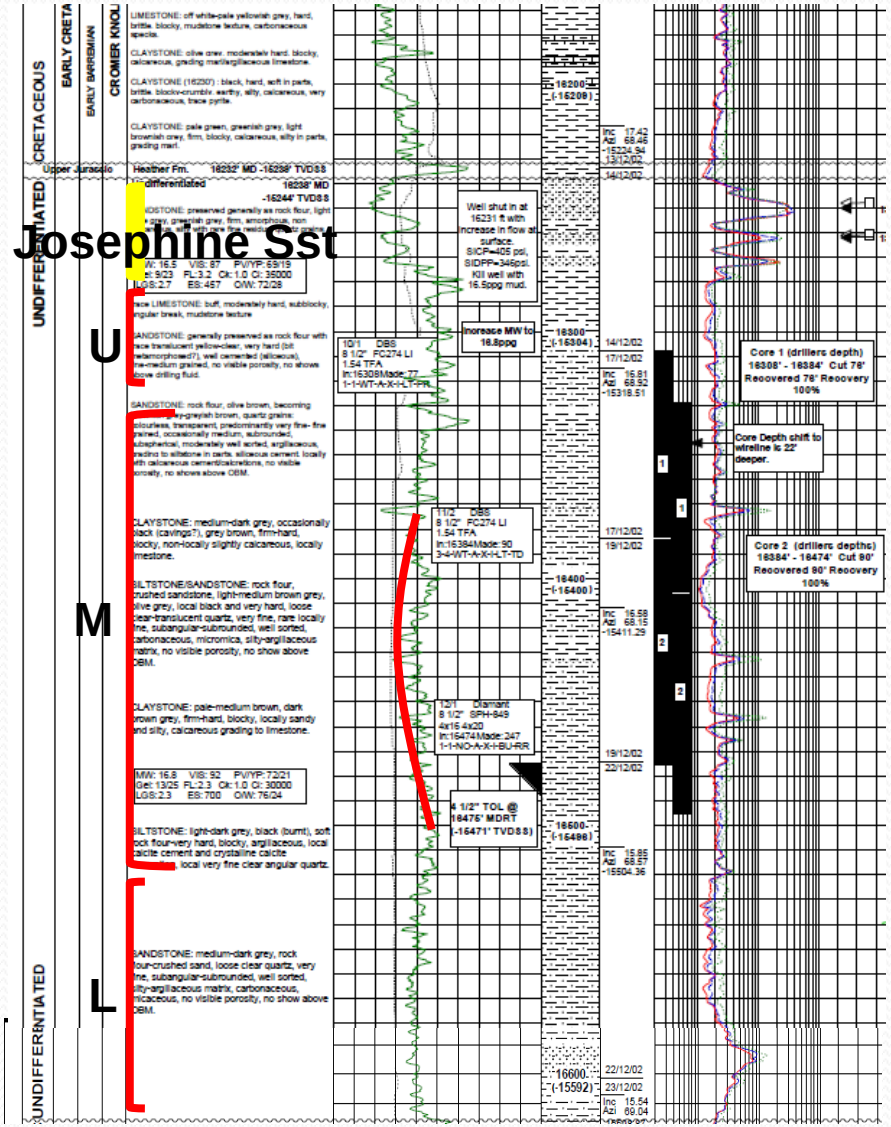
– – – 100 m

- 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.

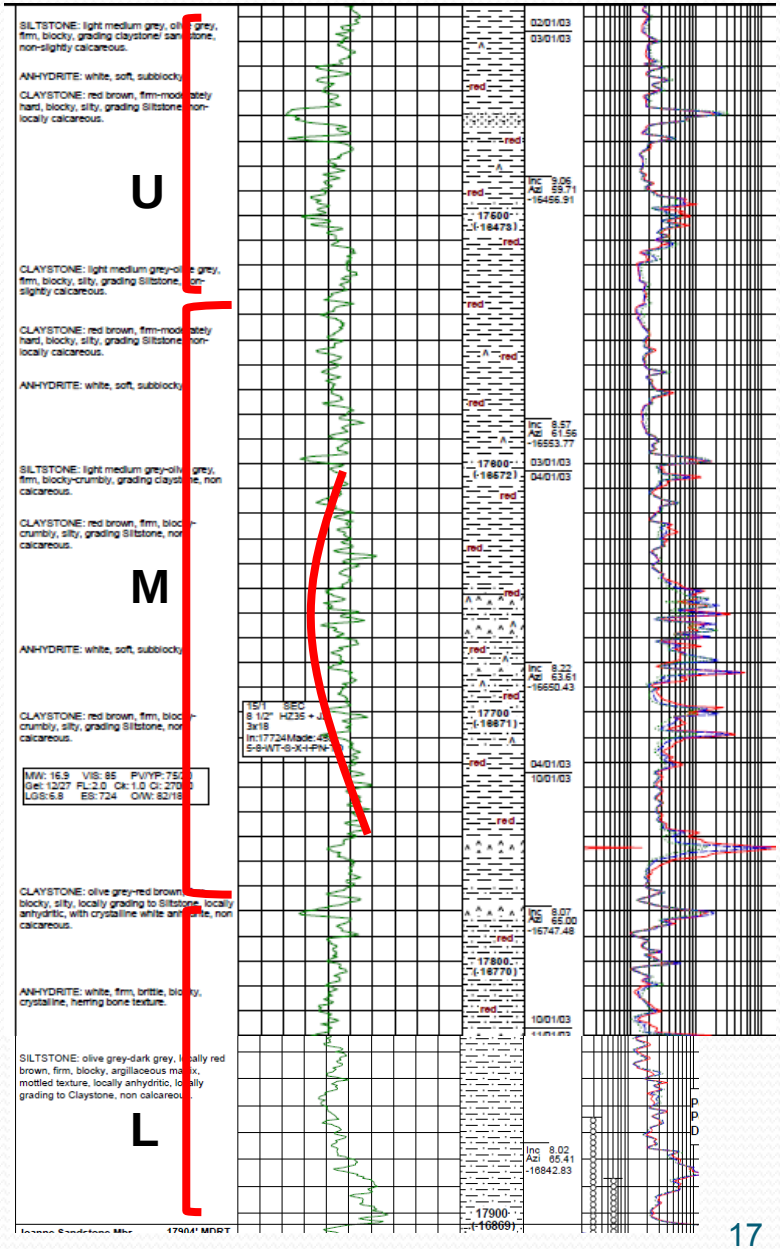

Jade
Judy
30/2c-J7
30/7a-P7
30/7a-8
30/7a-P1
30/13-4
Depth 0 GR 150 lith
2c-J7 Slump block
Distal 7a-8 MTCs
P1 Slump block
Reservoir interval
Key
Base Cretaceous Unconformity
Top Kimmeridge Clay
Top Heather Shale
Top Fulmar Sandstone
Top Freshney
30/2c-J7
30/7a-P1
30/7a-8
30/7a-P7
30/13-4
"J Block" well correlation panel

Jade olistolith vs in-situ strata

30/2c-J7 Olistolith



In situ Jonathan Mudstone



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

Judy Core analysis

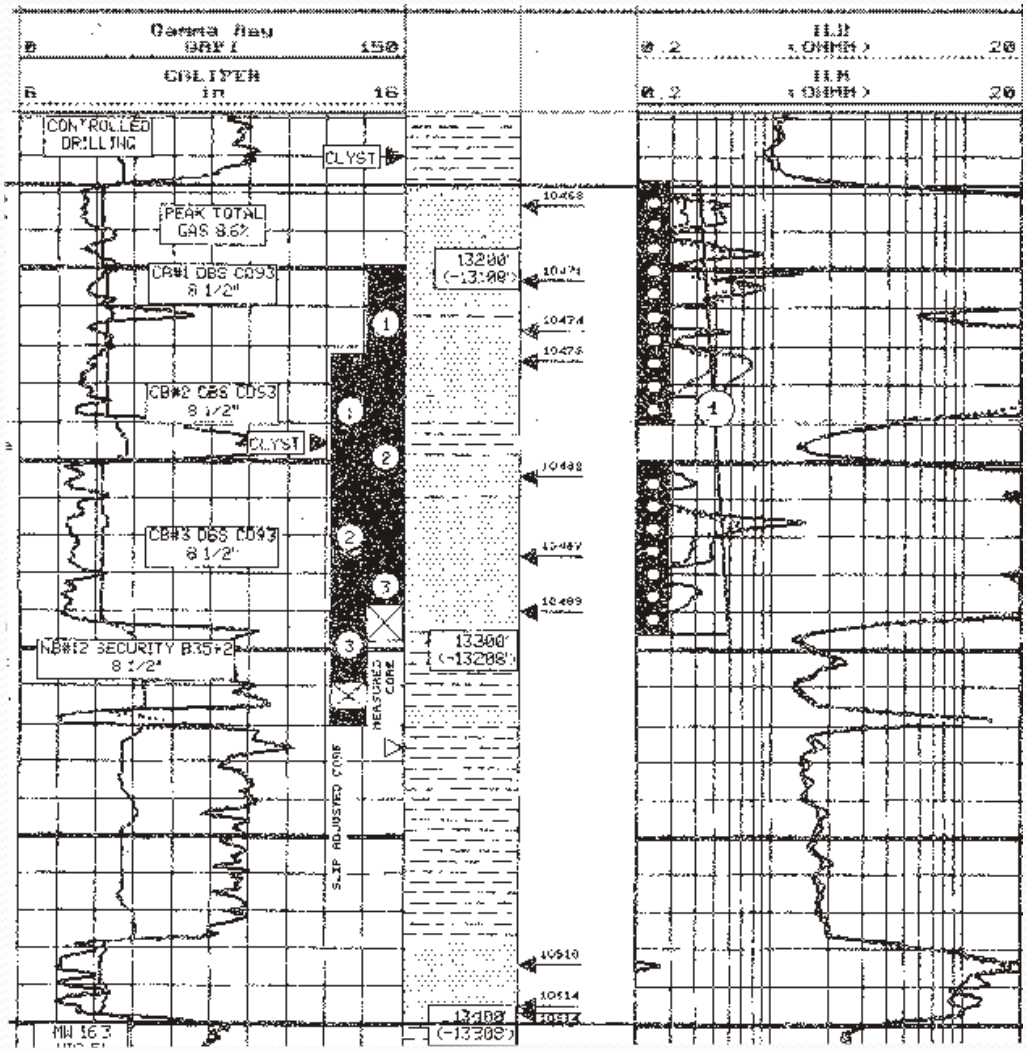
- Judy olistolith similar story to Jade.
- Distally 19 breccia and conglomerate intervals recognised from 10 – 50 cm in thickness.
- Chaotic, v. poorly sorted, matrix supported (coarse sandstone) deposits.
- Clasts sub rounded – angular, typically sub spherical, range <2 cm - >20 cm diameter.
- All events 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.

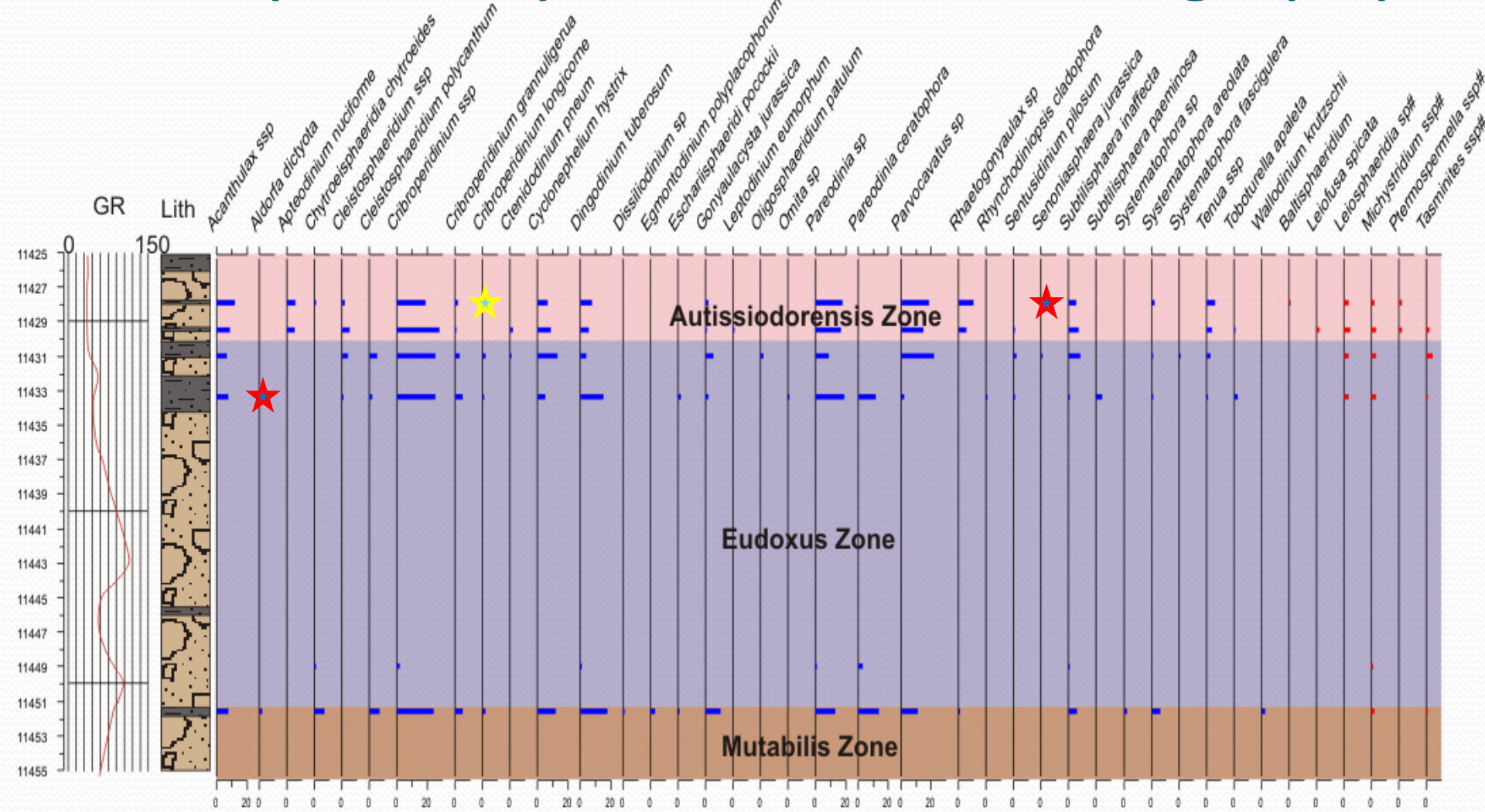
Freshney Sandstone

- 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

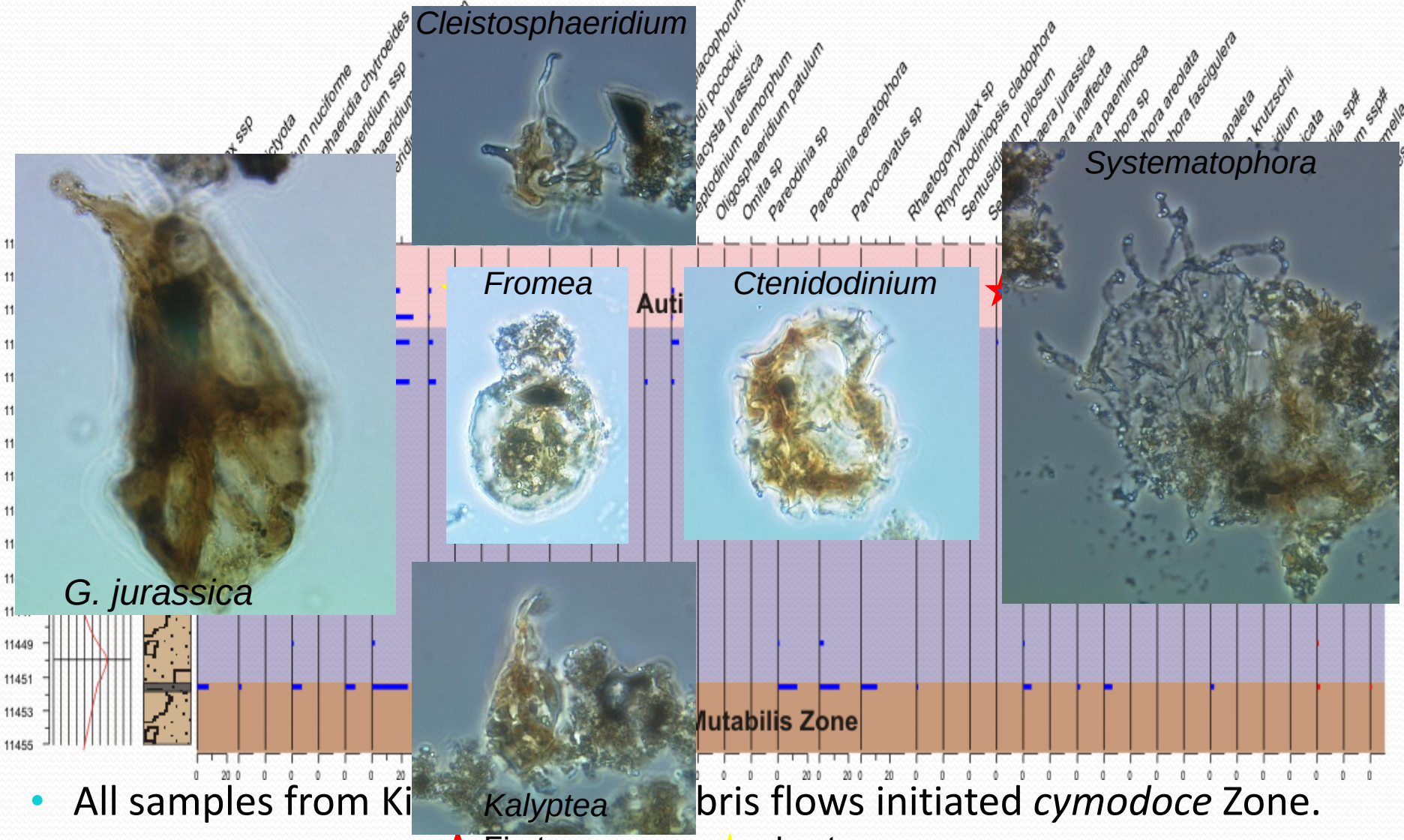
Sample analysis: 7a-8 - biostratigraphy



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

★ First occurrence ★ Last occurrence

Sample analysis: 7a-8 - biostratigraphy



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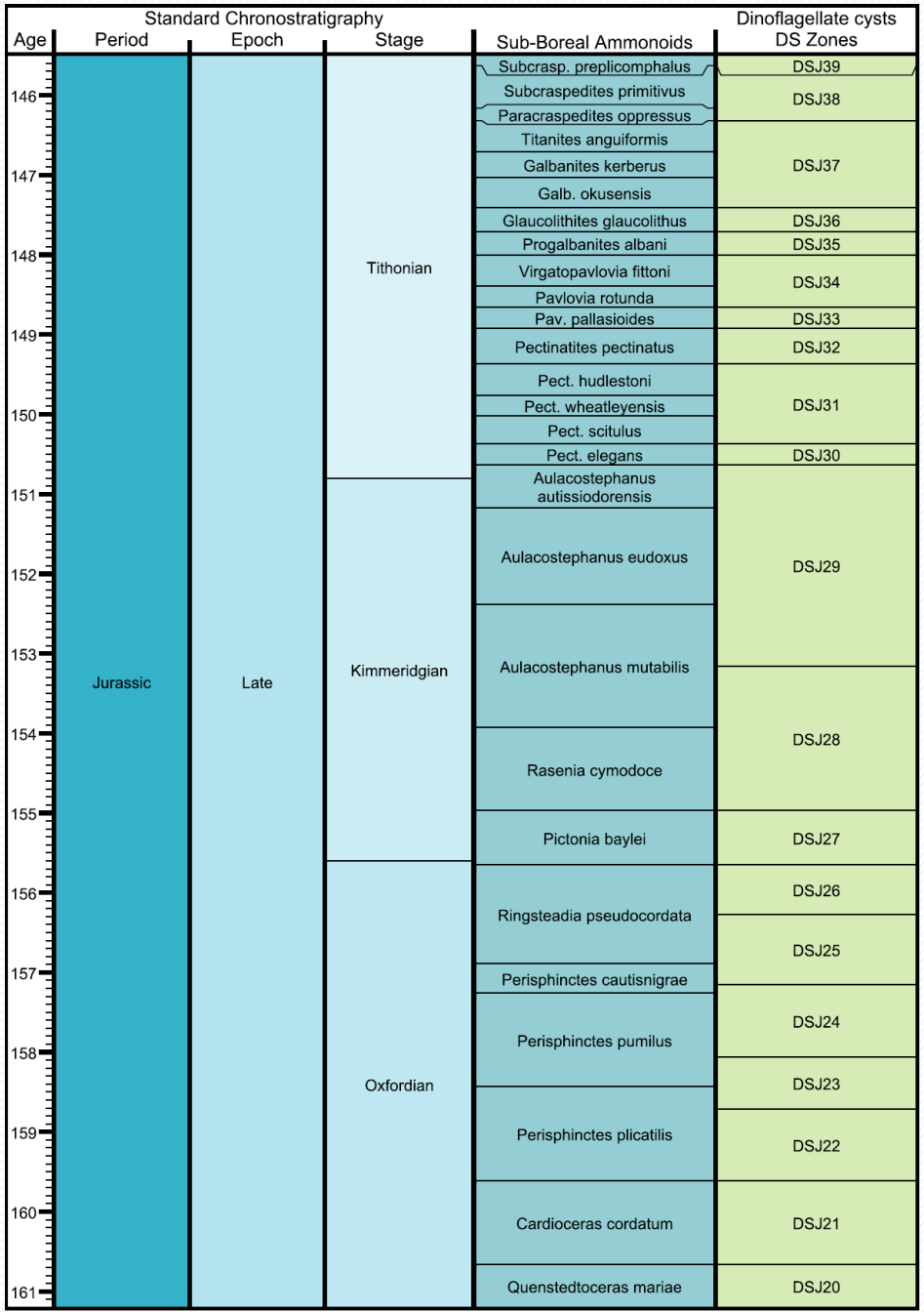


Biostratigraphy

Judy debris flows

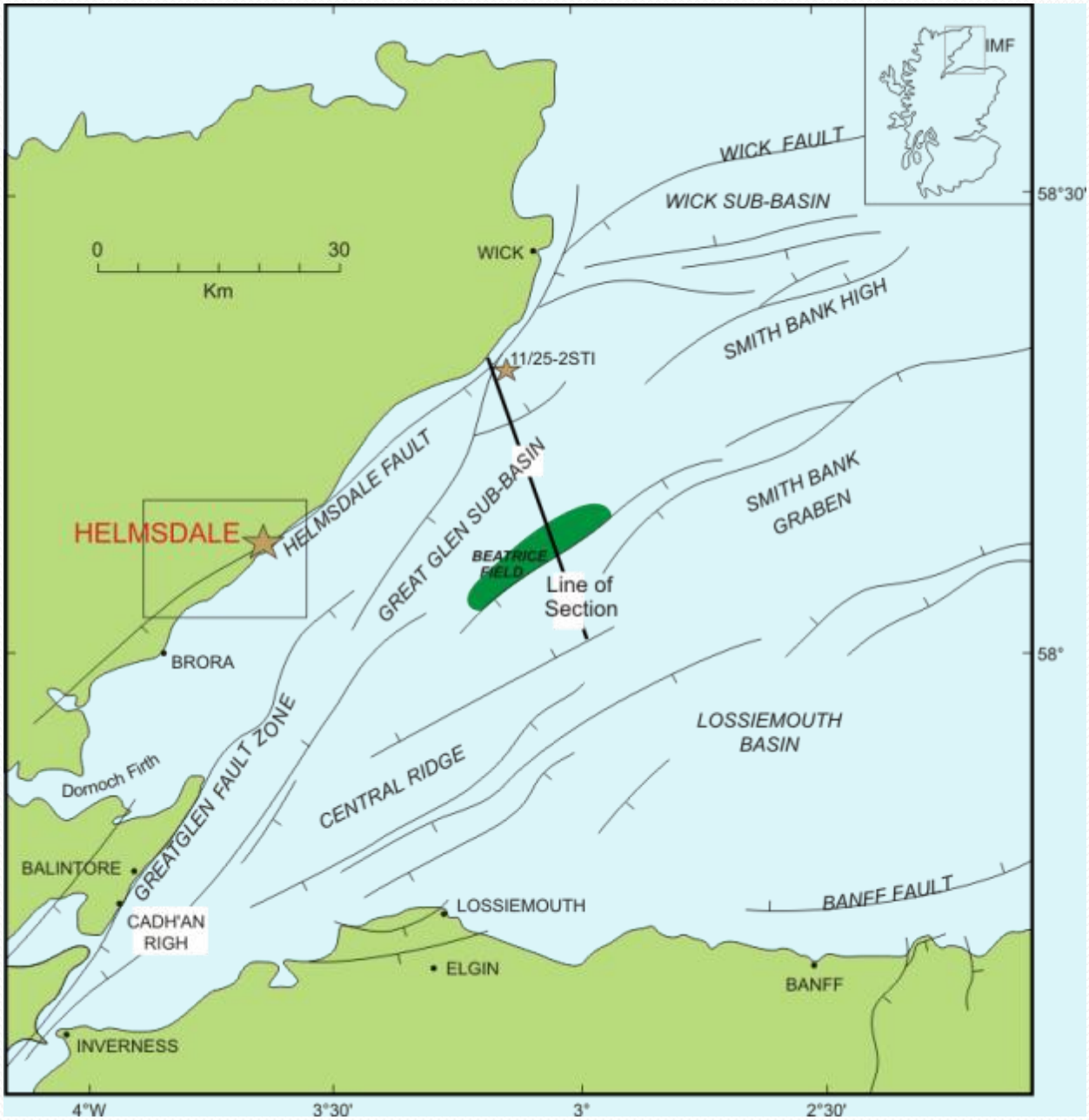
Judy olistolith

Jade olistolith

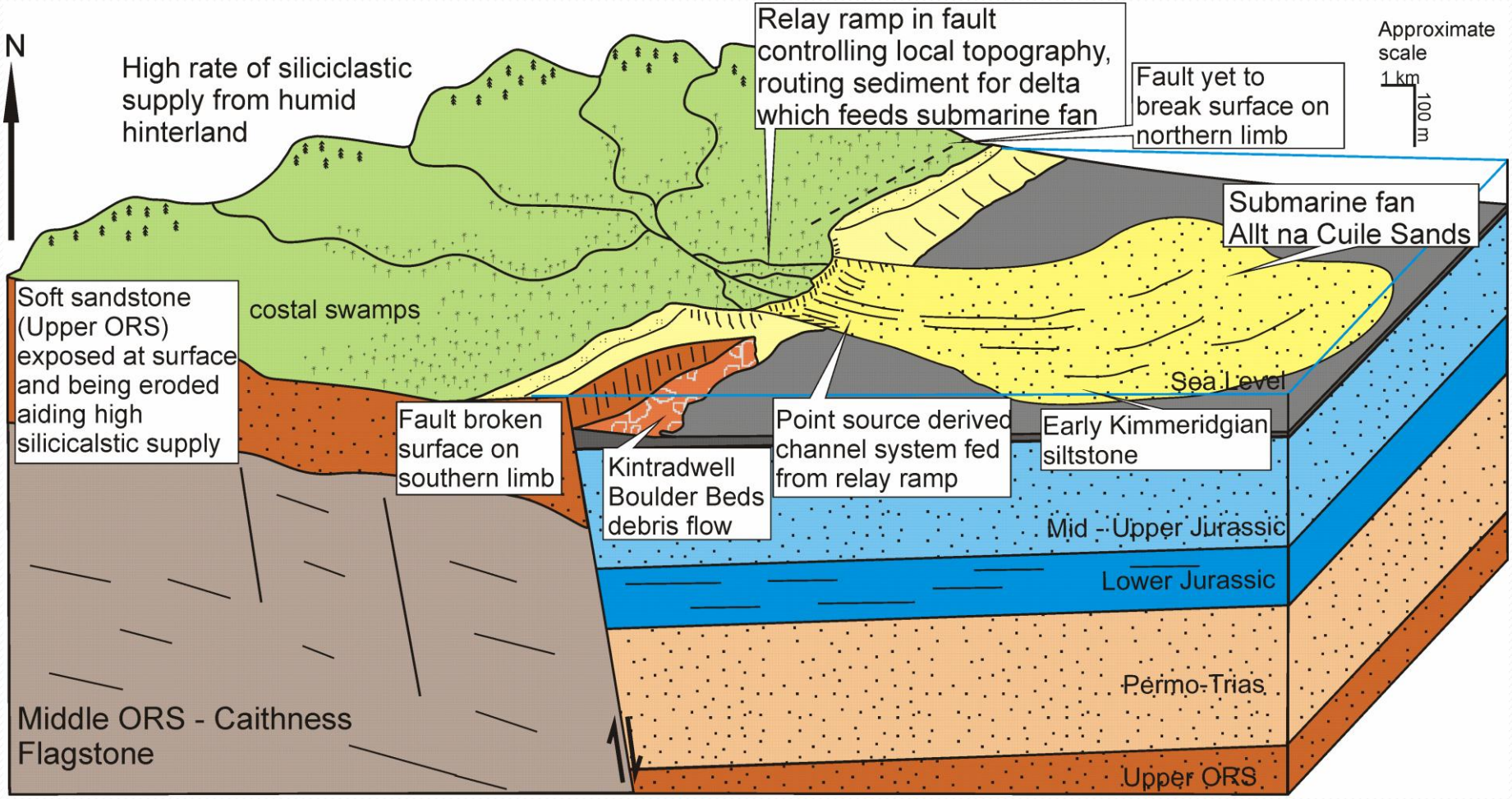
Freshney Sandstone - turbidite system

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.

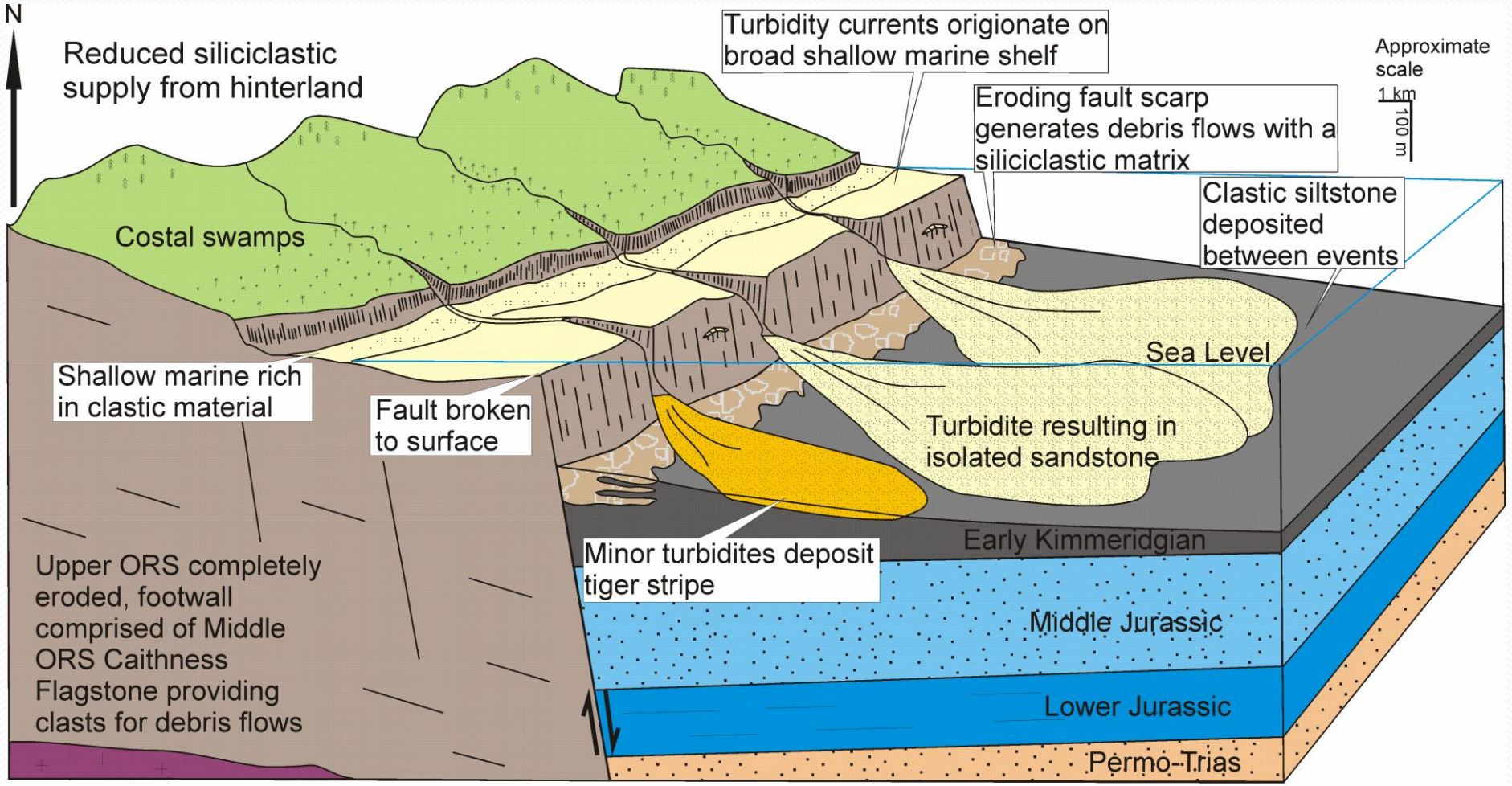


Helmsdale – initial rift



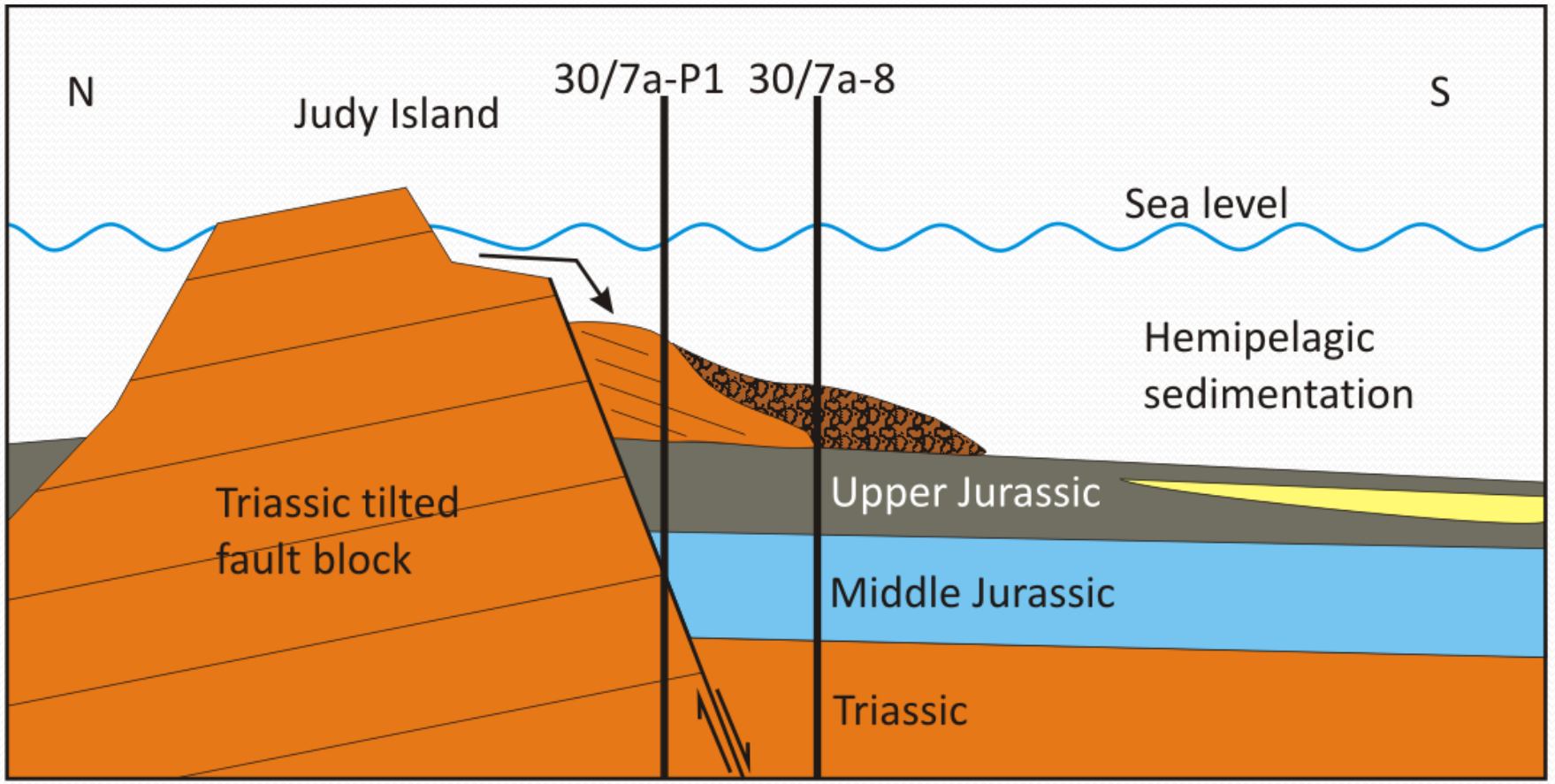
- Subtle alteration of topography sheds sediment captured in hinterland. Deposition of reservoir quality turbidite sandstones in the deep marine.

Helmsdale – rift climax



- Once major faults broken to surface. Helmsdale & “J Block” limited sediment supply, rift climax only minor hanging-wall fans interbedded with MTCs.

MTCs post date turbidites



- 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.
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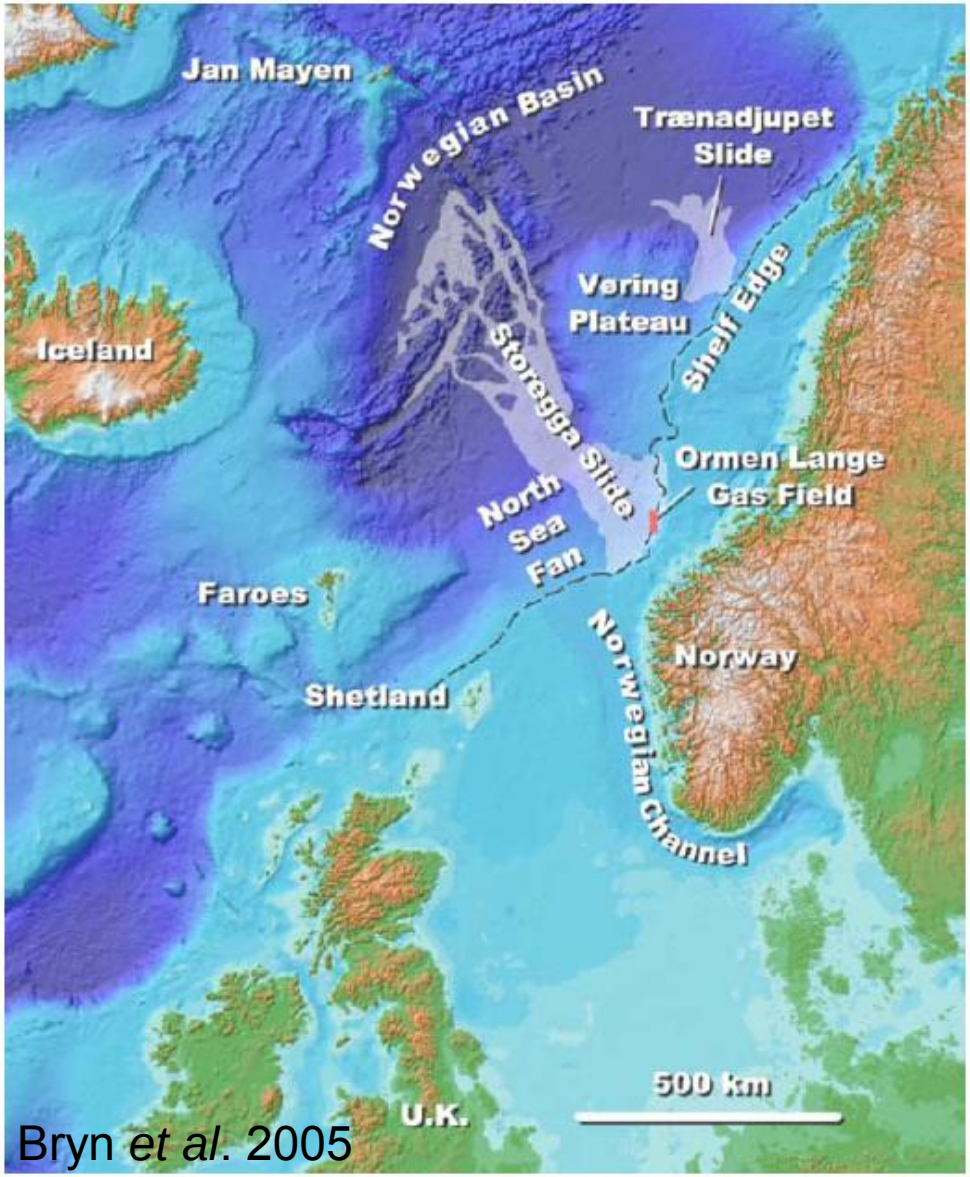

Bryn *et al*. 2005

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.
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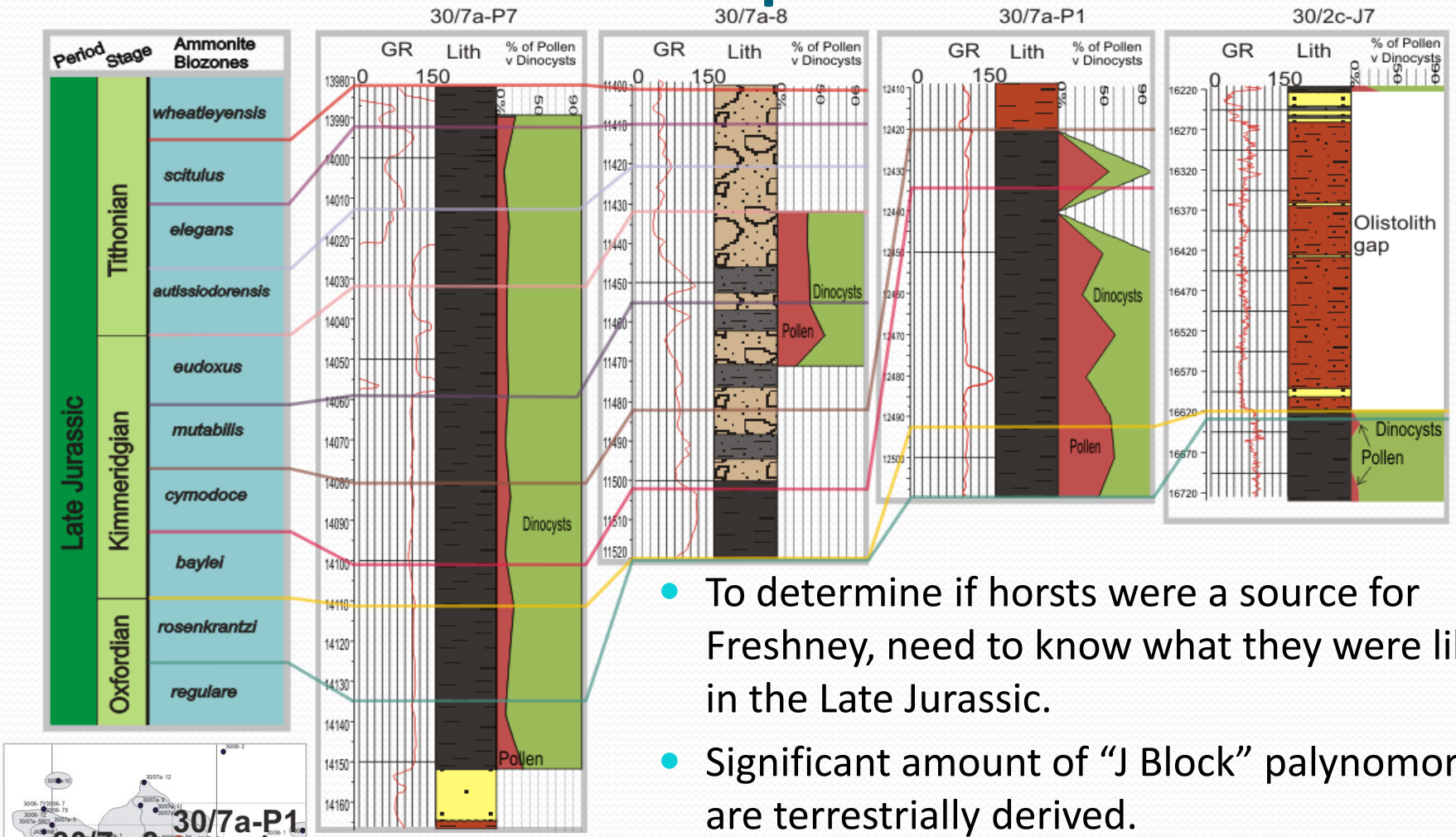
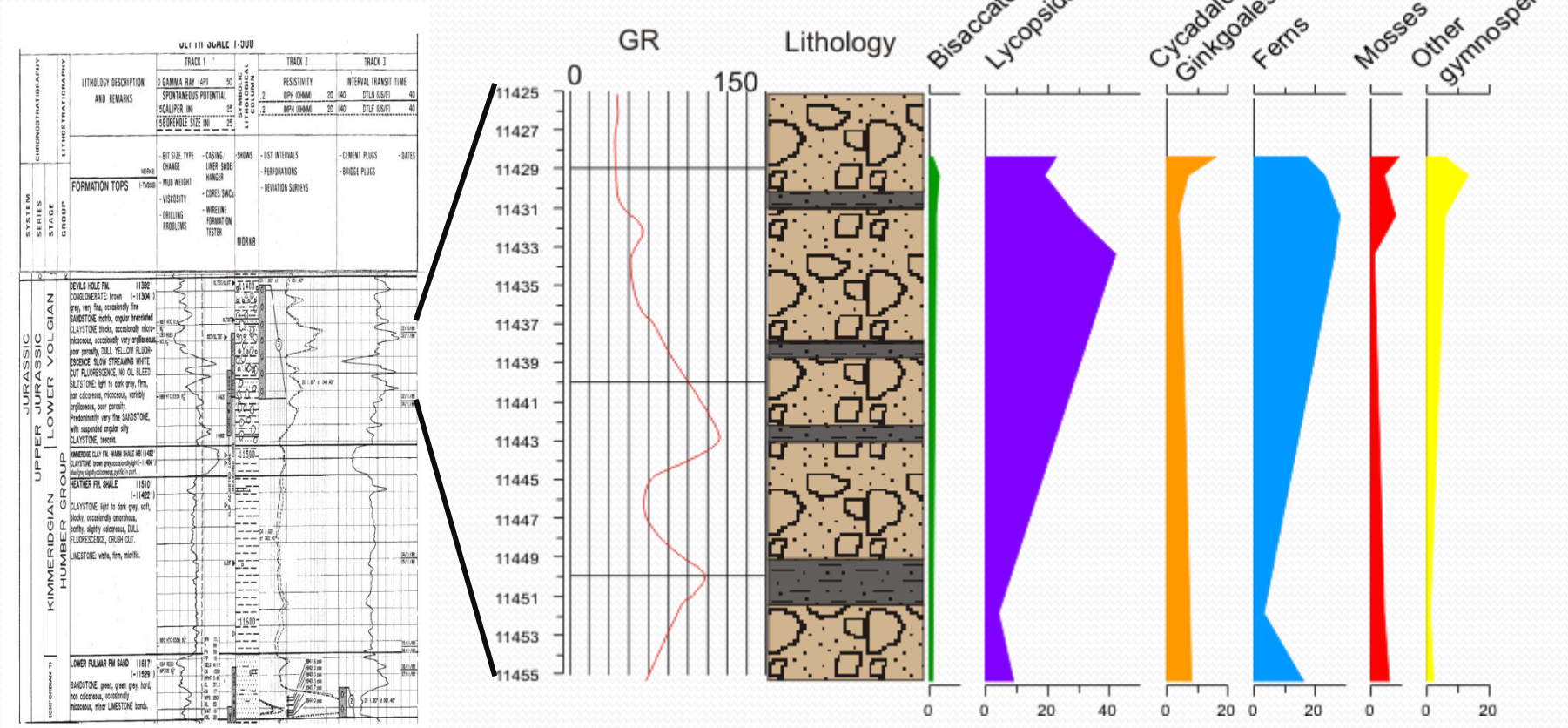
Terrestrial miospores



- 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

32

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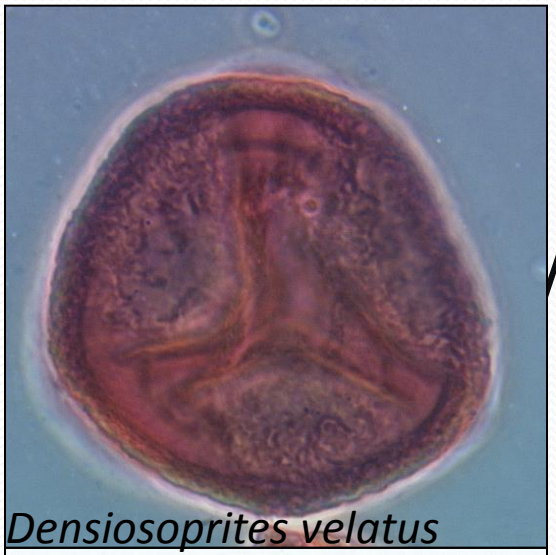
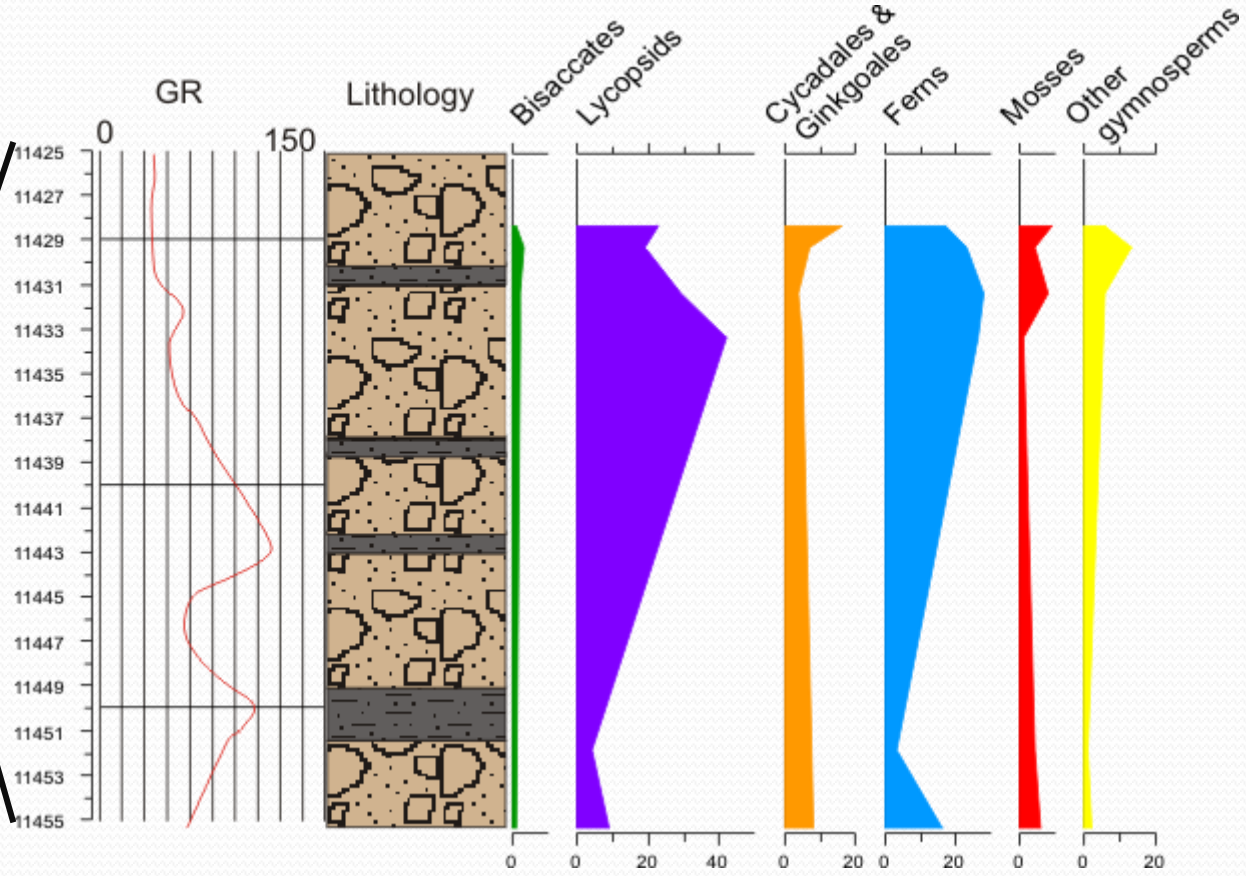


Densiosoprites velatus

Deltoidospora sp.



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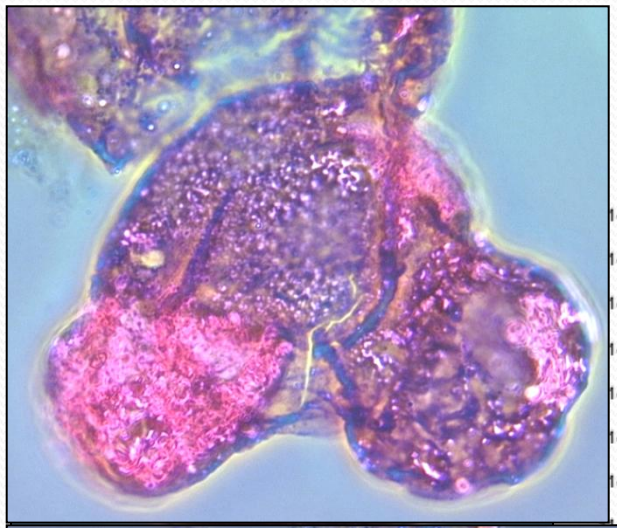
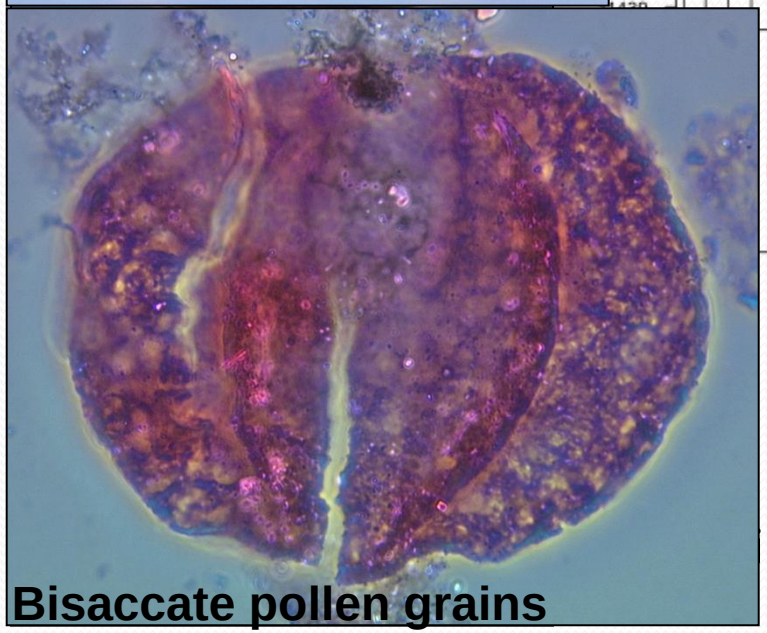
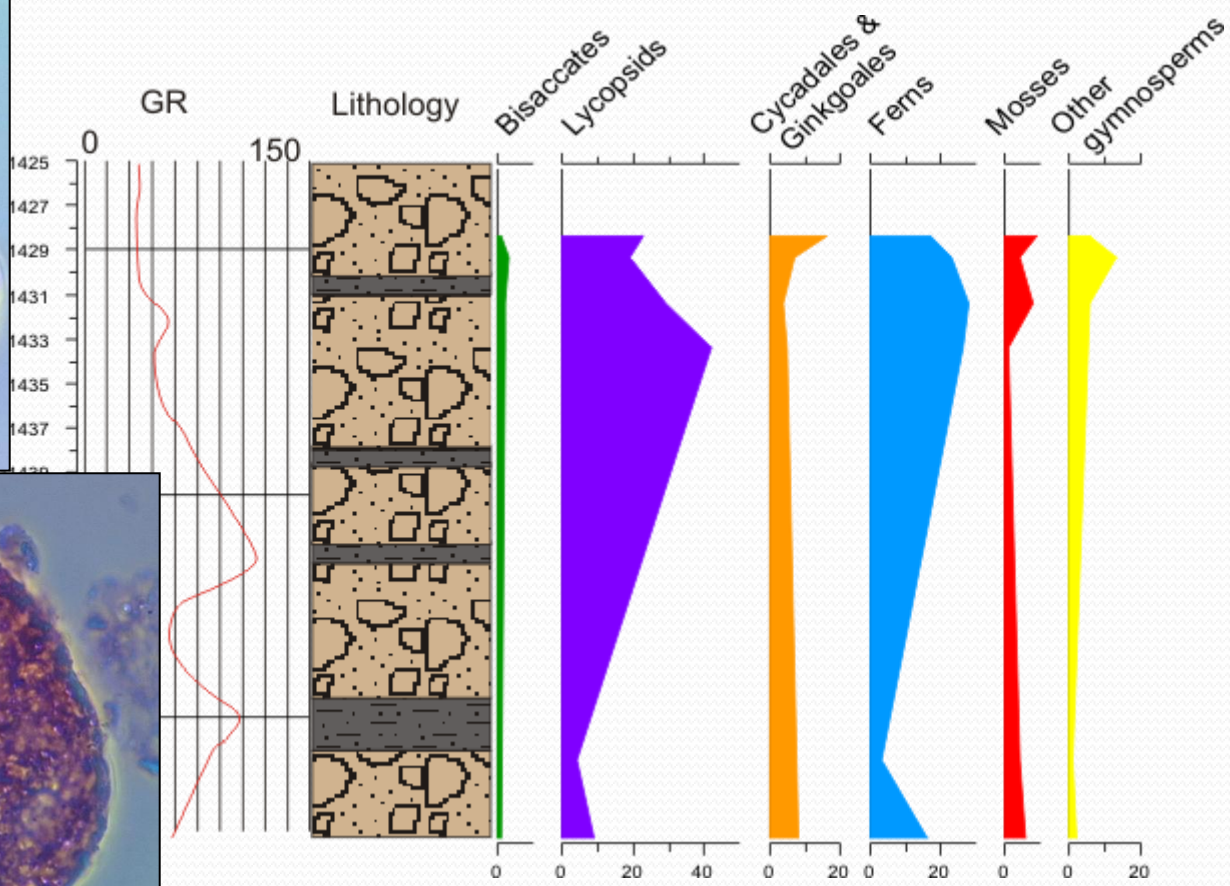




Bisaccate pollen grains



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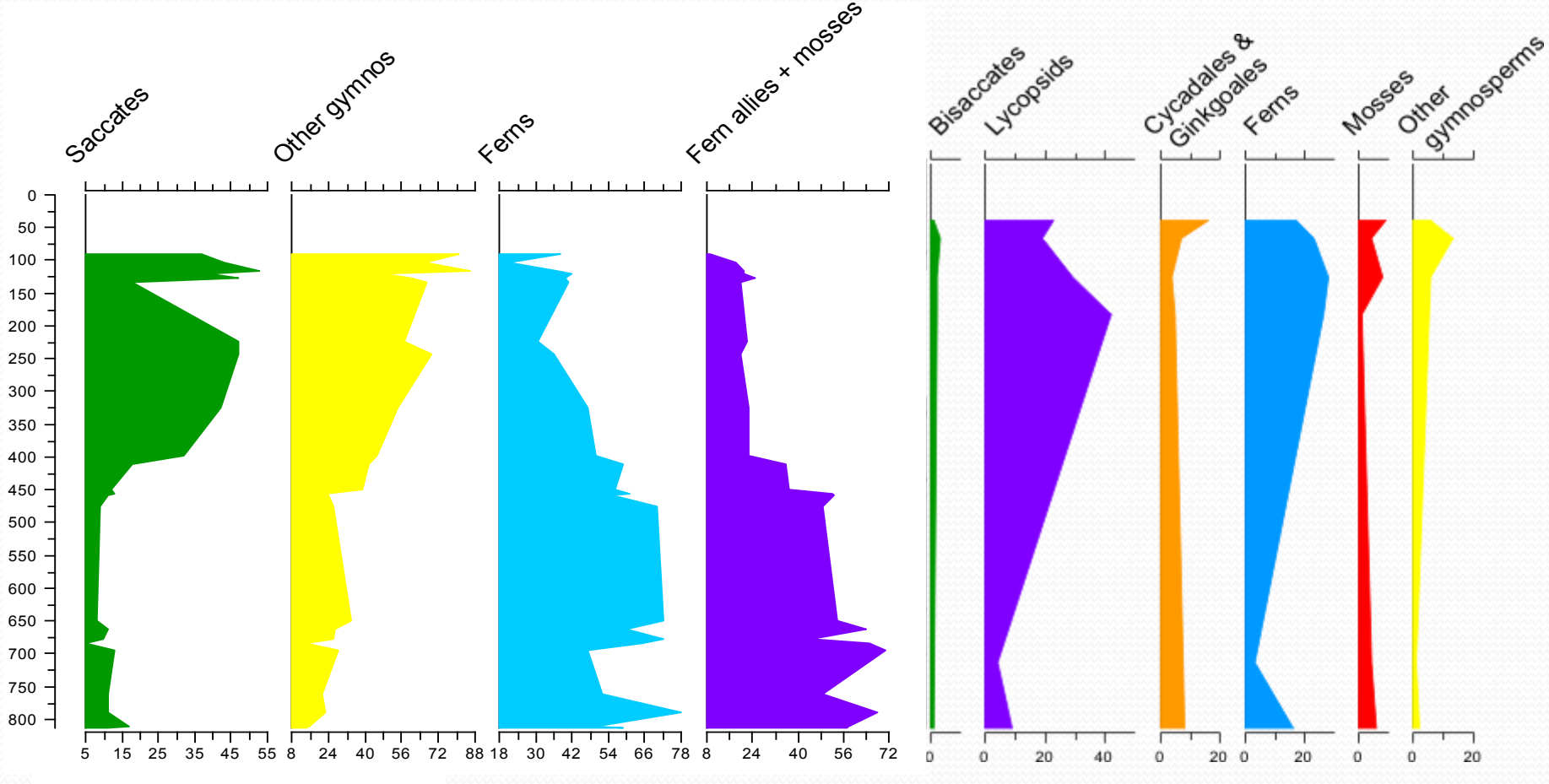

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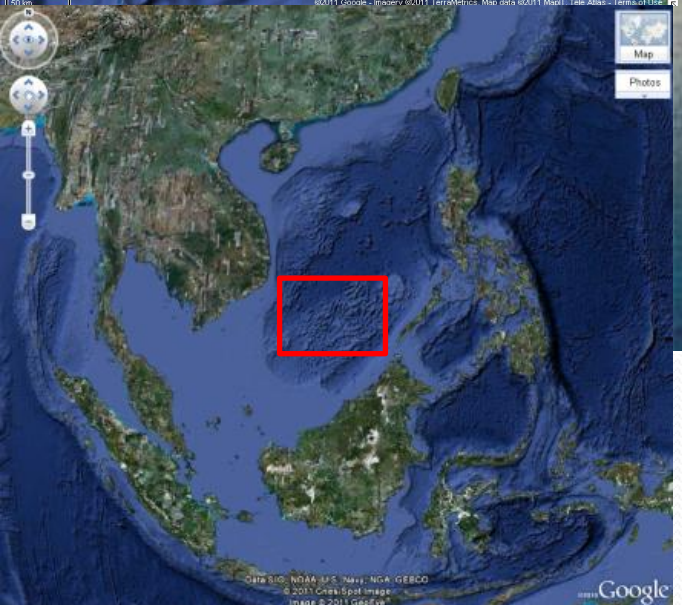

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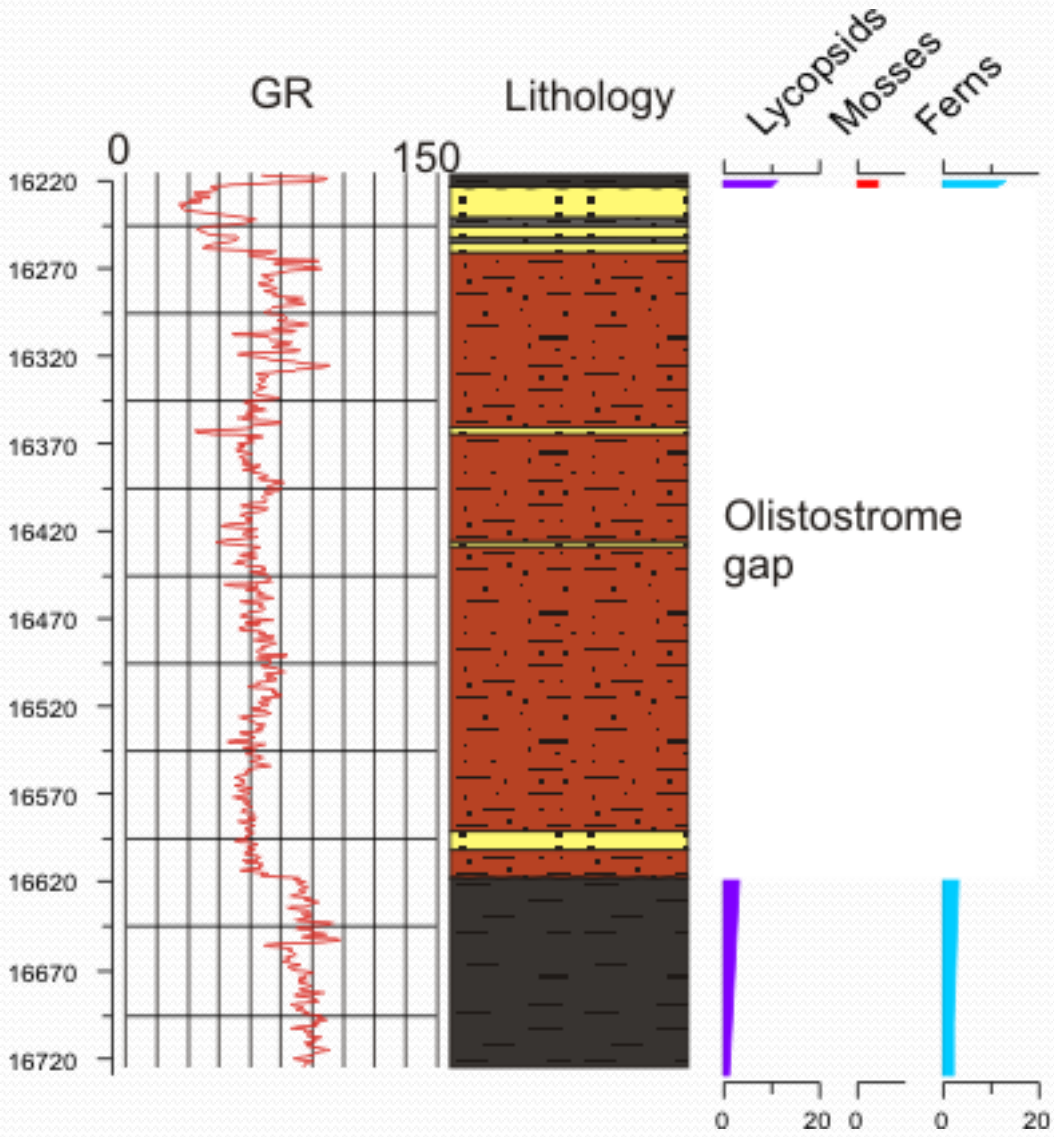
36

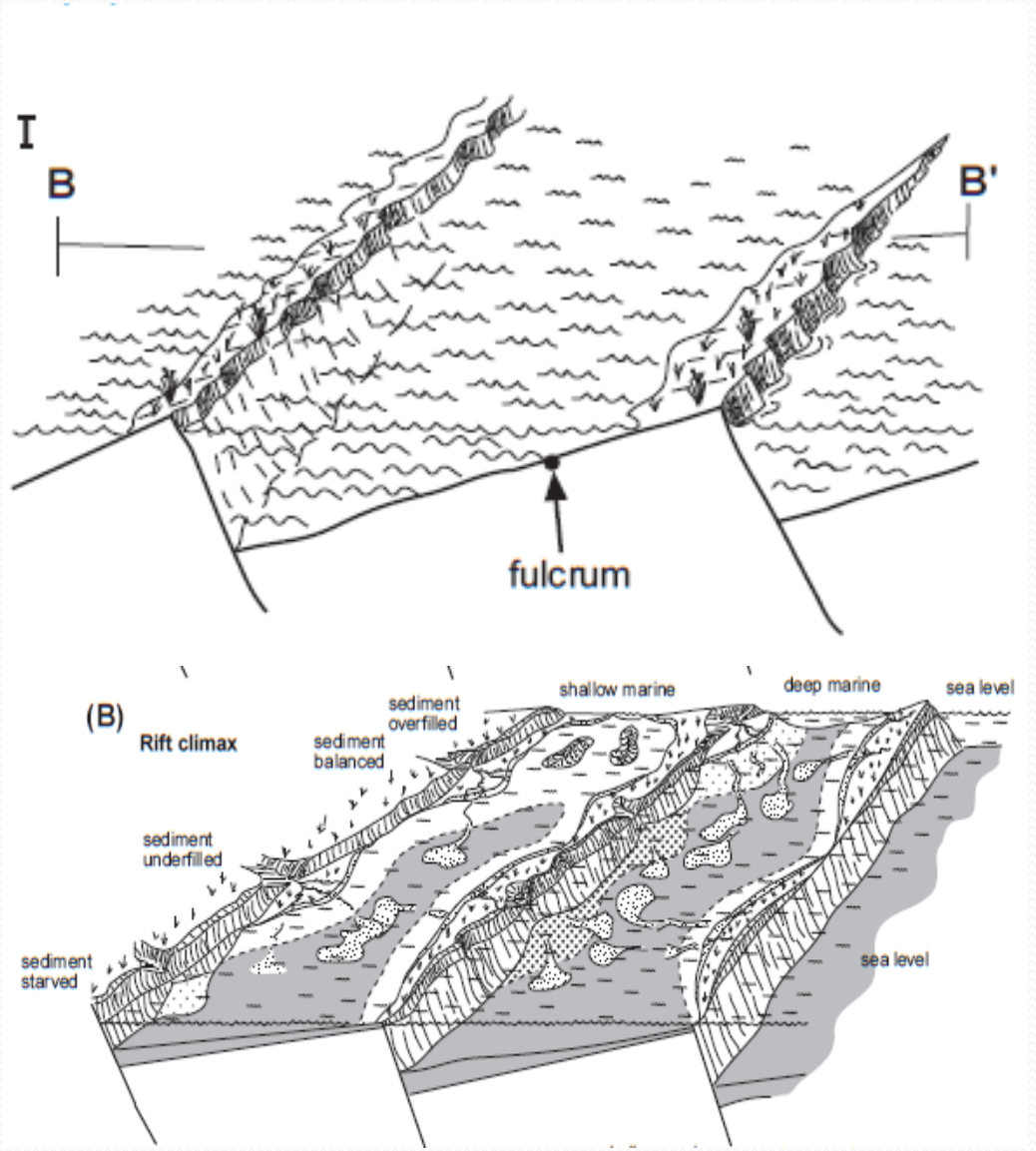
Sample analysis: Jade miospores

- 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?



Ravnås & Steel 1998

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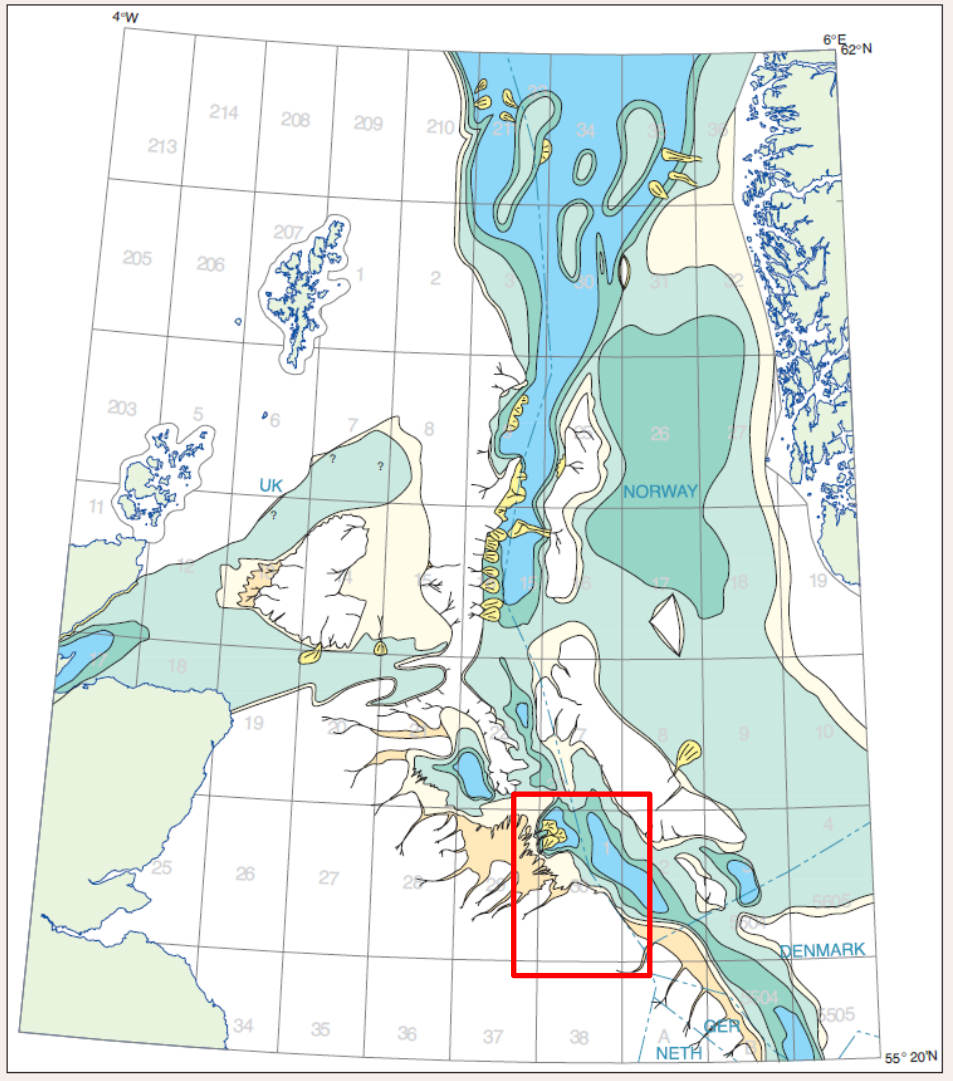

Fraser *et al*. 2003

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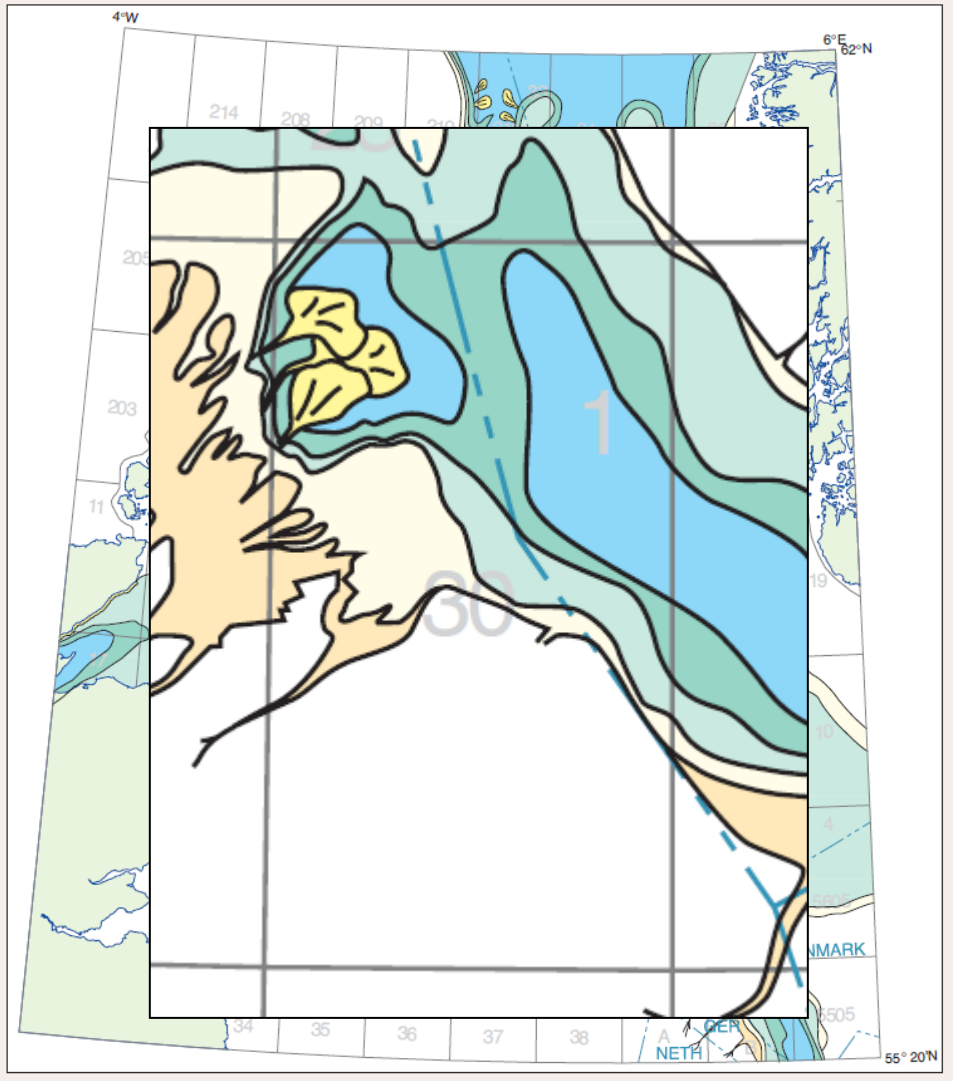

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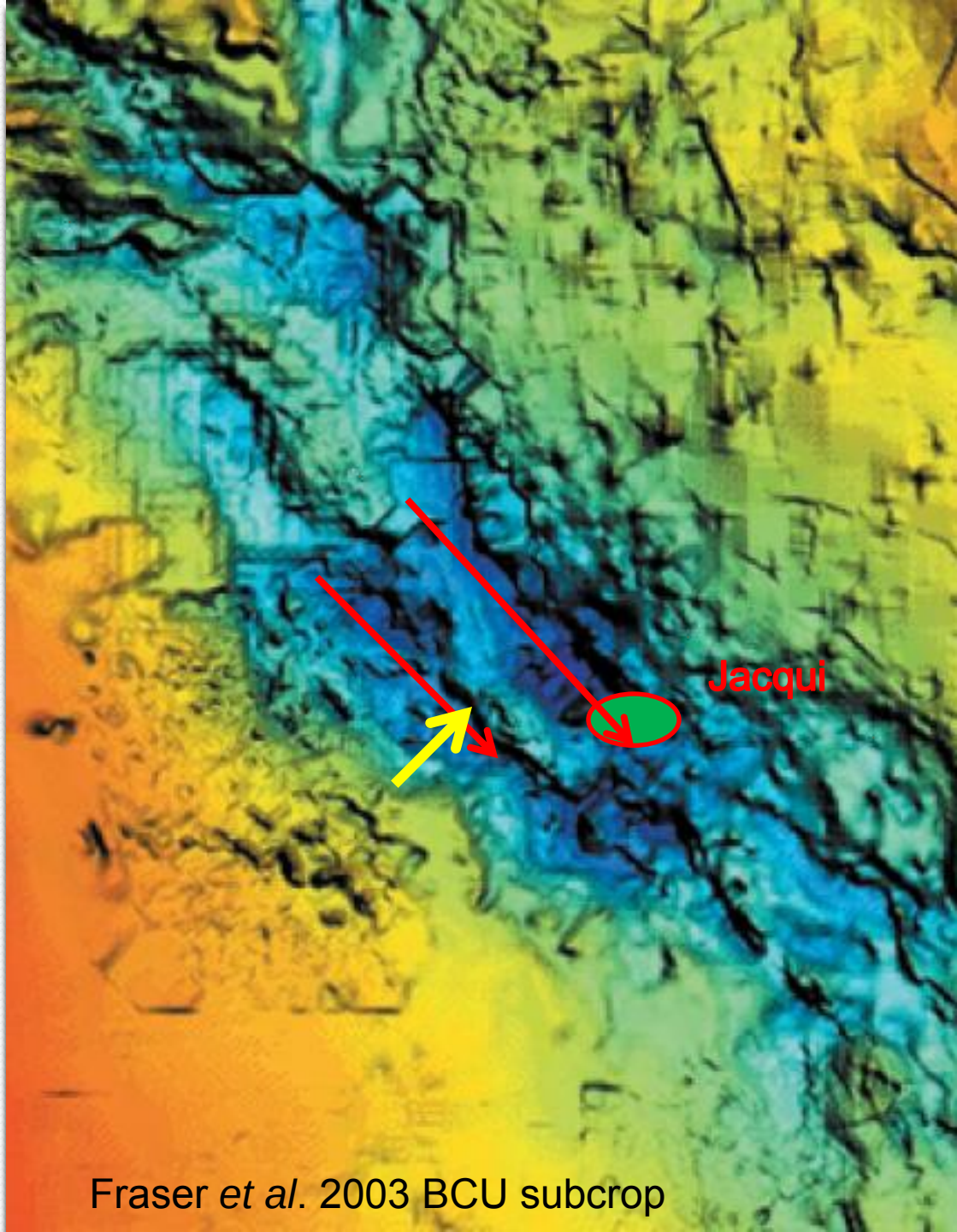

Fraser *et al*. 2003 BCU subcrop

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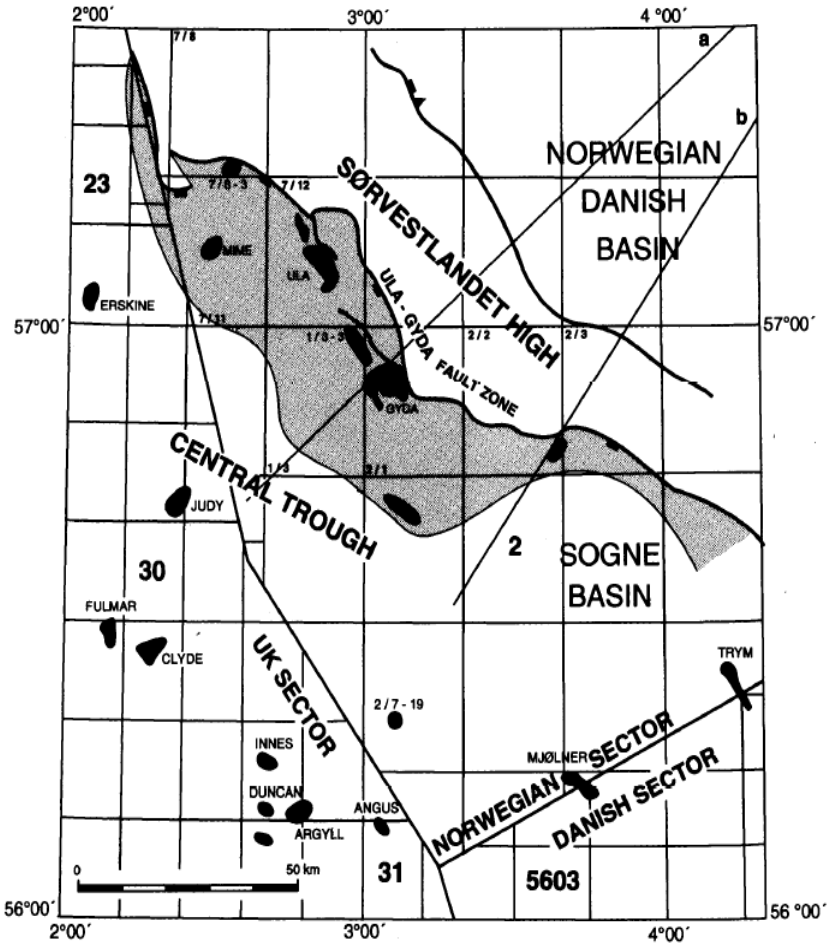

Stewart 1993

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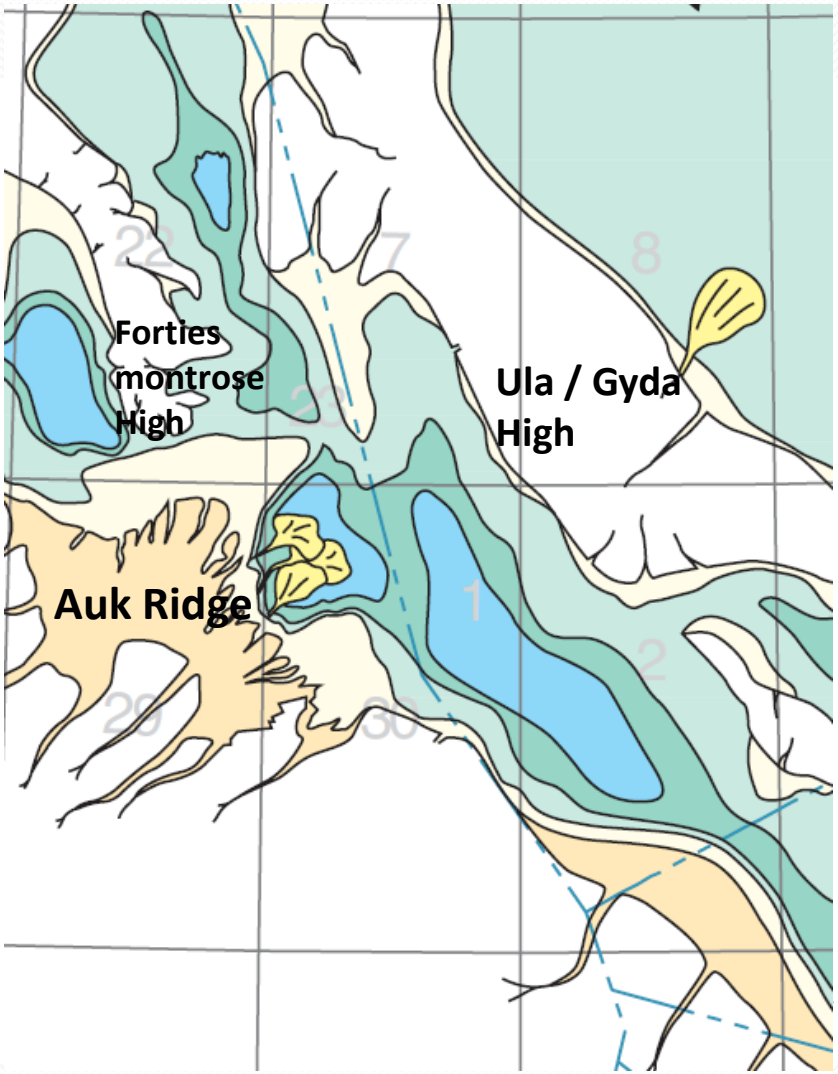

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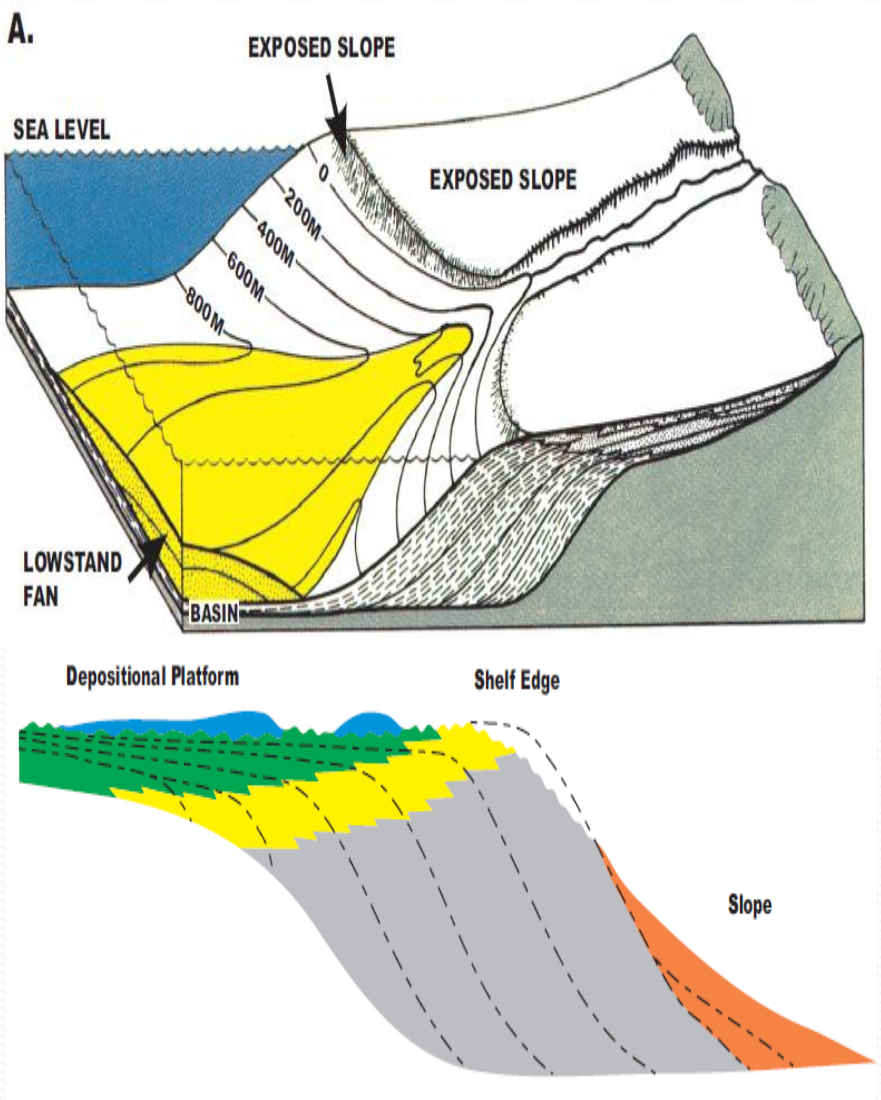
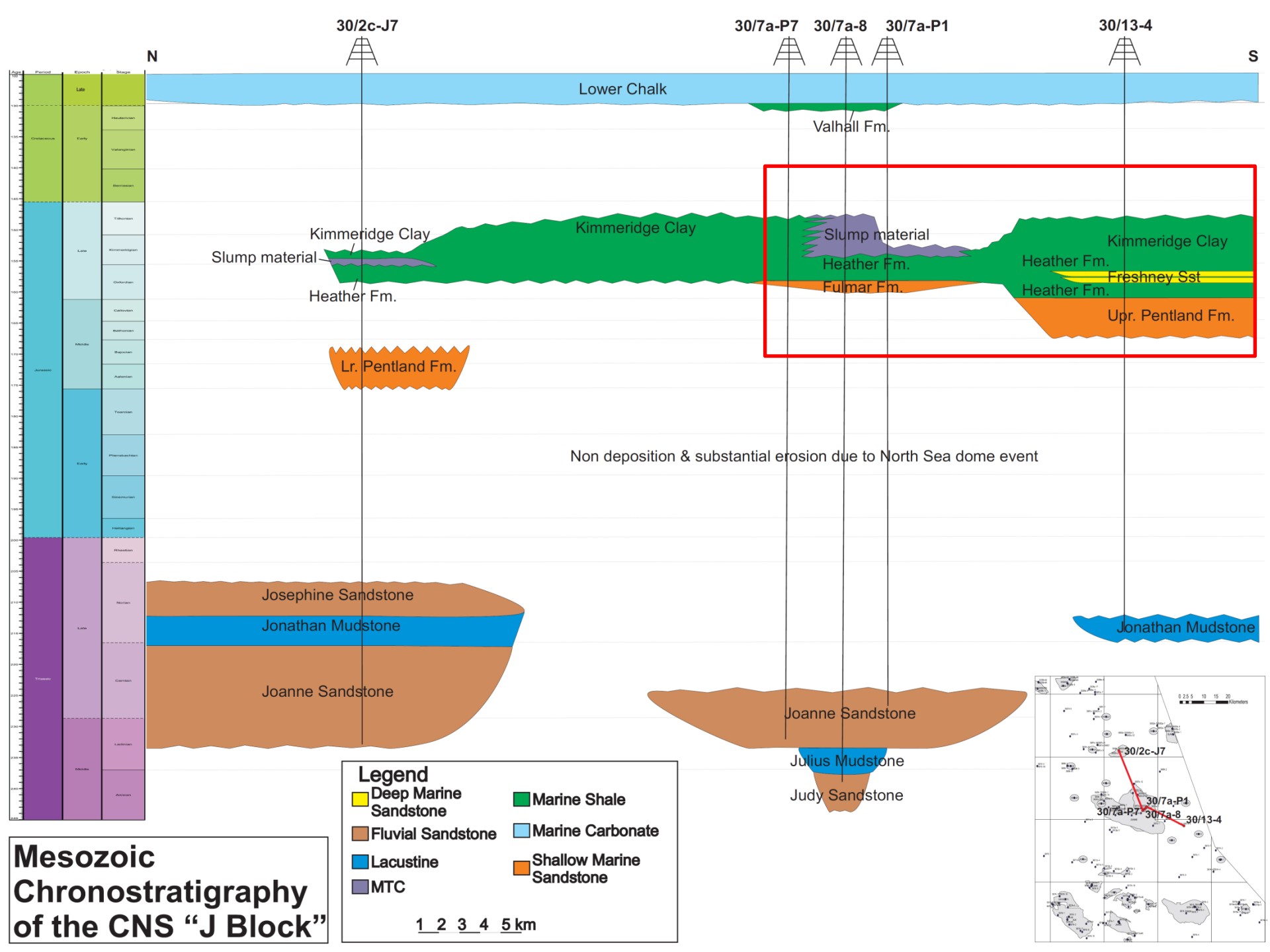
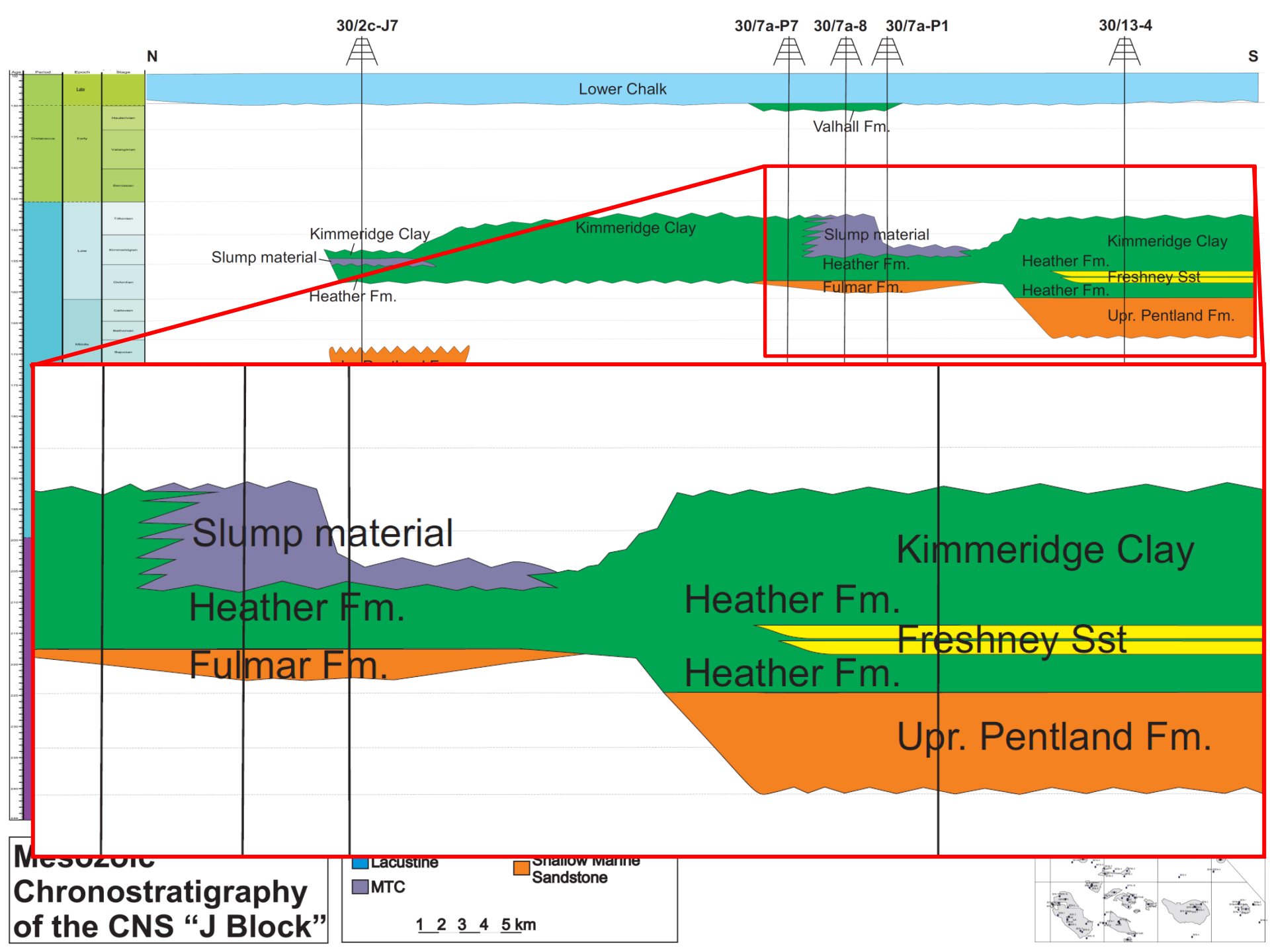


Weimar & Slatt 2007

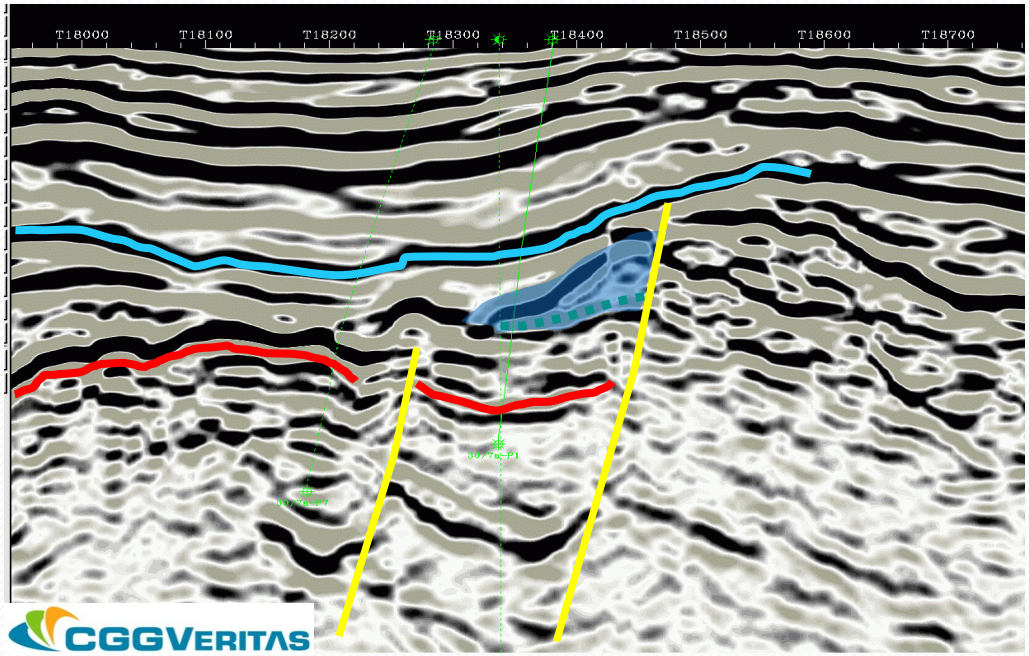

30/2c-J7
30/7a-P7
30/7a-8
30/7a-P1
30/13-4
N
S
Lower Chalk
Valhall Fm.
Kimmeridge Clay
Slump material
Heather Fm.
Kimmeridge Clay
Slump material
Heather Fm.
Fulmar Fm.
Kimmeridge Clay
Heather Fm.
Freshney Sst
Heather Fm.
Upr. Pentland Fm.
Lr. Pentland Fm.
Non deposition & substantial erosion due to North Sea dome event
Josephine Sandstone
Jonathan Mudstone
Joanne Sandstone
Joanne Sandstone
Julius Mudstone
Judy Sandstone
Jonathan Mudstone
Legend
Deep Marine Sandstone
Fluvial Sandstone
Lacustine
MTC
Marine Shale
Marine Carbonate
Shallow Marine Sandstone
1 2 3 4 5 km
Mesozoic Chronostratigraphy of the CNS "J Block"
30/2c-J7
30/7a-P1
30/7a-P7
30/7a-8
30/13-4



Mesozoic Chronostratigraphy of the CNS "J Block"

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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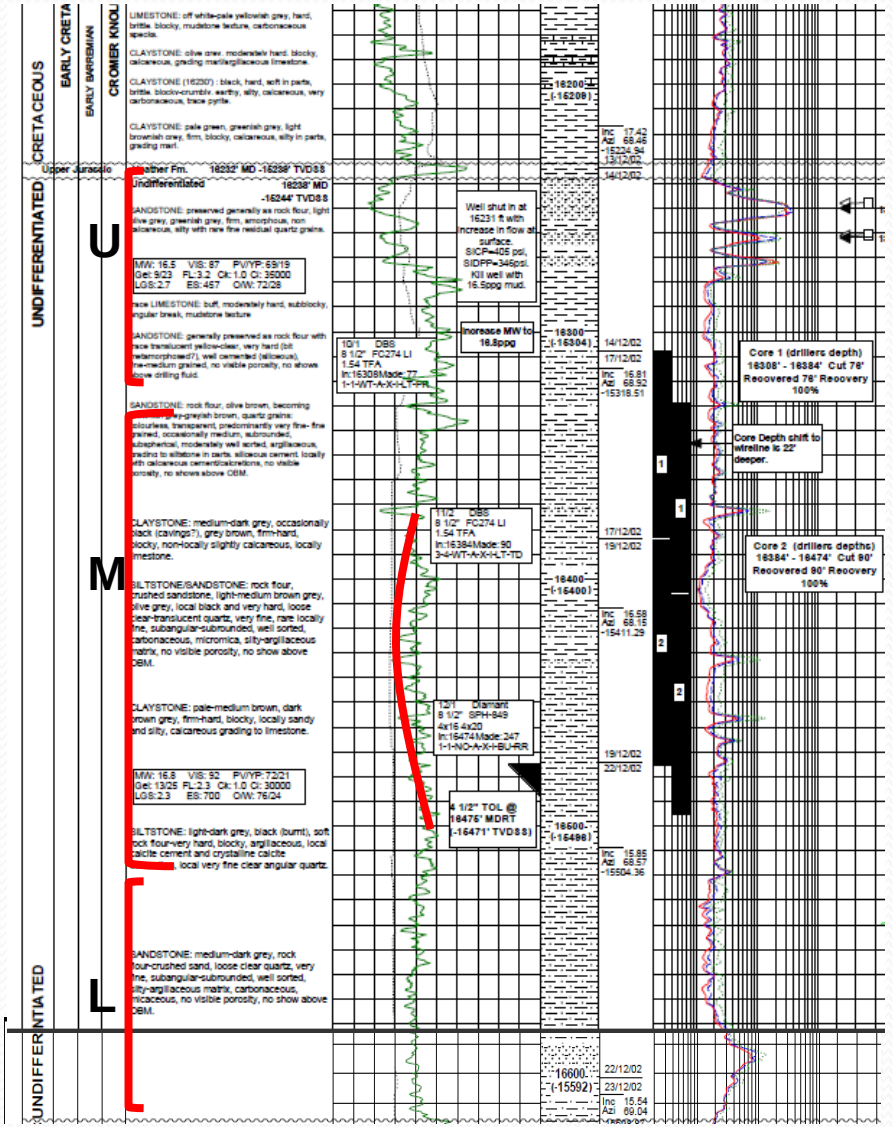

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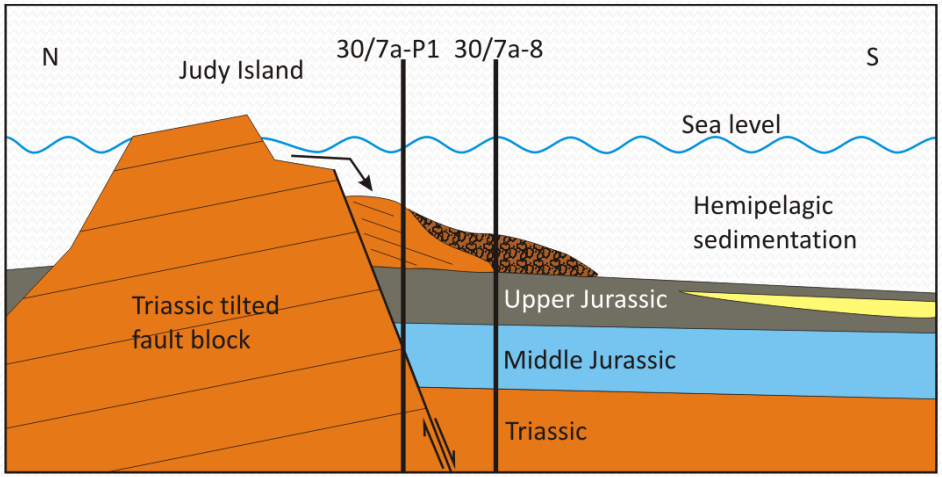

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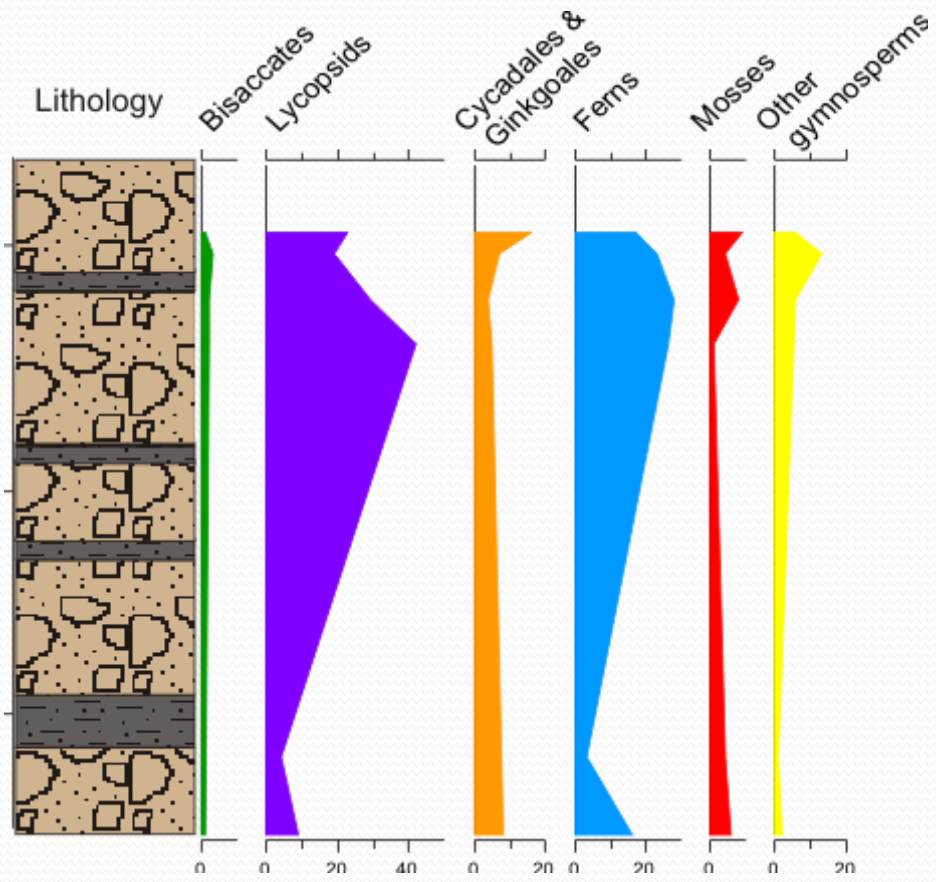

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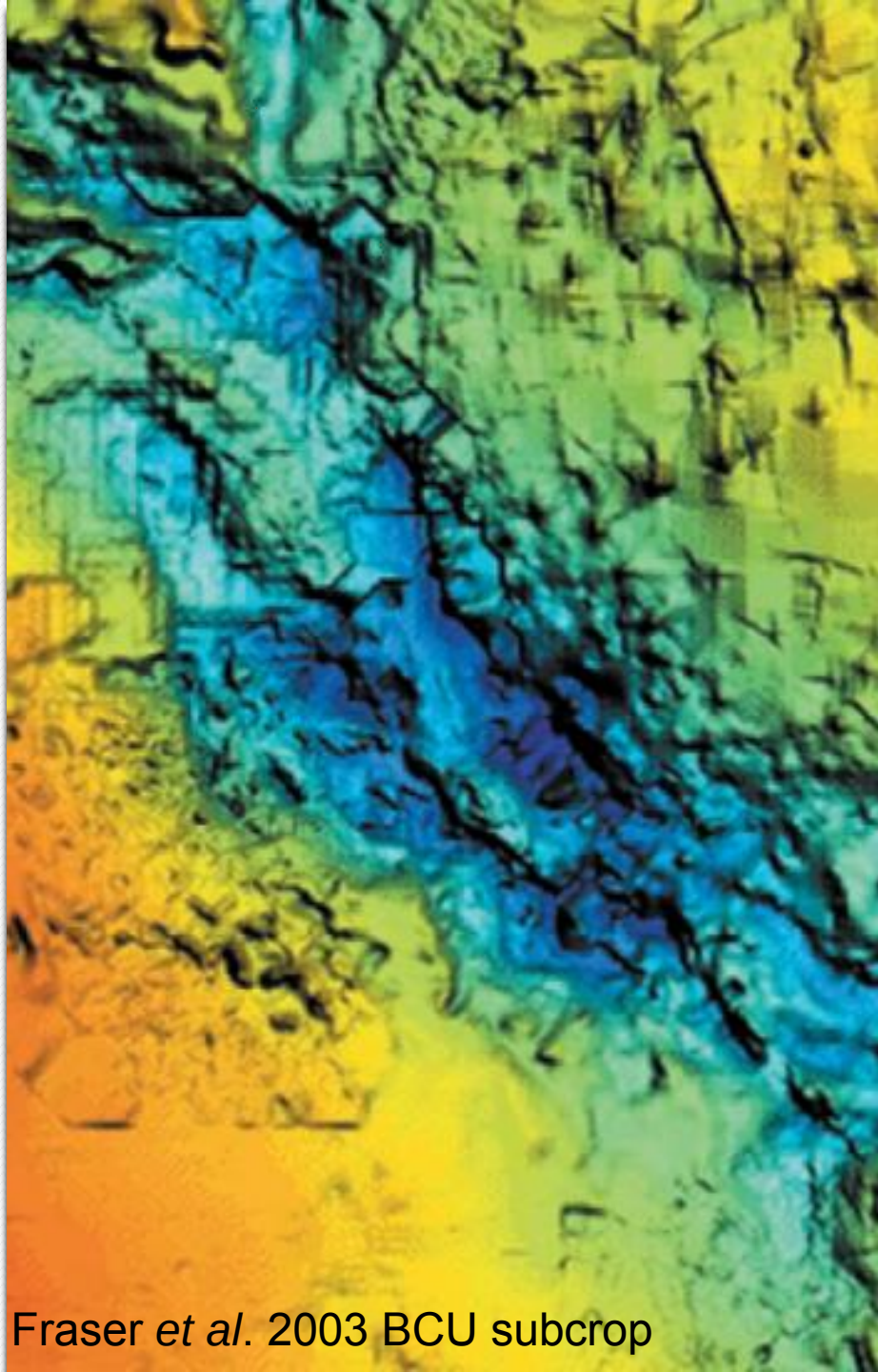

Fraser *et al*. 2003 BCU subcrop

Thanks to: