The Role of Polygonal Fault Mapping in De-Risking Deepwater Reservoir Presence: A 3-D Seismic Reflection Case Study from Offshore Norway*

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Abstract

Polygonal fault systems (PFS) are composed of relatively low-displacement (<50 m) normal faults that form in response to burial, compaction and dewatering of smectite-rich claystones. In many petroliferous sedimentary basins, PFS occur in the same stratigraphic interval as deep-water sandstone reservoirs, thus the geometry and distribution of PFS, which are both sensitive to the lithology of the host rock, should provide important insights into the distribution of deep-water reservoirs. There are, however, relatively few detailed studies that have focused on the utilisation of PFS mapping to de-risk deep-water reservoir presence, or that have outlined exploration workflows that may be implemented by industry geoscientists. In this study we use 3-D seismic reflection and borehole data from the Cretaceous-to-lowermost Tertiary succession of the Måløy Slope, offshore Norway to demonstrate that the distribution of polygonal faults can be used to de-risk the presence of a deep-water reservoirs. We first use a variety of seismic attribute mapping techniques to image the reservoir and PFSs, and then present a detailed, statistical analysis of polygonal fault geometry and distribution, both vertically (i.e. stratigraphically) and laterally. Our data indicates that the an Upper Cretaceous (Turonian) submarine fan reservoir, which is up to 120 m thick and pinches out into slope mudstone, is largely unfaulted, but that polygonal faults are abundant in the time-equivalent, mudstone-dominated slope succession; the polygonal faults thus define the areal extent of the reservoir at this particular stratigraphic level. Furthermore, polygonal faults below and above the reservoir tip out upwards and downwards, respectively, into the sandstone-dominated reservoir succession, thereby constraining its stratigraphic extent. The reservoir that forms the focus of this study is very well imaged, but we suggest that the general workflow we describe here is equally applicable to the exploration for deep-water reservoirs that are poorly imaged on seismic reflection data. We stress that polygonal faults are not just an academic curiosity, but that they may have economic applications by serving as a key deep-water exploration tool.

References Cited

Cartwright, J.A., 2011, Diagenetically induced shear failure of fine grained sediments and the genesis of polygonal fault systems: Marine and Petroleum Geology, v. 28, p. 1593-1610. doi: 10.1016/j.marpetgeo.2011.06.004.

Lonergan, L. and J.A. Cartwright, 1999, Polygonal faults and their influence on deep-water sandstone reservoir geometries, Alba Field, United Kingdom central North Sea: AAPG Bulletin, v. 83, p. 410-432.

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The role of polygonal fault mapping in de-risking deepwater reservoir presence; a 3D seismic reflection case study from offshore Norway

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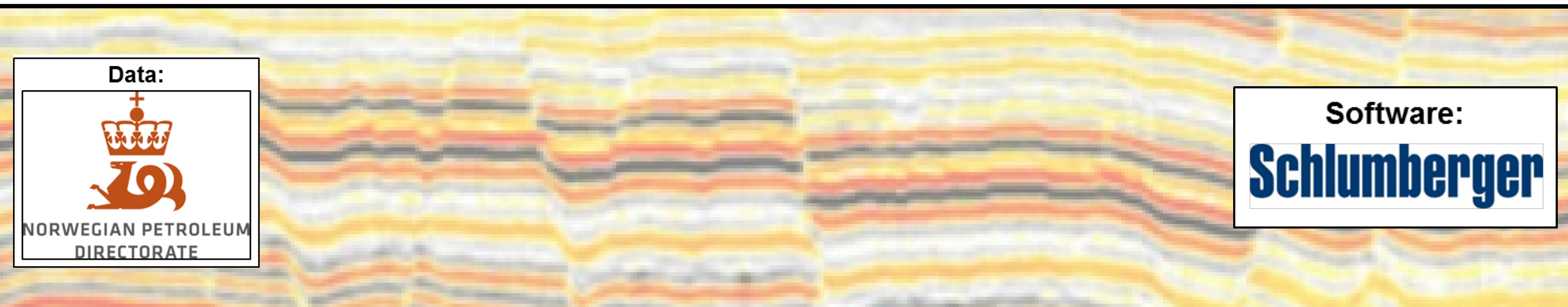

Polygonal Faults - Expression

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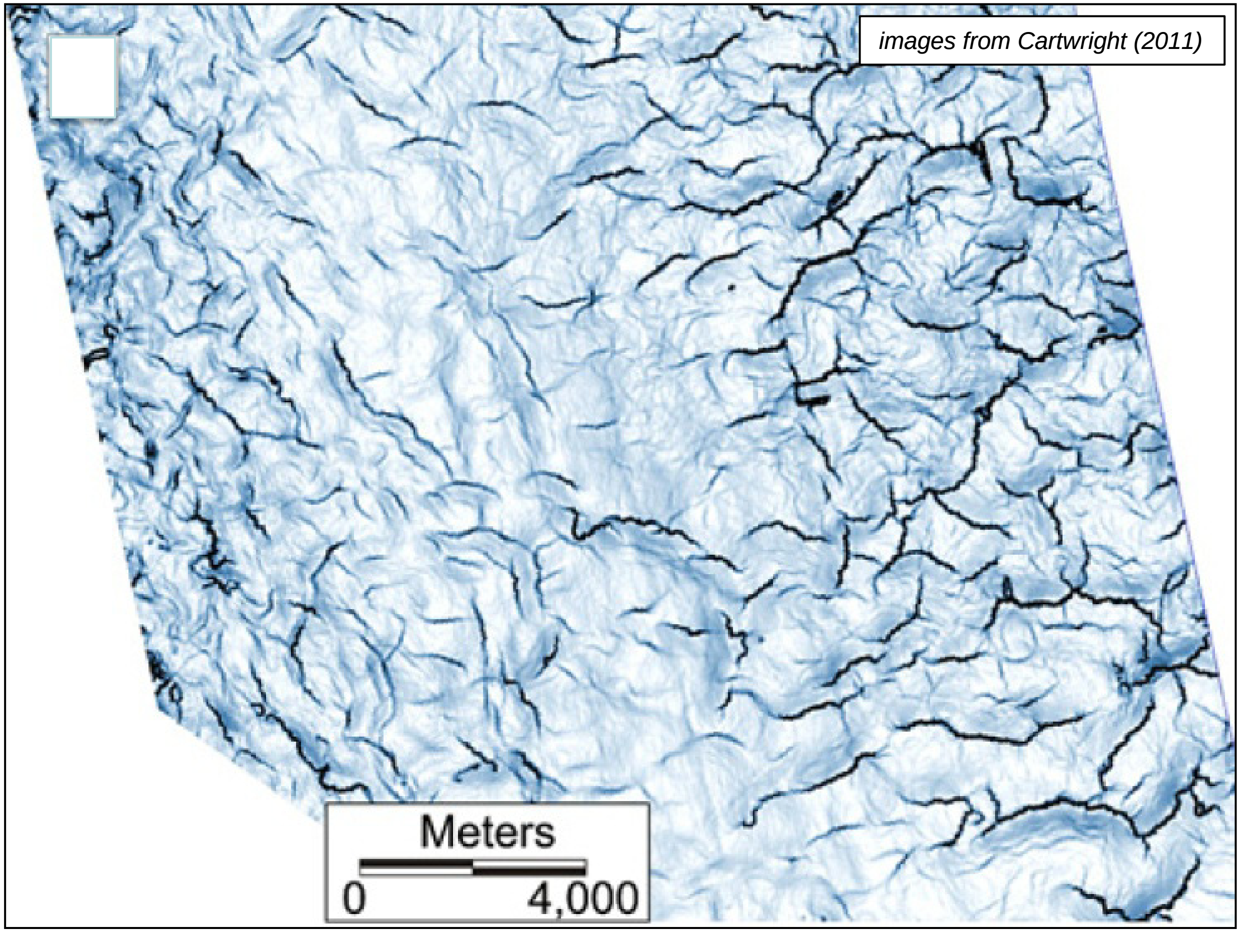

- Layerbound, low-throw (<50 m) normal faults, developed in fine-grained rocks
- Broadly polygonal map-view pattern
- ***Origin widely debated…practical applications poorly understood…***

Polygonal Faults - Application

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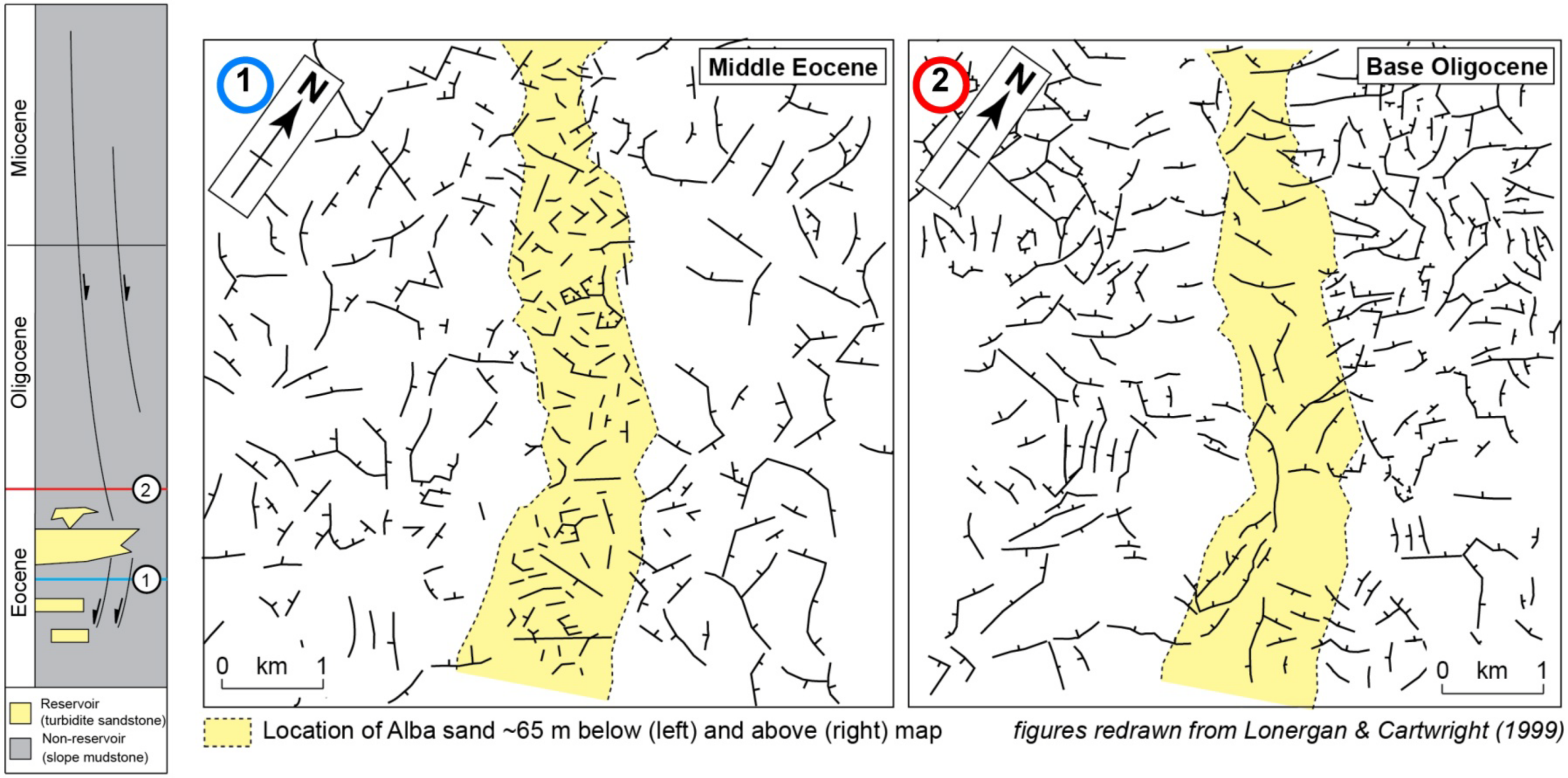
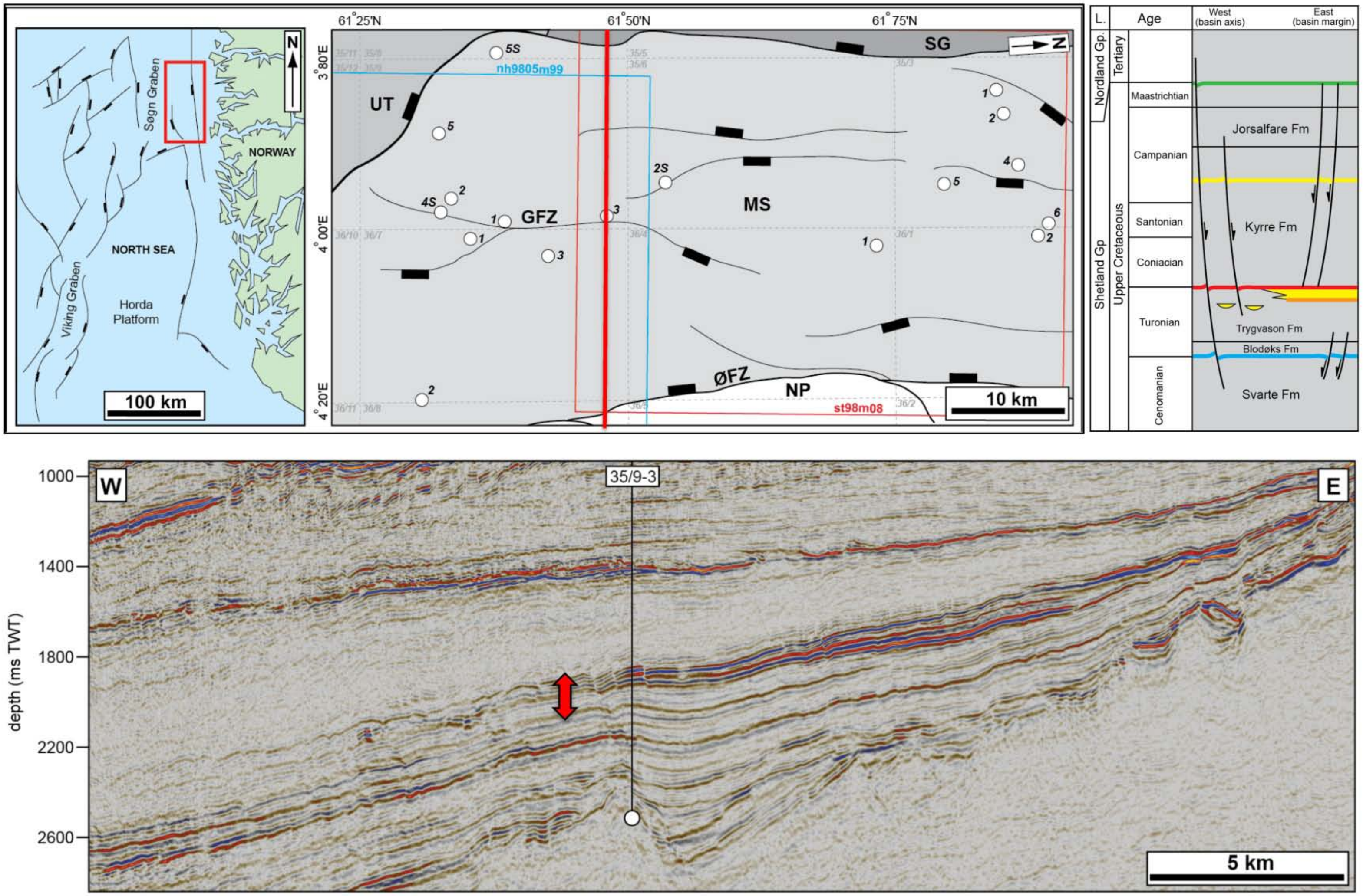


1. Can polygonal fault mapping help de-risk reservoir presence in deep-water settings?
2. What tools highlight the relationship between polygonal faults and deep-water reservoirs?
3. Does polygonal fault mapping have global applications?

Presenter's notes:

- This example comes from the Eocene-to-Miocene of the NNS and represents one of the very few studies to explicitly consider the role PFS mapping may have for HC exploration
- Several PF tiers; lower tier beneath reservoir regionally developed and upper tier better developed in off-field mudrocks
- Decrease in PF density above reservoir suggests mechanical control on PF propagation and final 3D geometry of PFS

Geological Setting



Presenter's notes:

- Måløy Slope, NNS
- Two 3D seismic surveys and numerous wells
- Reservoir of interest is Upper Cretaceous (Late Turonian); as will be shown later, a PFS is developed in encasing mudstones
- Reservoir expressed as a package of high-amplitude reflections that dim basinward and along-strike

Reservoir Seismic Expression

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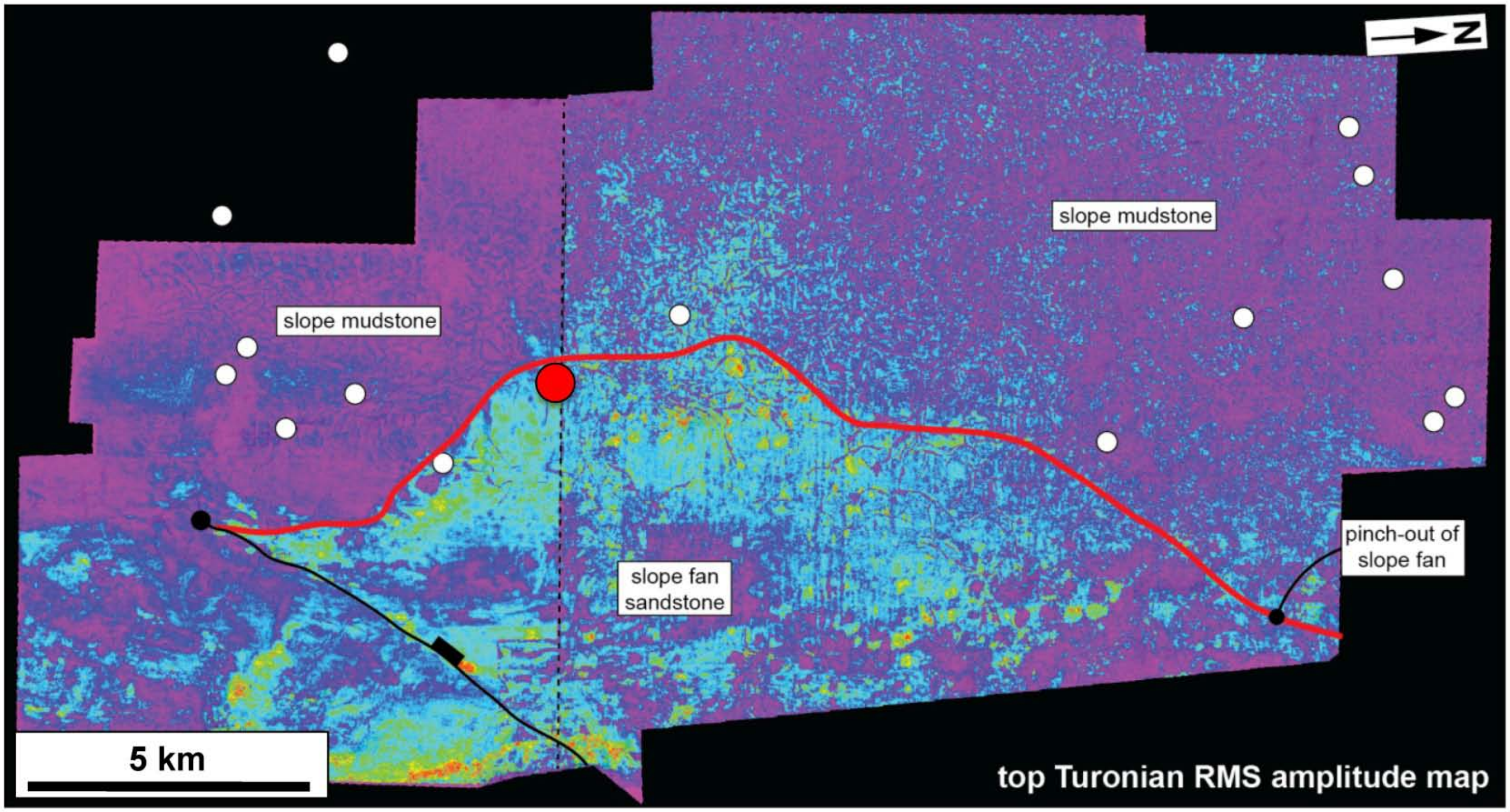
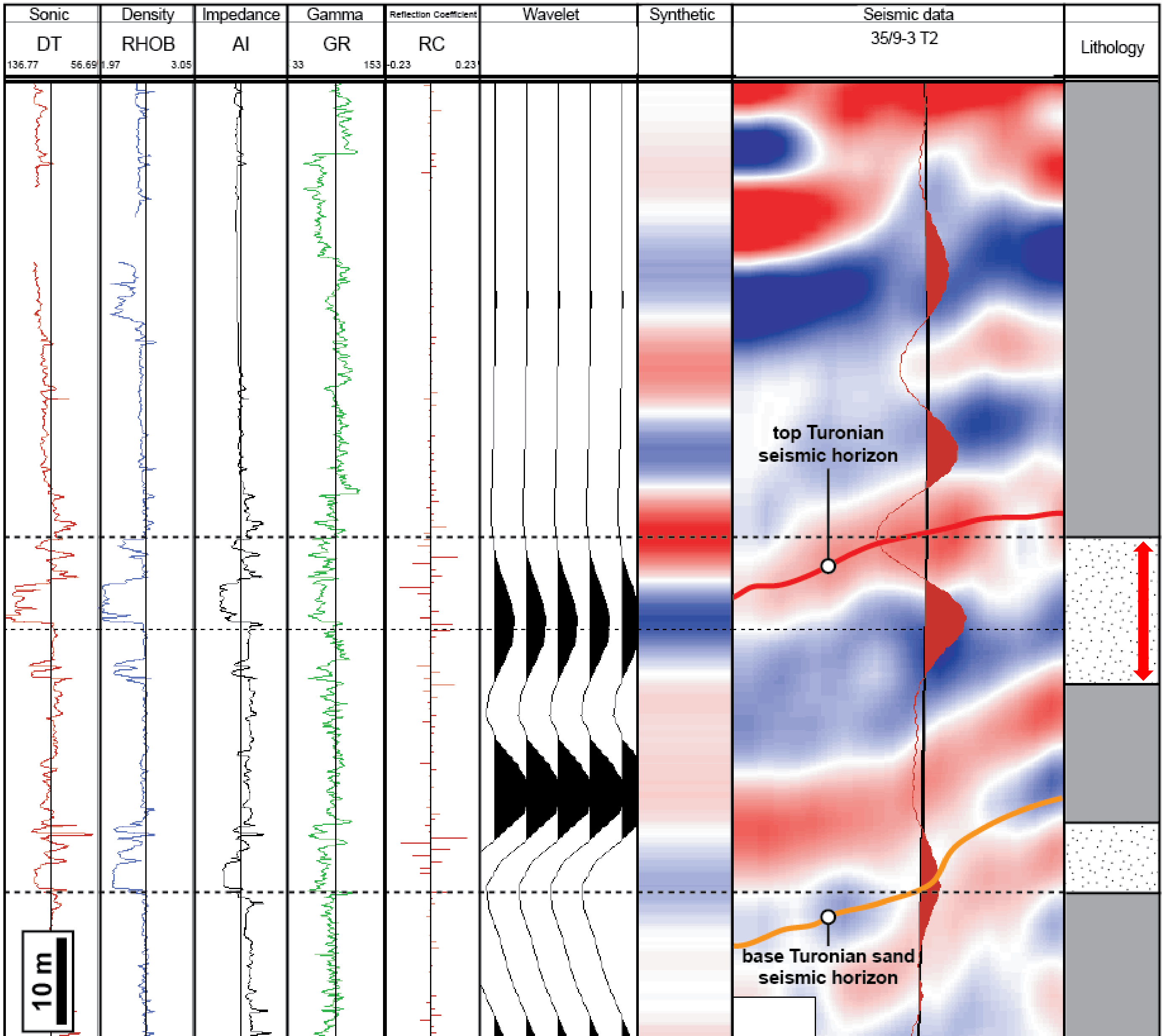
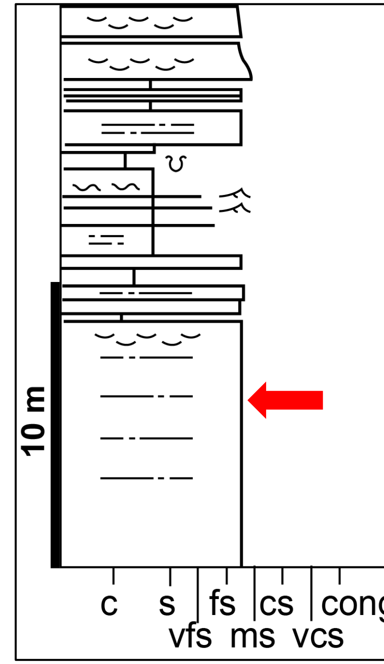


Presenter's notes:

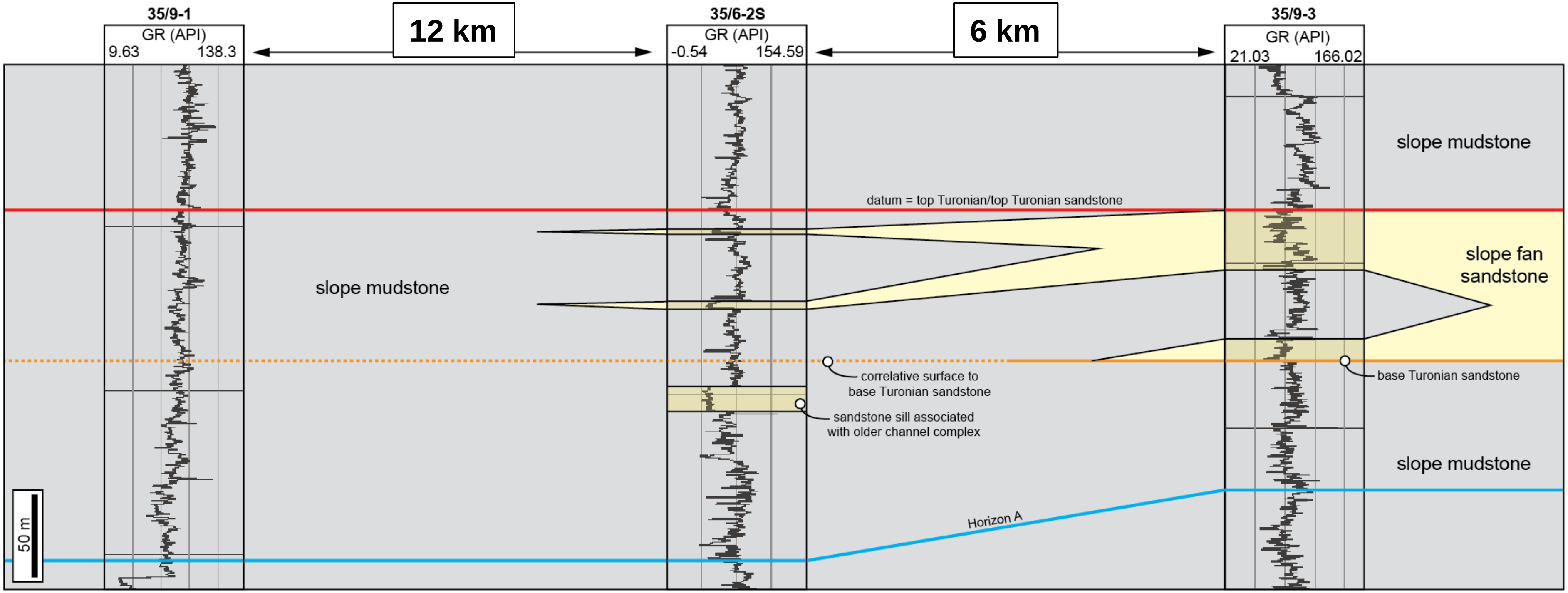
- 18 km radius slope fan
- Pinch-out defined by seismic amplitude dimming and stratal thinning; confirmed by well data (see later)
- Fault-bound to the SE
- Internal seismic variability related to intra-reservoir heterogeneity?
- Now we will look at the reservoir sedimentology and stratigraphic architecture…

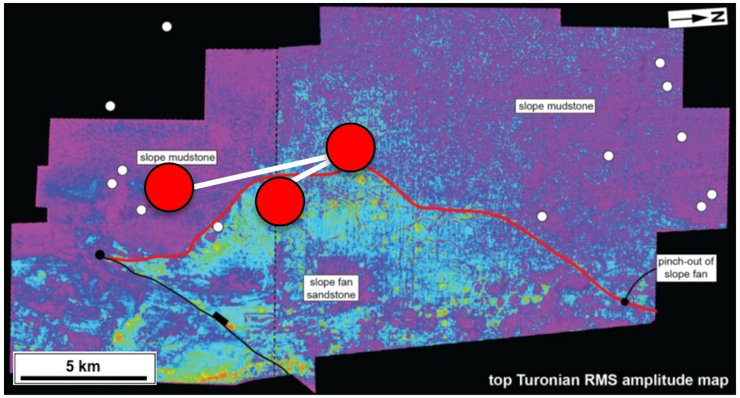
Reservoir Sedimentology

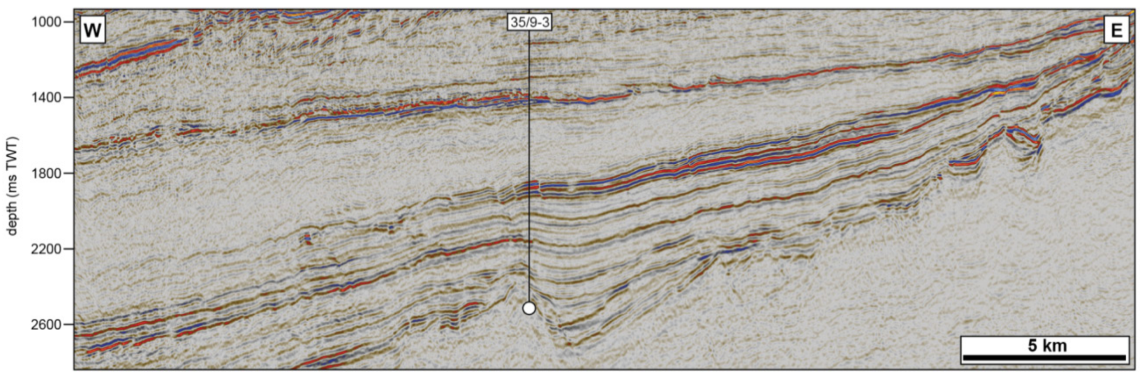




Reservoir Architecture







Fault-Reservoir Relationships

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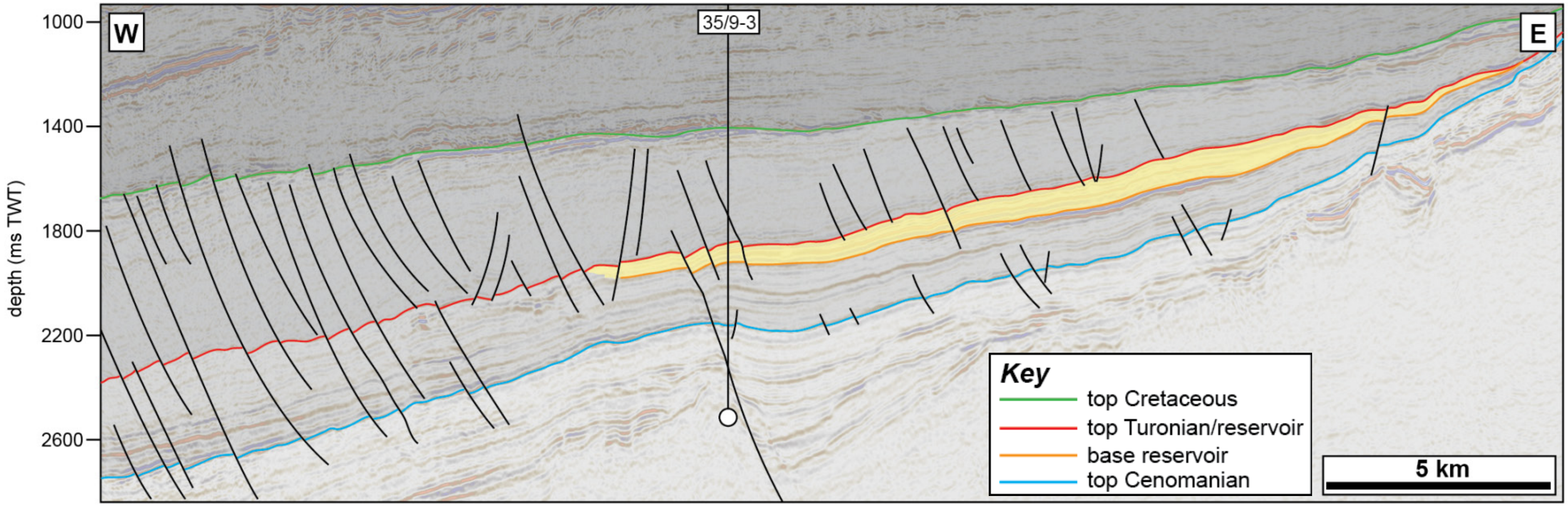

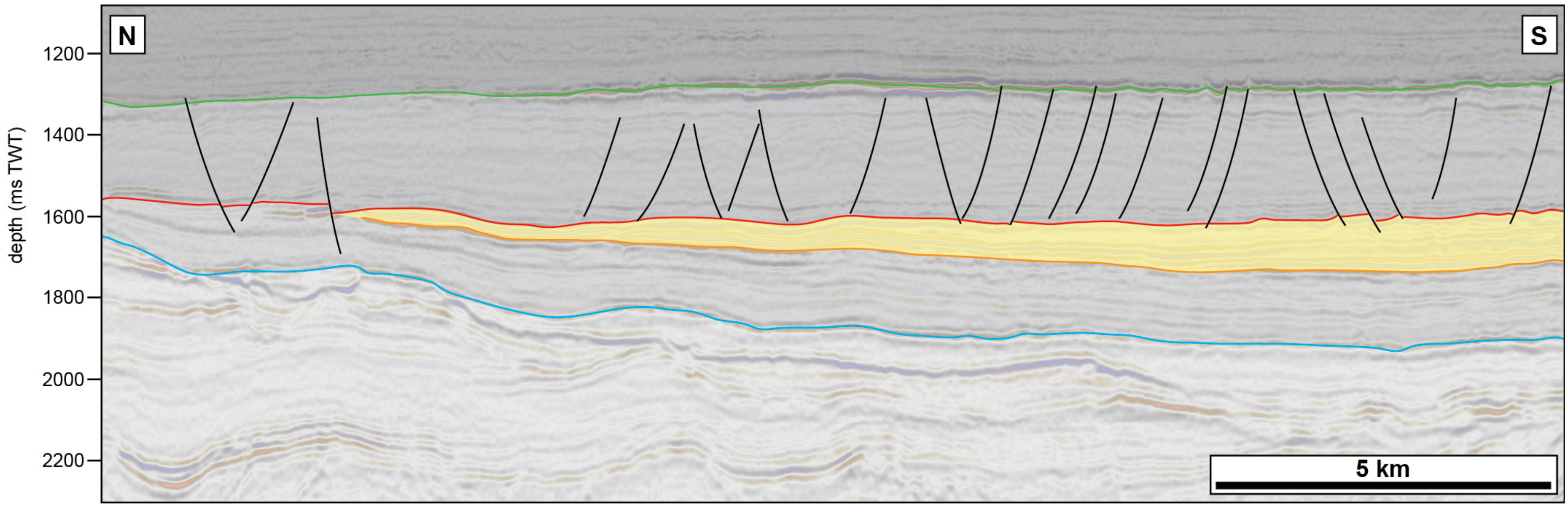

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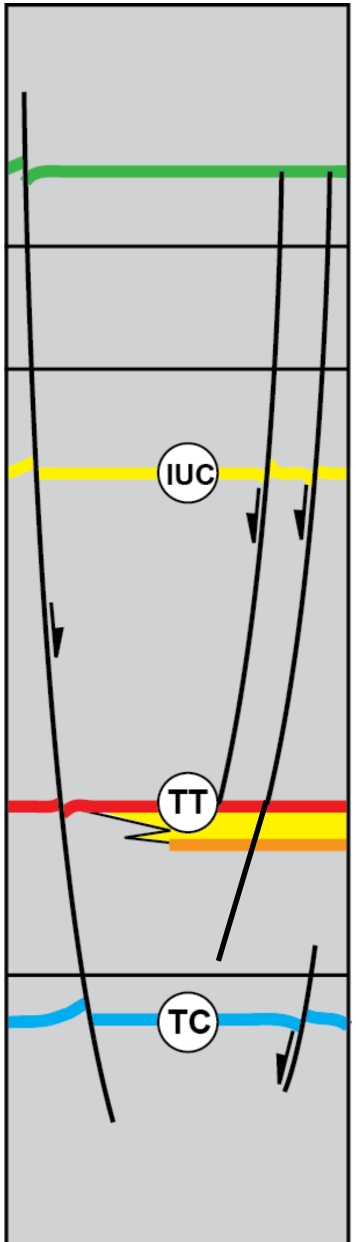

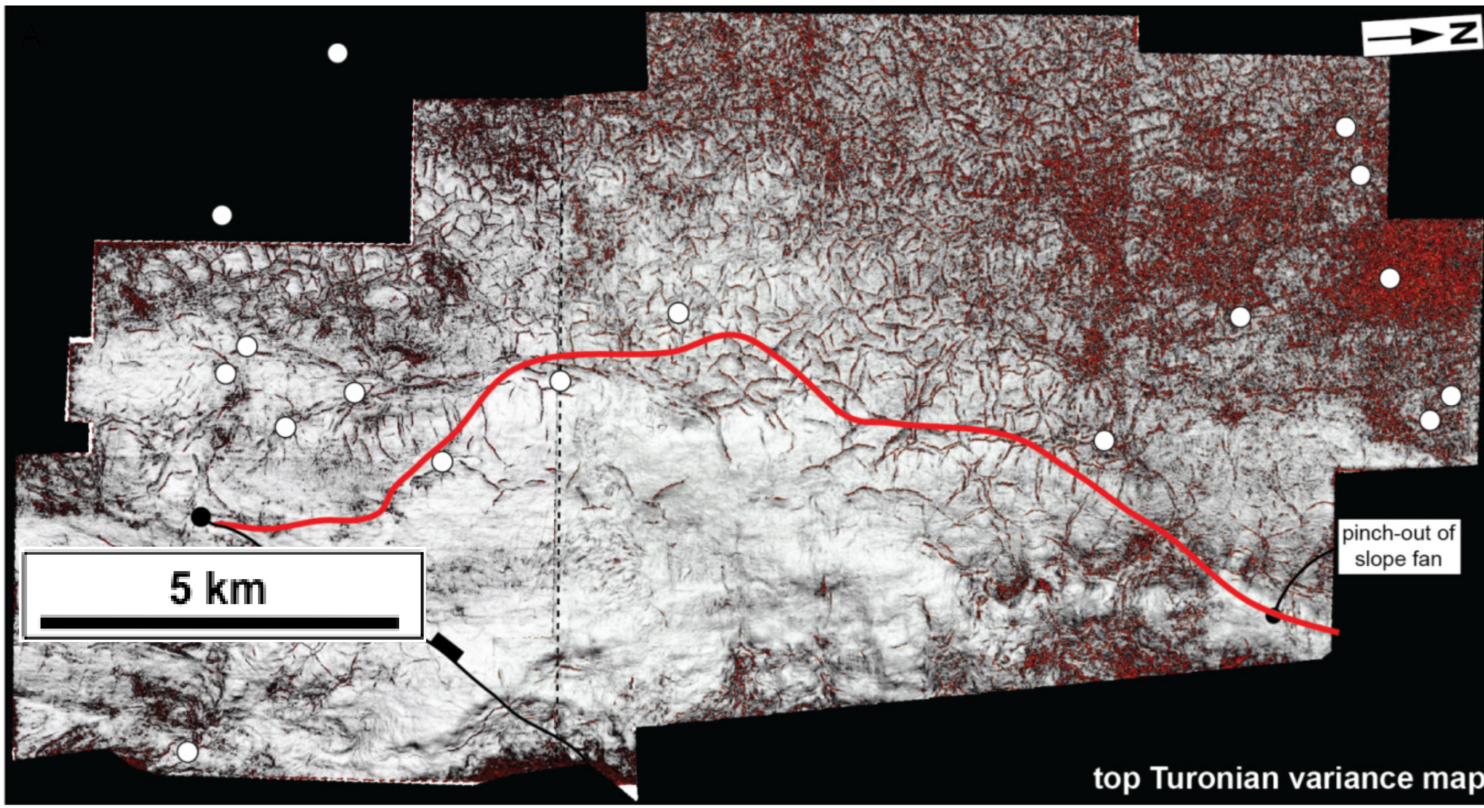

Fault-Reservoir Relationships

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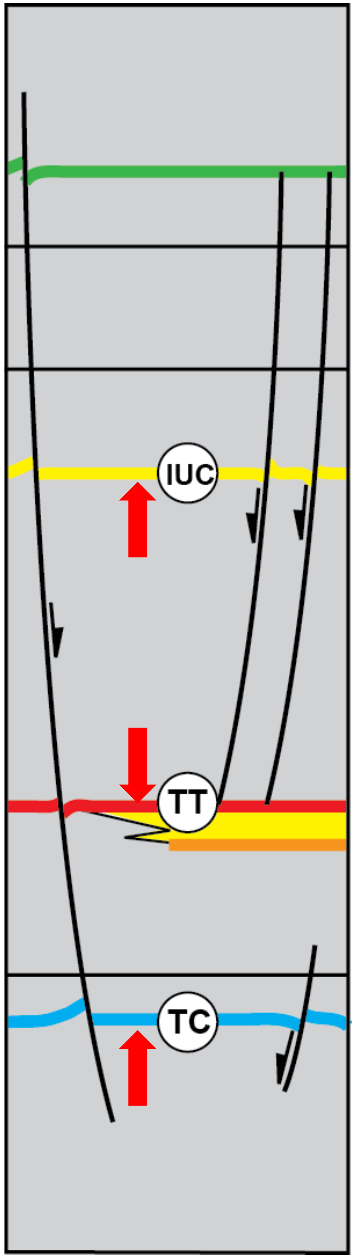
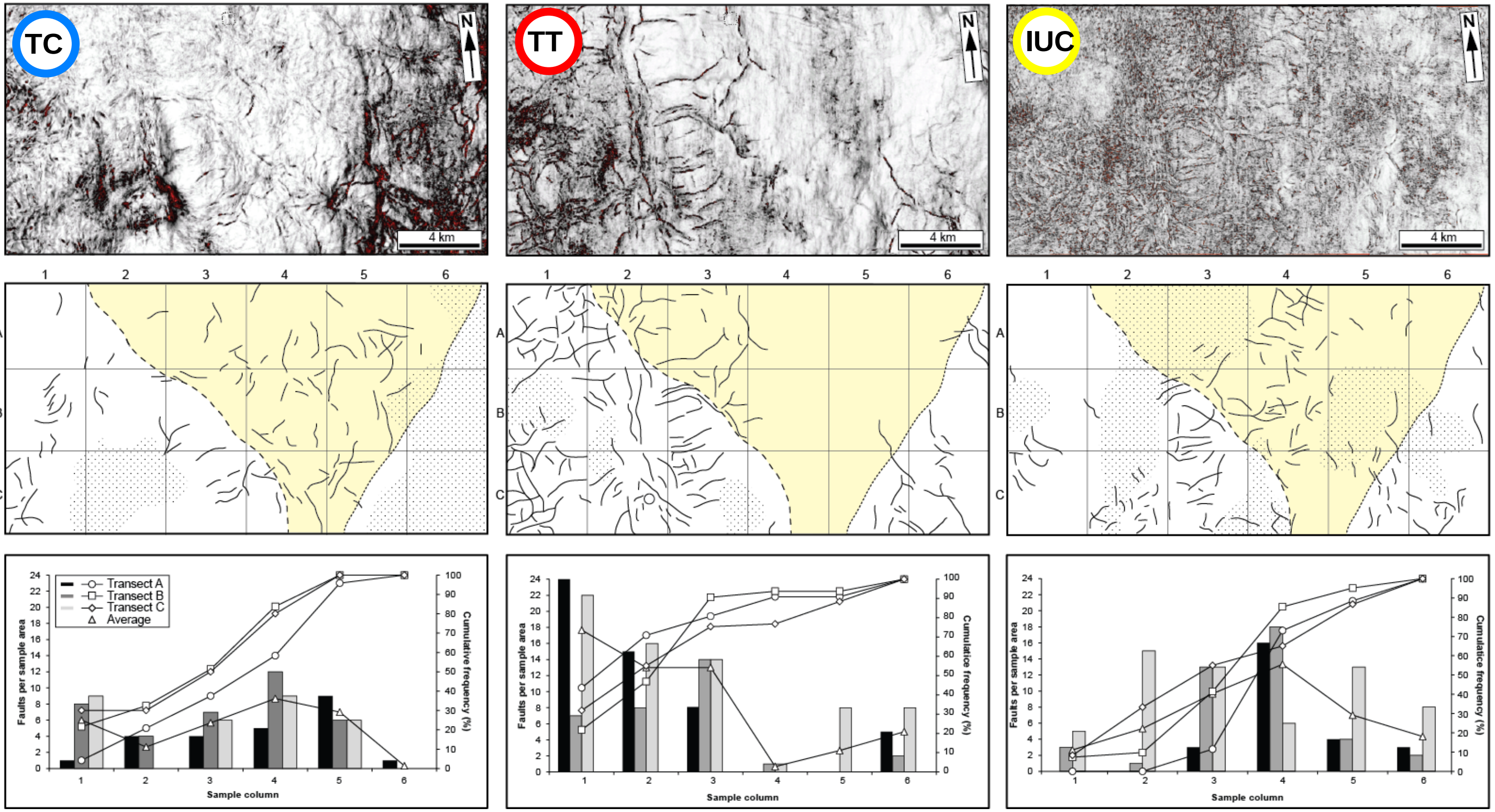
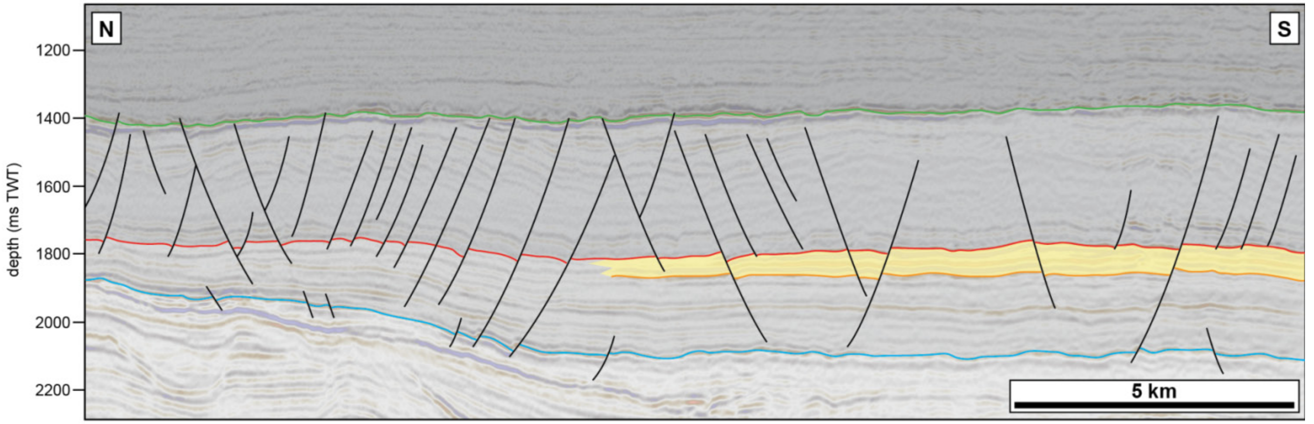
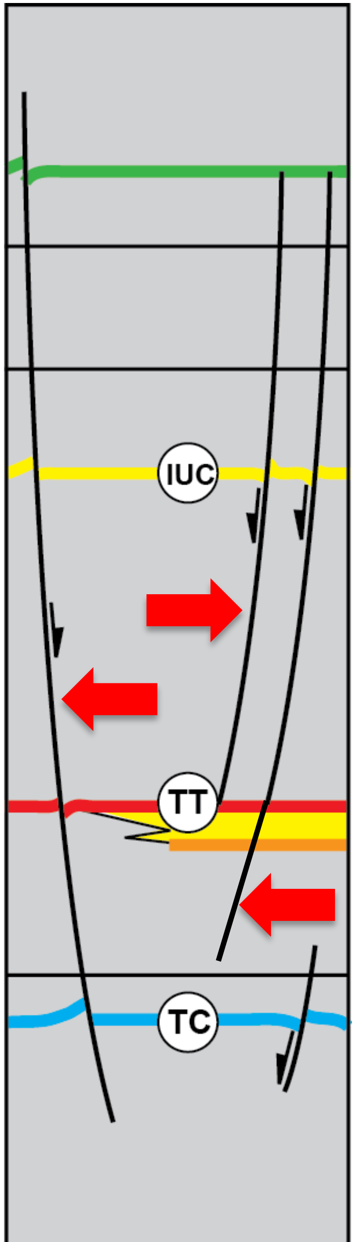
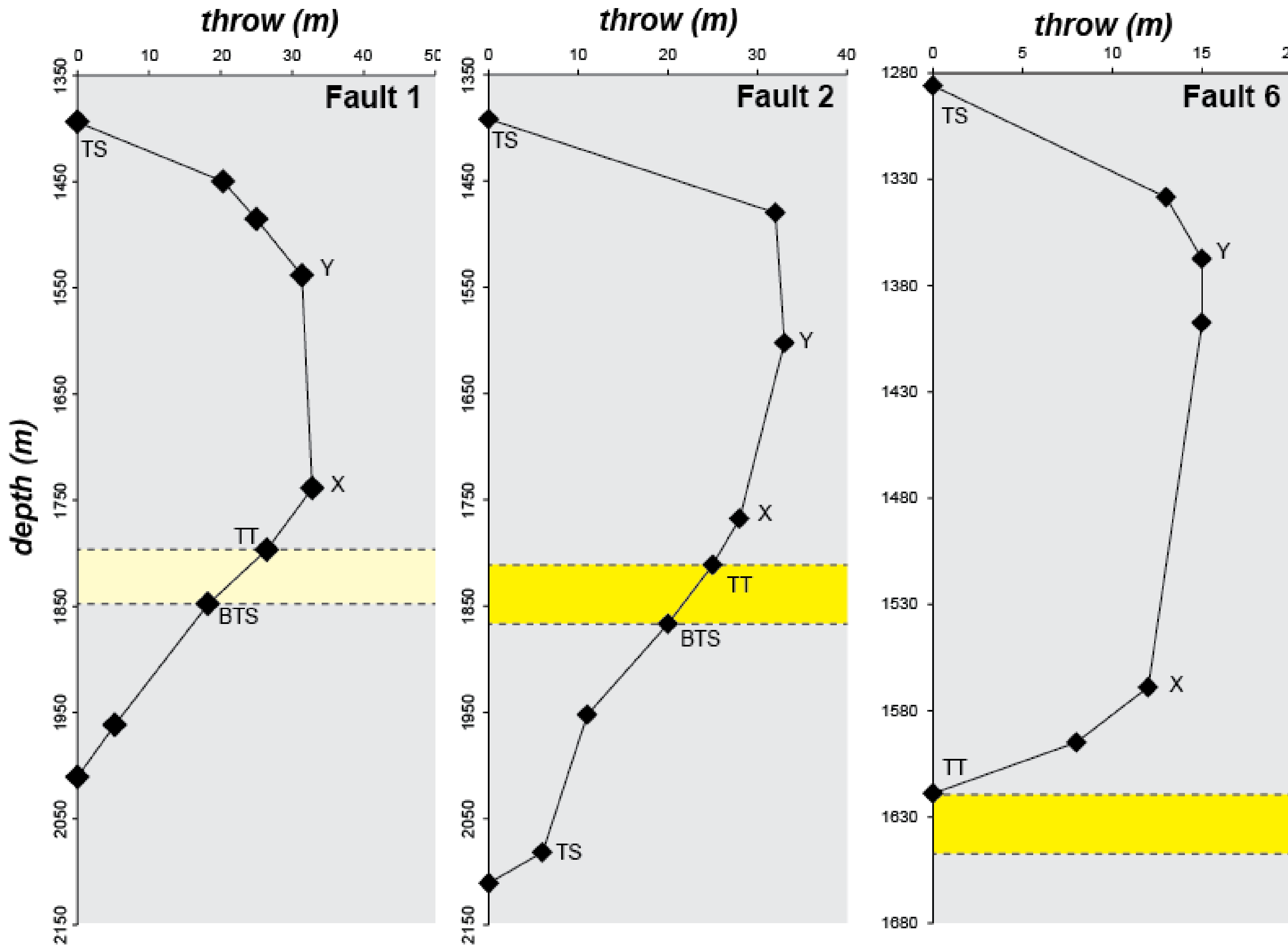






Fault Geometry and Growth





Summary

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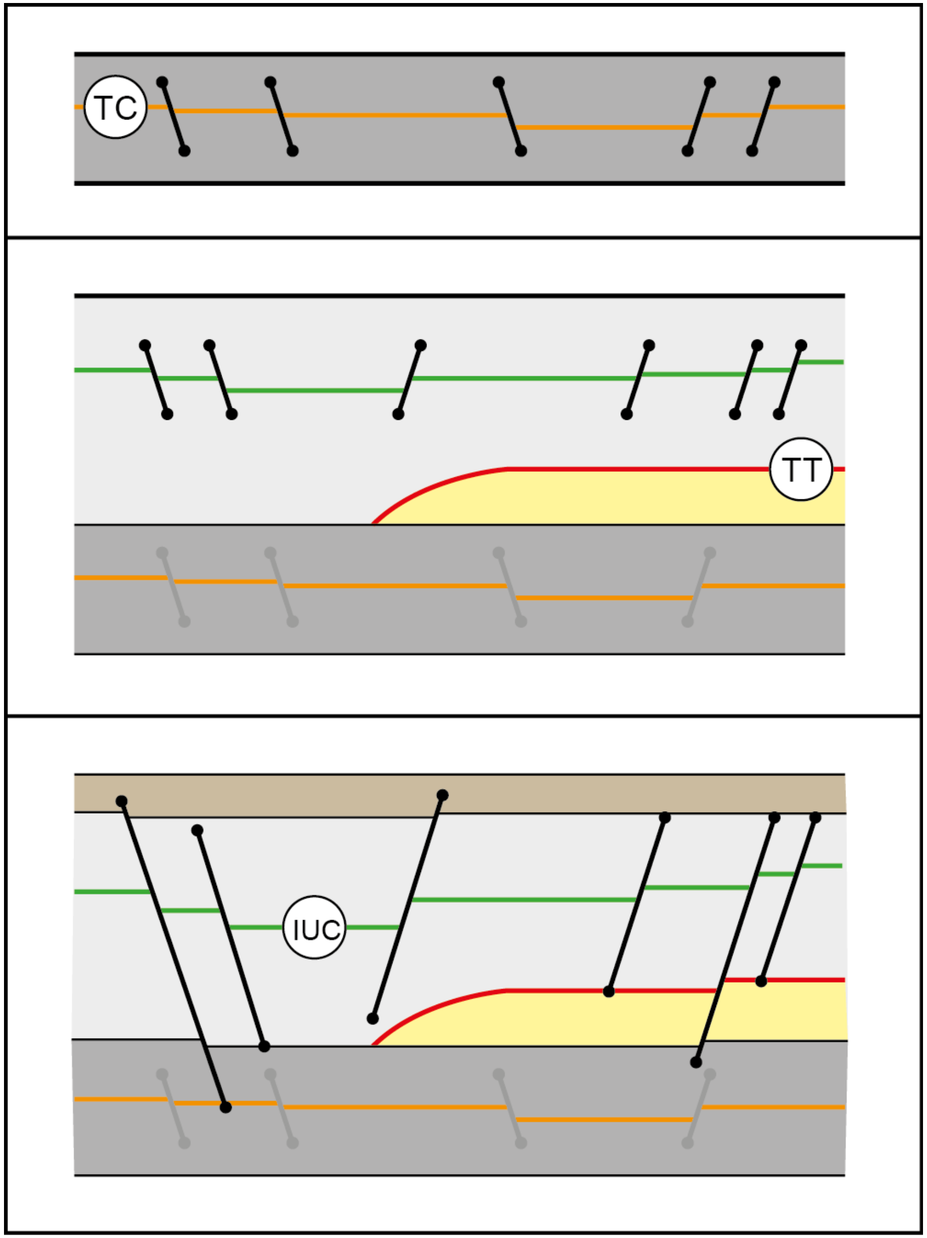
- Sandstone-rich, slope fan reservoir
  - *53 m thick*
  - *56% N:G*

- Reservoir sealed in polygonally-faulted, mudstone-dominated slope succession

- Three styles of polygonal faults recognized:
  - *Sub reservoir-restricted*
  - *Supra reservoir-restricted*
  - *Through-going*

- **What model can explain the relationship between polygonal faults and deep-water reservoirs and what implications might this have?**

Synoptic Model



- **Stage 1 (E.Tur.)**
  - Development of lower tier
- **Stage 2 (L.Tur-Maas.)**
  - Deposition of reservoir
  - Initiation of upper tier
- **Stage 3 (Danian)**
  - Growth of upper tier
  - Faults interact with reservoir

Exploration Model

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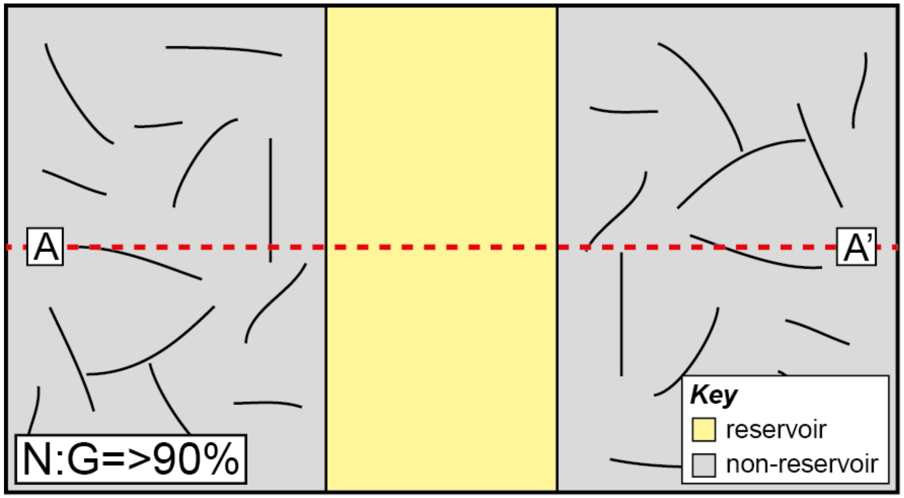
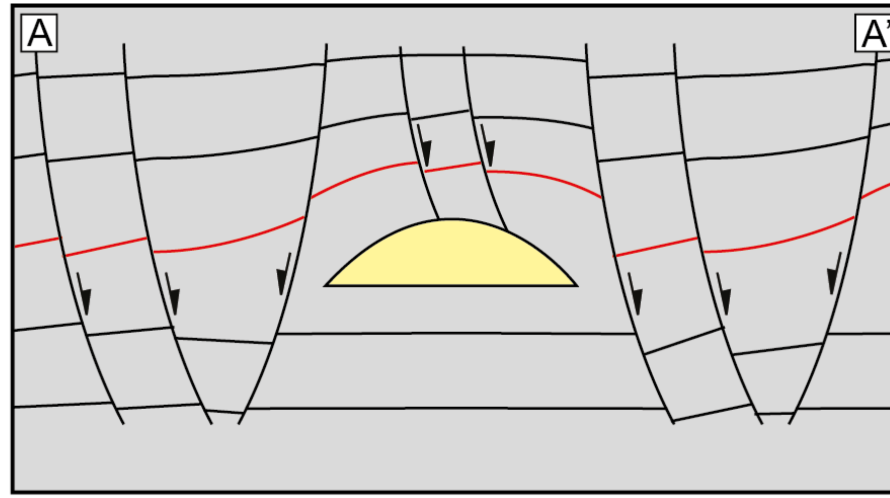
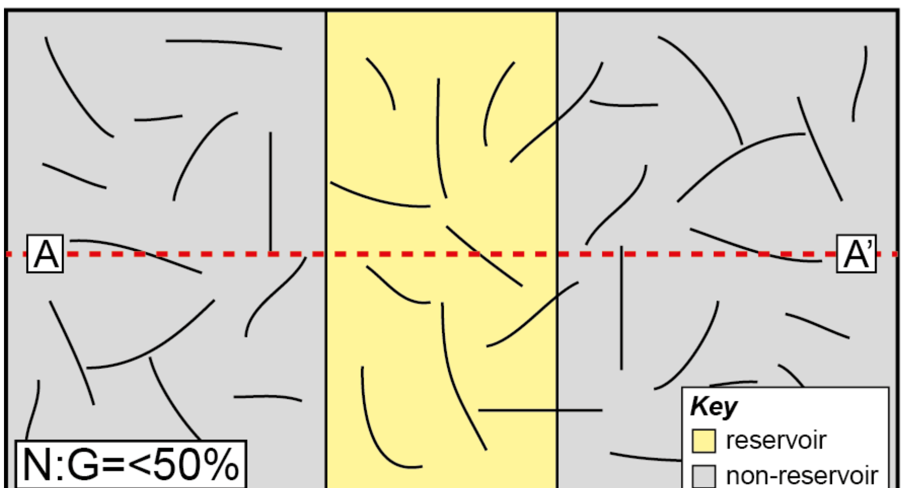
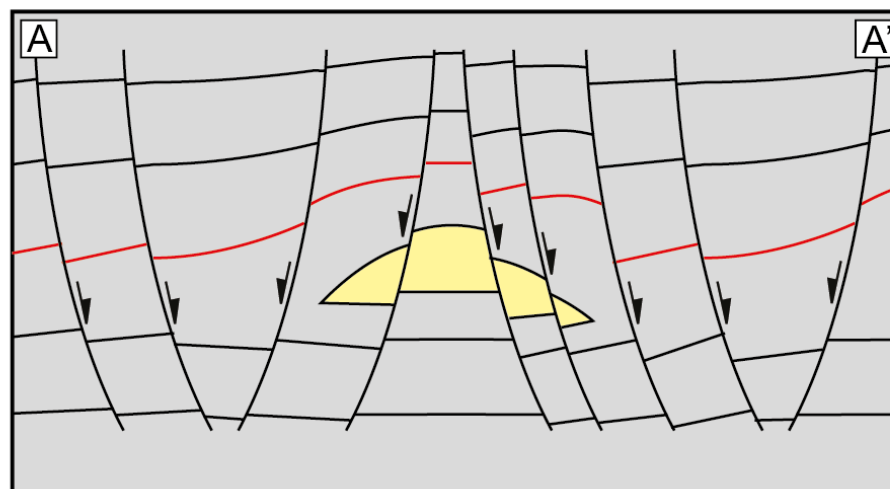
Map-view



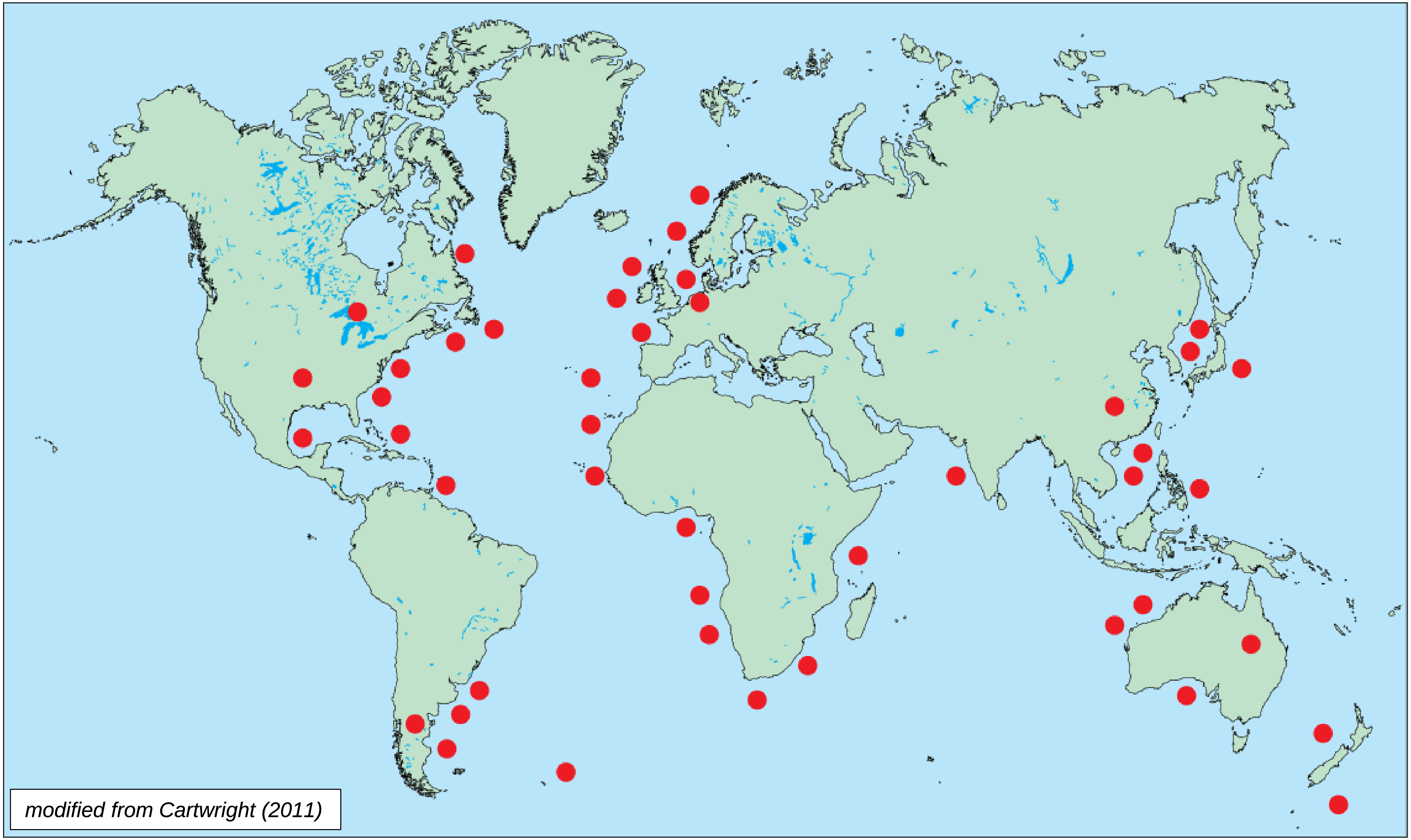
Cross-section







Wider Applicability



modified from Cartwright (2011)

Conclusions

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- Can polygonal fault mapping help de-risk reservoir presence in deep-water settings?
- **Polygonal fault distribution reflects distribution, thickness and N:G of deep-water reservoirs**

- What techniques highlight the relationship between polygonal faults and deep-water reservoirs?
- **Amplitude- and variance-based structural-stratigraphic mapping through reservoir interval; quantitative analysis of fault throw**

- Does polygonal faults mapping have global applications?
- **Deep-water reservoirs associated with polygonal faults in many petroliferous basins**