

Evolution and Plays of the Banda Arc*

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Abstract

The horseshoe-shaped Banda Arc situated north of Australia and including parts of eastern Indonesia and Timor Leste, one of the most geologically complex areas on Earth, is the product of complex Neogene and Quaternary collision between the Indo-Australian, Pacific, and Eurasian tectonic plates. The Banda Arc (“arc” in the geometric sense” comprises the Banda Sea enclosed by a largely continental outer larger islands (the largest are Timor and Seram) and an inner, active volcanic arc (Banda or Spice Islands) with typically medium-K calc-alkaline compositions related to (now ceased) subduction. Until the mid-19th century the Banda Islands were the world's only source of the spices nutmeg and mace. The area has long been of interest to petroleum explorers because of abundant onshore and offshore oil and gas seeps and similarities with geologically contiguous Mesozoic and Cenozoic successions in Australia where numerous petroleum systems exist and have been exploited. Exploration of the offshore Banda Arc has previously been limited because of water depths, remoteness, and seismic imaging problems associated with a zone of deformation occurring between a series of fore-deeps (Timor, Tanimbar, and Seram ‘troughs’) and the Banda Sea. South of the Timor Trough, exploration drilling has shown that much of the Mesozoic section (and in particular, the Jurassic) is immature for hydrocarbon generation. The formation of a fold-and-thrust between 5.0 and 3.0 million years ago over relatively undeformed Mesozoic section has pushed Jurassic (and older) source rocks into the oil window and explains the presence of oil seeps such as found in the deep water Raksasa mud-volcano, east of Timor. Potential traps north of the Timor Trough include horsts and fault-related features in the Mesozoic section beneath the fold-and-thrust belt and structural highs associated with large normal faults observed to present within the deformed zone. Mapping of multiclient 2D datasets has revealed several large fault-dependent anticlinal leads up to 250 km² in areal extent with Jurassic Plover Formation and Triassic reservoir targets.

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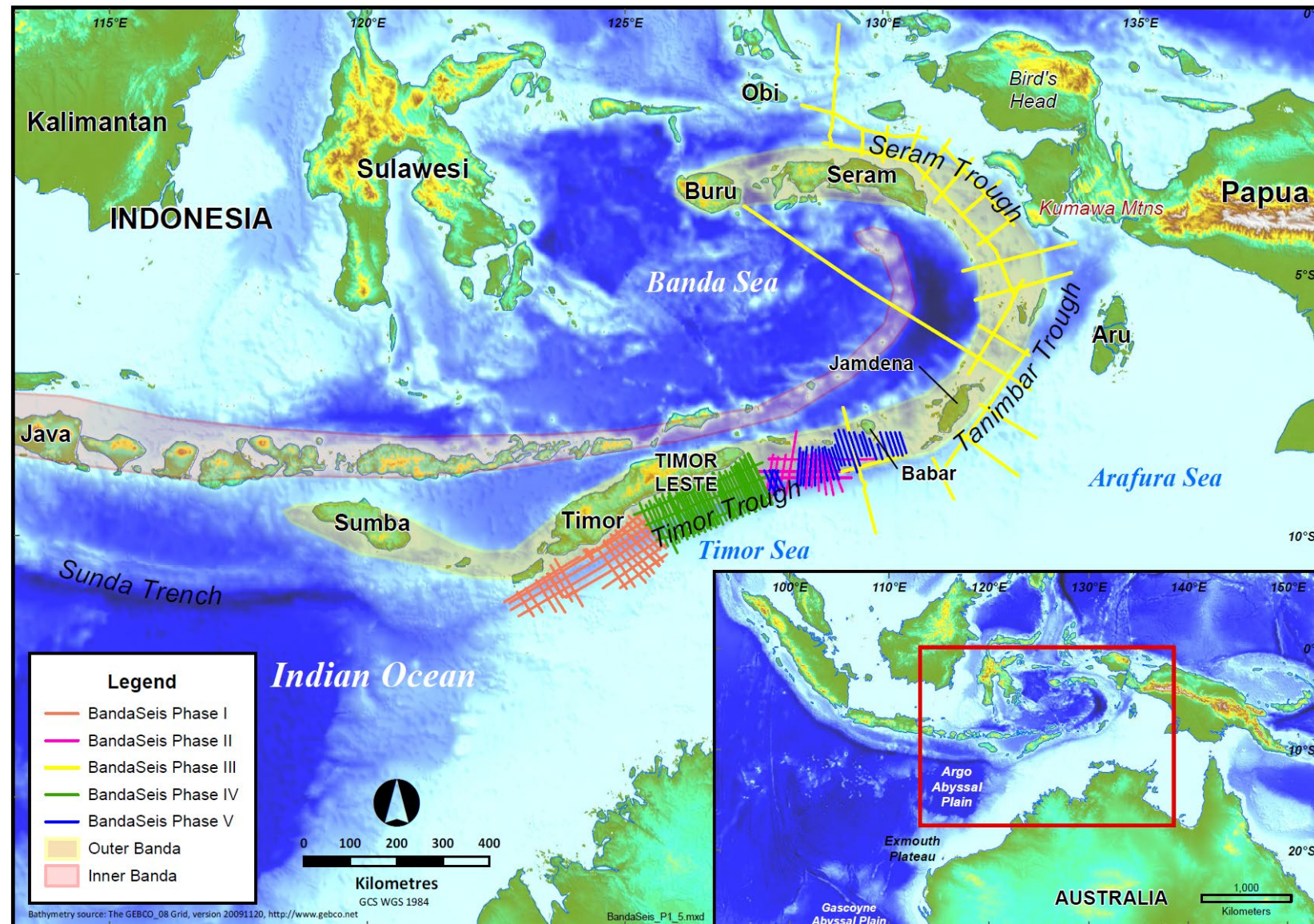


Geological Evolution & Petroleum Systems

Banda Arc



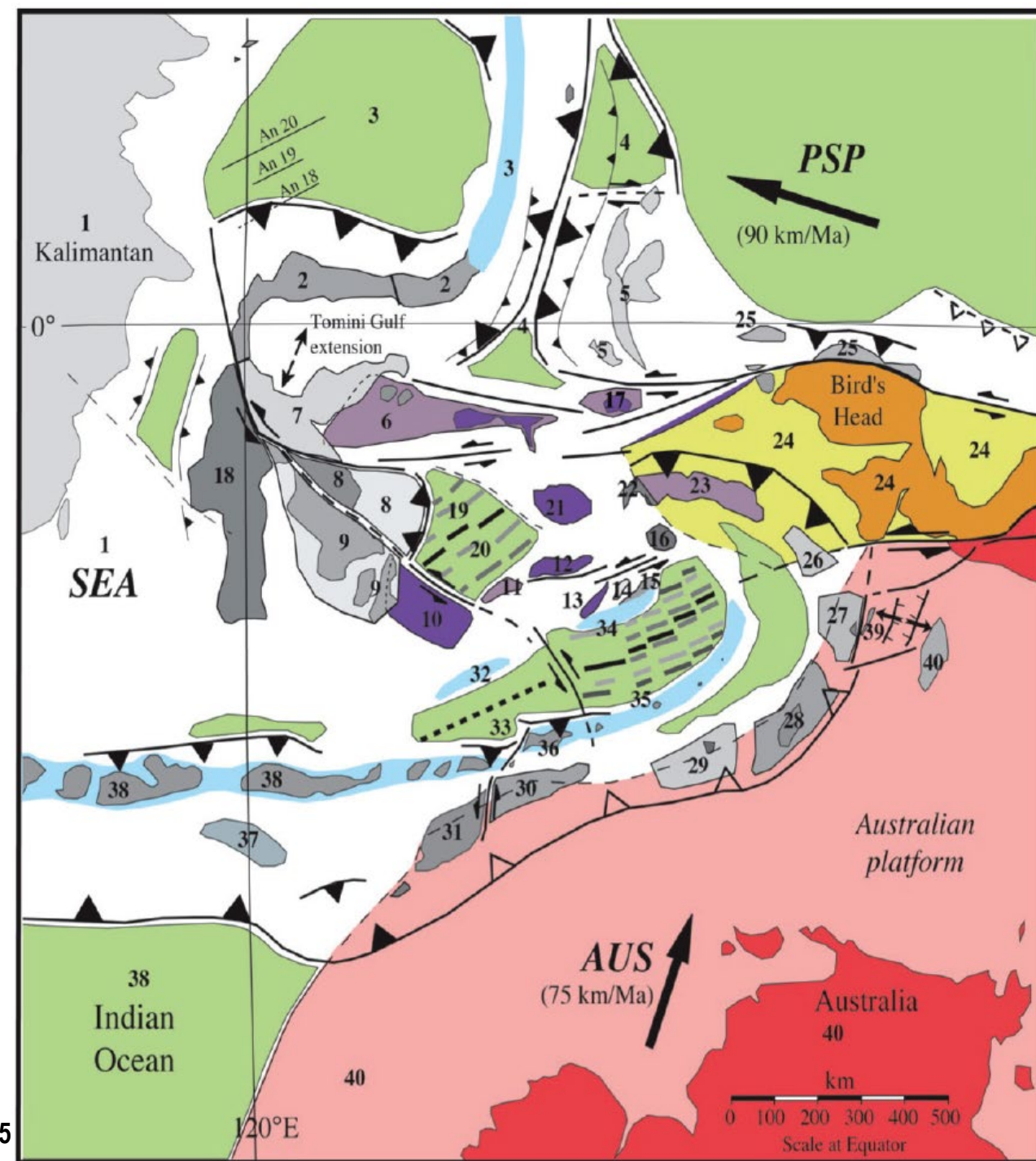
- Horseshoe-shaped double “arc”
 - Outer Arc, larger islands (largest Timor and Seram), continental, NO ophiolites
 - Inner, active volcanic arc (Banda or Spice Islands)
 - Weber Deep between Inner and Outer arcs, at area of greatest curvature
- Over 10km relief from deepest Weber Deep to highest mountains in Outer Arc
- 16,209 line km 2D broadband data
 - **Indonesia**
 - BandaSeis Phases I, II & III
 - BandaSeis Phase V
 - **Timor Leste**
 - BandaSeis Phase IV
- The interpretation of this dataset advances our understanding of the tectonic mechanisms that shaped the region and highlights potential implications this may have on petroleum systems



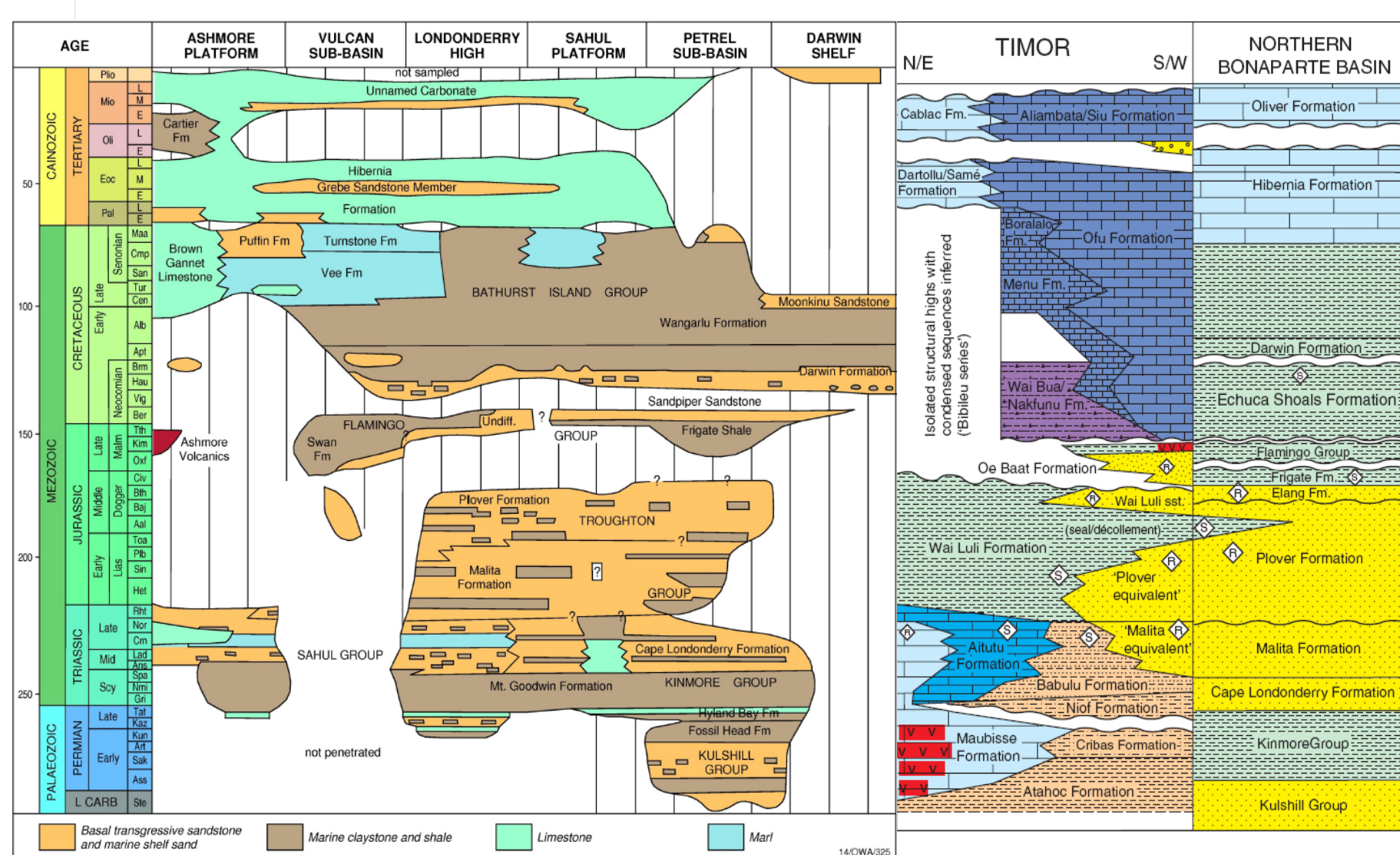
Tectonic Setting

- At least since Jurassic, close to relatively magma-poor continental margin; Jurassic crust of Argo Abyssal Plain currently being subducted beneath Java Trench
- Present complex geology results from two opposing tectonic forces: N movement of Australian Plate (MOR far to the S) and sinistral shear on Greater Sorong Fault System (plate boundary)
- Timor at leading edge of collision with Indonesian island arc; GPS measurements confirm part of Australian Plate
- Banda embayment became aligned with Java trench at ~17 Ma; subduction zone propagated rapidly E
- Progressive rollback of the Banda subduction zone into embayment
- System jams

Modified after Hinschberger et al. 2005



Lithostratigraphy & Petroleum Systems

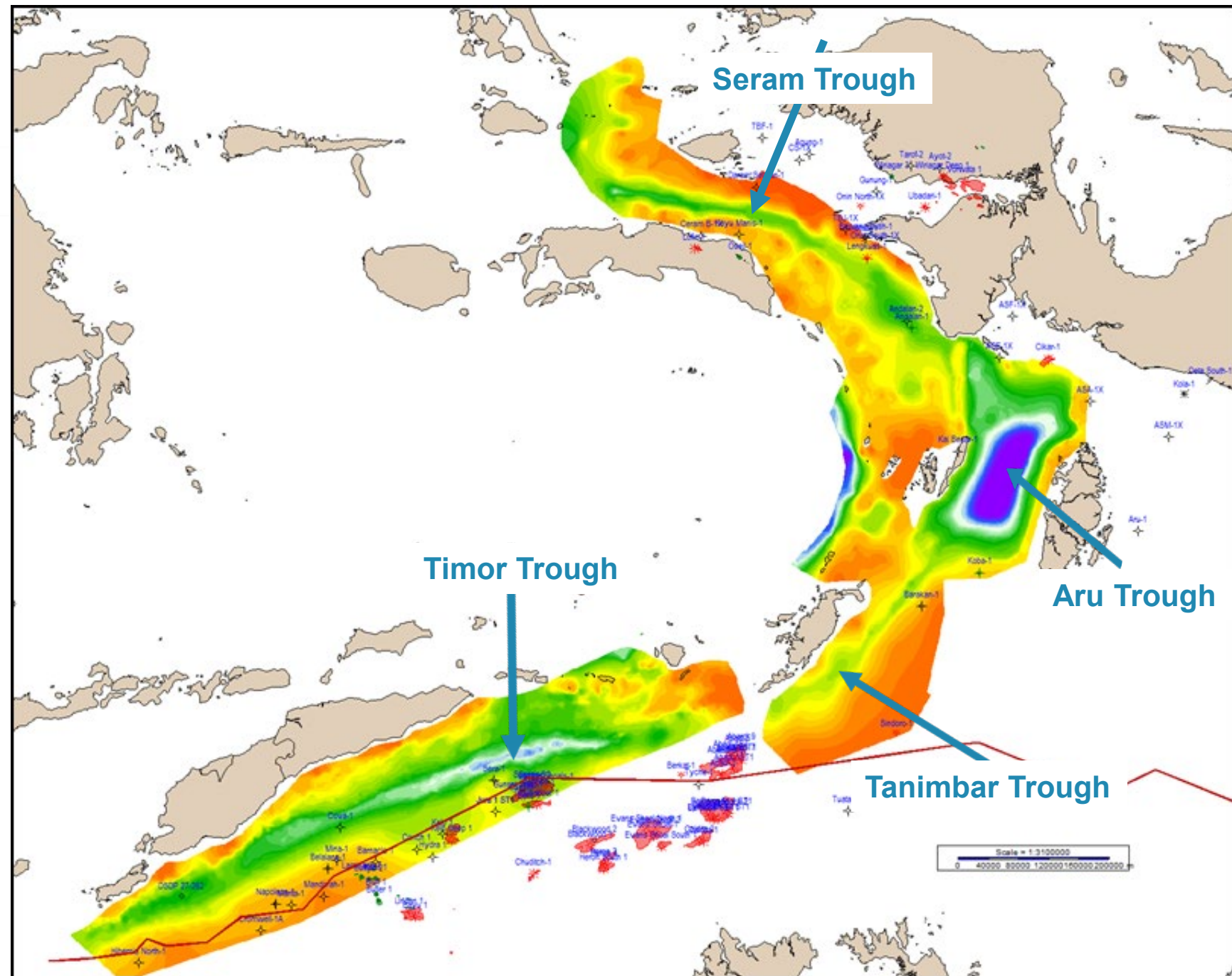
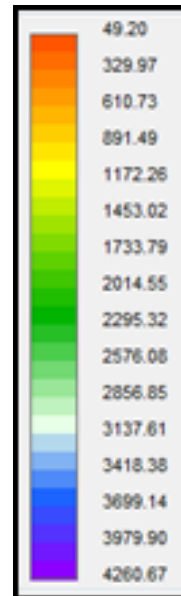


- Primary petroleum systems are:
 - Jurassic
 - Triassic
 - Permian
- “Find the Plover”* – the principal exploration target has been the deltaic and marginal marine Lower to Middle Jurassic Plover Formation
- Triassic offers new and potentially important targets
- The existence of several adjacent multi-TCF gas and gas/condensate fields and the onshore and deep-water seeps attest to active petroleum systems across the region

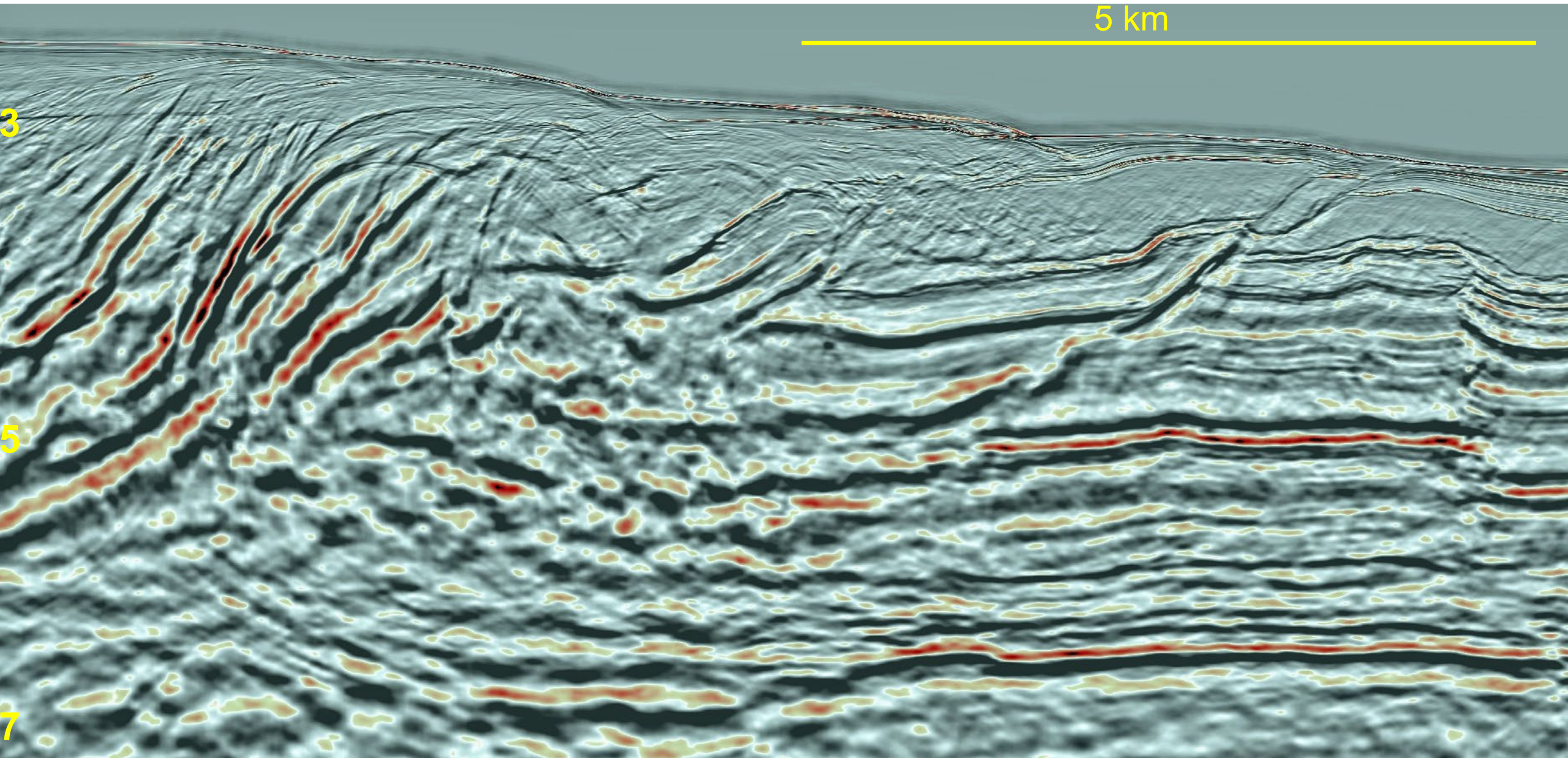




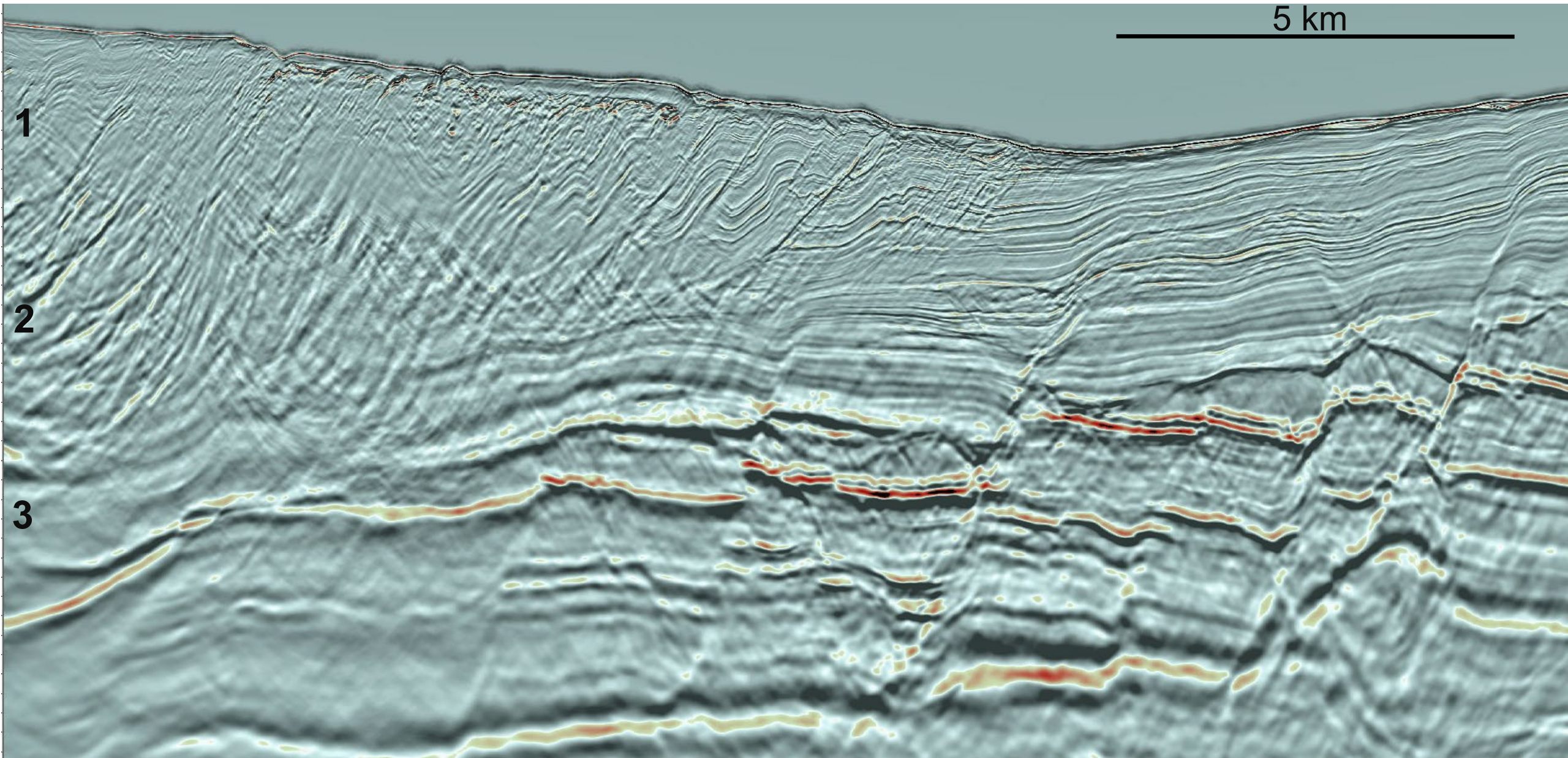
Water Depths



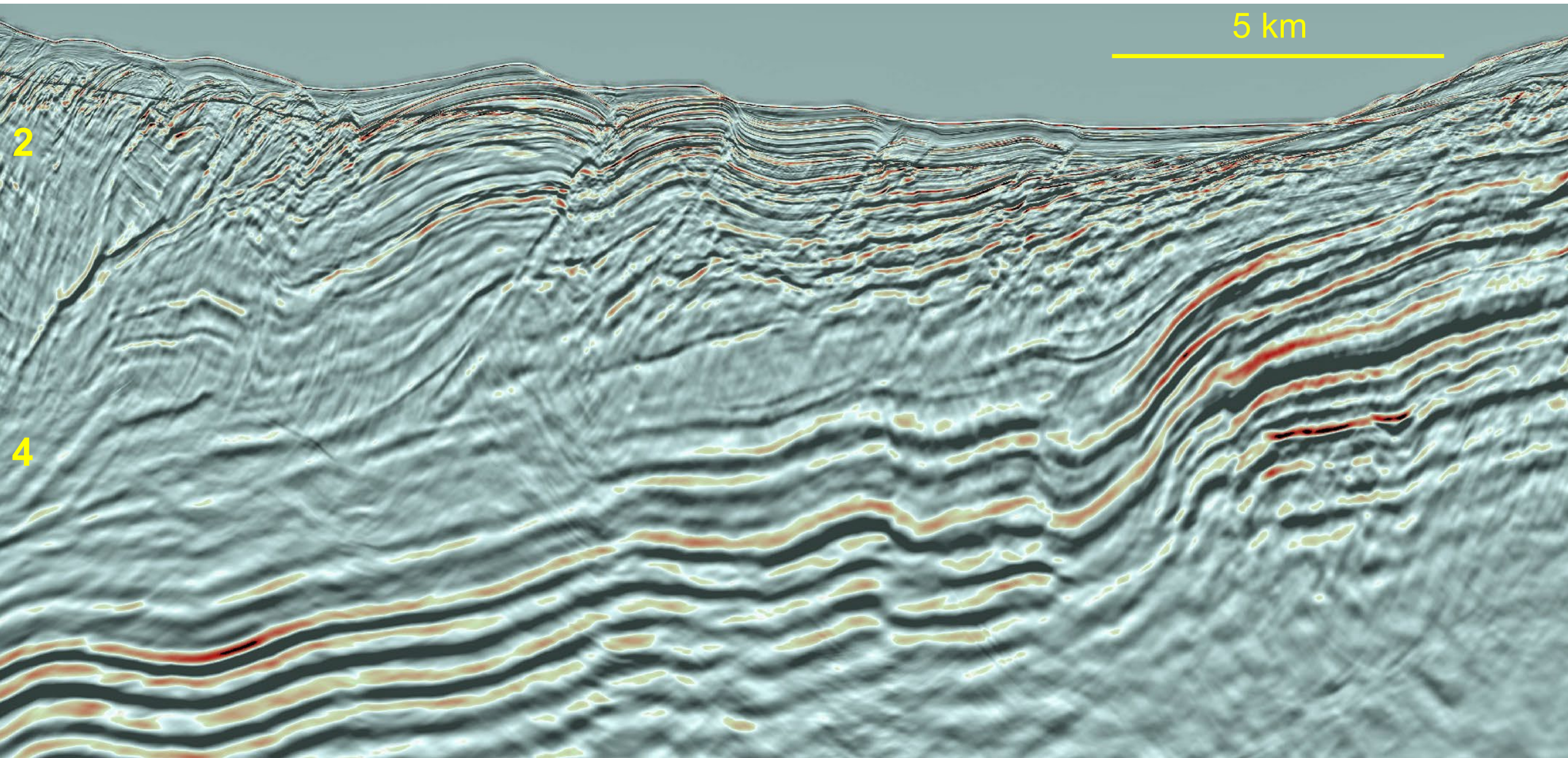
Timor Fold & Thrust Belt



Tanimbar Fold & Thrust Belt



Seram Fold & Thrust Belt

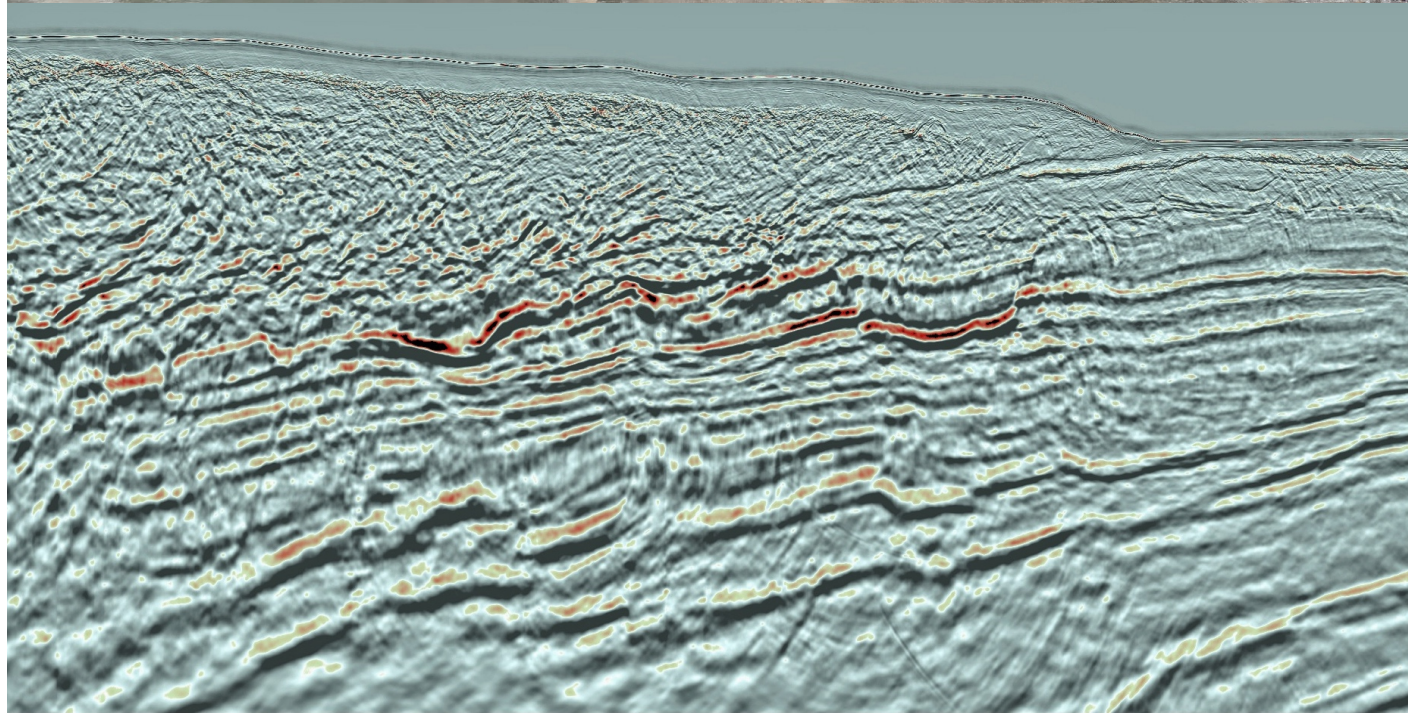


South Banda Prospectivity



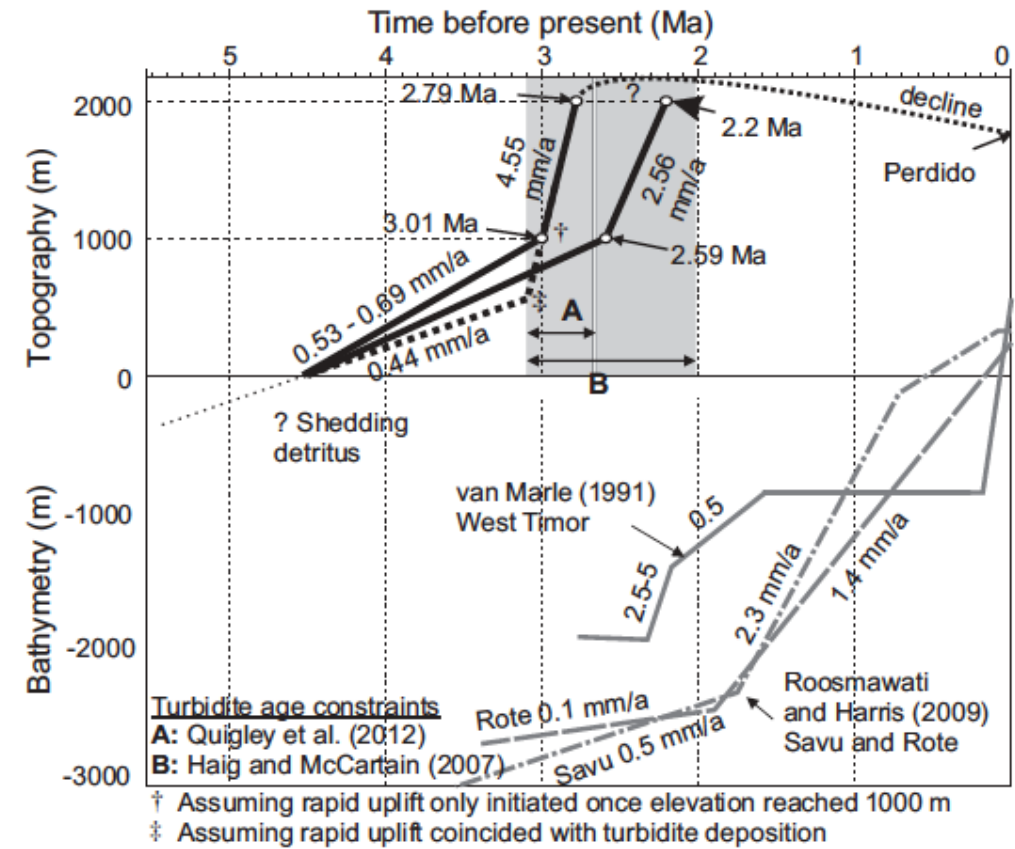
Timor Orogen

- Normal subduction to 10 Ma
- Contraction 10–5.5 Ma
 - Includes metamorphism
- 1 m.y. aseismic hiatus
- 4.5 Ma and ongoing (onshore):-
 - Strike slip deformation
 - Doming (isostatic rebound)
- 4.5 Ma and ongoing (offshore):-
 - Gravitational fold-and-thrust belt
 - Strike slip deformation





Timor Uplift

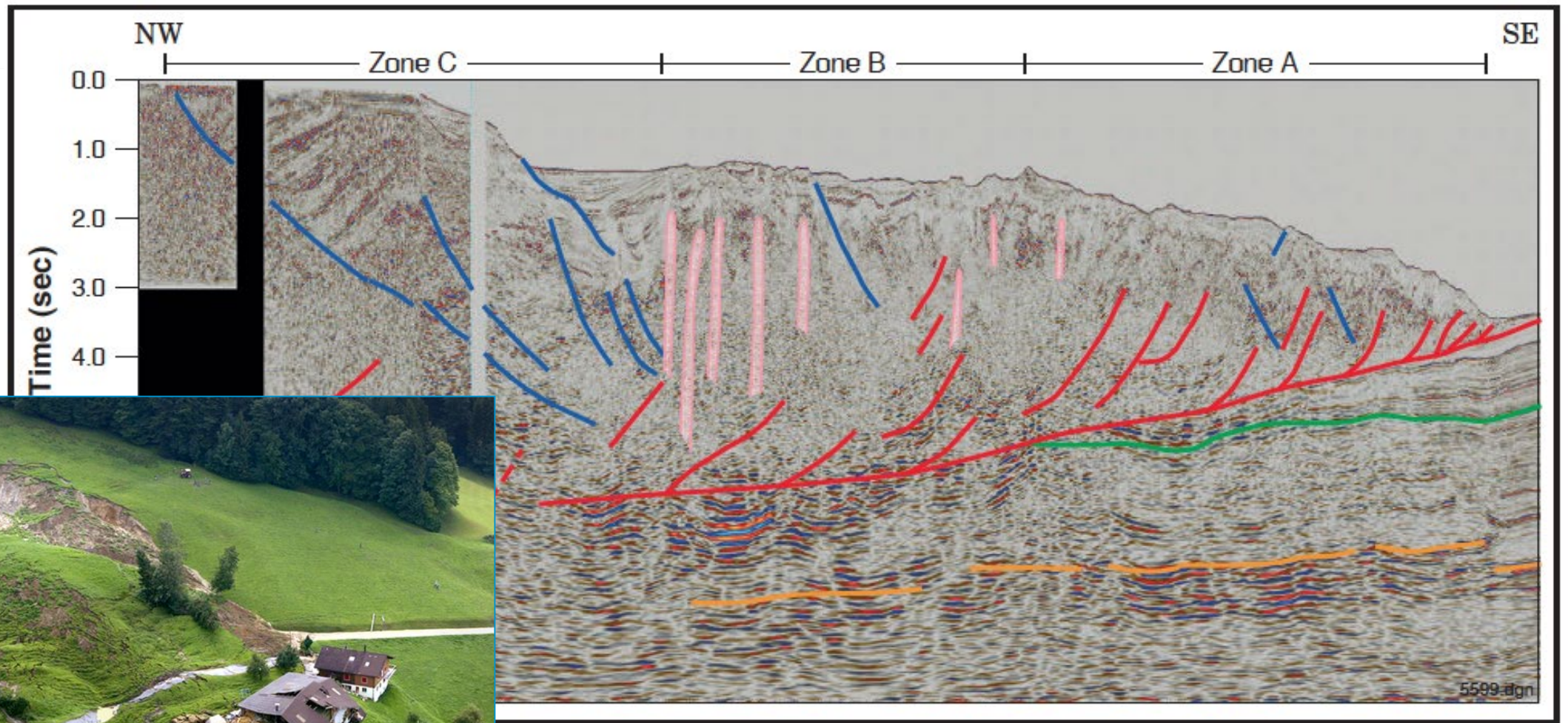


Nguyen et al. 2012





(Offshore) Timor Fold and Thrust Belt



Poynter et al., 2013 WABS





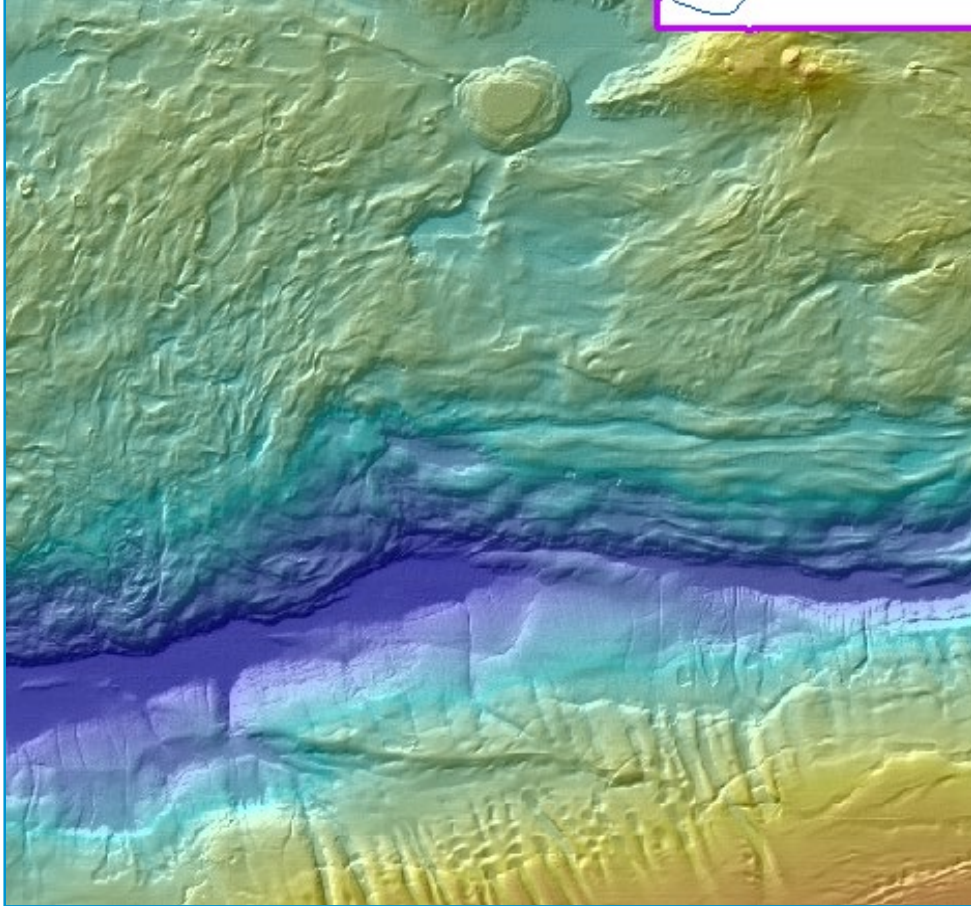
Timor Oil Seeps



- Oils are derived from (a) peak mature source rock dominated by mixed marine and terrestrial organic matter, and (b) peak mature marine carbonate/marl source rock.
- Late Triassic samples with good to very source rock potential for oil and gas generation and marginal potential for oil generation contain mixed terrestrial and marine (dominated by herbaceous or woody organic matter) organic matter, with Type III oil-prone and Type III/II gas-prone kerogens.



Raksasa Mud Volcano

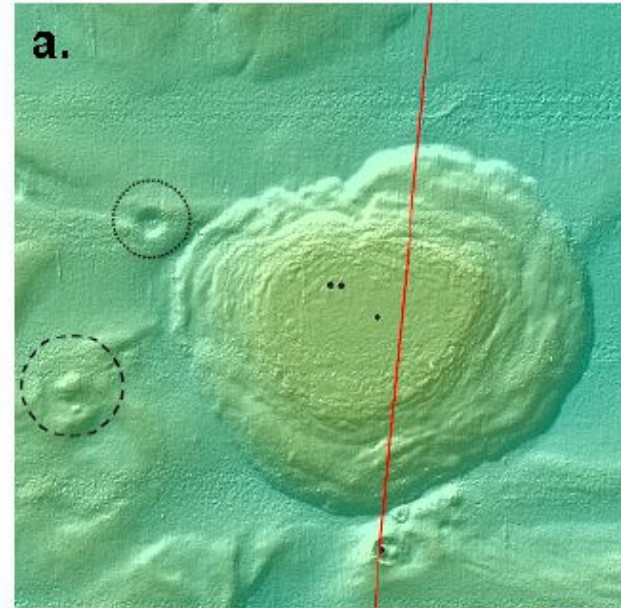


P. Baillie, 2008 – presentation at AAPG International Conference, Cape Town, RSA

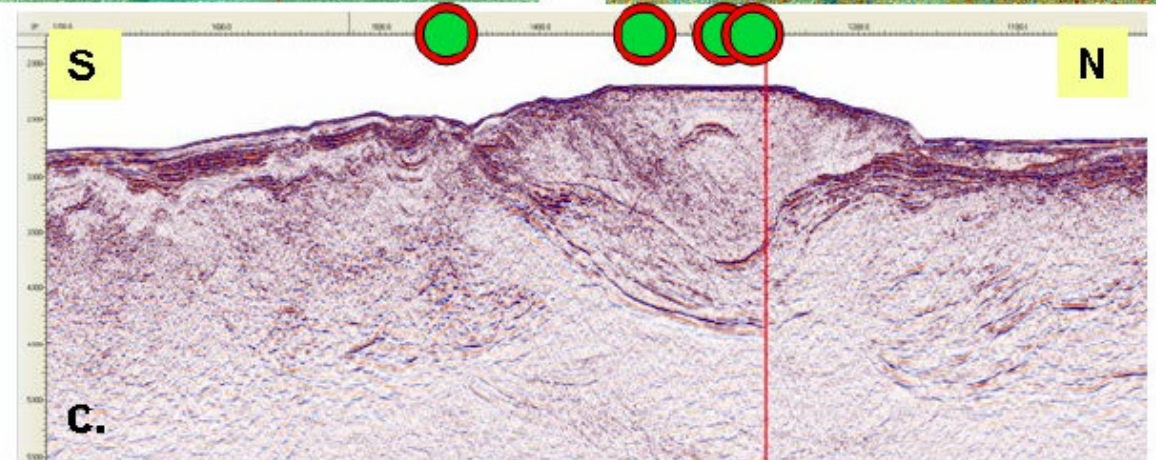
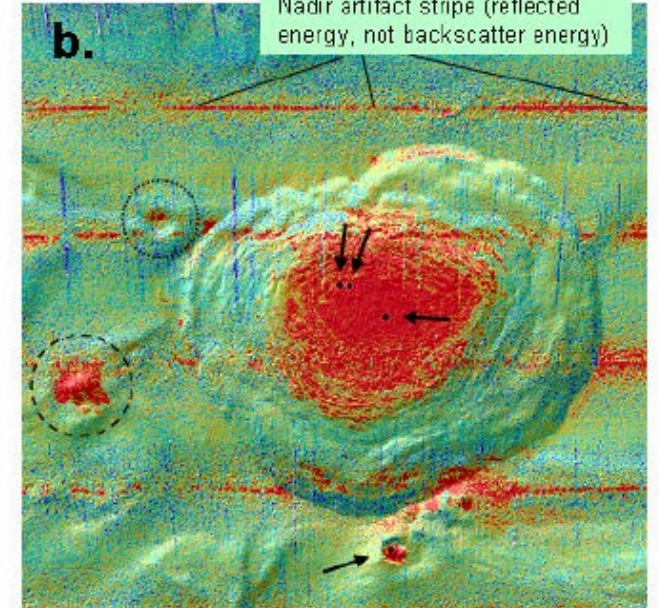
Orange et al., 2009 IPA

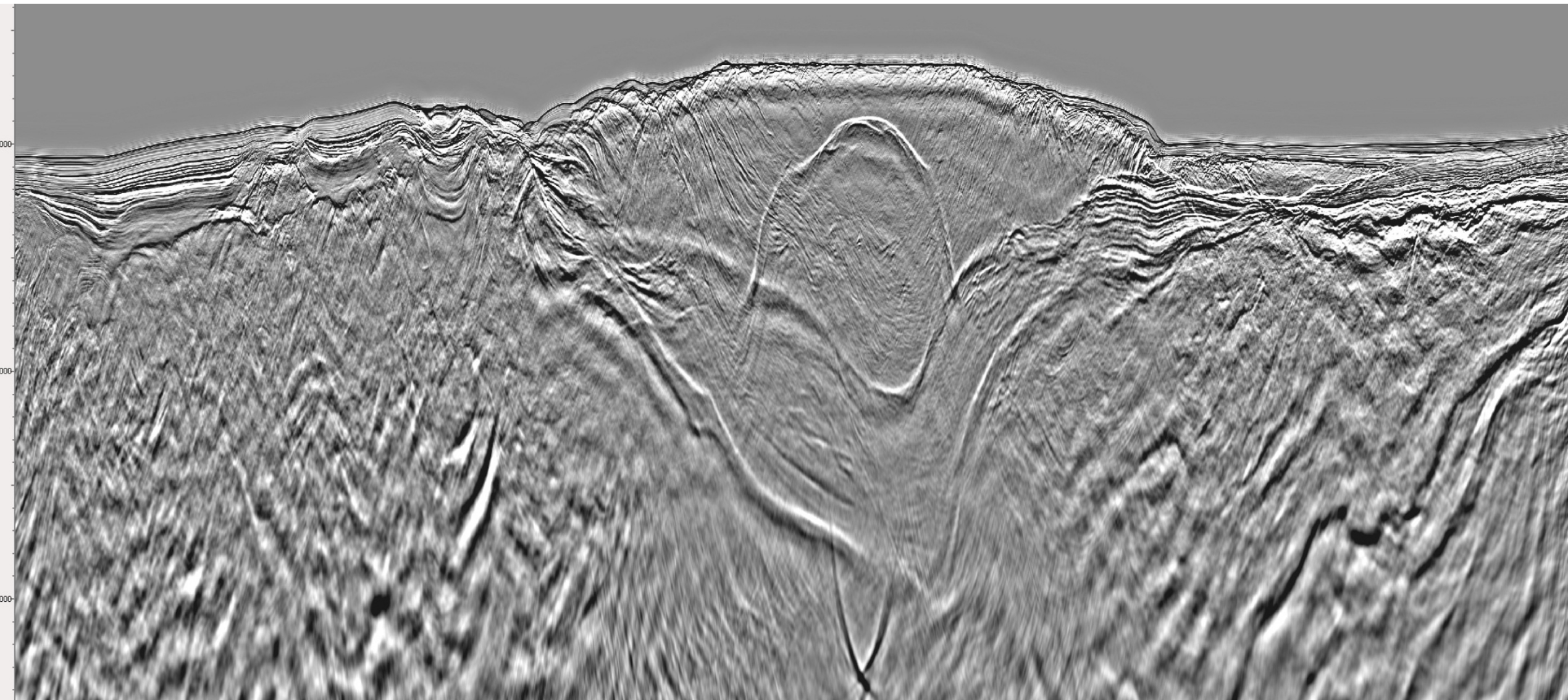
Shaded Relief Bathymetry

Scale = 12 km

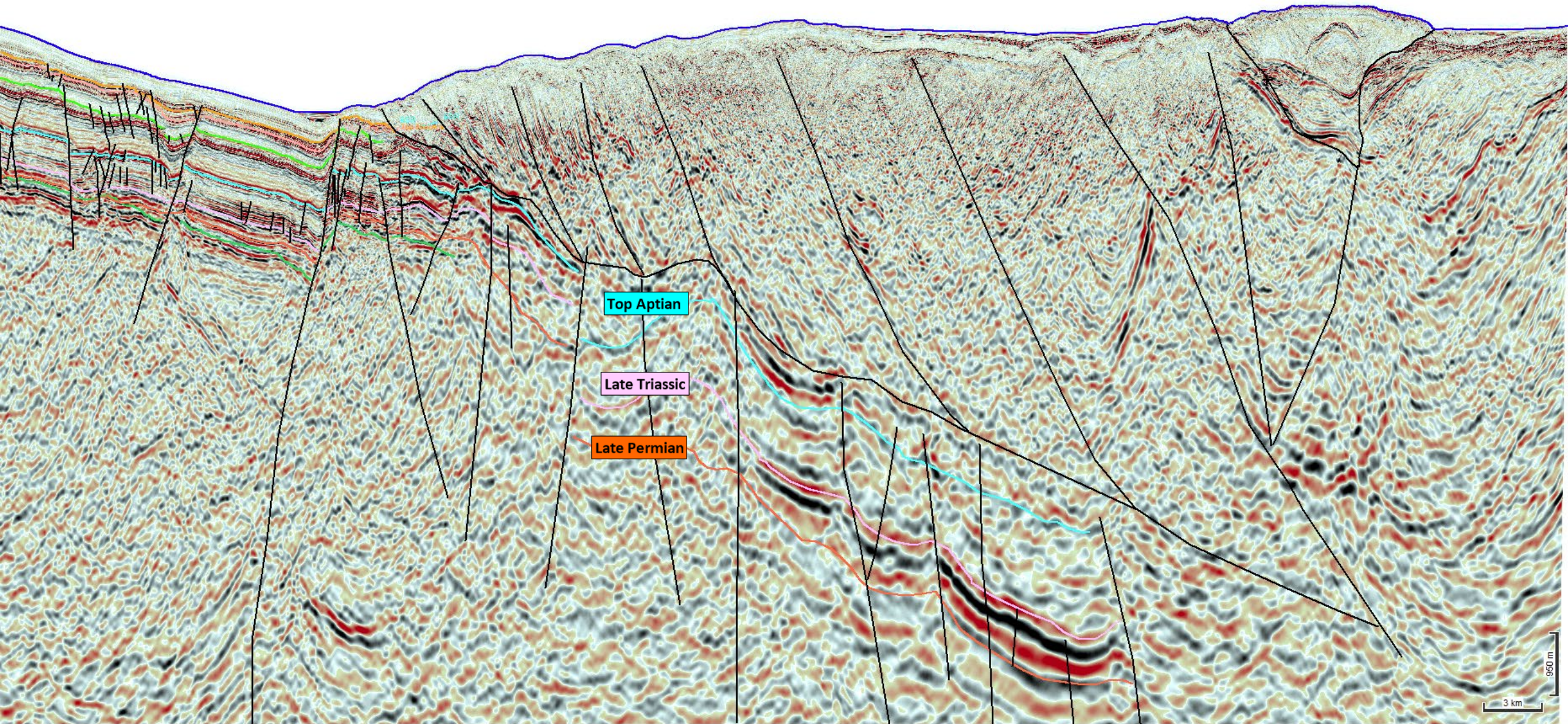


Backscatter on Shaded Relief Bathymetry



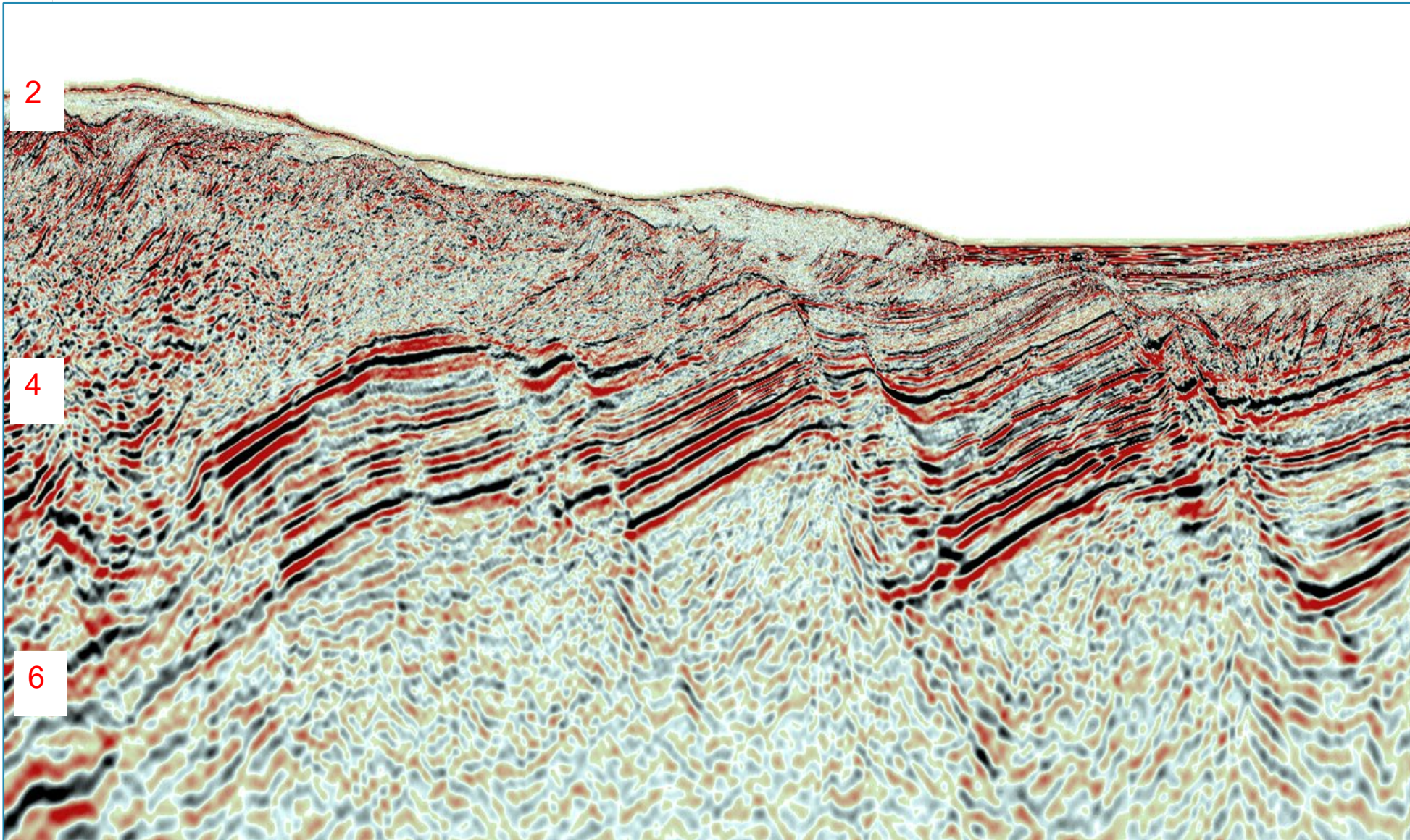


Raksasa Regional Context





New Play Fairway



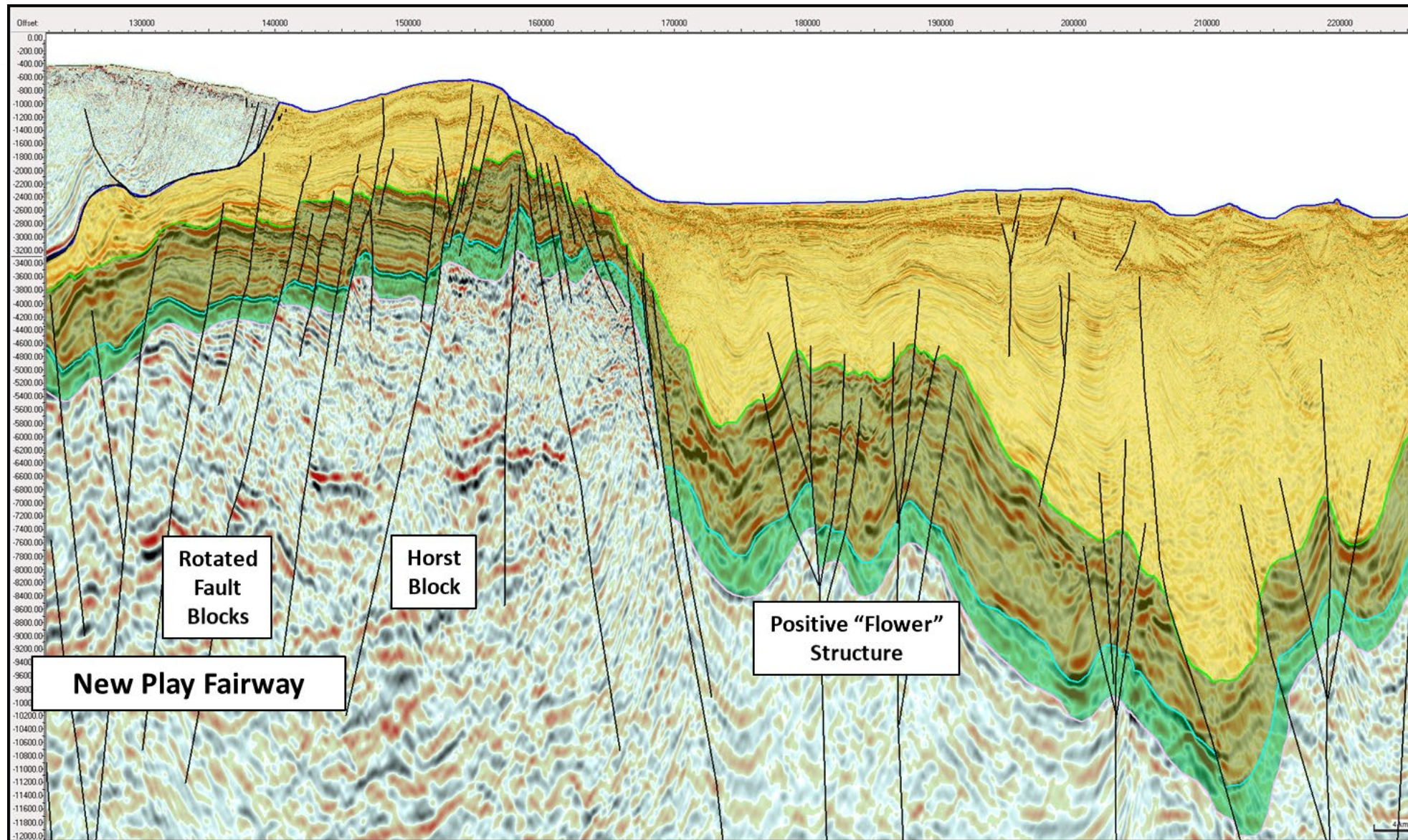
- **Seal**
 - Intraformational seals at several levels
- **Trap**
 - Structural - horst blocks, tilted fault blocks, fault-propagation folds
- **Plays**
 - Inversion anticlines, roll-over anticlines, fault blocks
 - Closures below the Timor Orogenic wedge
 - Adjacent Jurassic source rocks would not be buried deep enough to be over-mature
 - Reactivated normal faults terminate near the décollement surface (~top seal)

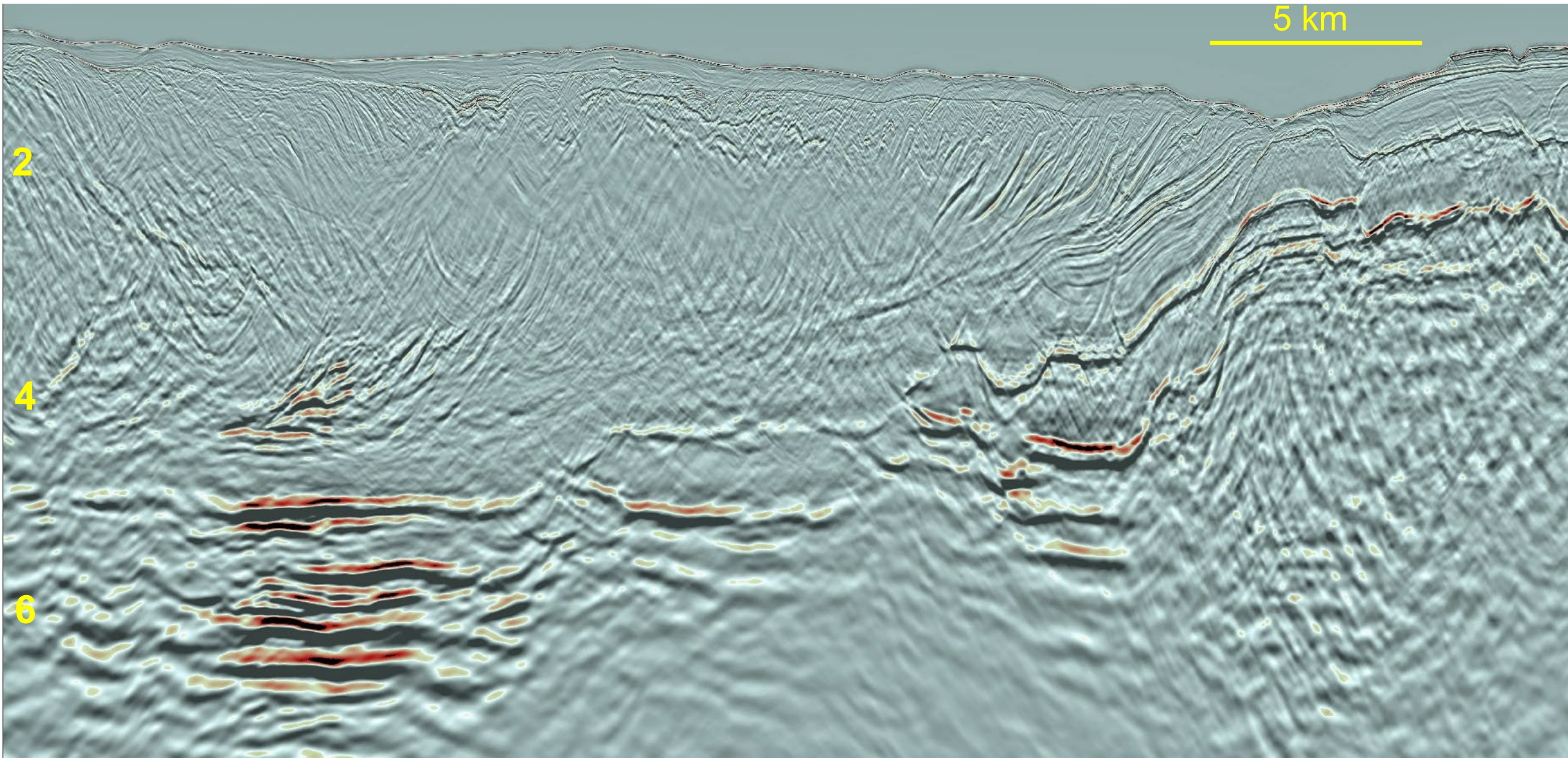


North Banda Prospectivity



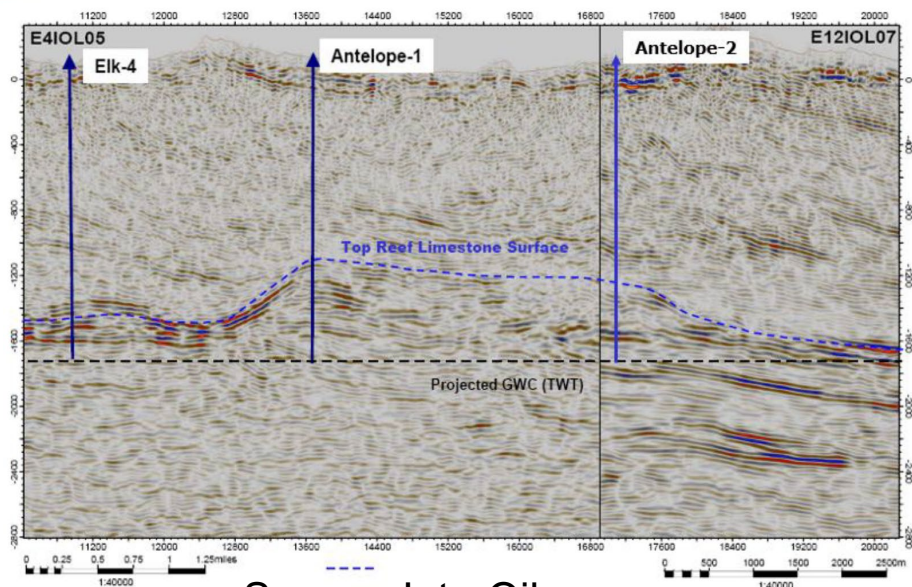
Mesozoic Plays





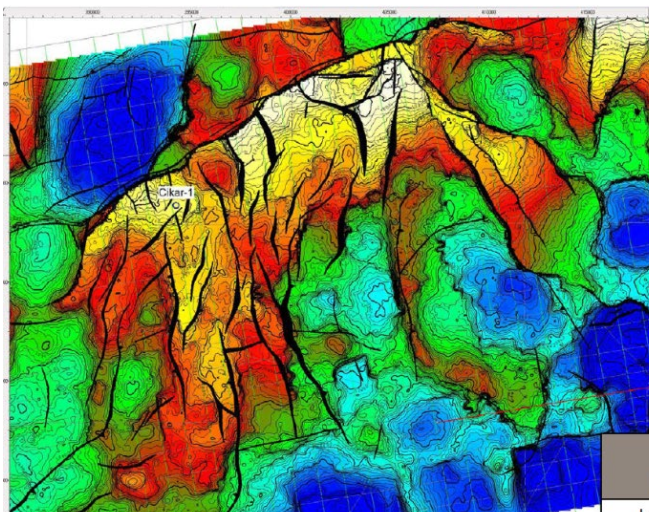


N. Banda Tertiary Play



Source: InterOil

West Papua IV Block – Cikar-1 Prospect



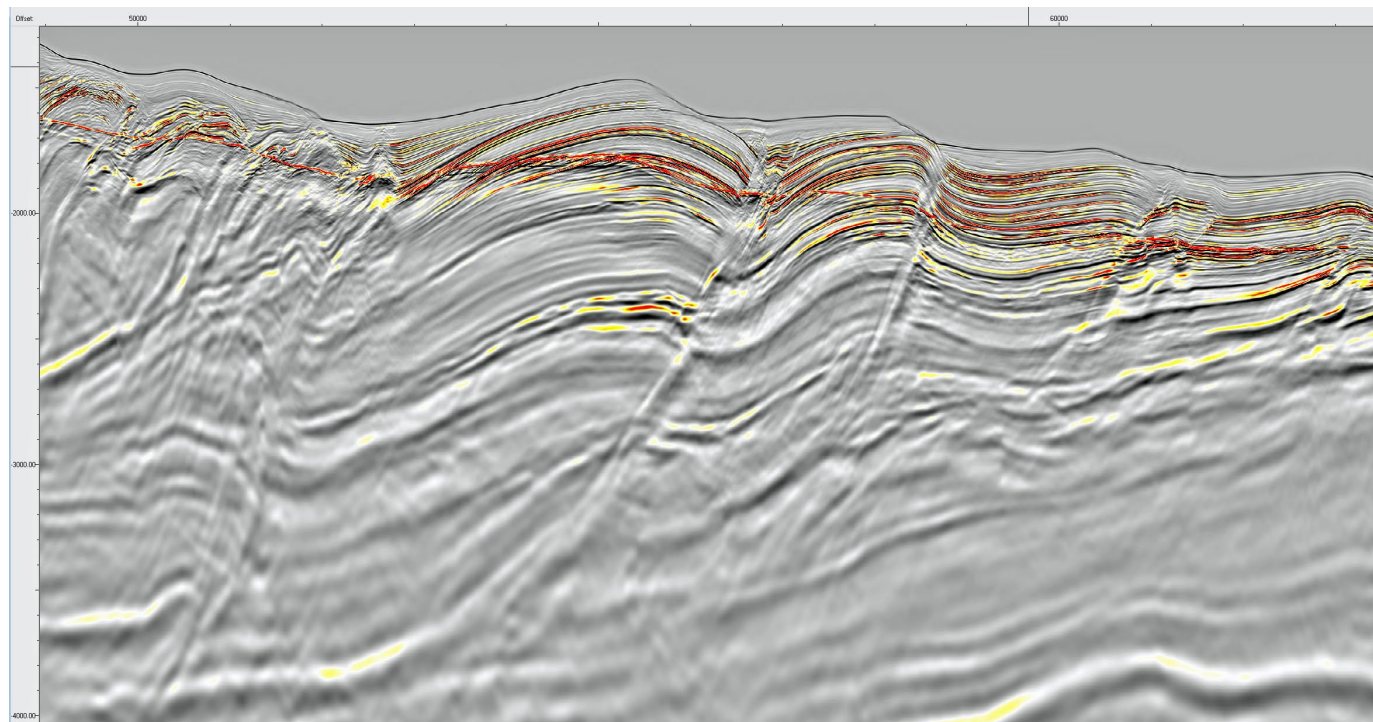
Cikar-1 well

- Projected drilling time of 60-70 days
- Targeting large Miocene carbonate prospect

Gross Prospective Resources, MMBOE

Low	Best	High
119	380	1216

Niko Website 2013



Summary



Banda Prospectivity Summary

- Banda Arc geology complicated – contraction resulting from ongoing arc/continent collision
- Strong indications of working petroleum system(s)
 - Onshore and deep-water oil seeps, satellite slicks
- Past exploration (in part) hampered by imaging problems resulting from geological complexity
- Broadband acquisition and modern processing techniques have revealed much of the previously-hidden geology
- Timor field-based studies helped unravel details of the Neogene collision and petroleum geochemistry
- S Banda has significant exploration opportunities, similar to Bonaparte Basin
- N Banda had additional Tertiary carbonate play





Acknowledgments

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- CGG
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- UWA – David Haig, Myra Keep, Eujay McCartain



Rappart, 1885 – *Bandanaira*





Thank you

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