Drainage Systems in Rift Basins: Implications for Reservoir Quality*

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Abstract

Ancient and modern rift basins can be found on every continent of the world and account for 31% of giant fields discovered (Mann et al., 2003) with over 620,000 (MMBOE) of estimated recoverable hydrocarbons worldwide. New rift plays are just being discovered as we explore beneath salt deposits and penetrate deeper continental margin strata. The biggest challenge in these basins is understanding reservoir location, quality, and extent. Axial- and marginal-sourced rivers provide very different sediments to the system and have significant geomorphologic differences. The architecture of rift systems varies dramatically from those located within continental versus coastal/marine environments (Gawthorpe and Leeder, 2000). A three phase study of rift drainages was undertaken to document these differences and quantify the various morphologies of drainage that characterize rifts. A literature and imagery review of ancient and modern rift drainage systems was undertaken with the focus on ancient systems being issues and challenges to producing discovered, developed, and undeveloped hydrocarbon in rift system reservoirs. In the second phase of this work, a study of the morphology of a modern rift setting in East Africa using ArcGIS and satellite imagery allowed mapping and quantification of rift drainage morphologic characteristics, such as: drainage architecture, rift size, channel size and flow characteristics and the overall drainage nature versus catchment area. Phase 3 of this study focuses on applying the criteria and knowledge built in Phases 1 and 2 to improve prediction of drainage nature and subsequent reservoir distribution and development in a high resolution 3D seismic survey in the Dampier Sub-basin off the NW coast of Australia. Quantitative seismic geomorphological techniques have been employed to assess the morphology, flow character, and drainage size of this paleo-rift system toward a better understanding of reservoir distribution and risk.

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Sedimentary Analogs Database Research Program

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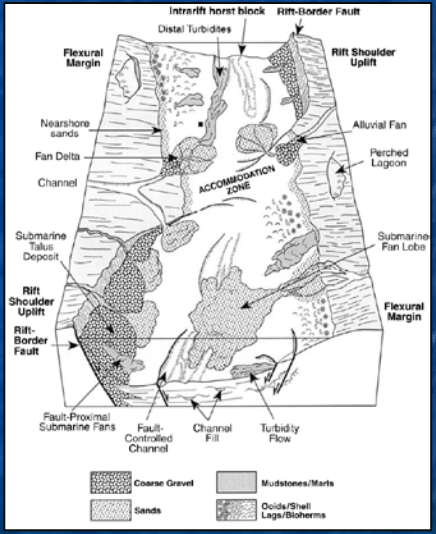
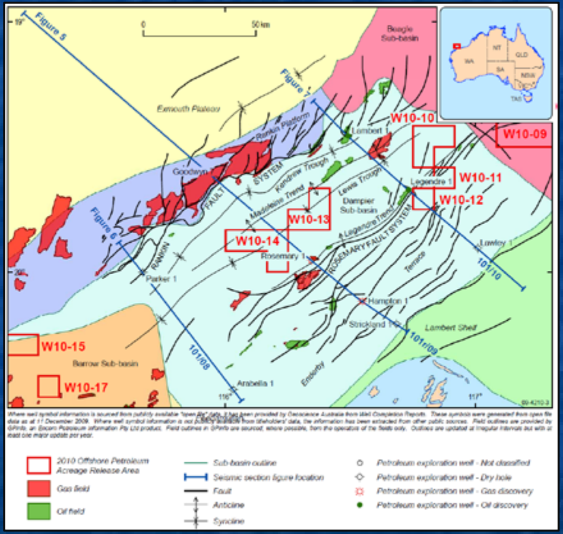
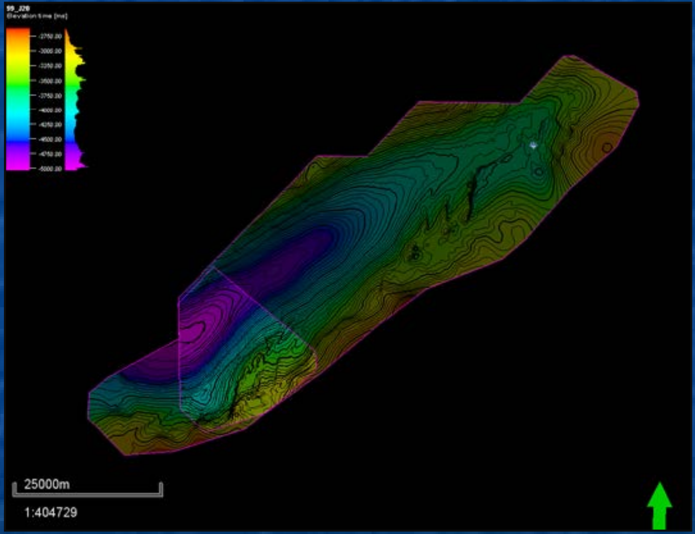
Drainage Systems in Rift Basins: Implications for Reservoir Quality







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Agenda

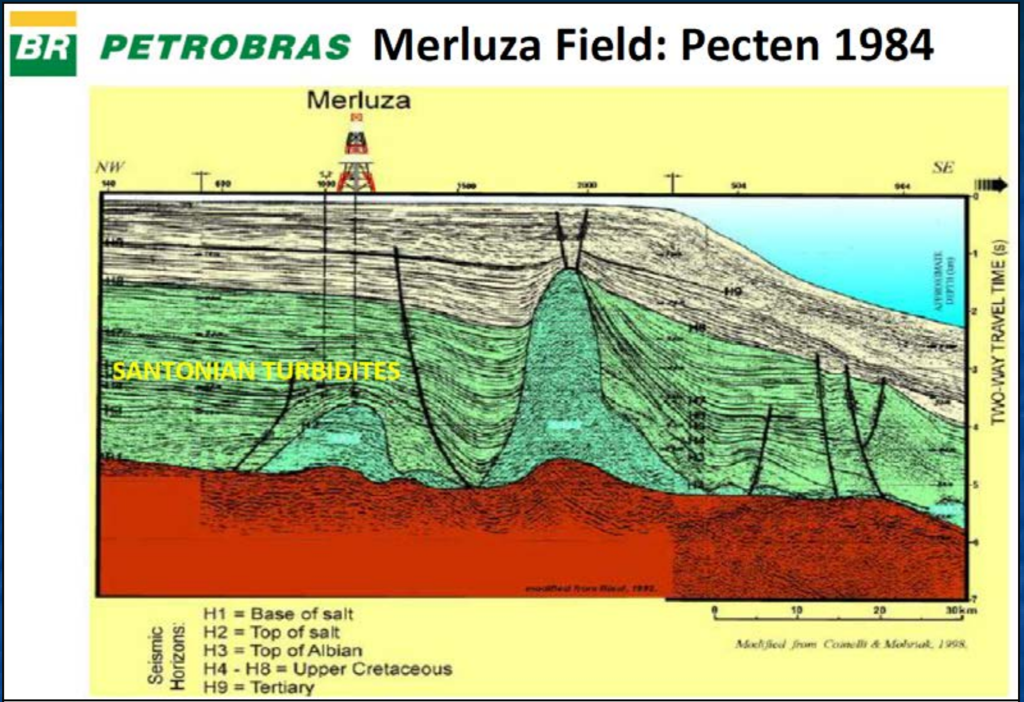
- Study Motivation
- Introduction to Rift Basins
- Geologic and Stratigraphic Background of the Dampier Sub-basin
- Seismic Geomorphology and Basin Fill
- Conclusions

Study Motivation

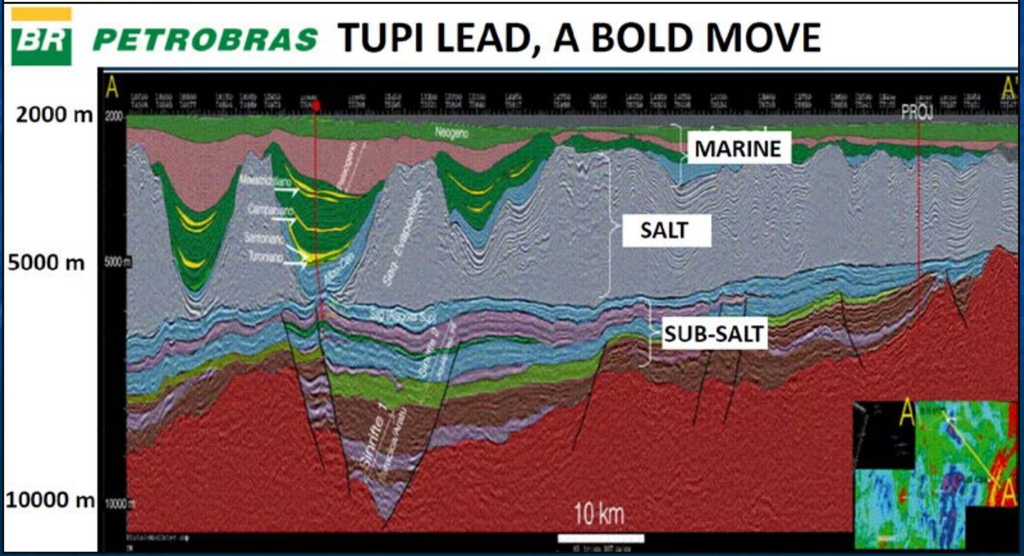
- Rift Basins account for 31% of discovered giant oil and gas fields (Mann et al., 2003)
- Continuing exploration into deeper areas demands ways to de-risk (Ex. Tupi discovery offshore Brazil)

Offshore Brazil: Passive Margin versus Rift

Post-Salt Targets



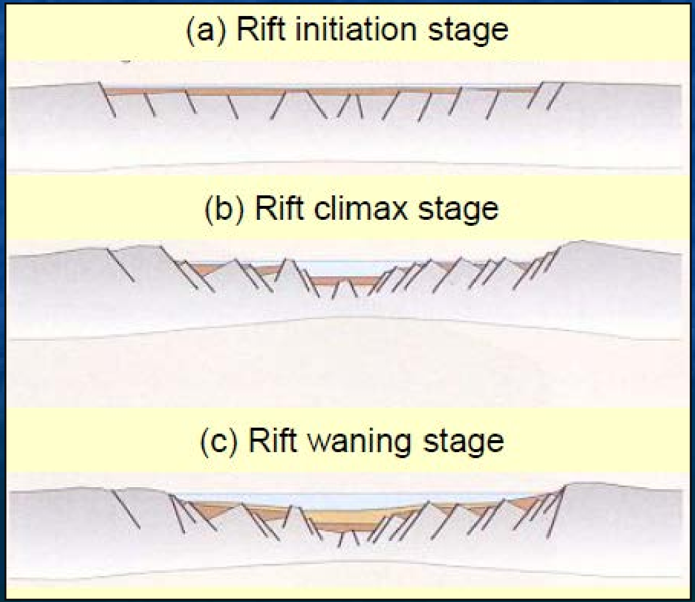
Pre-Salt Targets



(Feijo, 2013)

What is a Rift Basin?

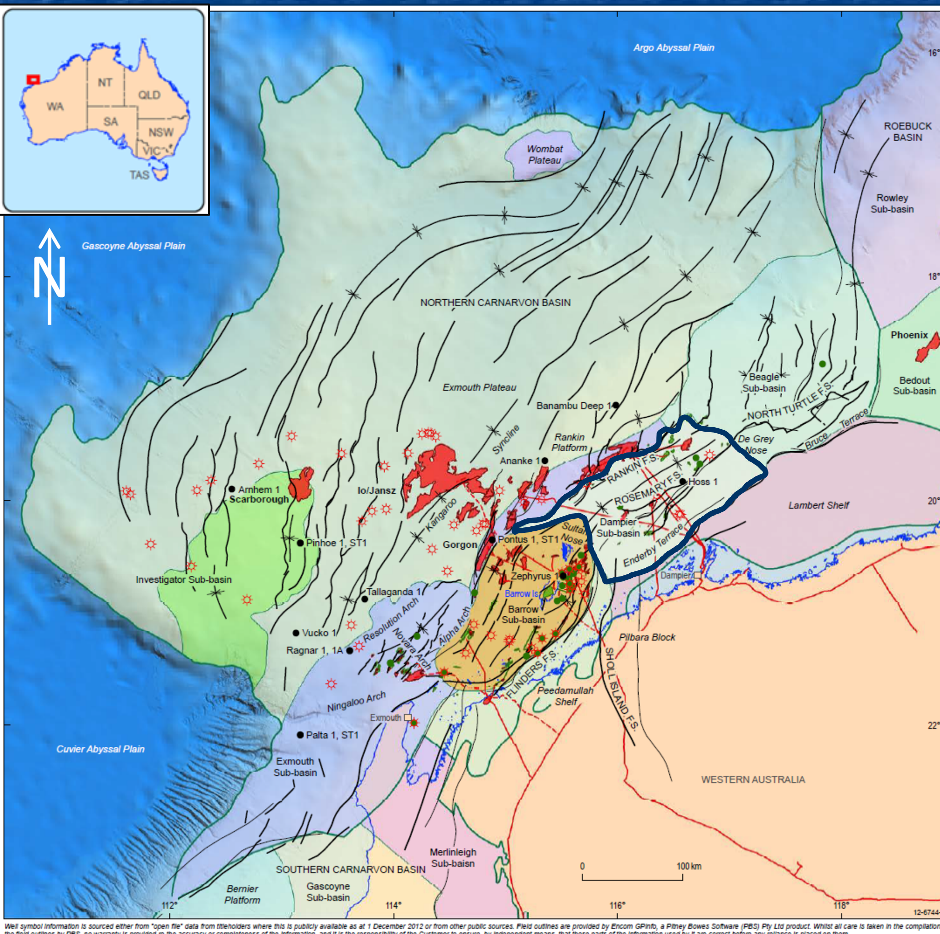
- Basin that has undergone crustal extension and passed through five sedimentary evolution cycles (Prosser, 1993):
  - Pre-rift (S1): everything deposited before active fault movement
  - Syn-rift (S2-S4): everything deposited during active faulting
  - Post-rift (S5): everything deposited after faulting has ceased
- Syn-rift stage comprises three main divisions:
  - Rift Initiation (S2)
  - Rift Climax (S3)
  - Rift waning stage (S4: Immediate Post-Rift (Prosser, 1993))



(Doust, 2015)

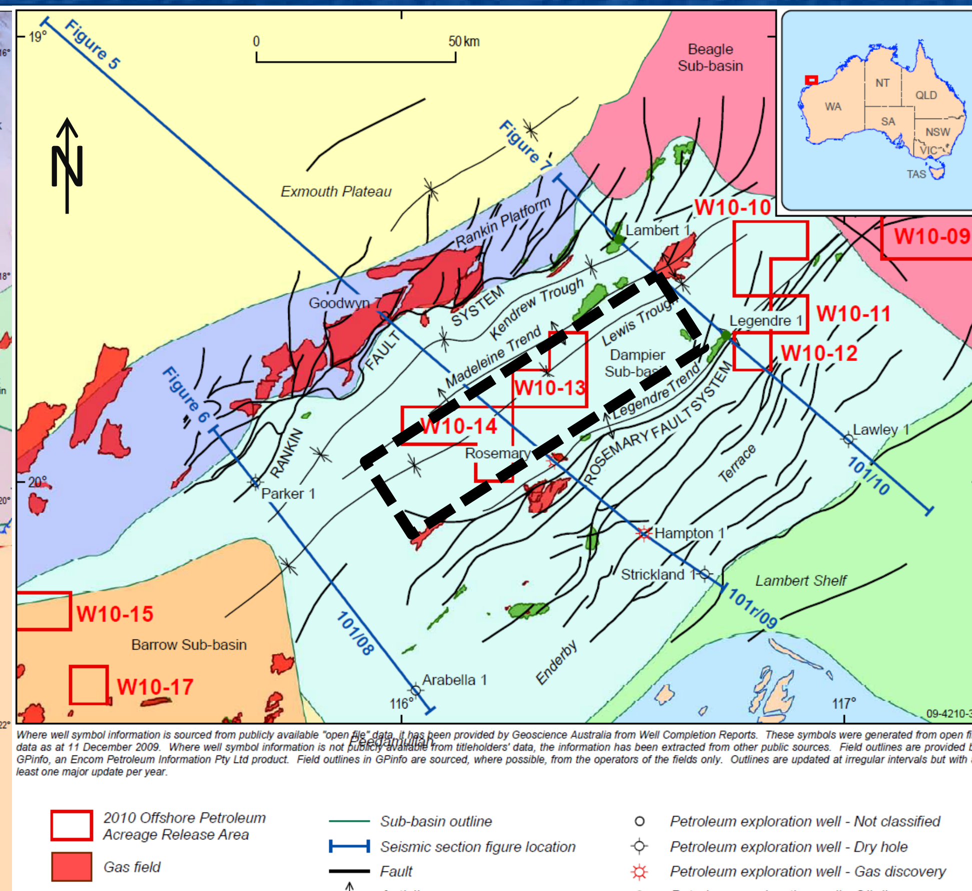
North-West Shelf of Australia

Northern Carnarvon Basin



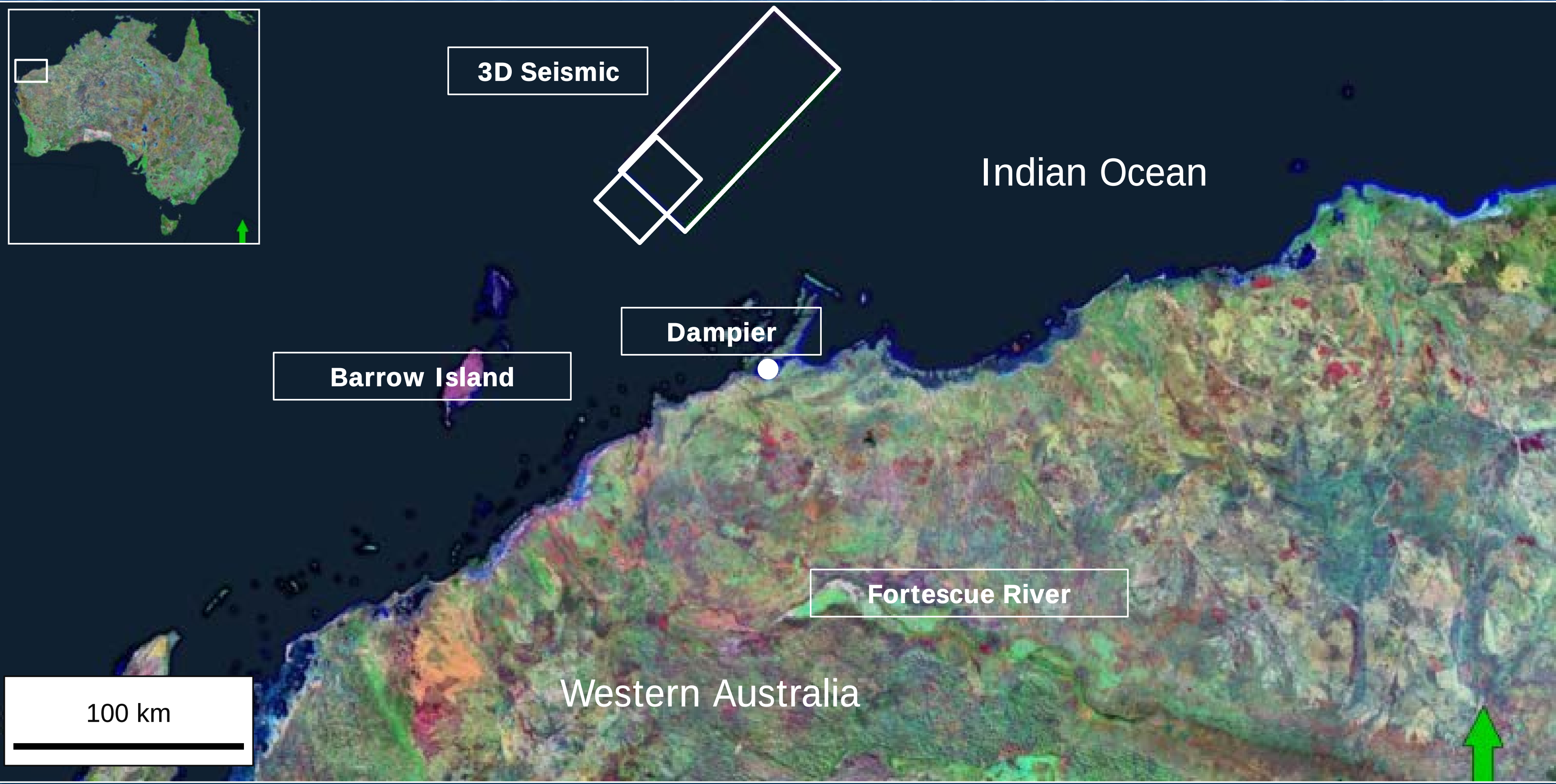
(Geoscience Australia, 2013)

Dampier Sub-basin

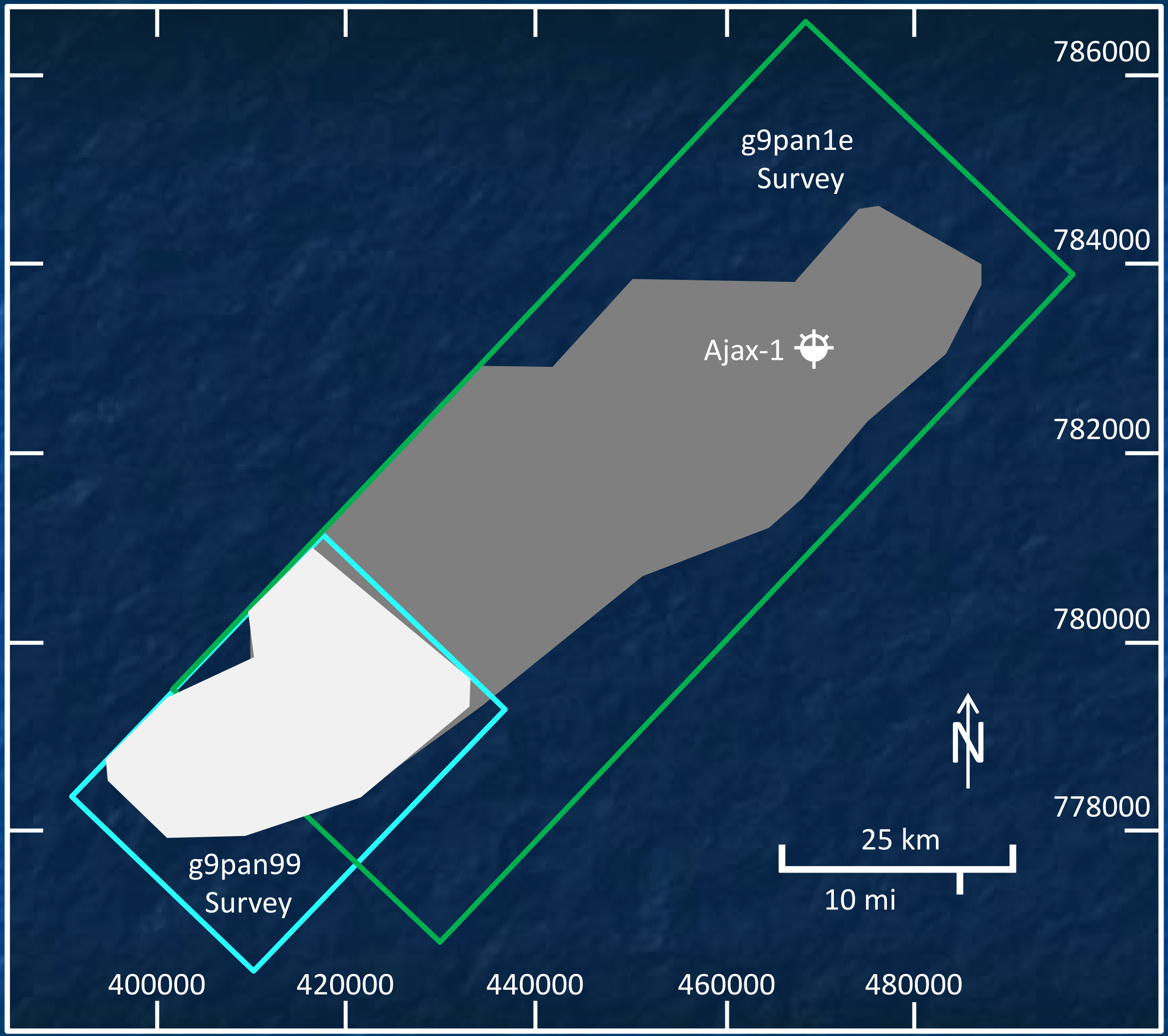


(Geoscience Australia, 2010)

Study Location

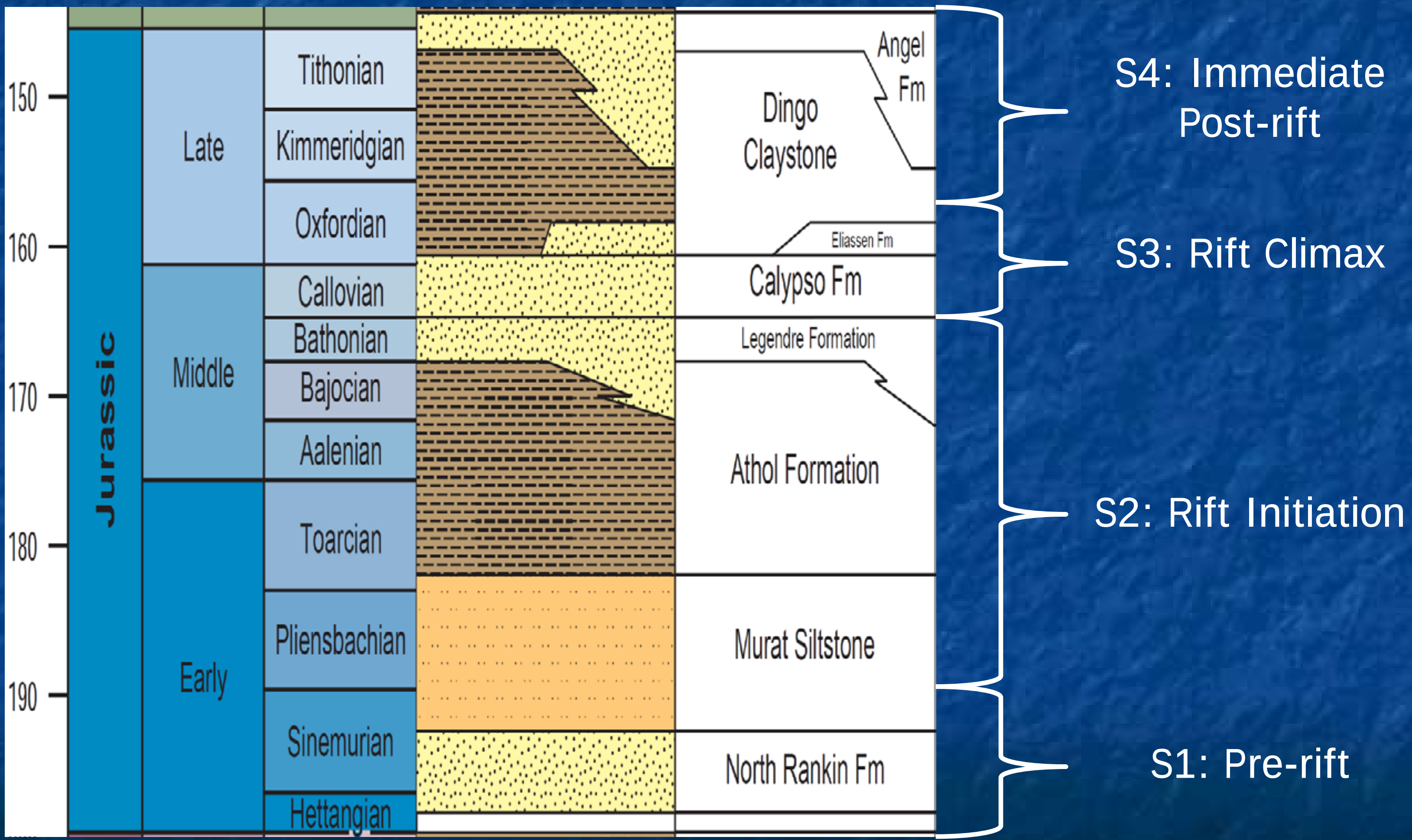


Seismic 3-D Surveys



- Approximately 2284 km^2 (882 mi^2) of seismic coverage
- Ajax-1: targeted and penetrates syn-rift sediments not on the rift shoulder
- Limited well coverage, as would be found in an exploration type project

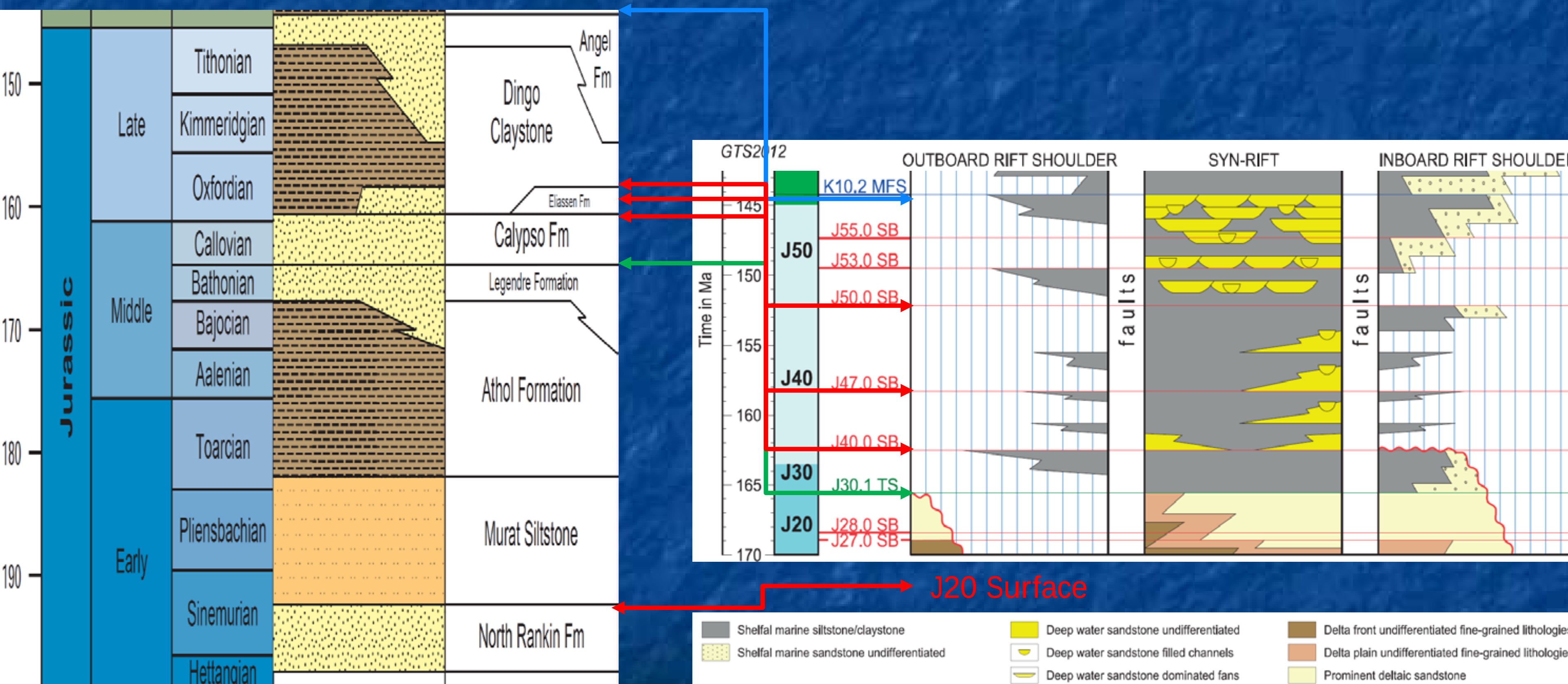
Jurassic Syn-rift Stratigraphy of the Dampier Sub-Basin



(Geoscience Australia, 2010)

Seismic Mapped Horizons from Stratigraphy

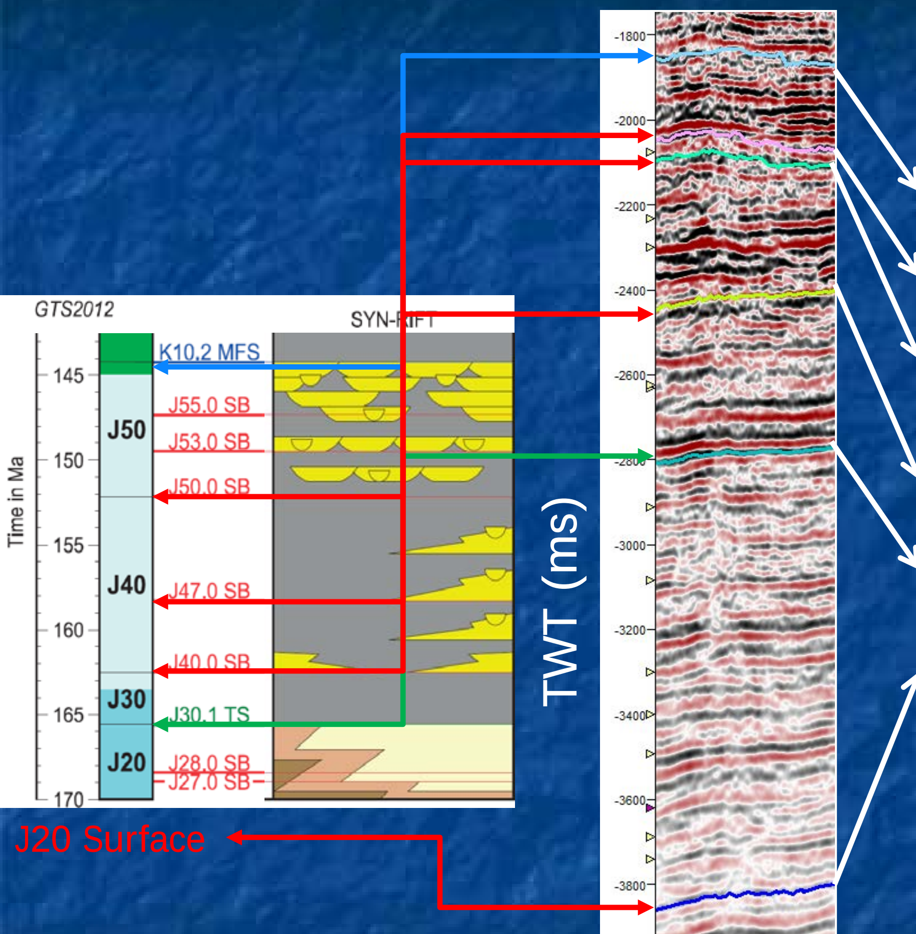
- Longley et al. (2002) first put together a regional play interval (RPI) stratigraphic naming convention based on seismic surfaces, well data, and biostratigraphy
- Marshall and Lang (2013) further refined this sequence stratigraphic framework



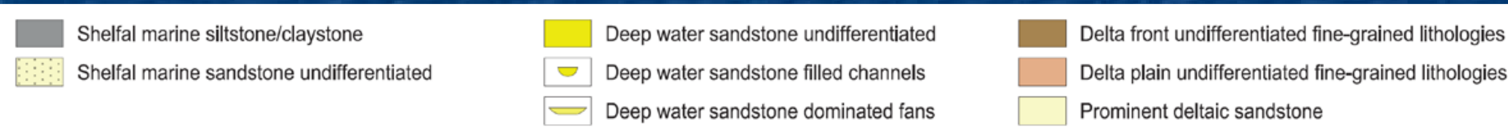
(Geoscience Australia, 2010)

(Marshall and Lang, 2013)

Seismic Mapped Horizons from RPI

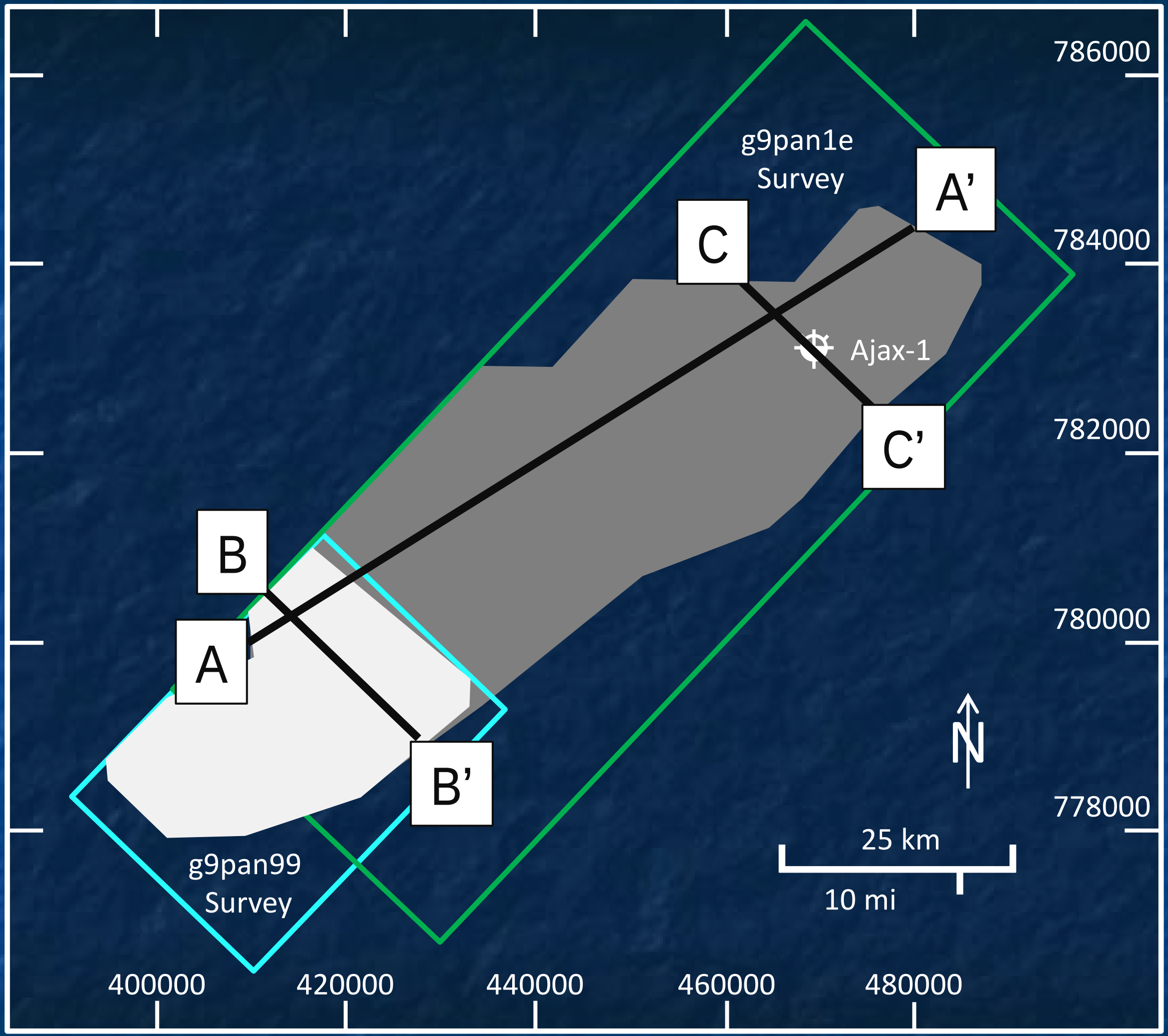


Horizon Name	Relative Age (Marshall and Lang, 2013)	Formation Top (Marshall and Lang, 2013)	Phase	Surface Type (Marshall and Lang, 2013)
K10	Top Jurassic	Dingo Claystone/ Angel Formation	Peak	Maximum Flooding Surface
J50	Late Jurassic (Tithonian)	Eliassen Formation	Peak	Sequence Boundary
J47	Late Jurassic (Oxfordian)	Oxfordian Sequence Boundary	Peak	Sequence Boundary
J40	Late Jurassic (Oxfordian)	Calypso Formation	Trough	Sequence Boundary
J30	Middle Jurassic (Callovian)	Athol Formation/ Legendre Formation	Peak	Transgressive Flooding Surface
J20	Early Jurassic (Sinemurian)	North Rankin Formation	Peak	Sequence Boundary



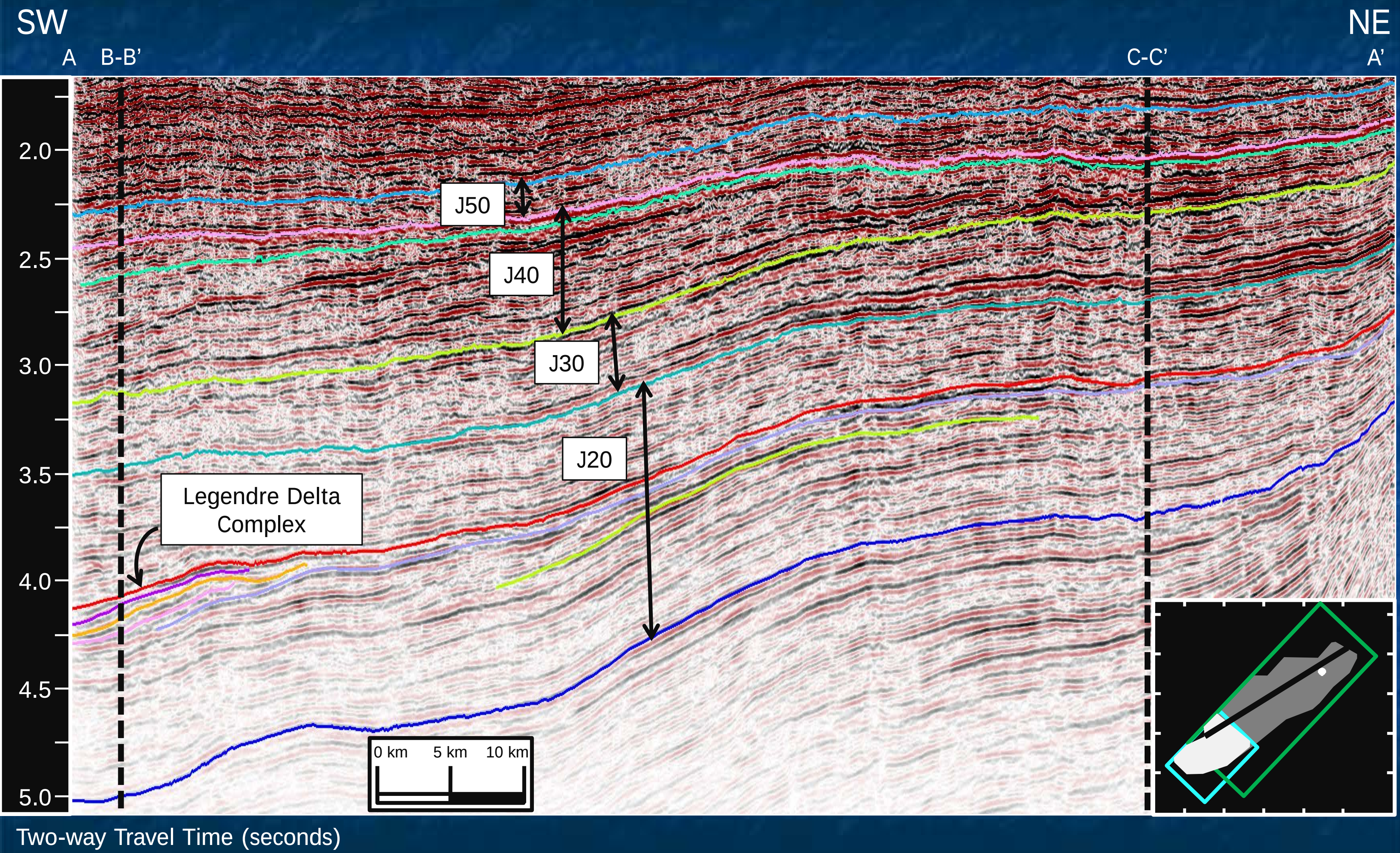
(Marshall and Lang, 2013)

Seismic 3-D Surveys

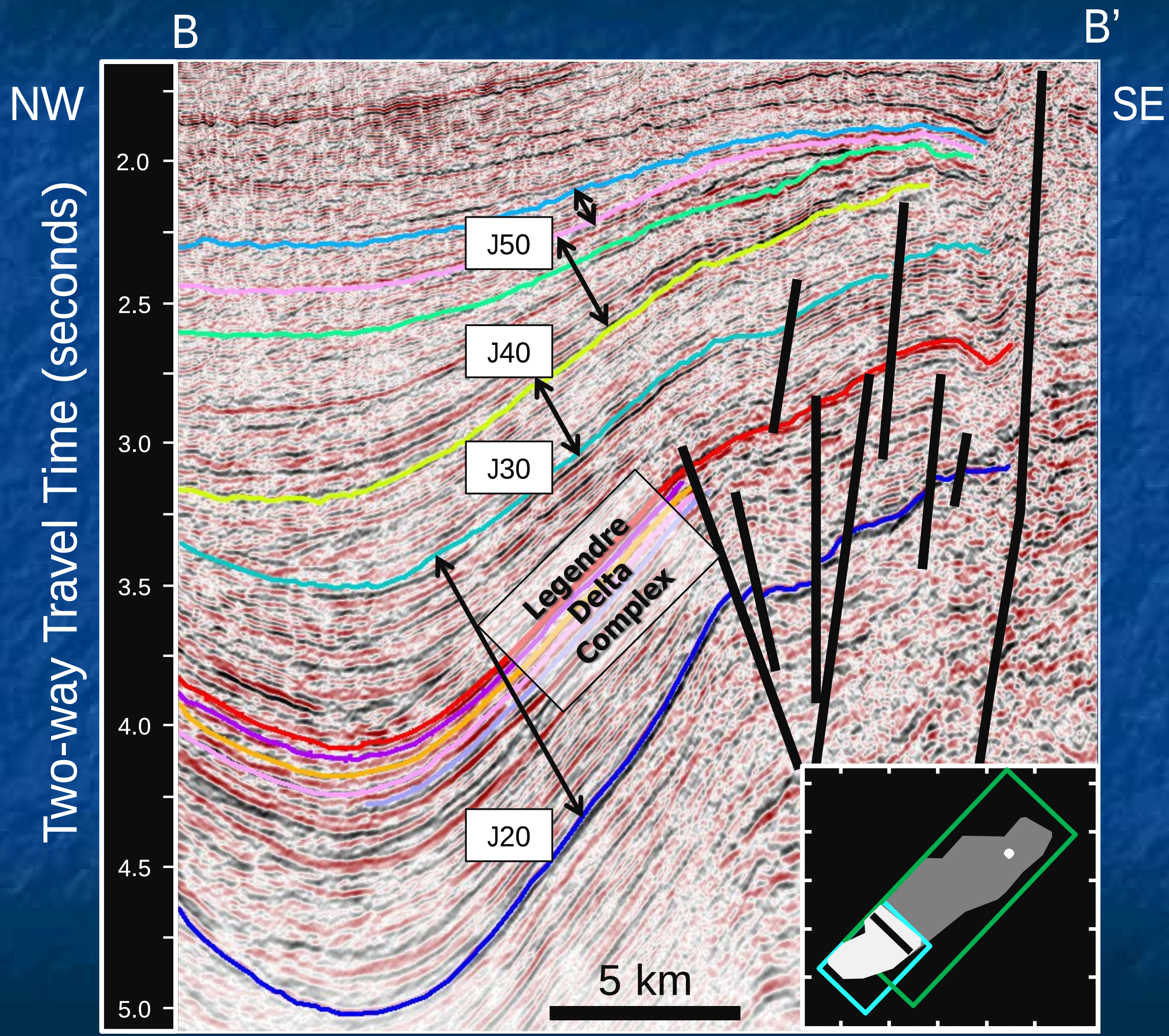


- A-A': parallel to rift axis
- B-B': orthogonal to rift axis
- C-C': orthogonal to rift axis, included Ajax-1 well

Cross-section A-A'

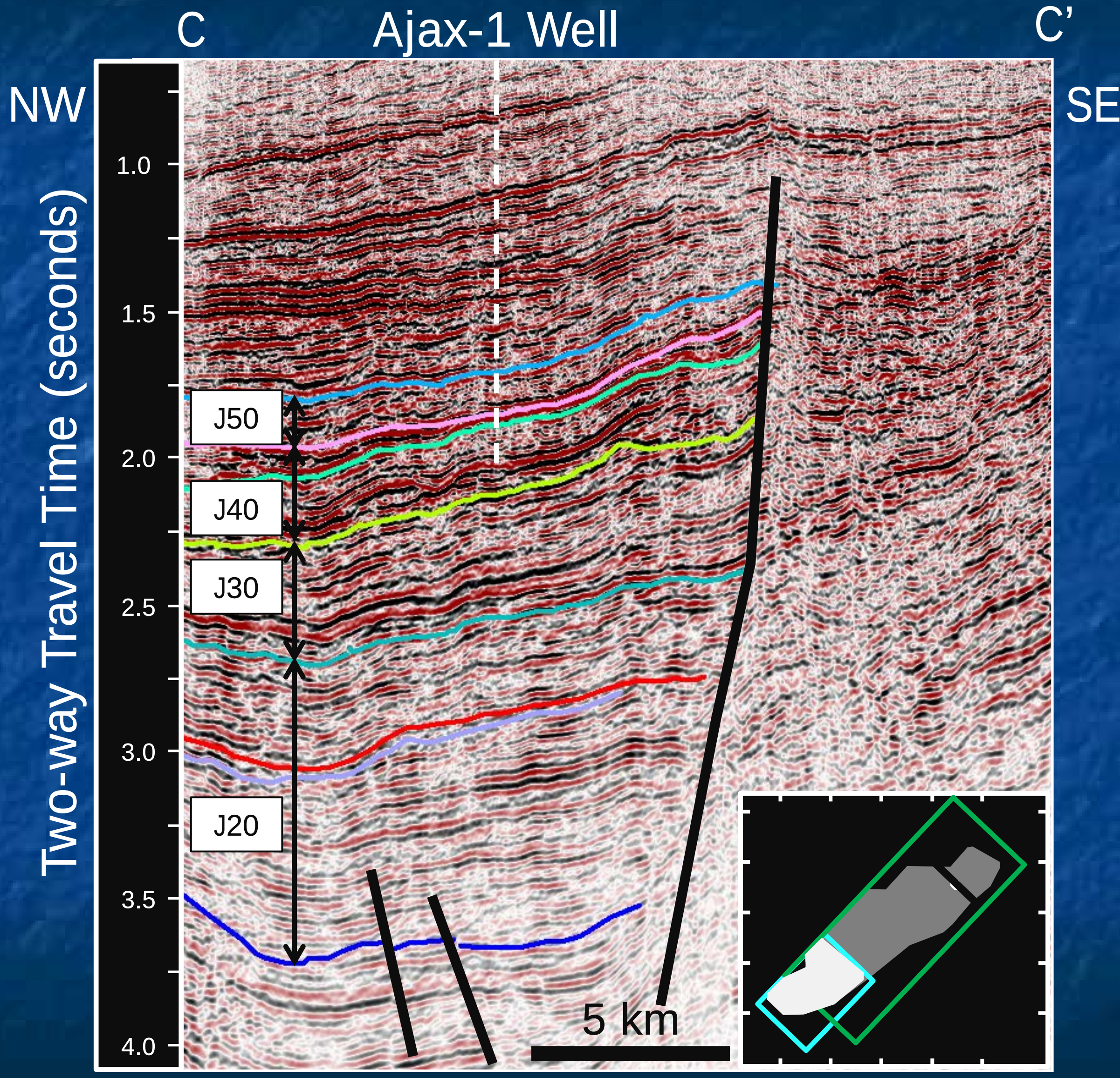


Cross-Section B-B’



X-line 17324 (survey g9pan99)

Cross-section C-C'

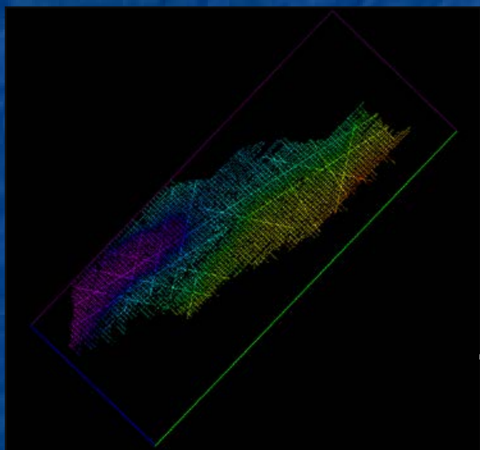


X-line 8220 (survey g9pan1e)

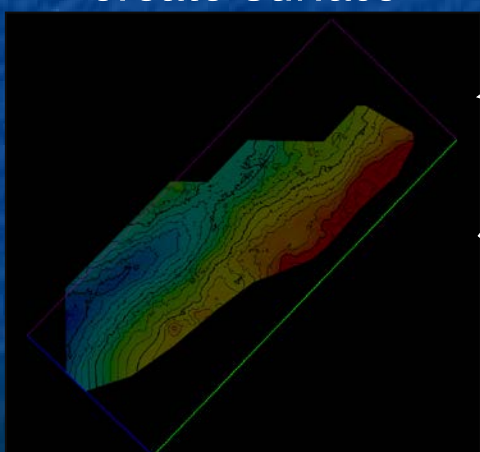
Integrated Surface Interpretation Workflow

K10 Surface Example

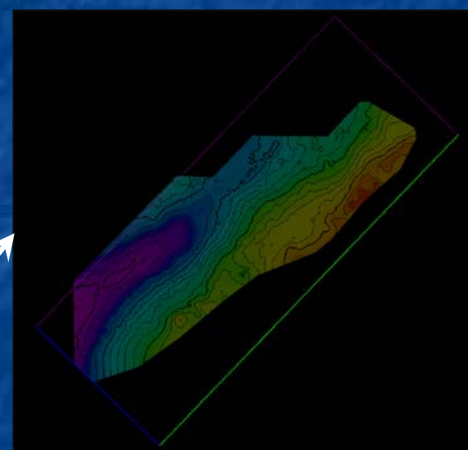
Interpret Horizon



Create Surface

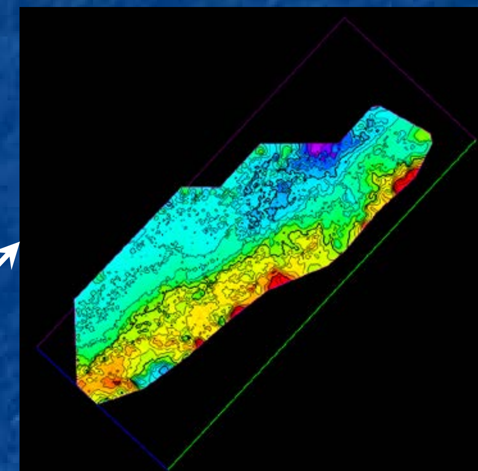


Smooth

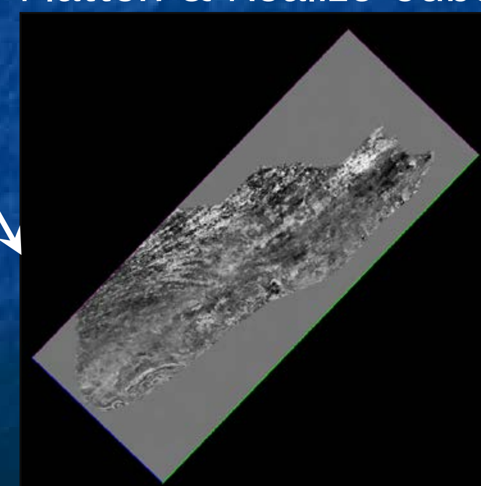


(7 iterations,
1 Filter Width)

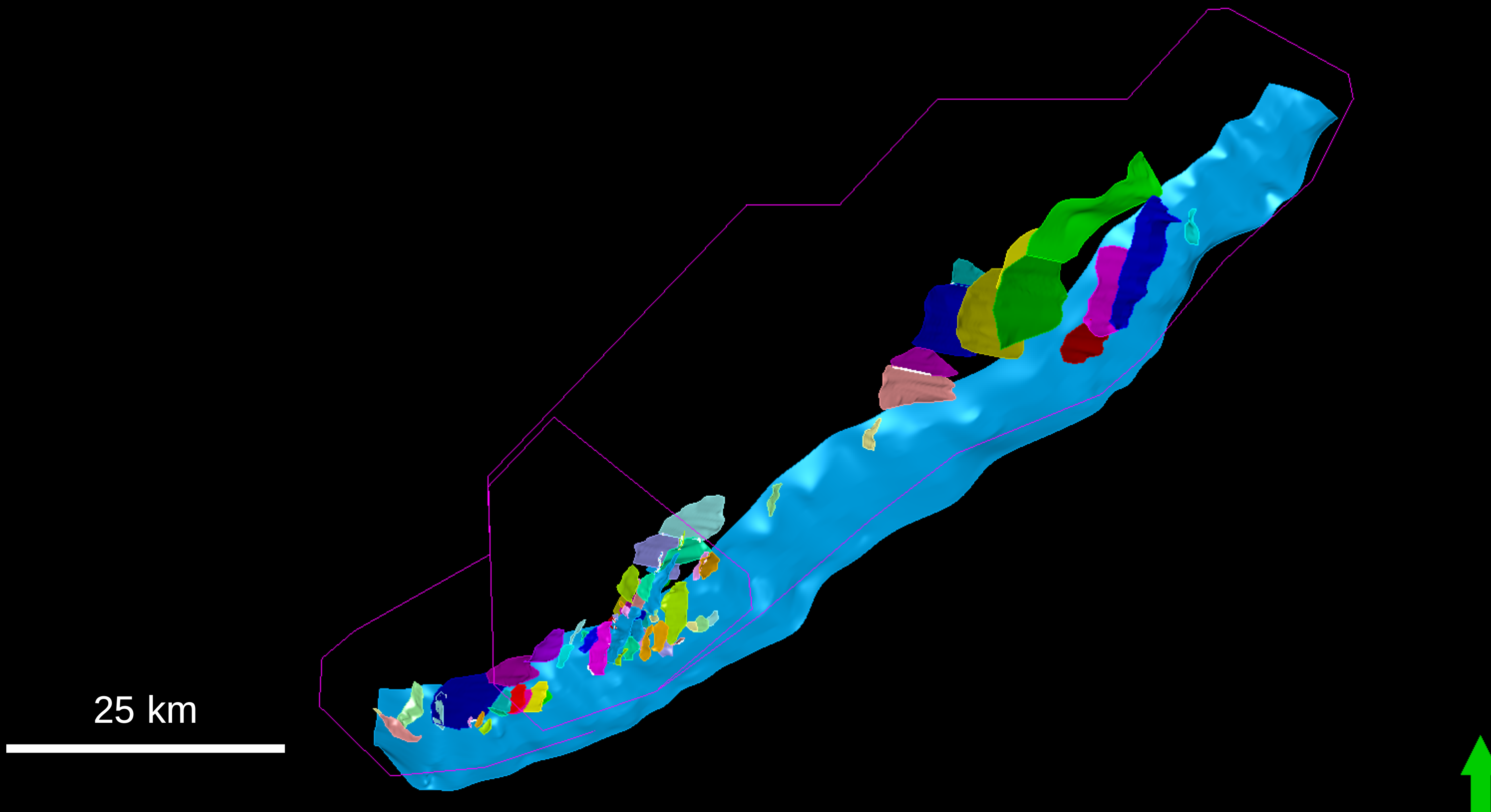
Isopachs



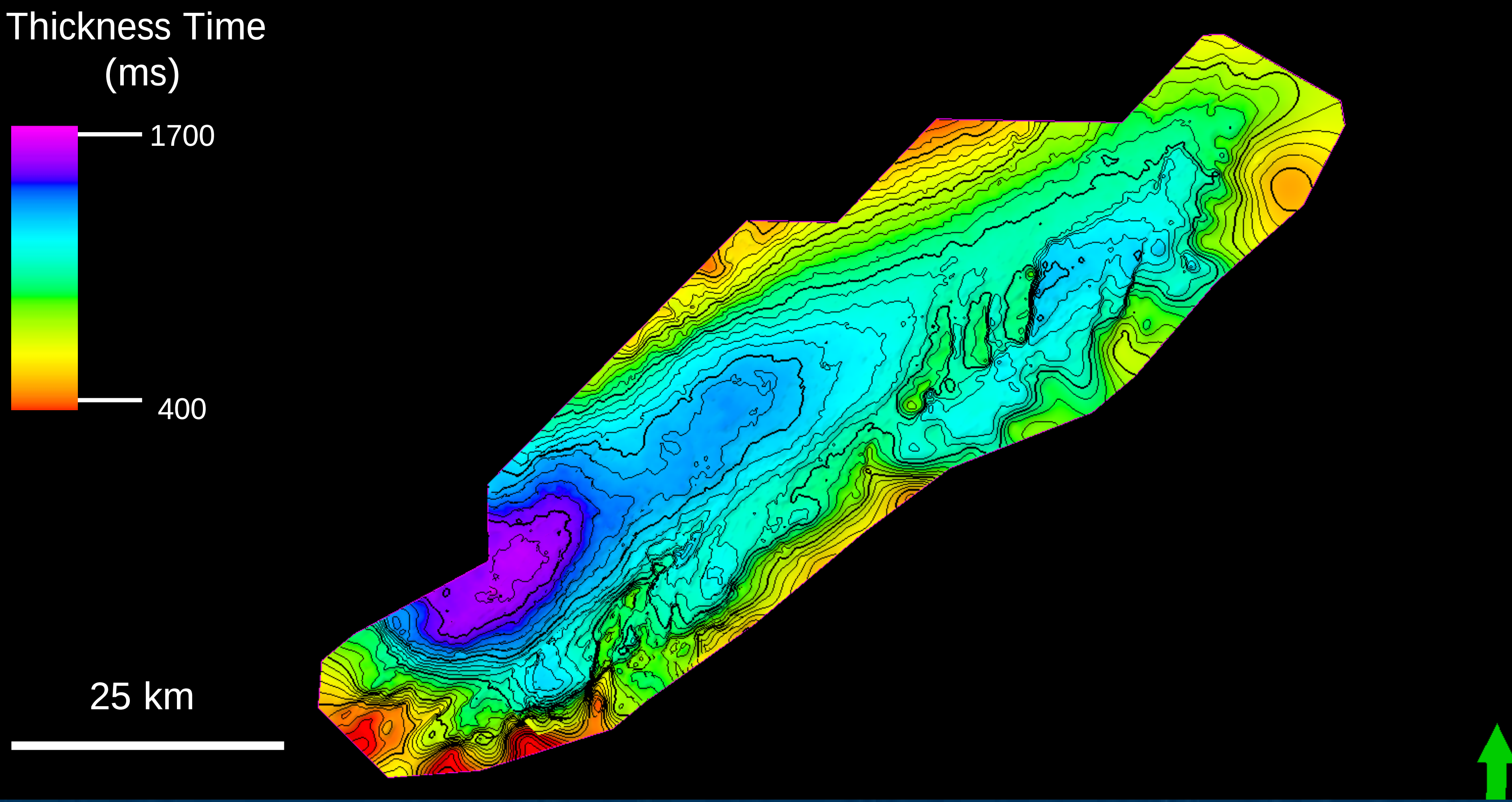
Flatten & Realize Cube



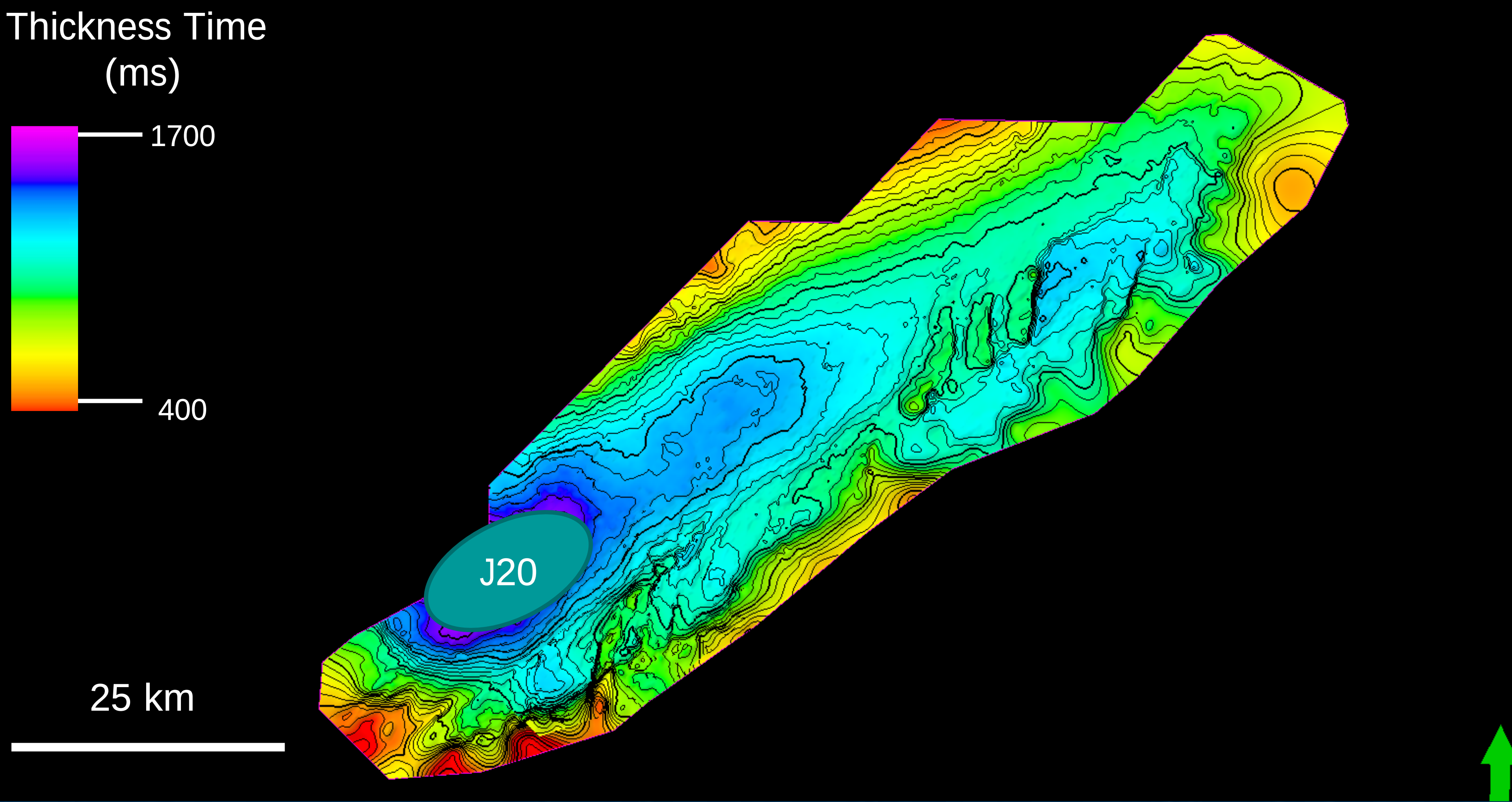
Faults within Dampier Sub-basin



J20 Isopach: S2 Rift Initiation



J20 Isopach: S2 Rift Initiation



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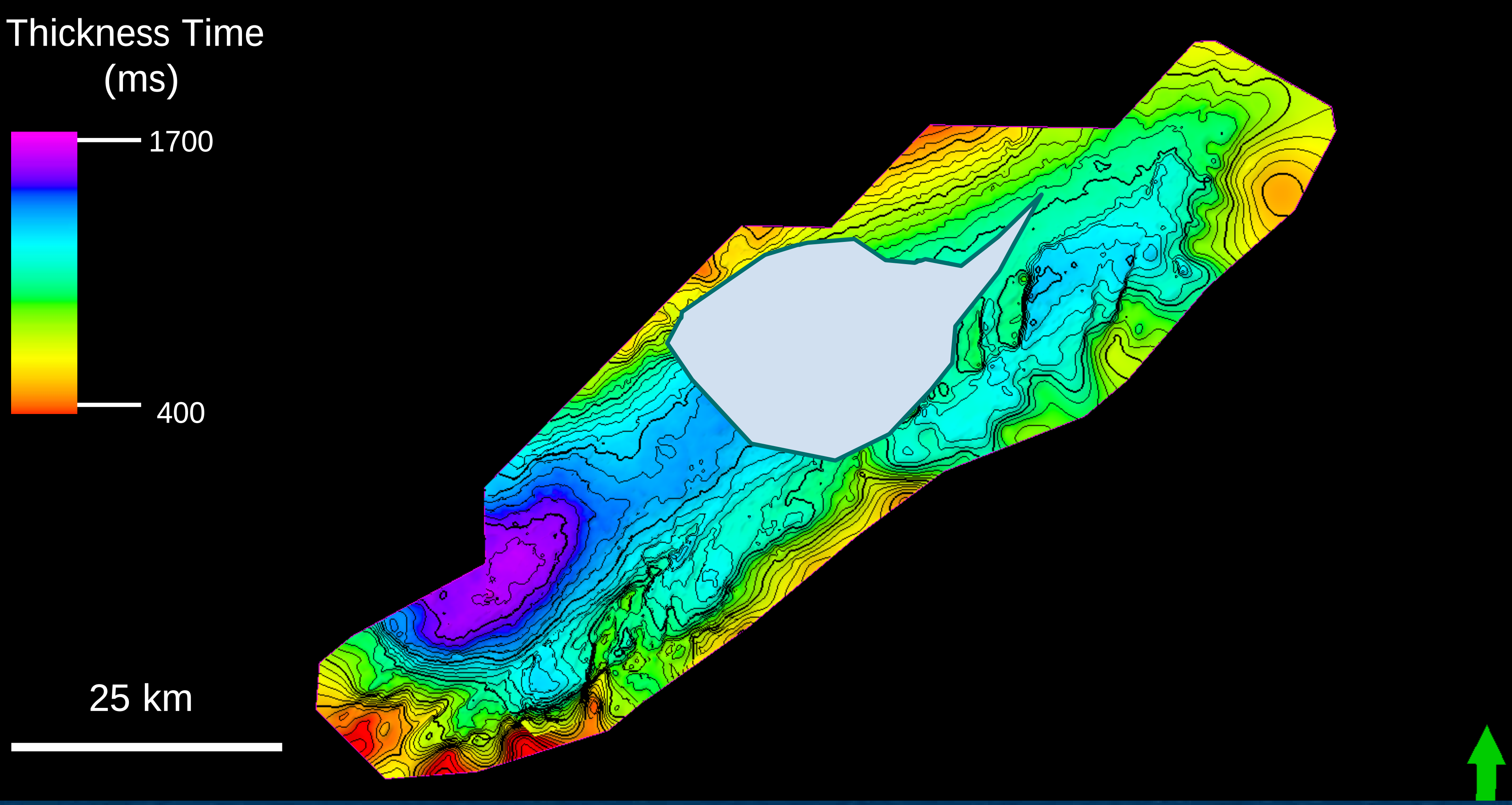

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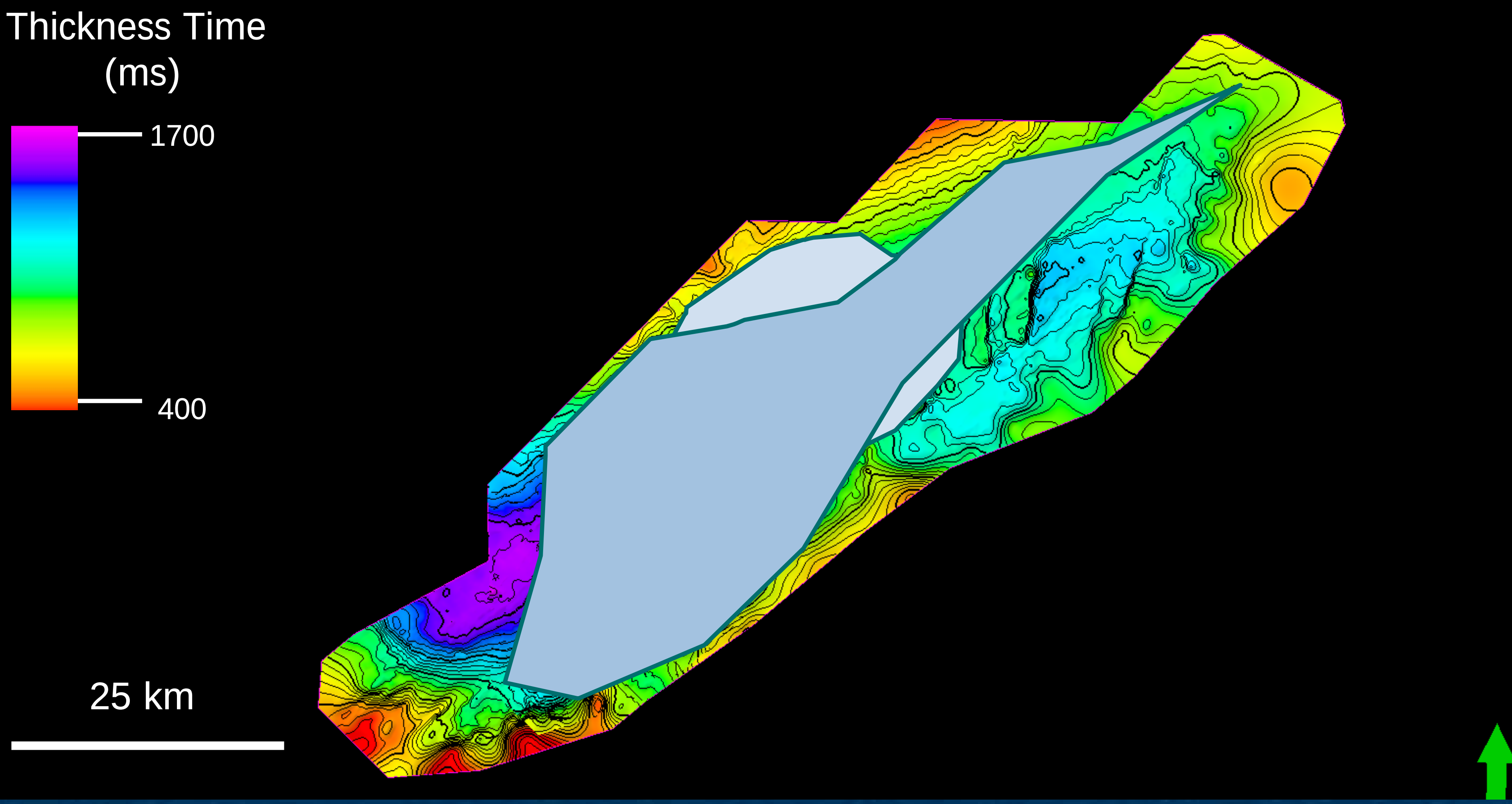

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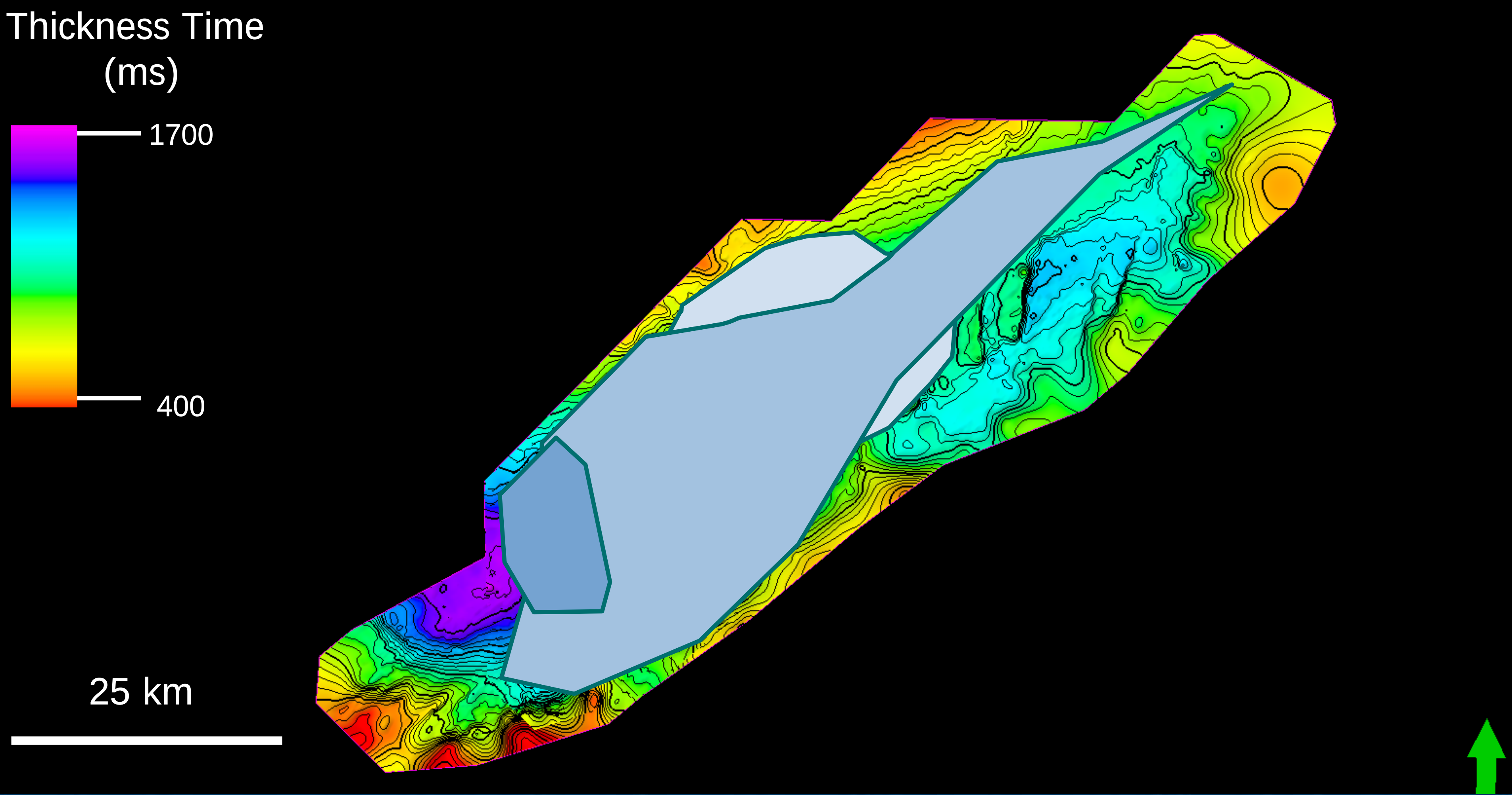

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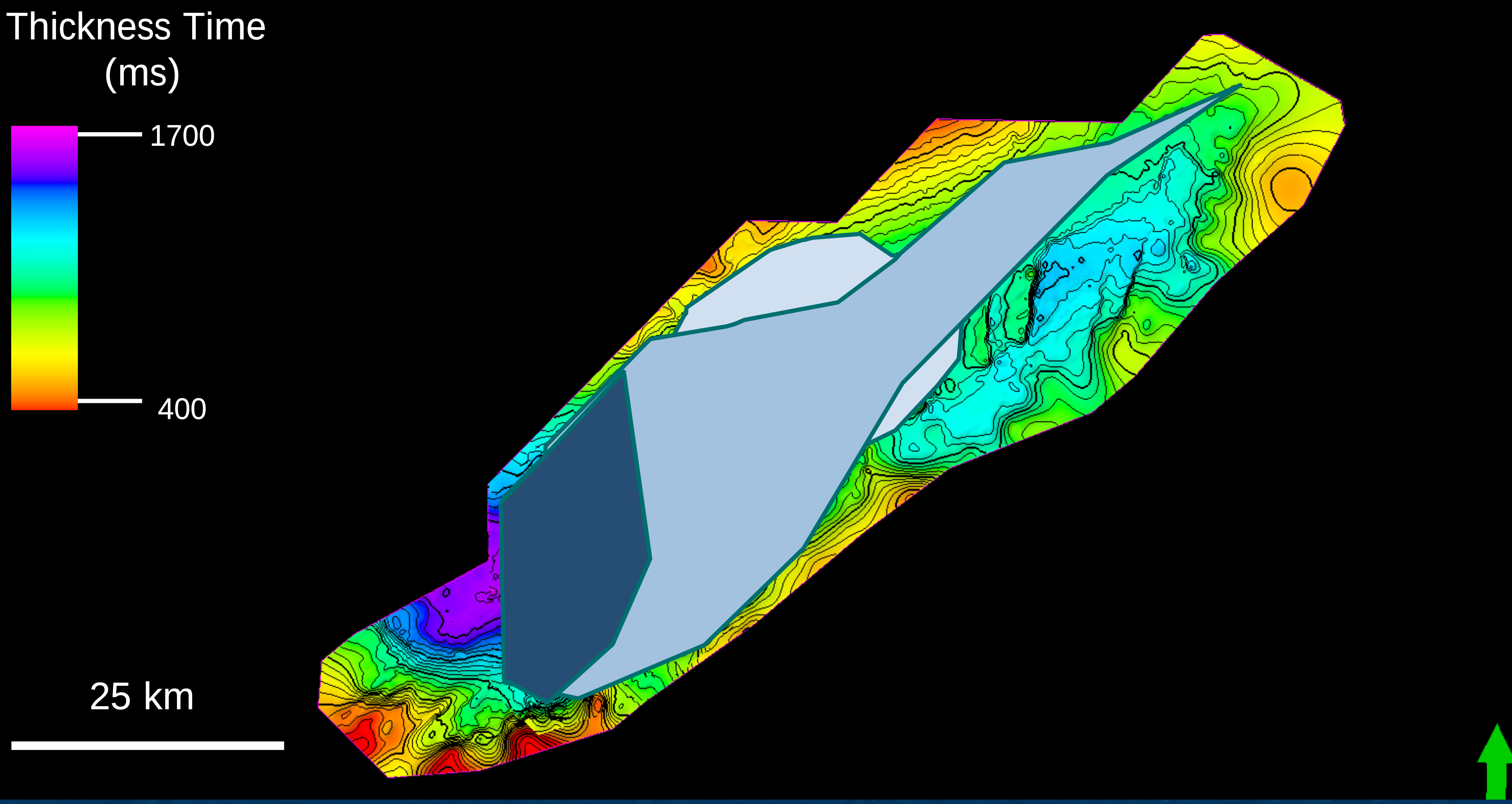
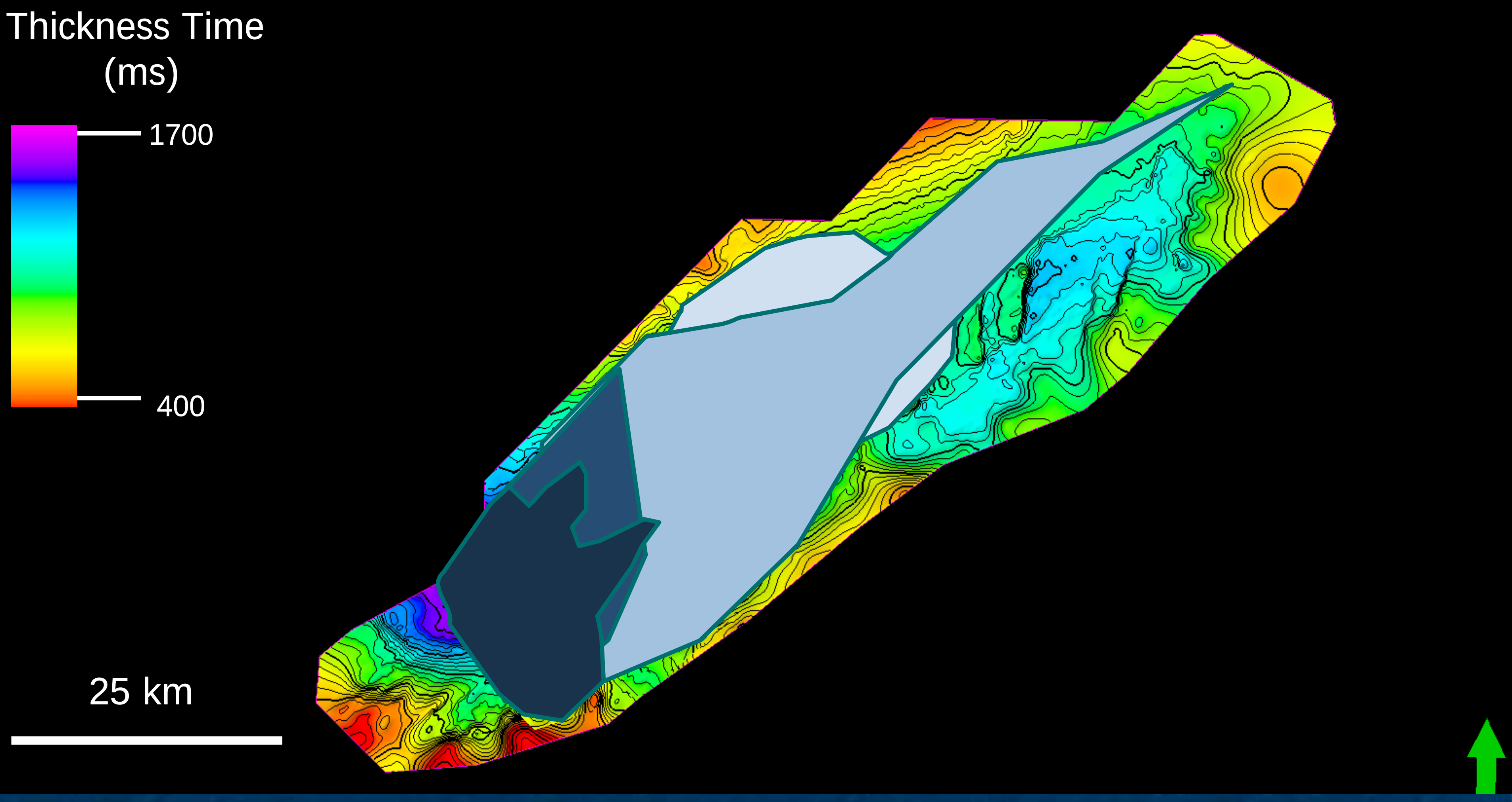


J20 Isopach: S2 Rift Initiation



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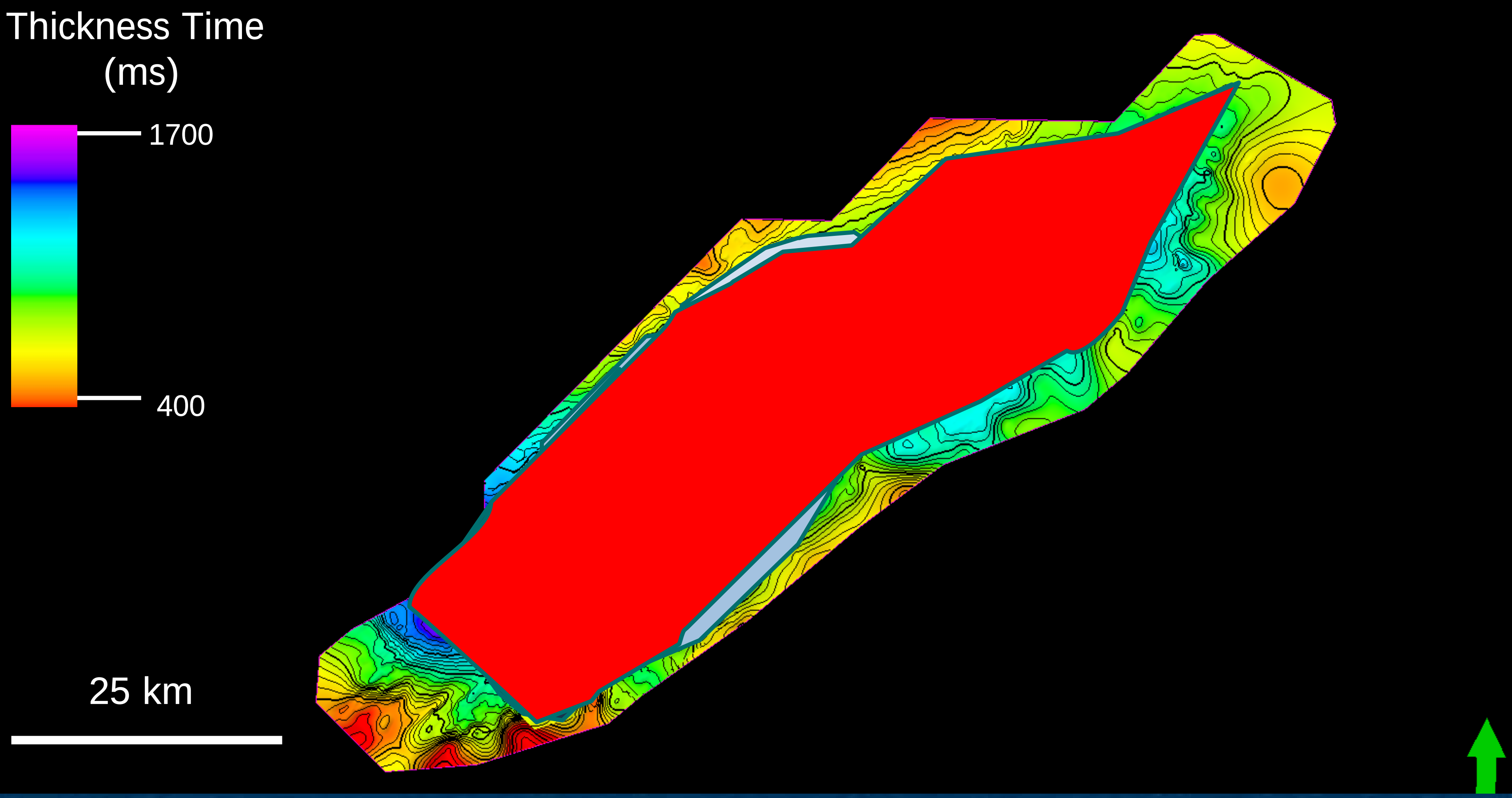
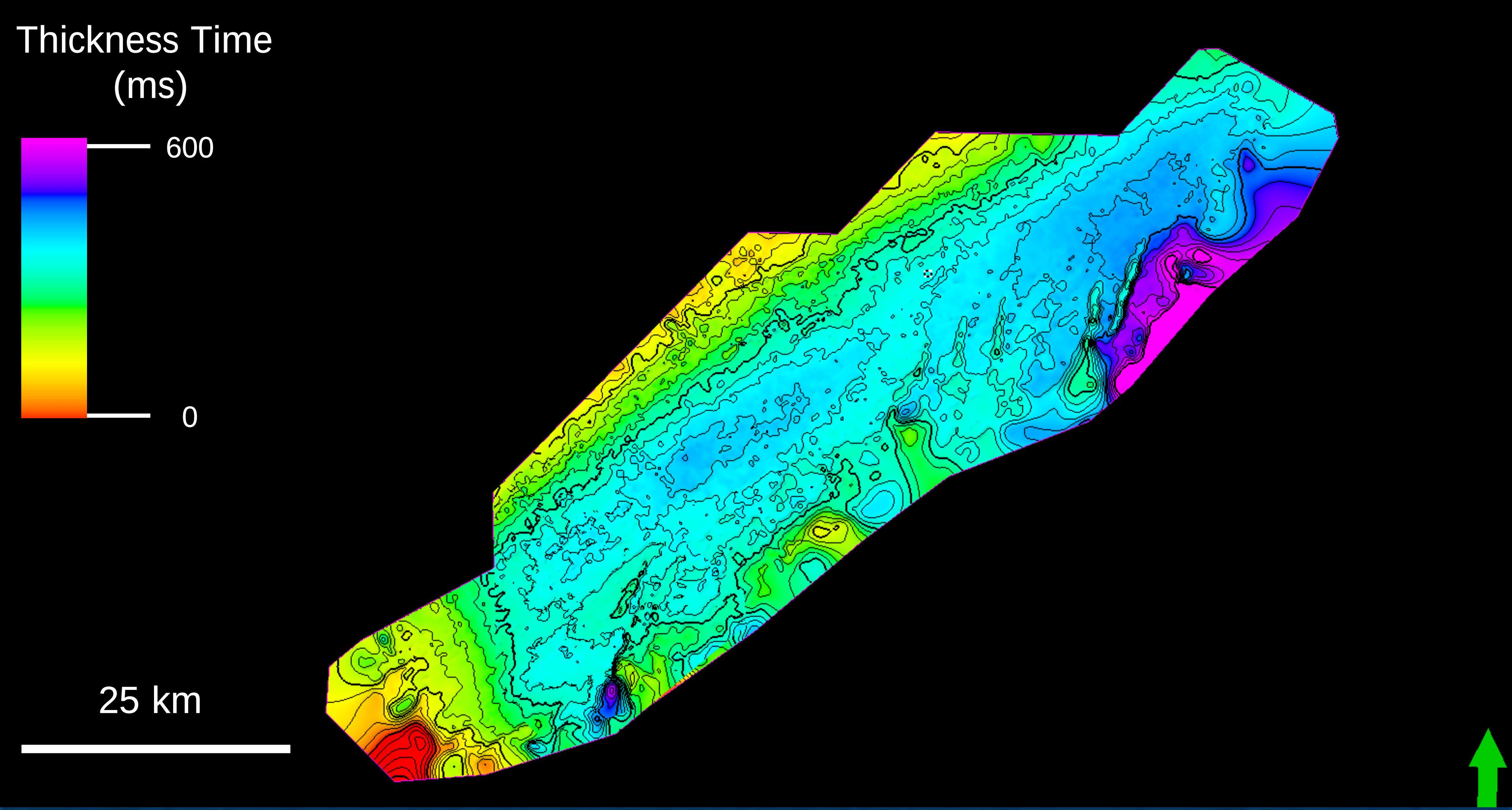
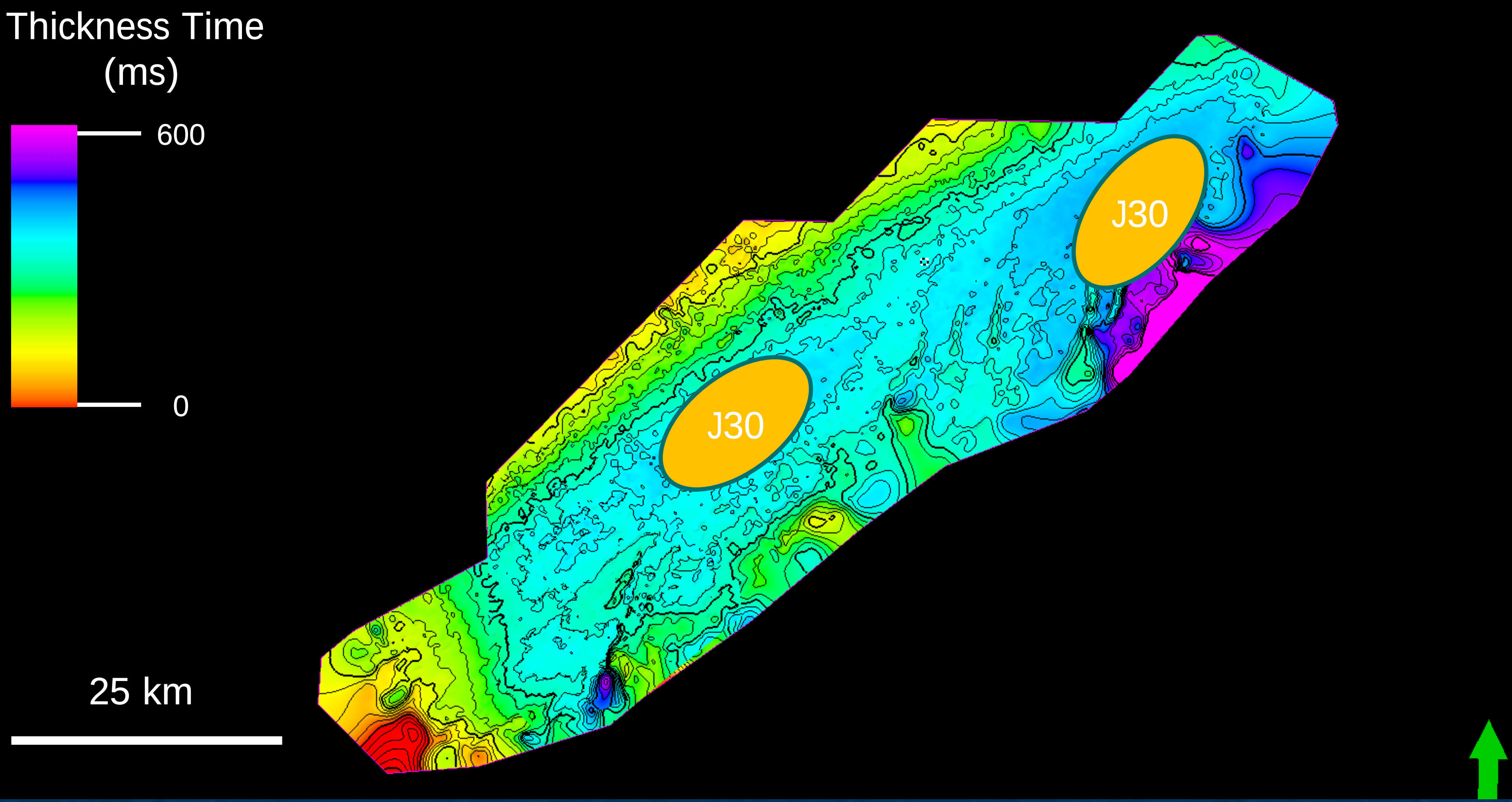


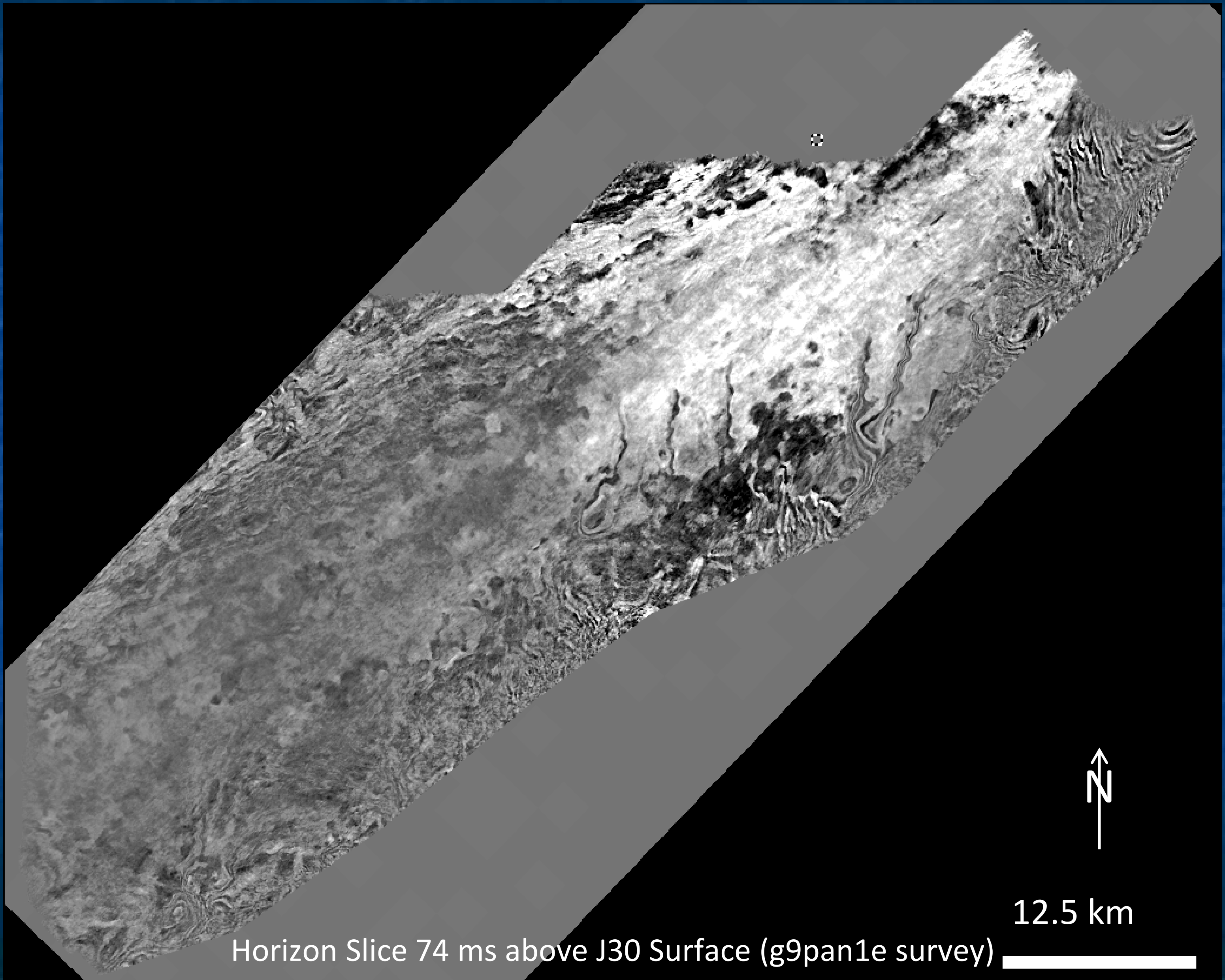
J30 Isopach: S3 Rift Climax



J30 Isopach: S3 Rift Climax

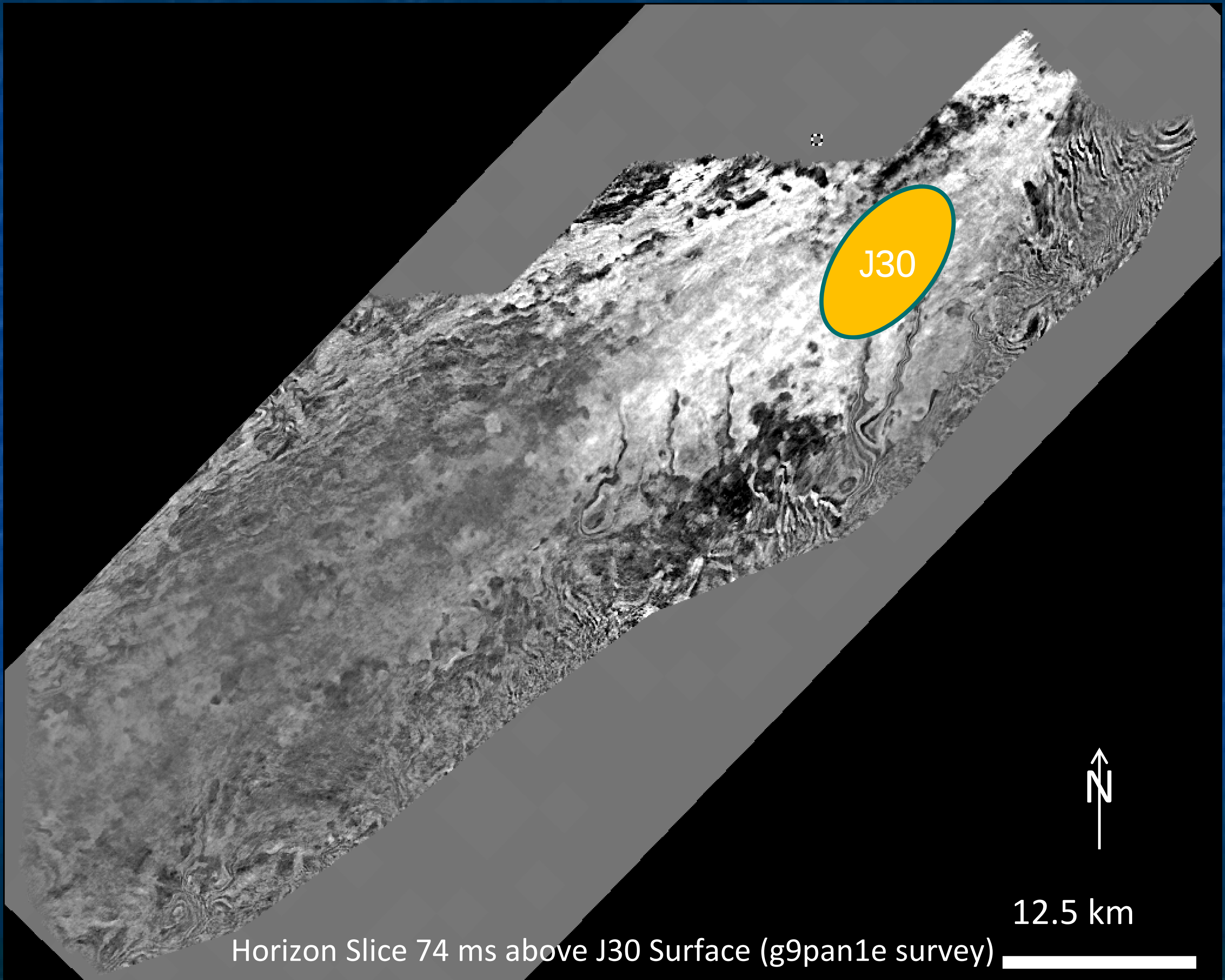


J30 Horizon Slice



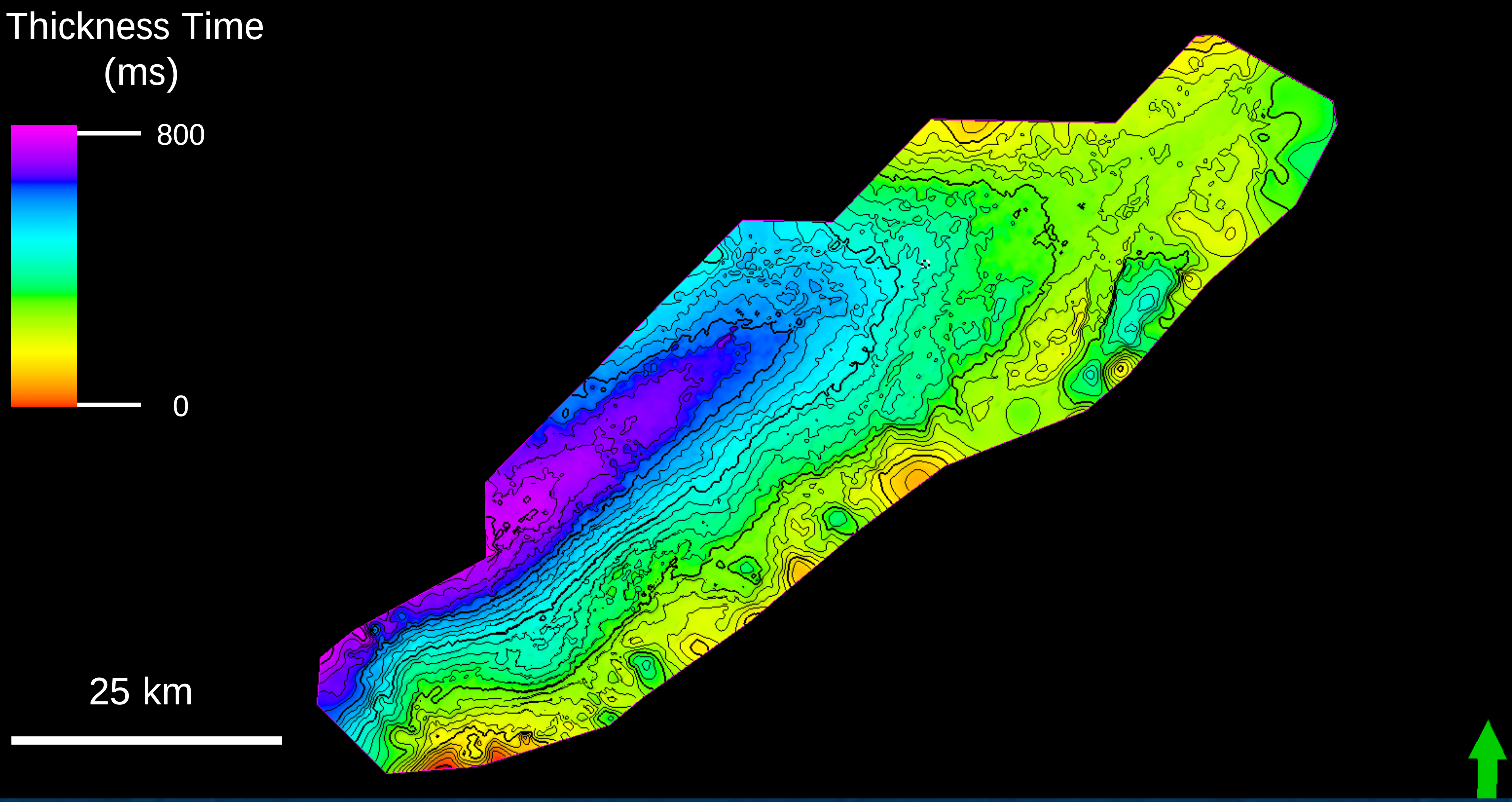
Horizon Slice 74 ms above J30 Surface (g9pan1e survey)

J30 Horizon Slice

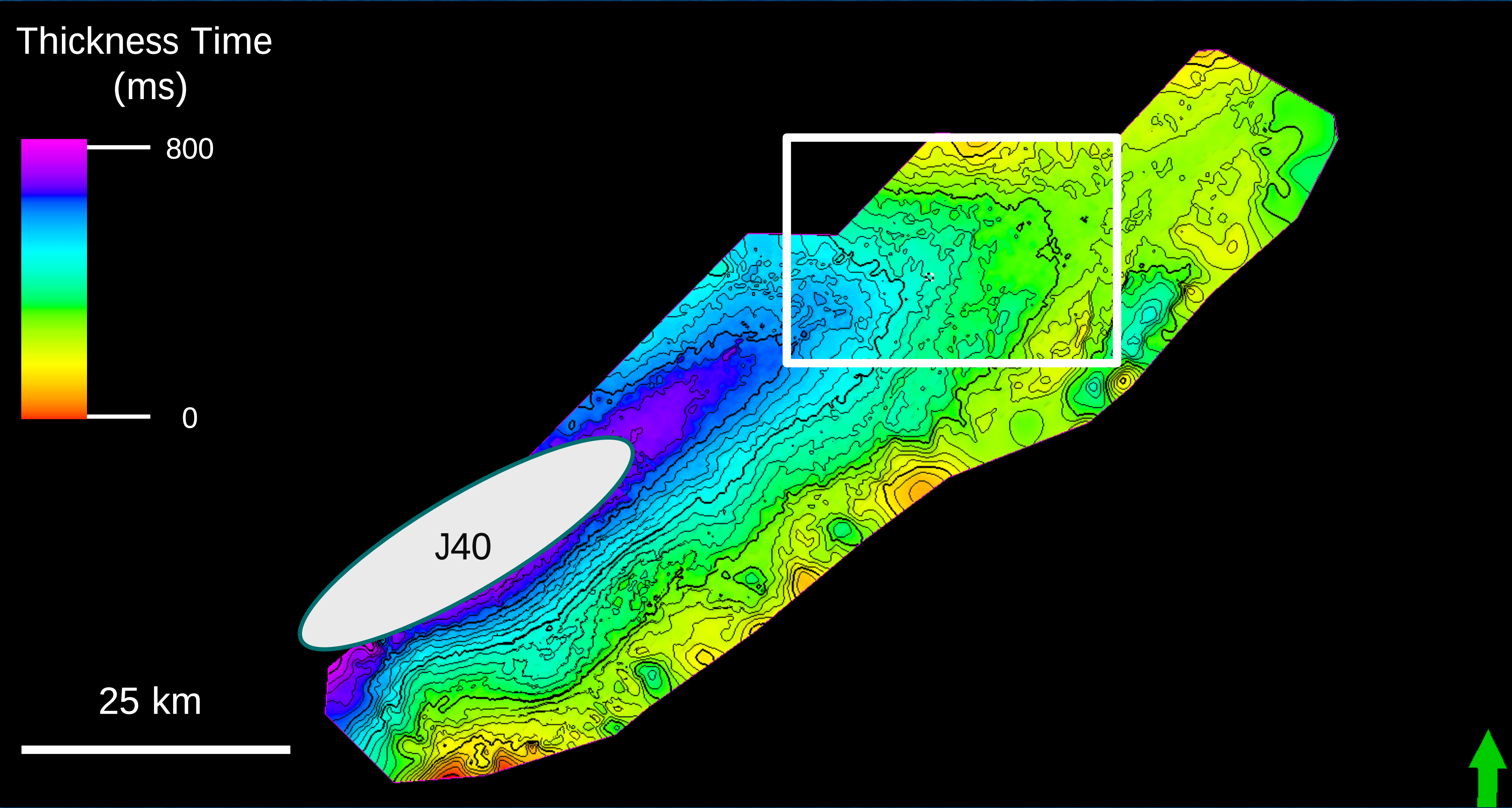


Horizon Slice 74 ms above J30 Surface (g9pan1e survey)

J40 Isopach: S3 Rift Climax

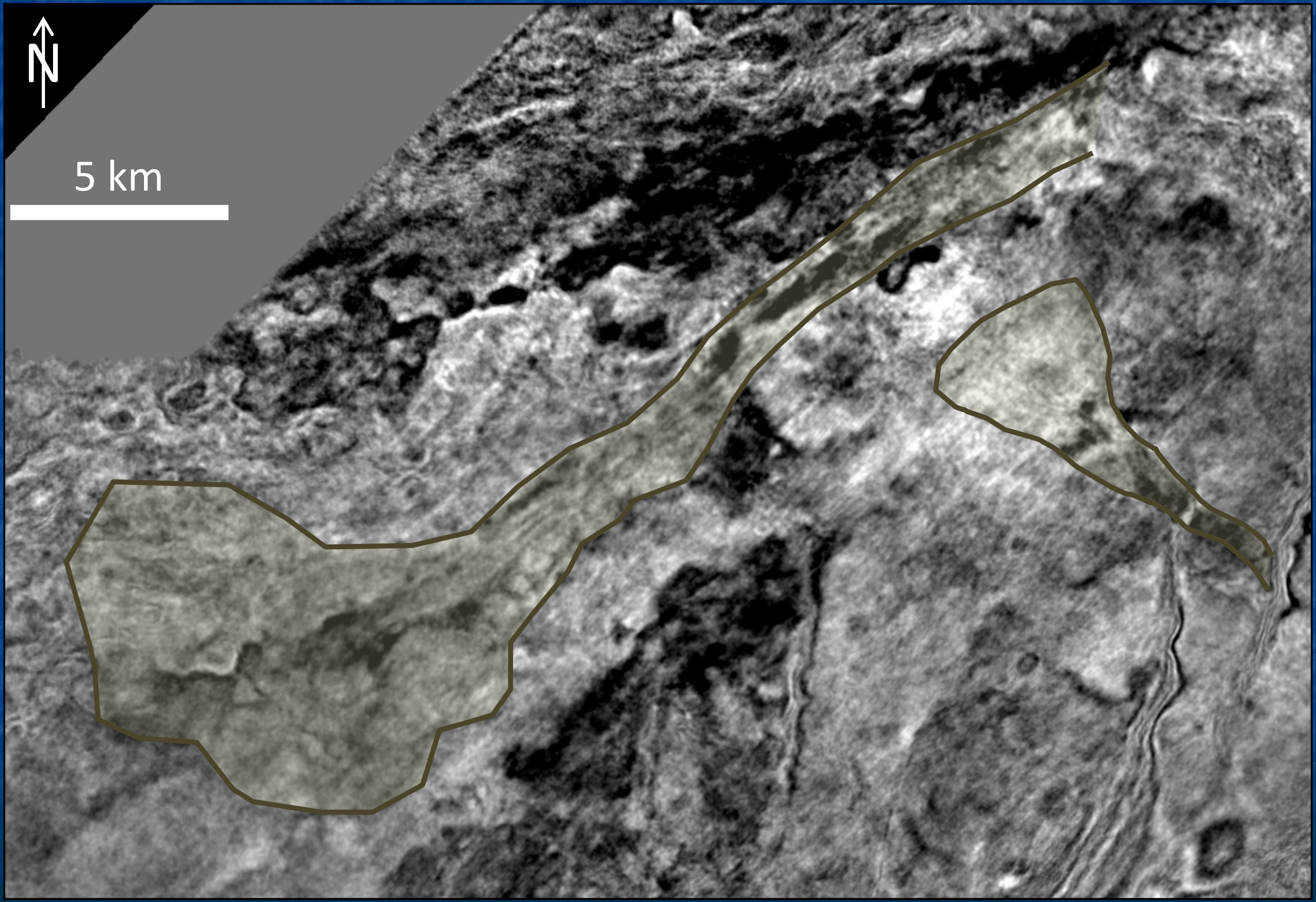


J40 Isopach: S3 Rift Climax

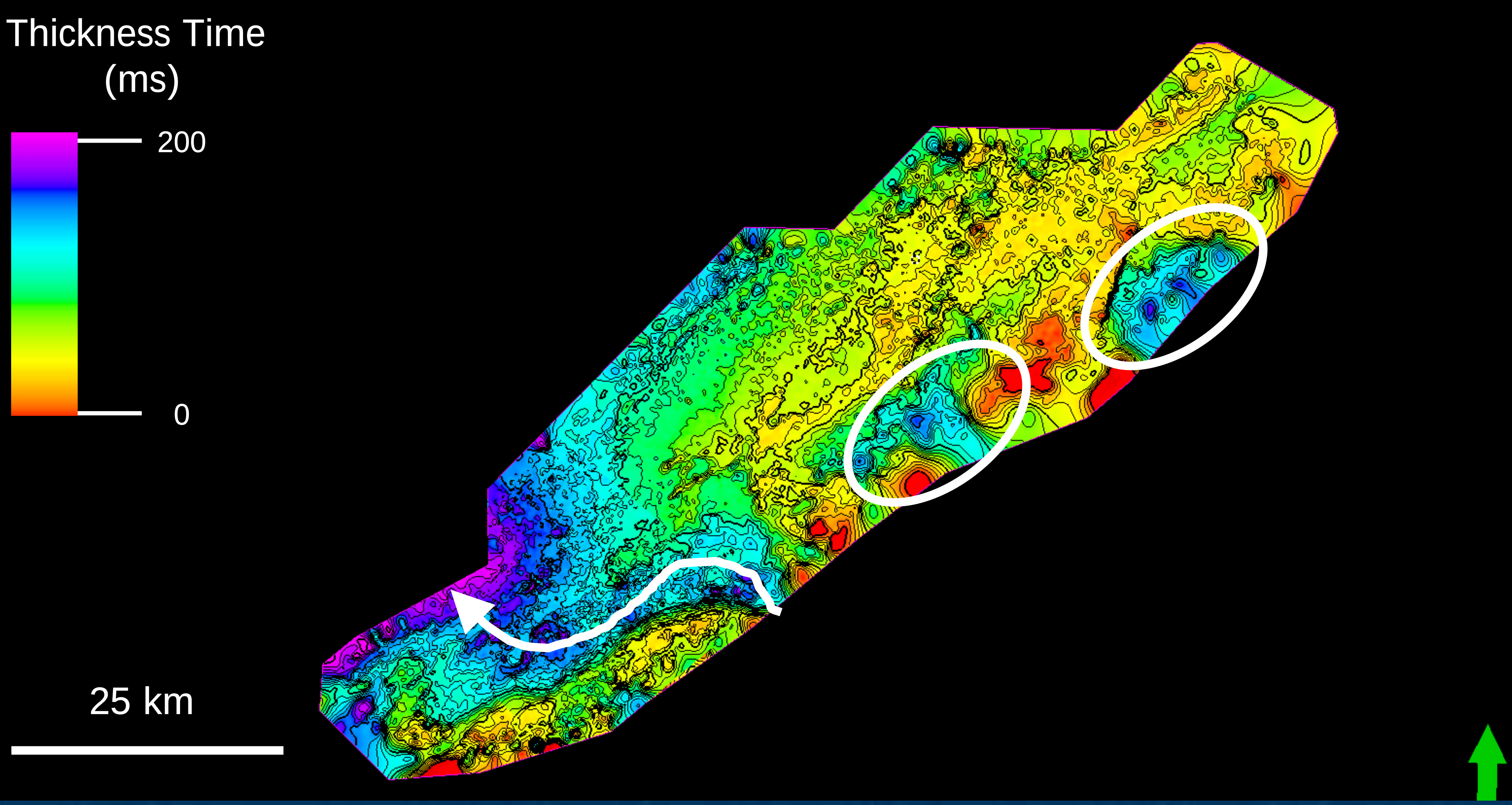


Submarine fans above J40 horizon

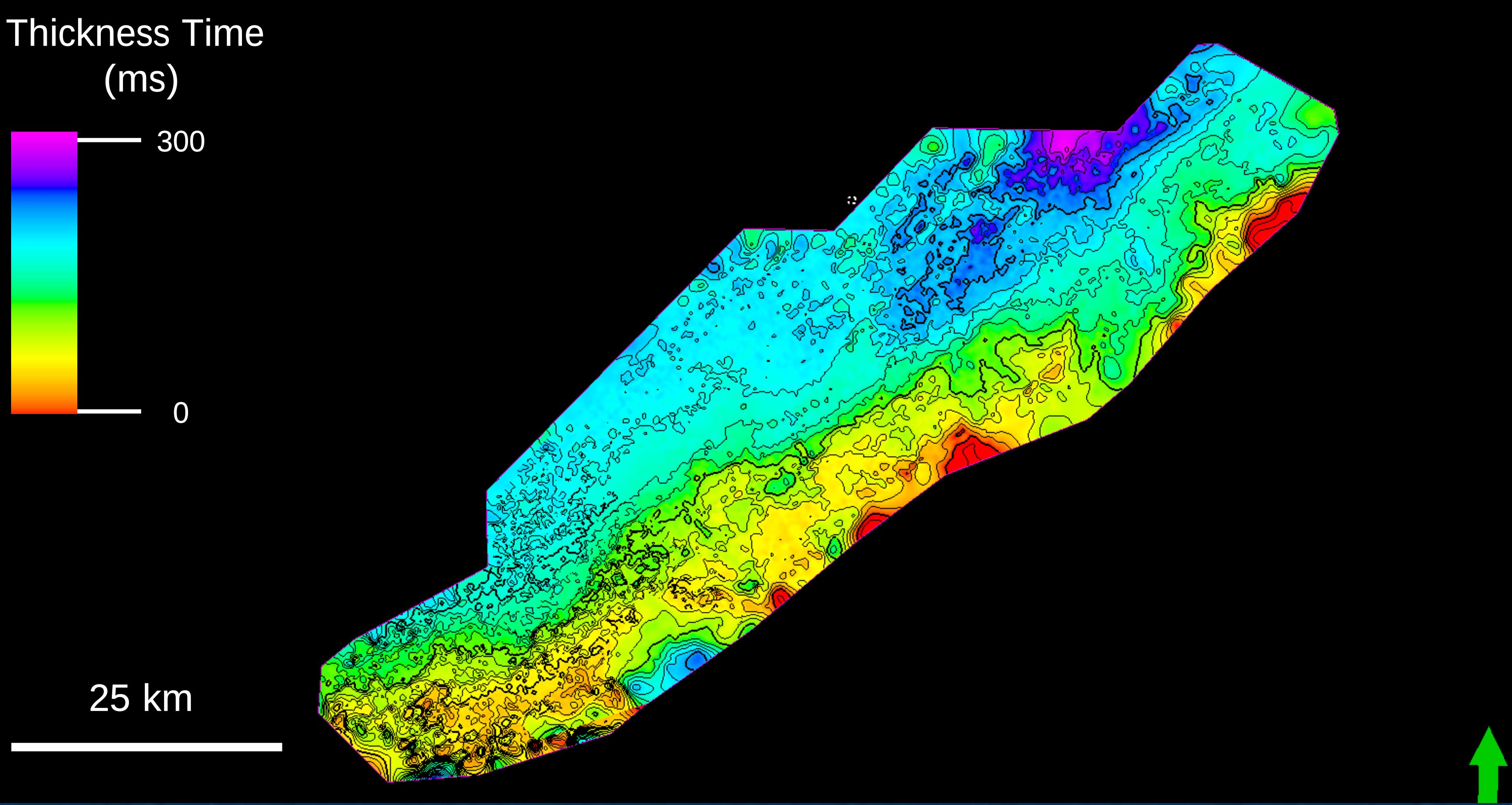
Horizon Slice 29 ms above J40 Surface (g9pan1e survey)



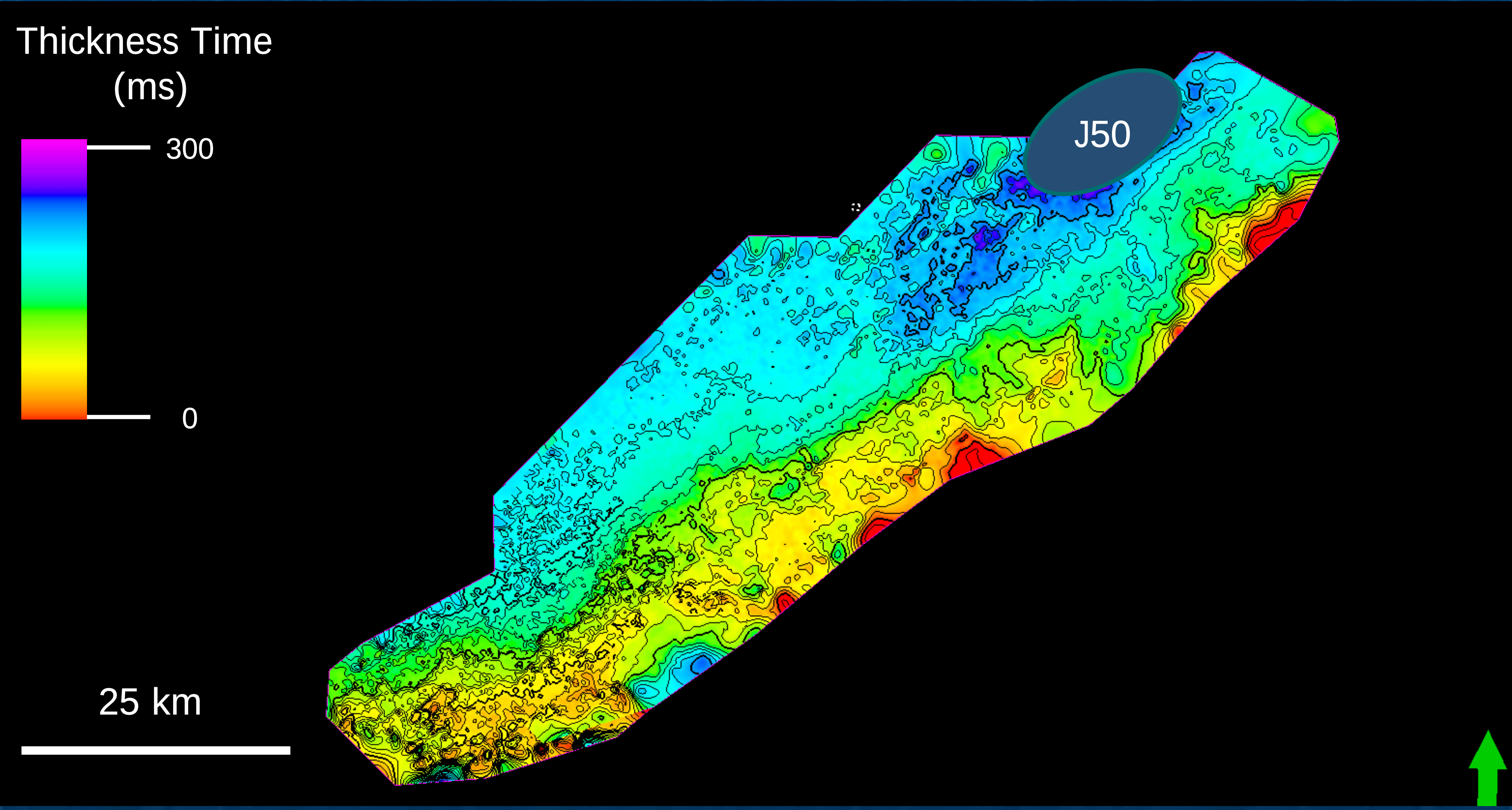
J47-J50 Isopach



J50 Isopach: S4 Immediate Post-Rift



J50 Isopach: S4 Immediate Post-Rift



Conclusions

- An integrated surface interpretation workflow allows for the use of a suite of information to inform on the spatial and temporal deposition of potential reservoirs
- Depocenter location in the Dampier Sub-basin changed through time
  - Not always located in modern structural “basin center”
  - Fault movement was asymmetrical and fault initiation (S2) extension is taken up by multiple faults until the border fault network links up and takes over the majority of extensional slip
  - Footwall uplift restricts transverse inputs, leading to development of major axial sediment deposition for much of rift basin evolution
  - Transverse sediment inputs are most abundant during rift climax

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