

Reservoir Distribution on a Salt-Influenced Deep-Water Slope: Santos Basin, Offshore Brazil*

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Abstract

Salt tectonics controls reservoir distribution, trapping development, and hydrocarbon migration in salt-influenced basins. It is therefore critical for the oil industry to understand how sediment interacts with salt in such basins. Previous studies in the Santos Basin, offshore Brazil suggest that most clastic sediment was trapped behind the ‘Albian Gap’, a salt-controlled, intra-slope depocentre. As a result, no significant post-salt deep-water exploration has been conducted on the assumption that little or no clastic sediment was dispersed basinward. In this study we challenge this notion by integrating 3D seismic and borehole data to determine the distribution and types of deep-water reservoirs of the previously underexplored post-salt sequence. We identify six main seismic facies types within the post-salt sequence, which we relate to the following deep-water depositional elements: (i) channels, (ii) levees, (iii) lobes, (iv) mass-transport complexes (MTCs), and (v) background deposits. We recognise three main tectono-stratigraphic phases during deposition of the post-salt sequence. During the first phase (Turonianmiddle Campanian), channels, lobes, and MTCs were confined within proximal minibasins and to the hanging walls of landward-dipping, salt-detached listric faults. During the second phase (middle Campanian-Maastrichtian), channels and lobes eventually filled and bypassed proximal minibasins, with deposition then occurring further downslope in distal minibasins. In these distal minibasins, salt-induced syn-depositional seabed deformation, caused: (i) channel diversion around salt-cored highs; (ii) asymmetric levee deposition, and uplift and rotation of levees on minibasin flanks; (iii) lateral channel migration, expressed in the form of lateral accretion packages (LAPs); and (iv) confinement of lobes. During the final phase (Maastrichtian-to-middle Oligocene), continued rise of proximal salt walls dissected previously deposited deep-water systems. In addition, diapir- and shelf-edge sourced MTCs filled the minibasins, and locally capped and spilled across flanking salt walls. These results have implications for post-salt hydrocarbon prospectivity in the Santos Basin, with a range of reservoir types and trapping styles being developed in this previously underexplored interval. In addition, the results of our study can be applied to other basins, where syndepositional salt-induced seabed deformation controls reservoir deposition and architecture.

Selected References

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Modica, C.J., and E.R. Brush, 2004, Postrift Sequence Stratigraphy, Paleogeography, and Fill History of the Deep-Water Santos Basin, Offshore Southeast Brazil: *American Association of Petroleum Geologists Bulletin*, v. 88, p. 923-945.

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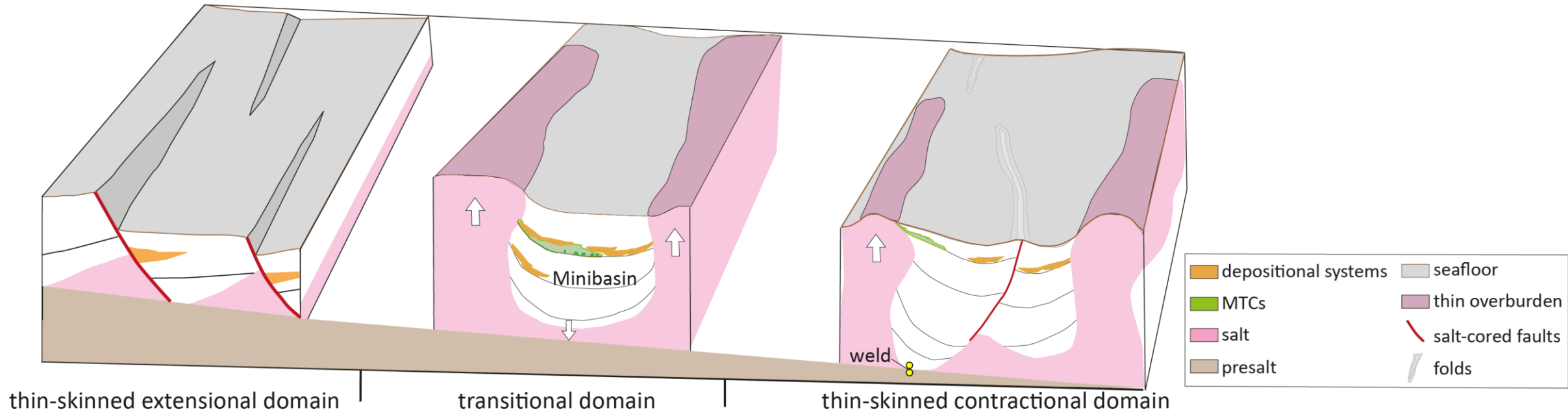
² Department of Earth Science, University of Bergen, Allegaten 41, 5007 Bergen, Norway

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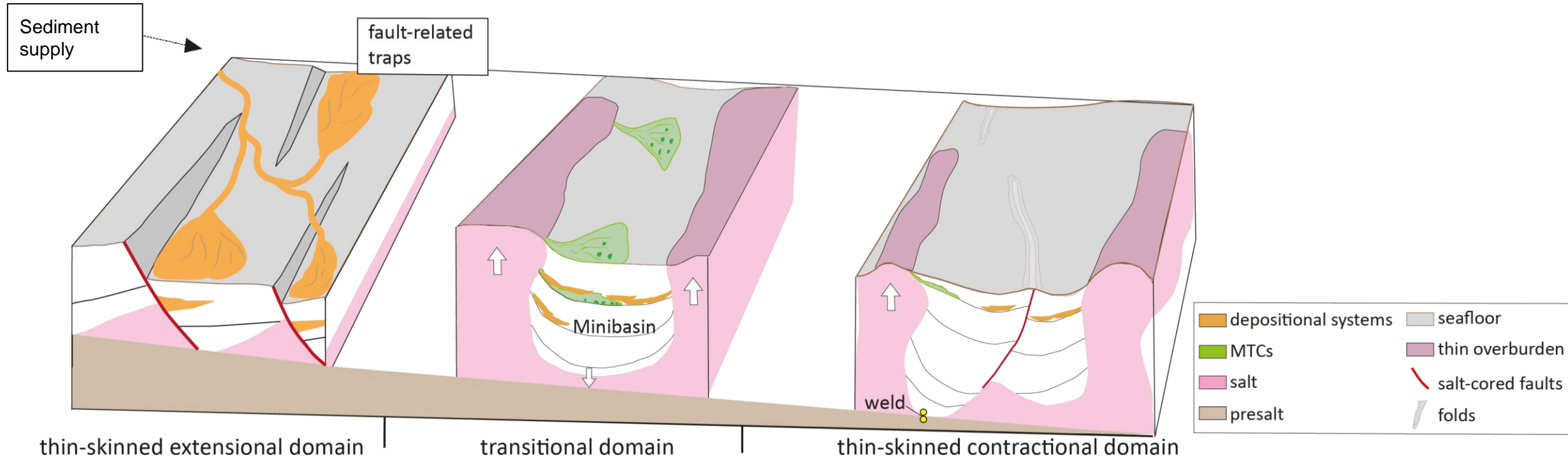
**email: c.rodriguez11@imperial.ac.uk*



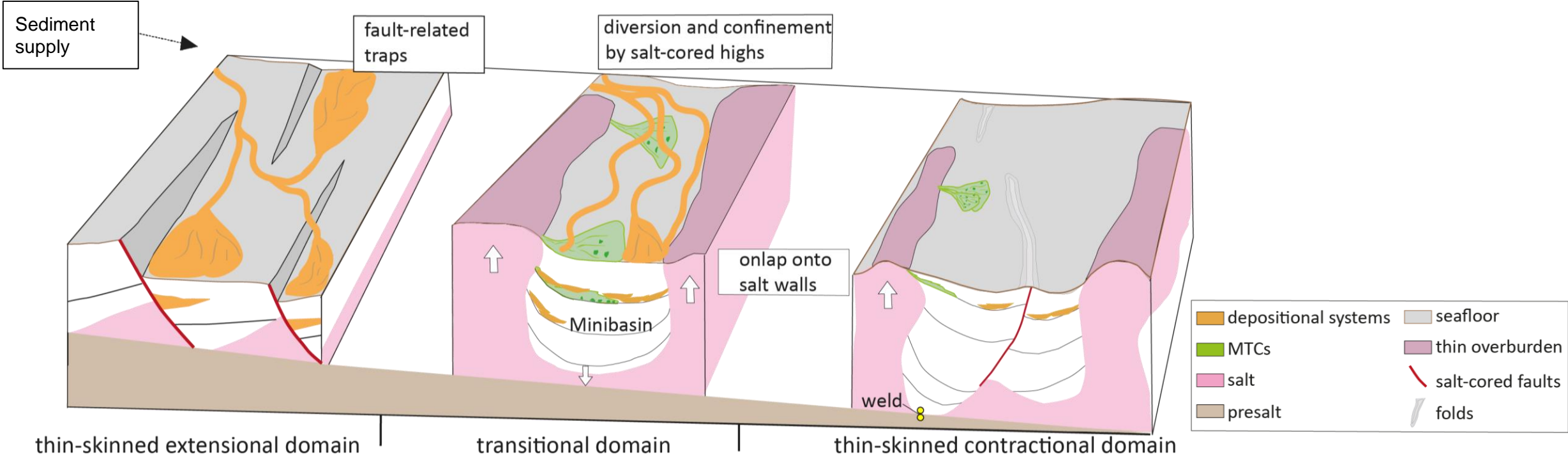
Salt-dominated slopes



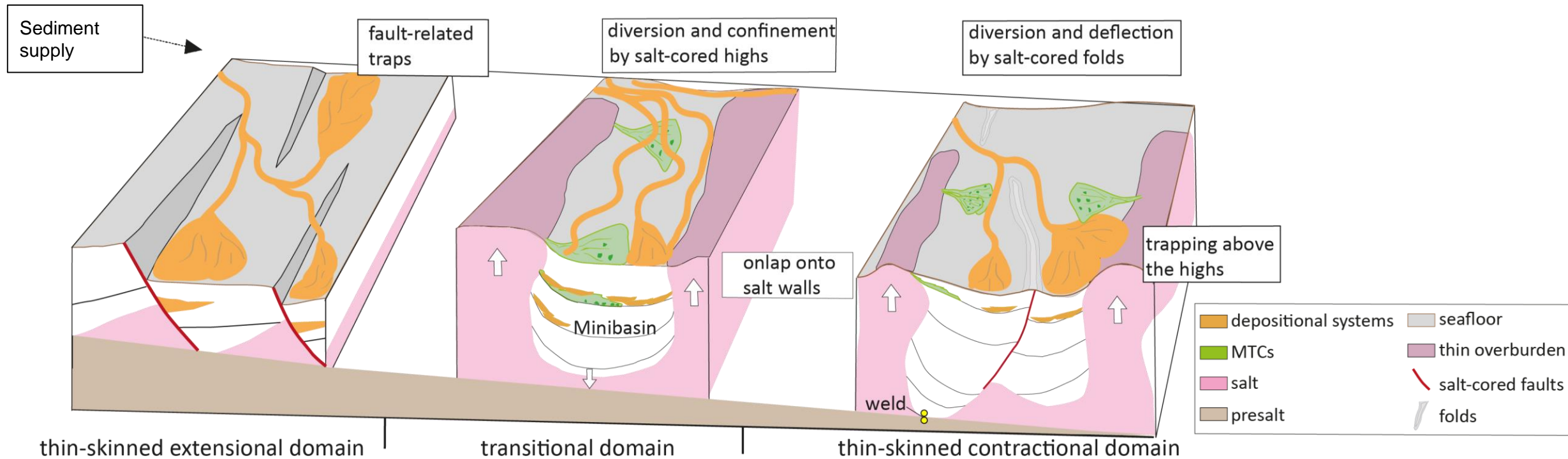
Salt-dominated slopes



Salt-dominated slopes



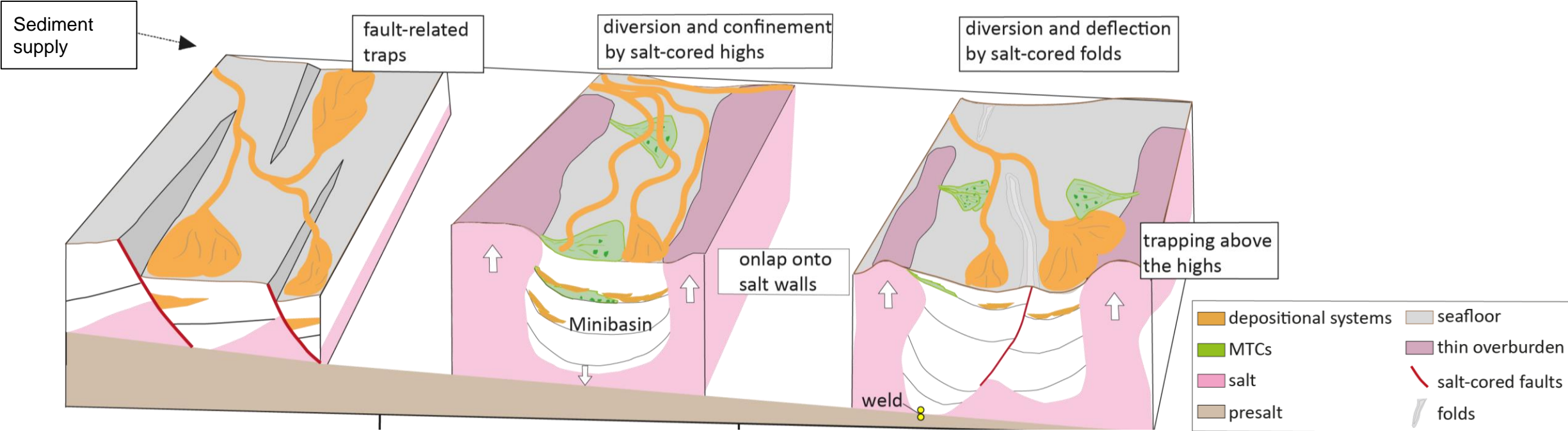
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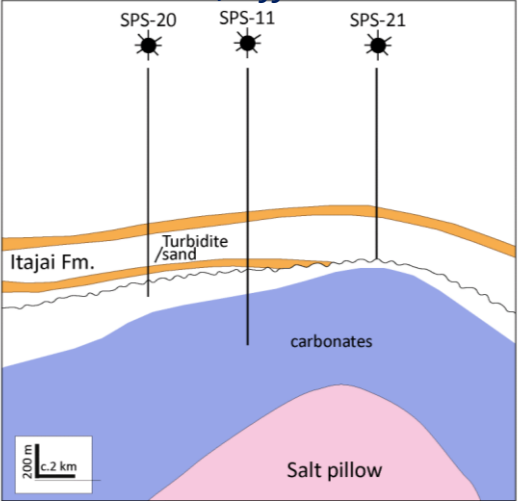
Key controls on reservoir distribution and architecture:

- Nature of deep-water depositional systems
- Salt-related structural styles along the slope
- Timing of deposition relative to salt-induced seafloor deformation

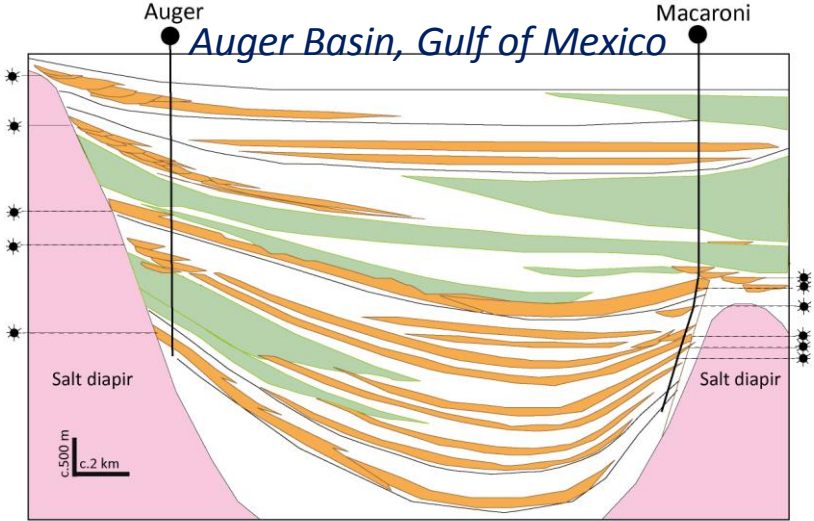
Salt-dominated slopes



Santos Basin, offshore Brazil

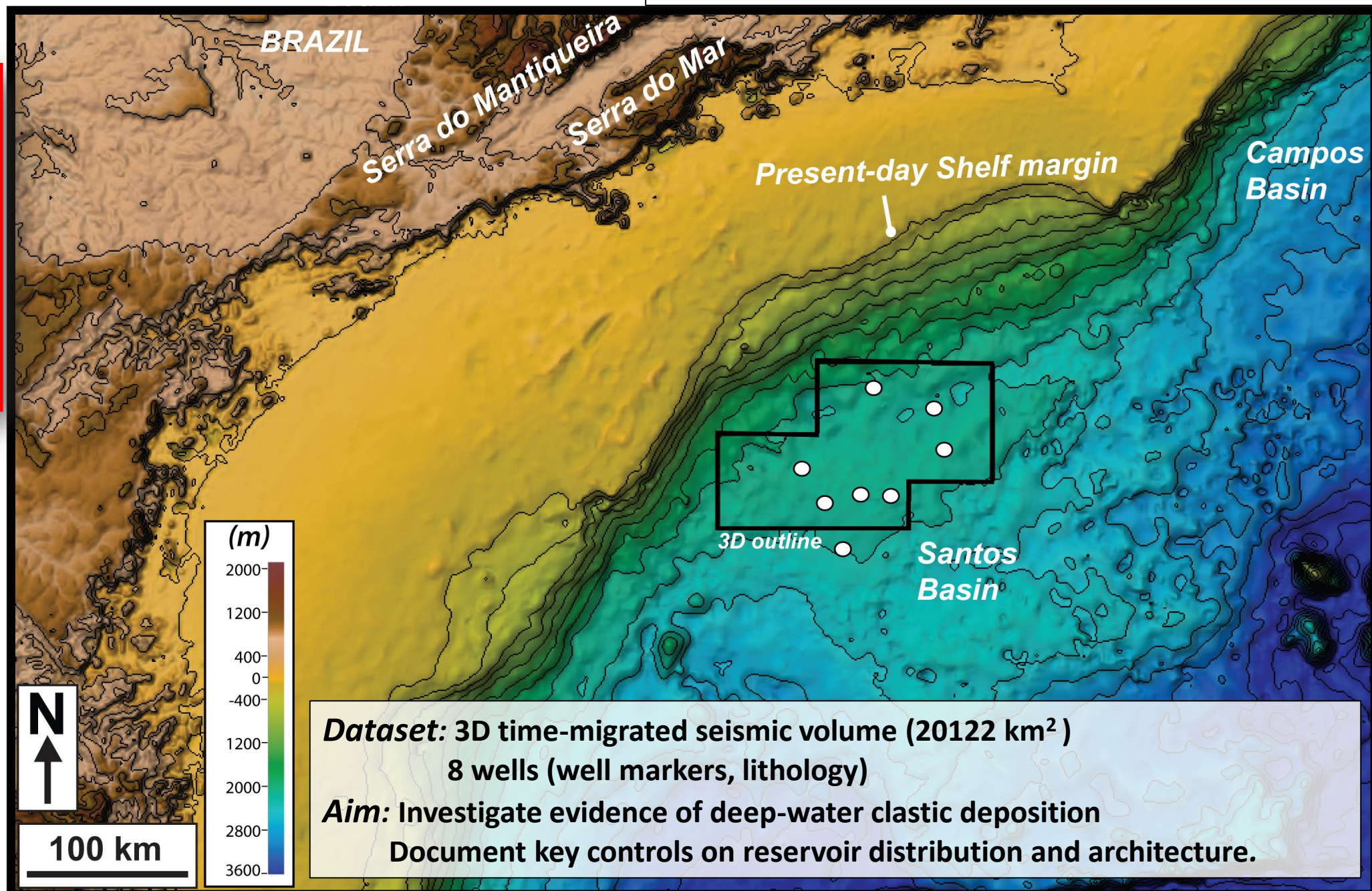


Modified from Riddle et al. (1995)



Modified from Booth et al. (2003)

Study area



Motivation

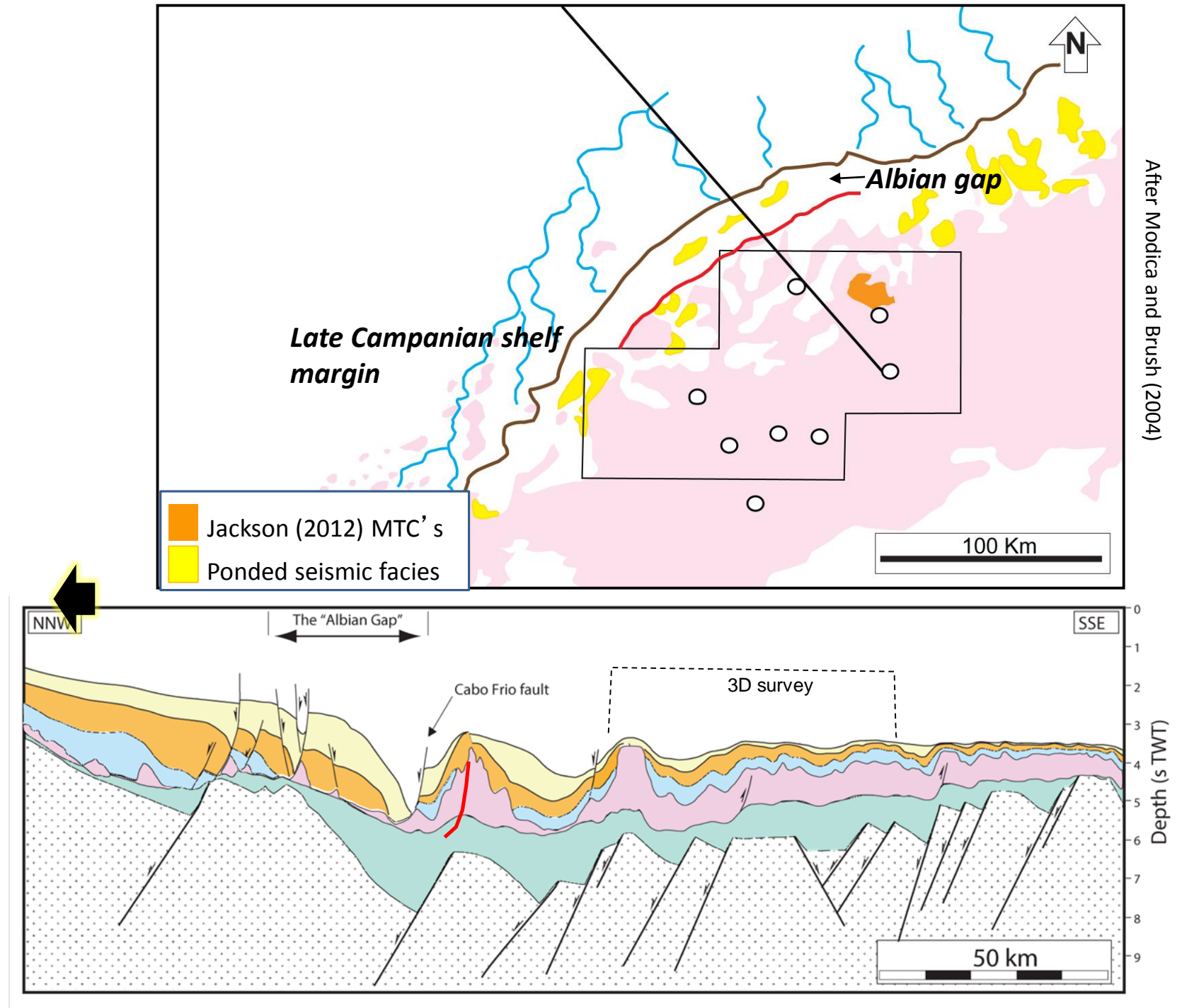
No exploration wells have targeted **post-salt, deep-water** reservoir in the **Santos Basin, offshore Brazil**.

Why?

Motivation

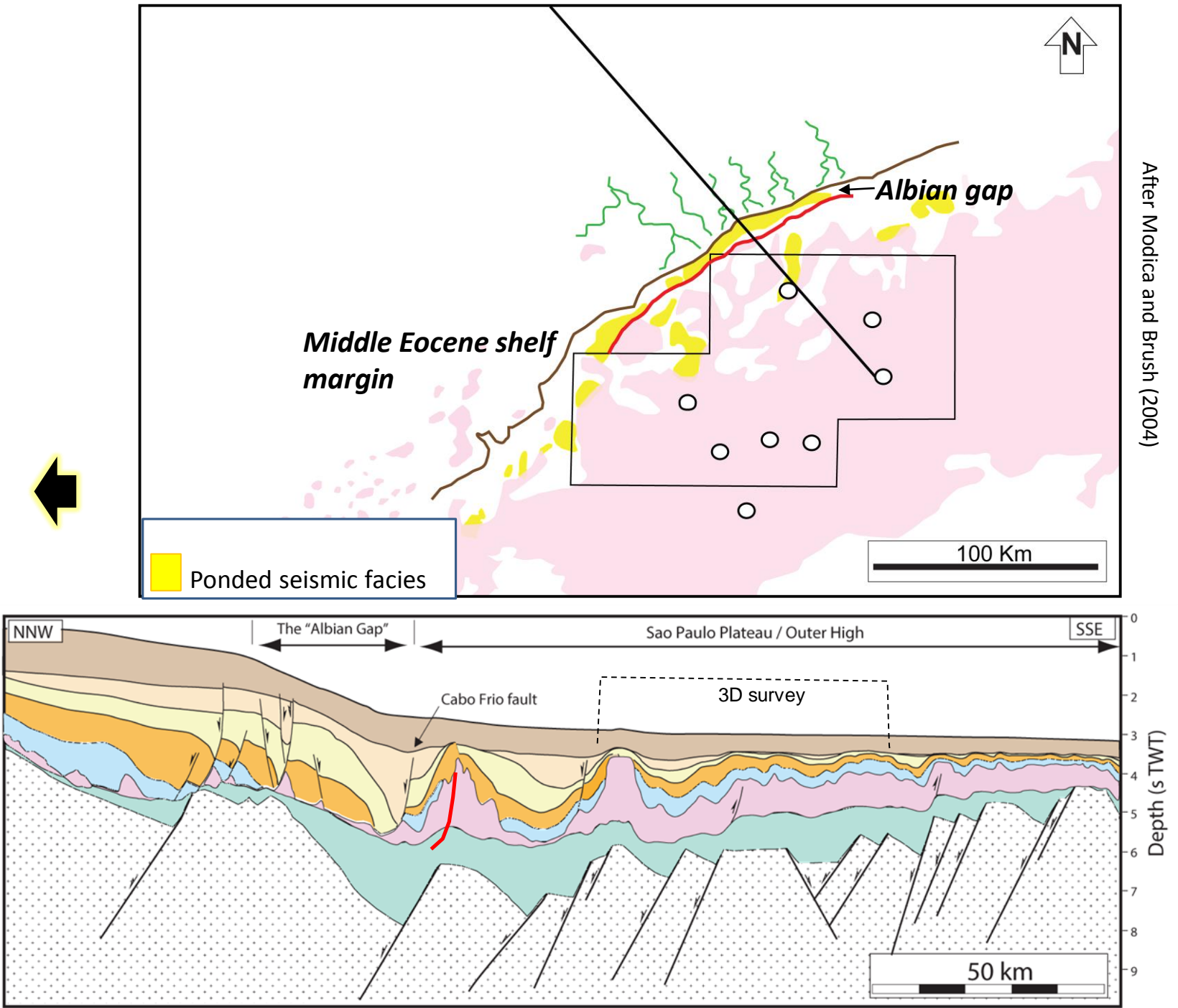
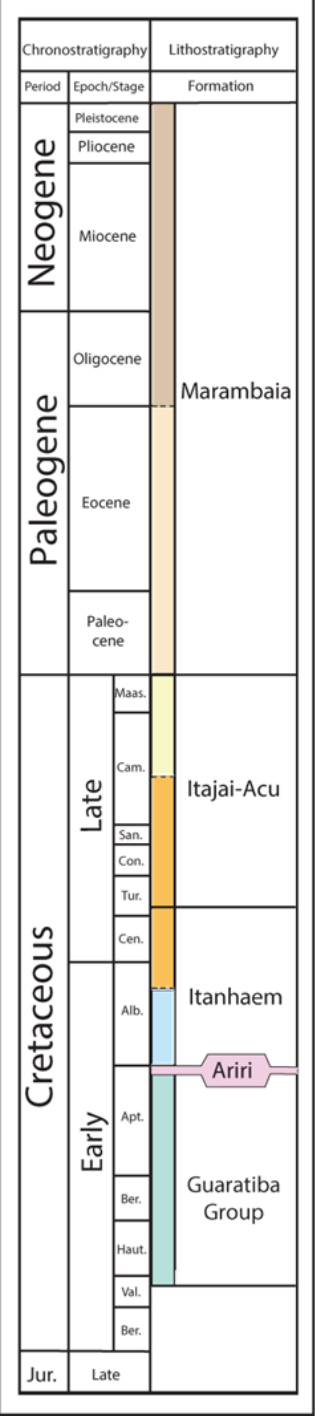
Post-salt clastic sediment trapped in proximal locations behind the Albian Gap

Chronostratigraphy		Lithostratigraphy		
Period	Epoch/Stage	Formation		
Neogene	Pleistocene			
	Pliocene			
	Miocene			
Paleogene	Oligocene			
	Eocene			
			Paleocene	
Cretaceous	Late		Maas.	Itajai-Acu
			Cam.	
		San.		
		Con.		
		Tur.		
		Cen.		
	Early	Alb.	Itanhaem	
		Apt.	Ariri	
		Ber.		
		Haut.	Guaratiba Group	
		Val.		
		Ber.		
		Jur.	Late	



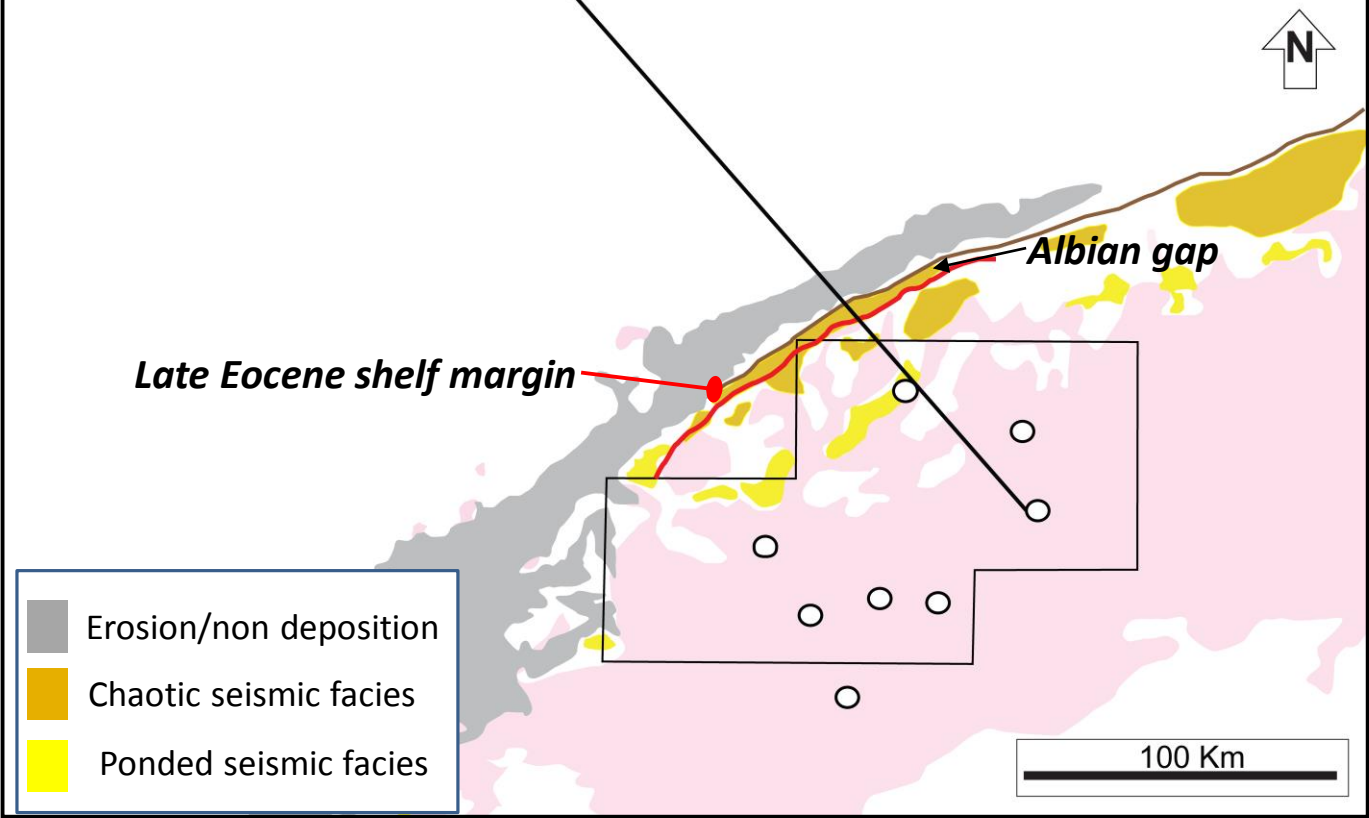
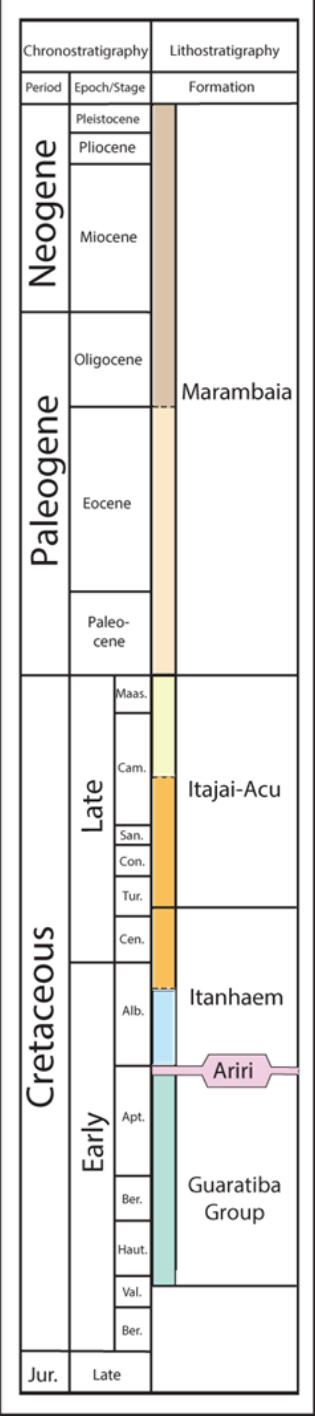
Motivation

Onshore uplift led to change in sediment supply to the North and towards the Campos Basin

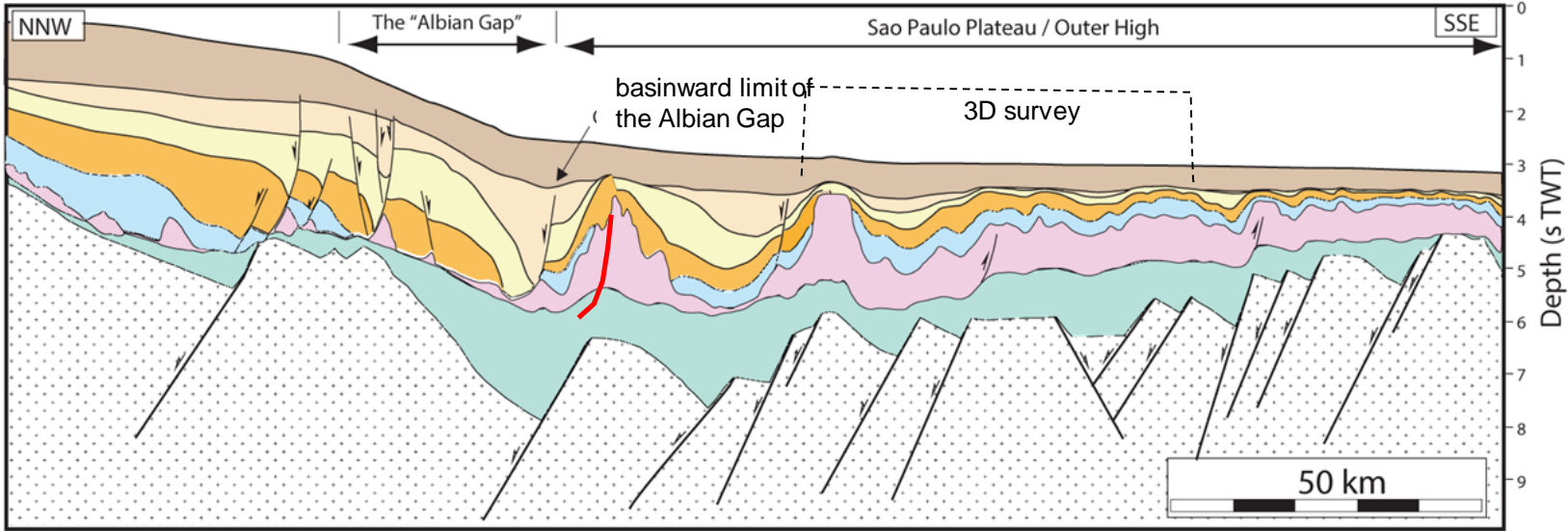


Motivation

Starved shelf.
Failure of the
shelf margin led
to widespread
MTCs deposition

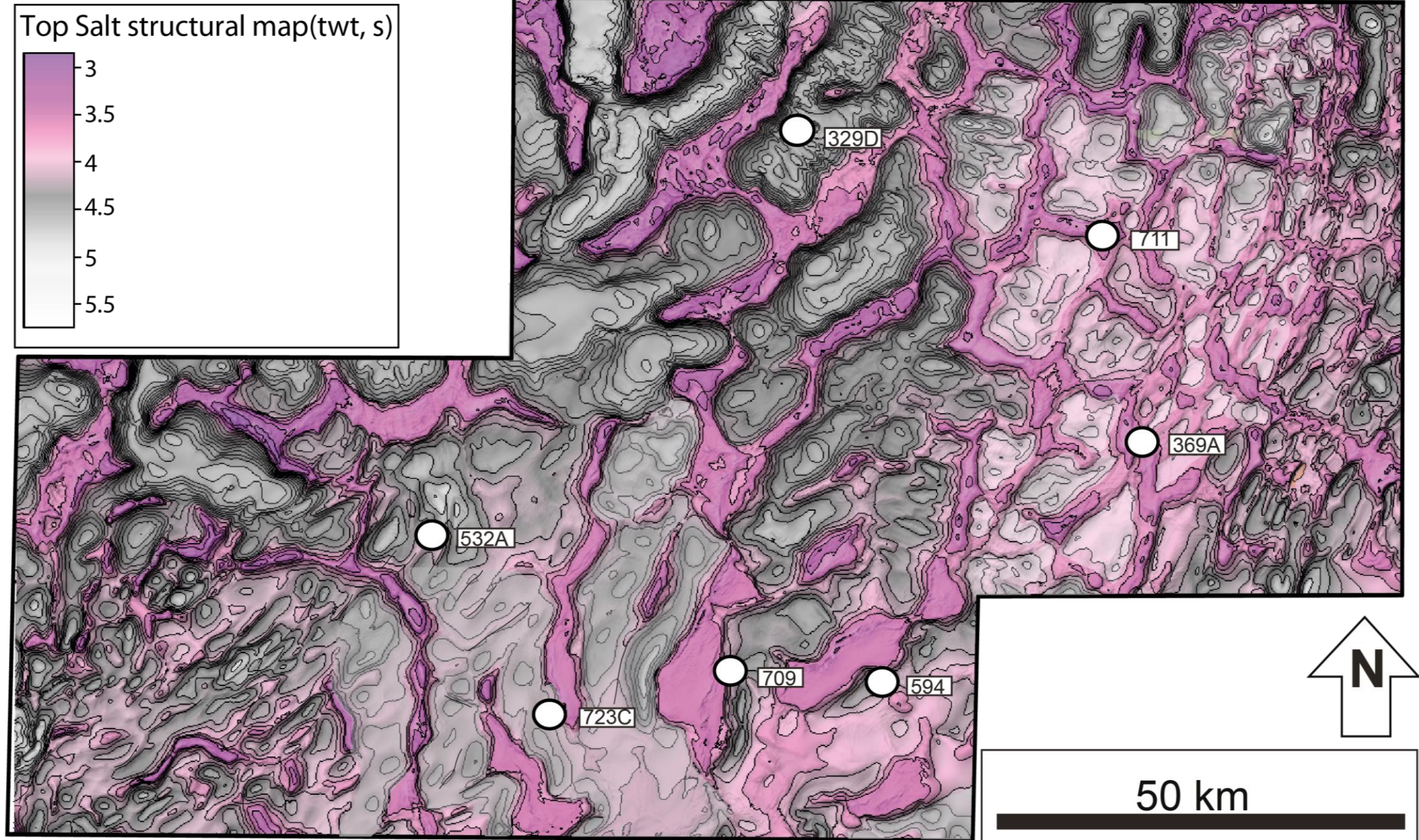


After Modica and Brush (2004)



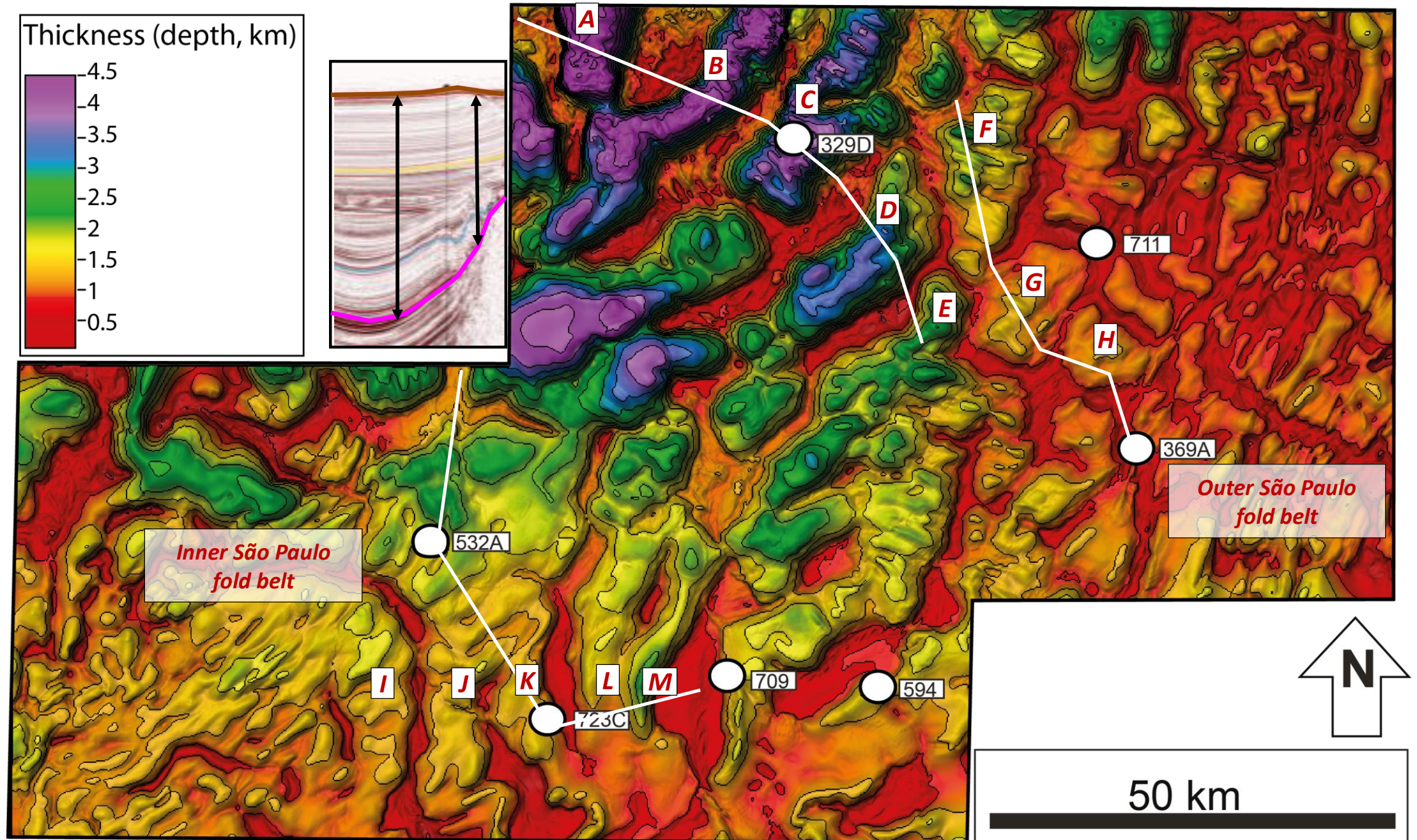
Minibasin structure and stratigraphy

Top salt structure



Minibasin structure and stratigraphy

Post-salt thickness distribution



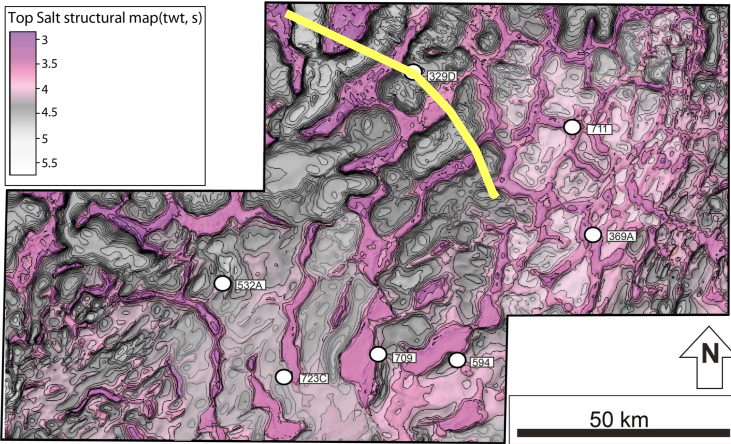
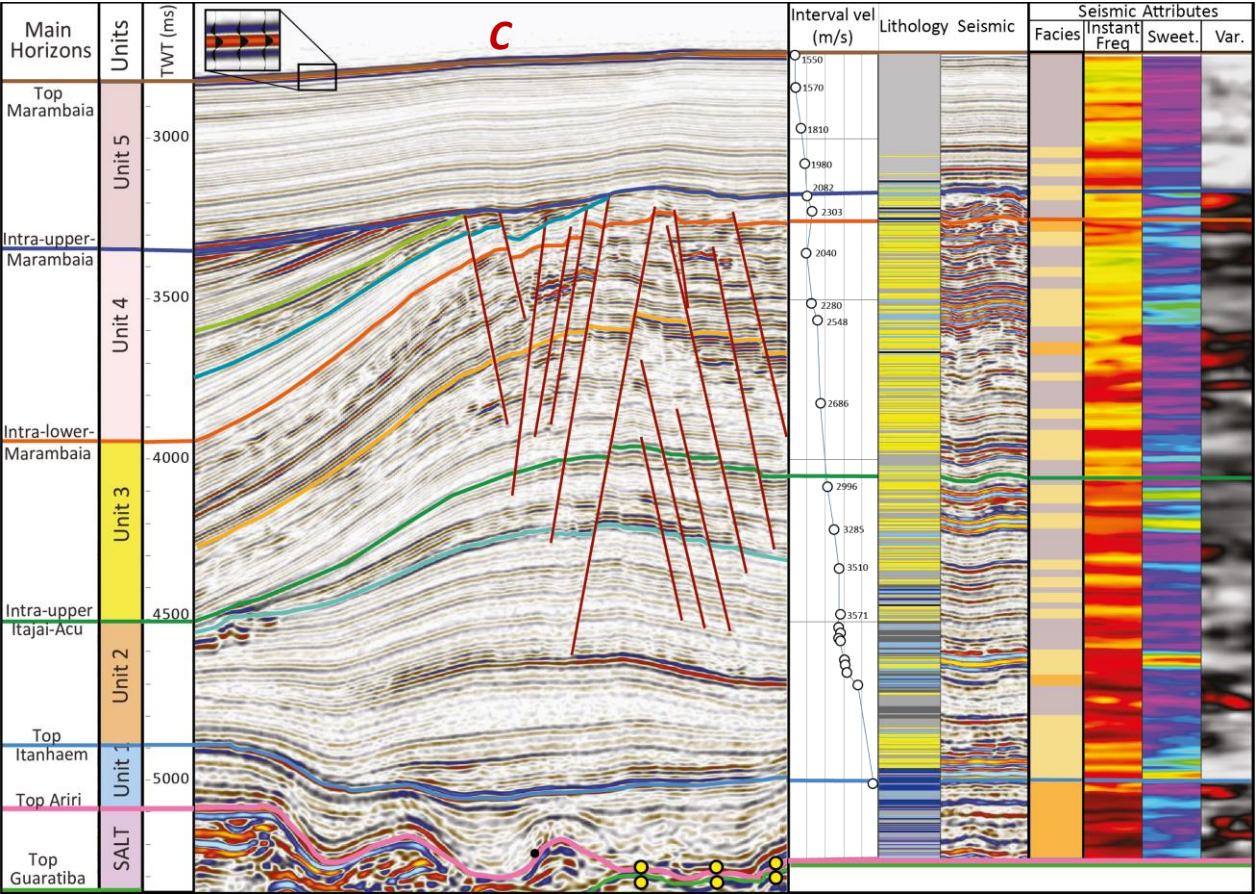
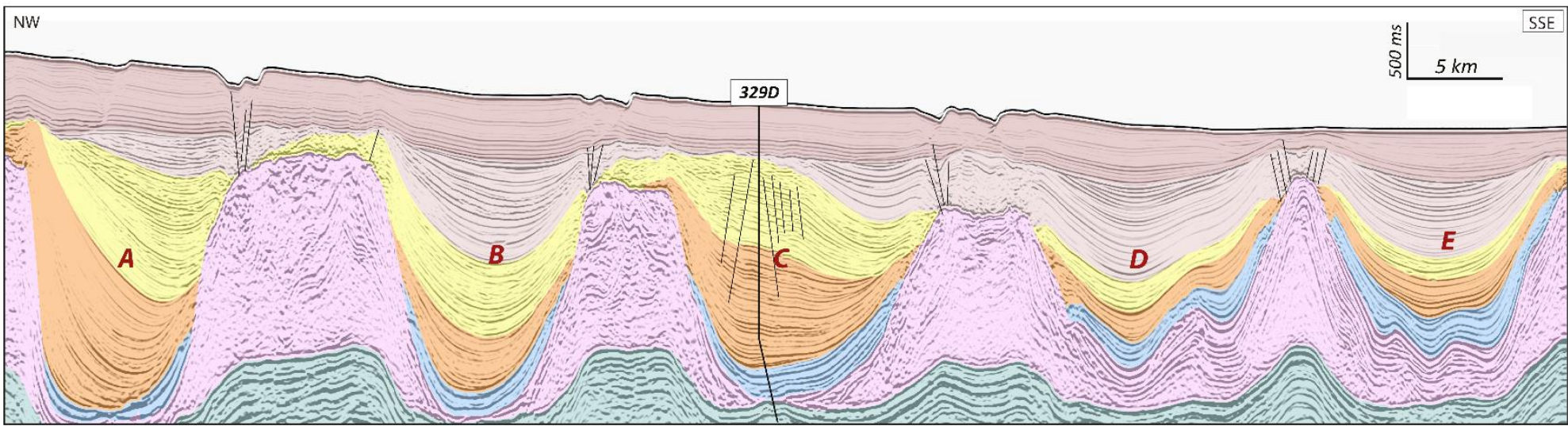
Proximal thick minibasins

> 2.5 km thick

Thin salt (< 500 m) or welded

Upright salt walls

Sandstone-rich units
(c.45%)



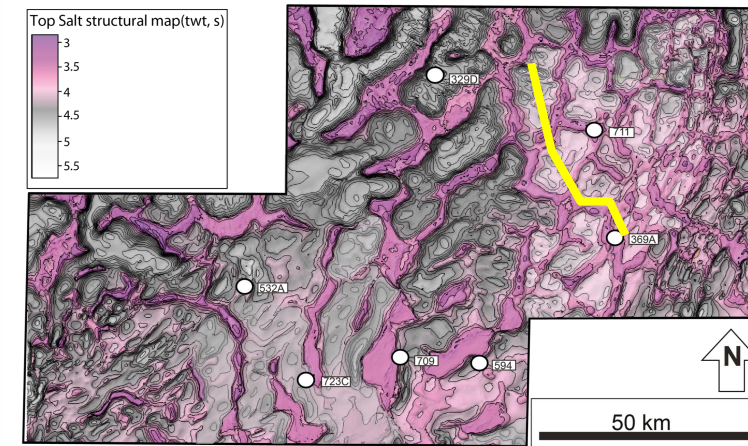
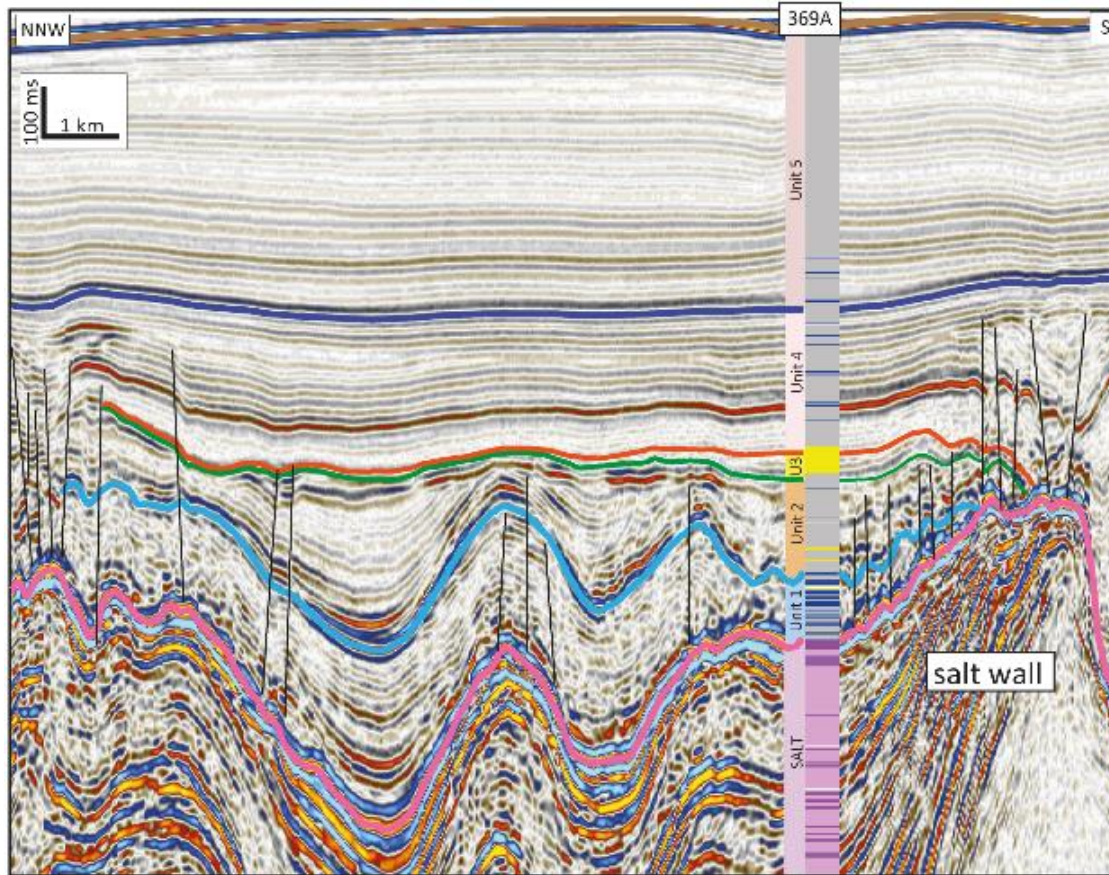
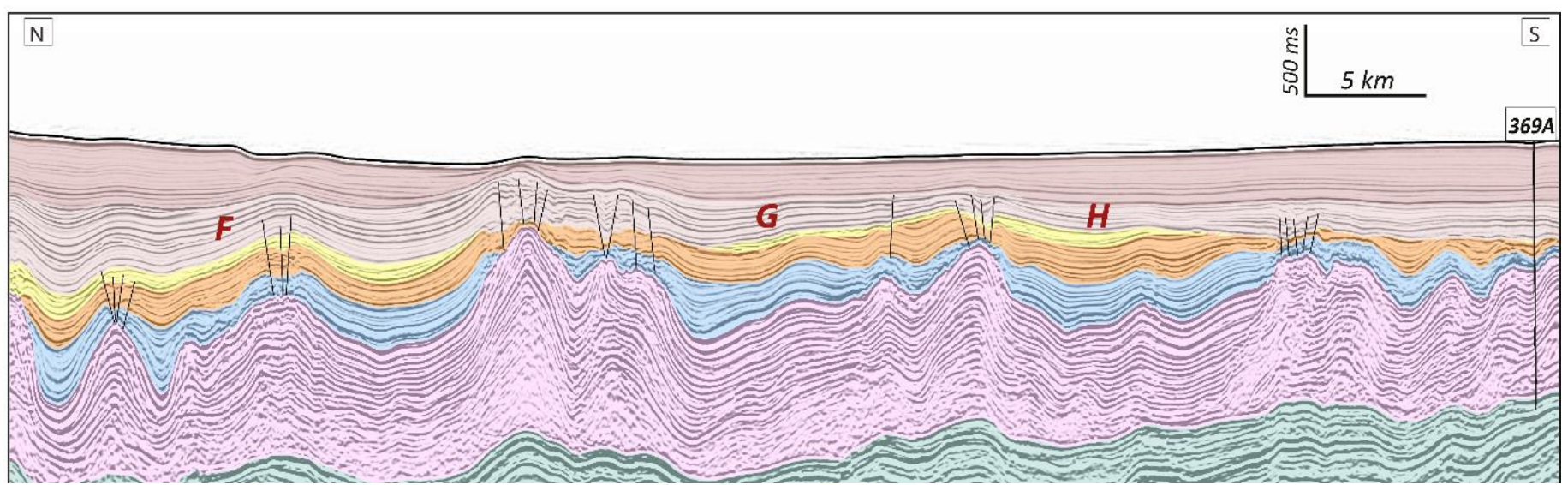
Medial shallow minibasins

< 1.5 km thick

Thick salt (>2 km)

Narrow, nearly-triangular salt
diapirs

Mudstone-dominated units



Distal elongated minibasins

< 1.5 km thin

Thick salt (c. 1km)

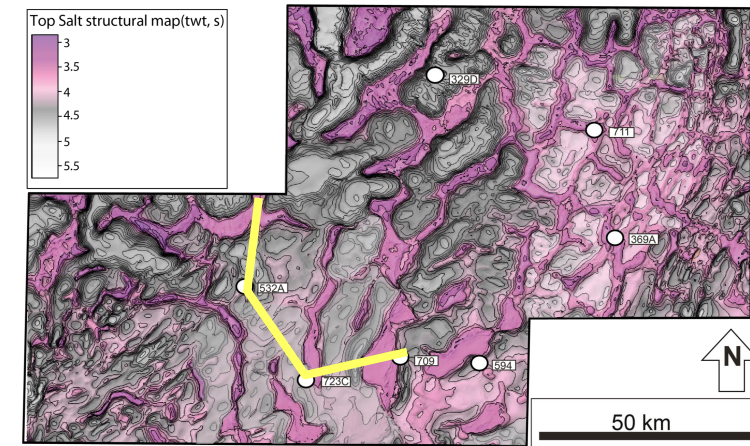
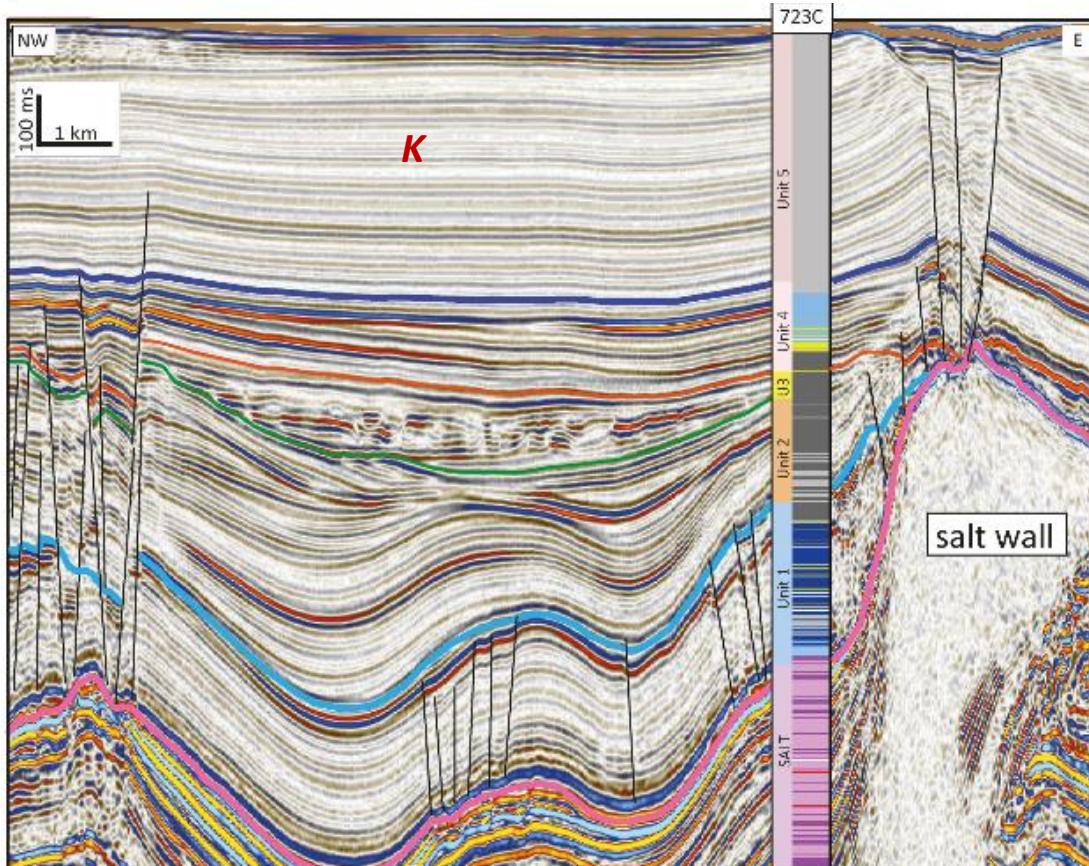
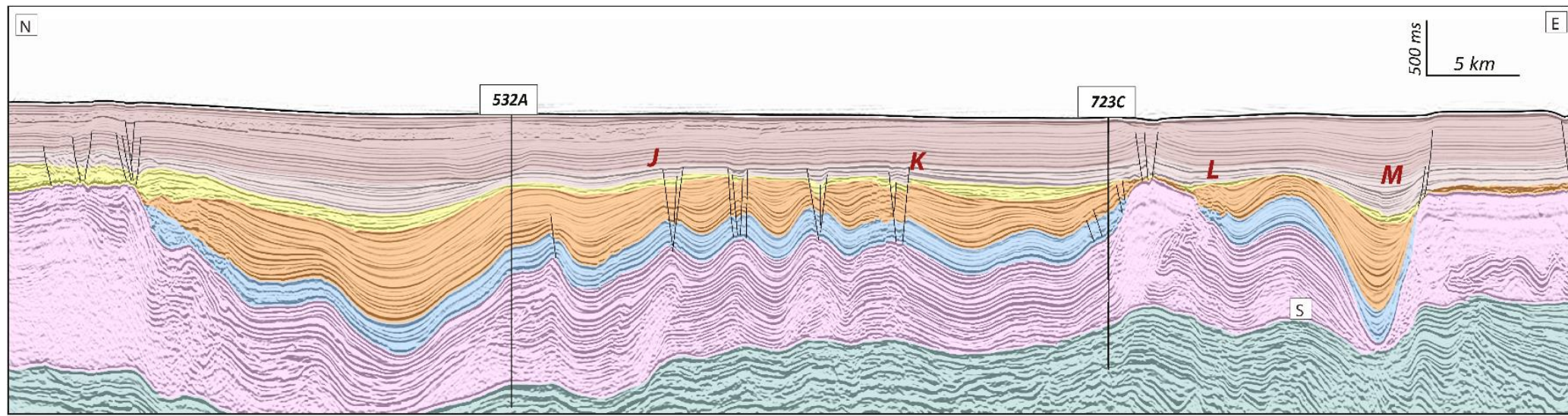
Highly-rugose or

flat-topped

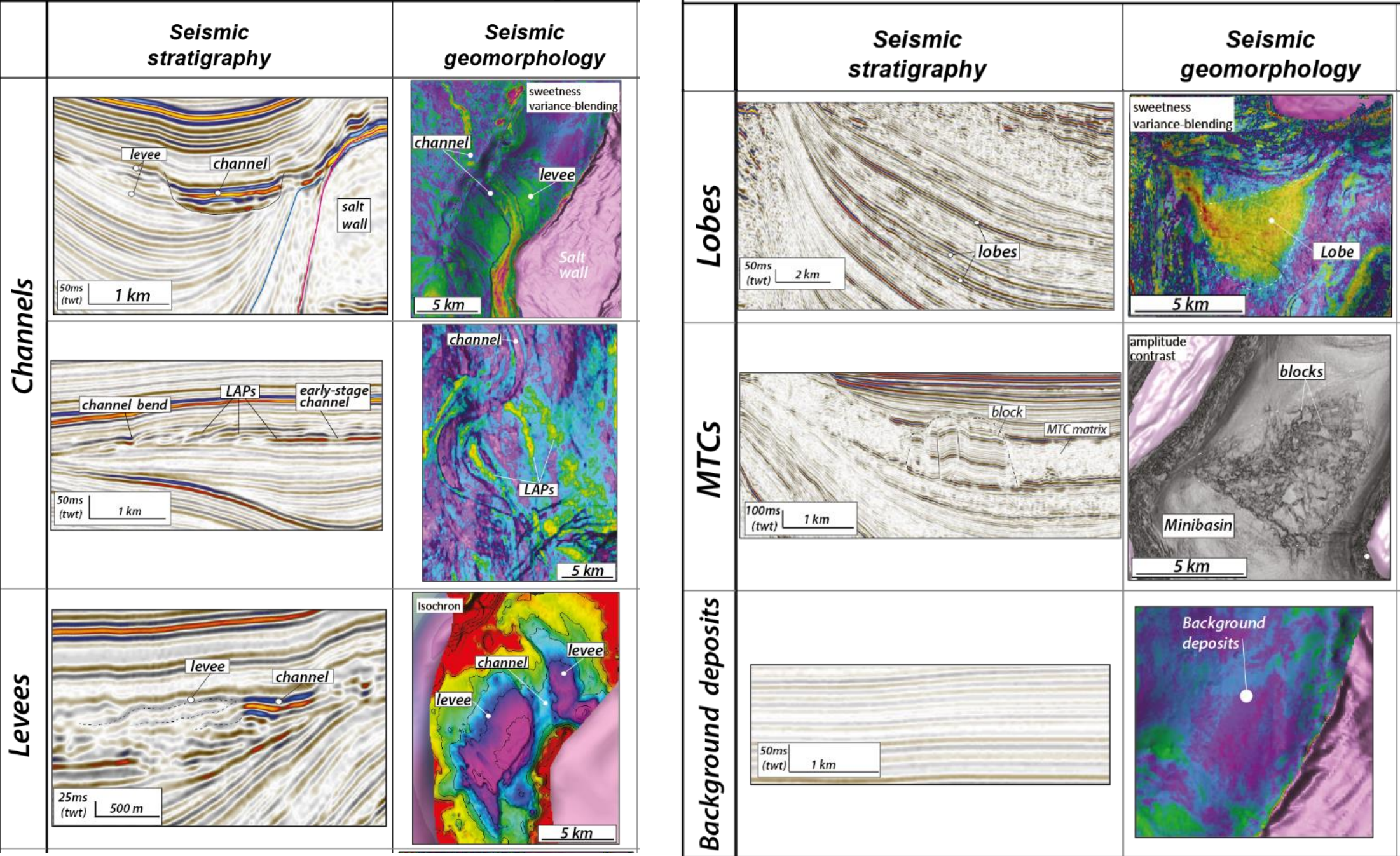
salt walls

Mudstone-

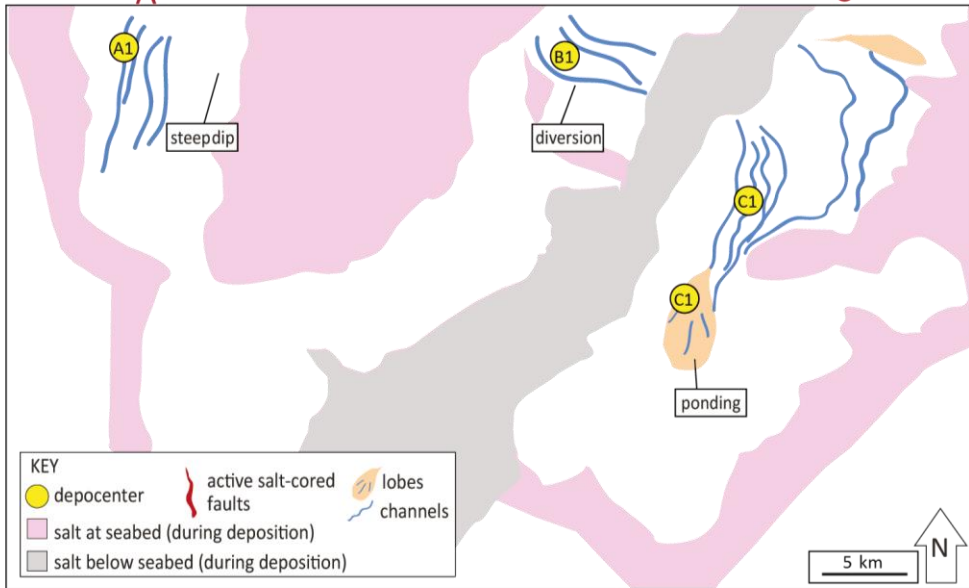
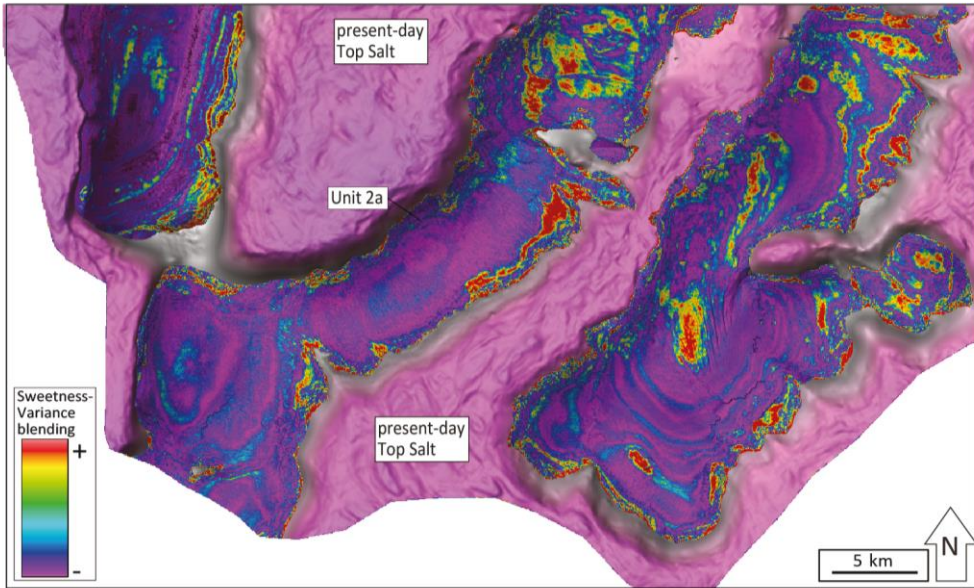
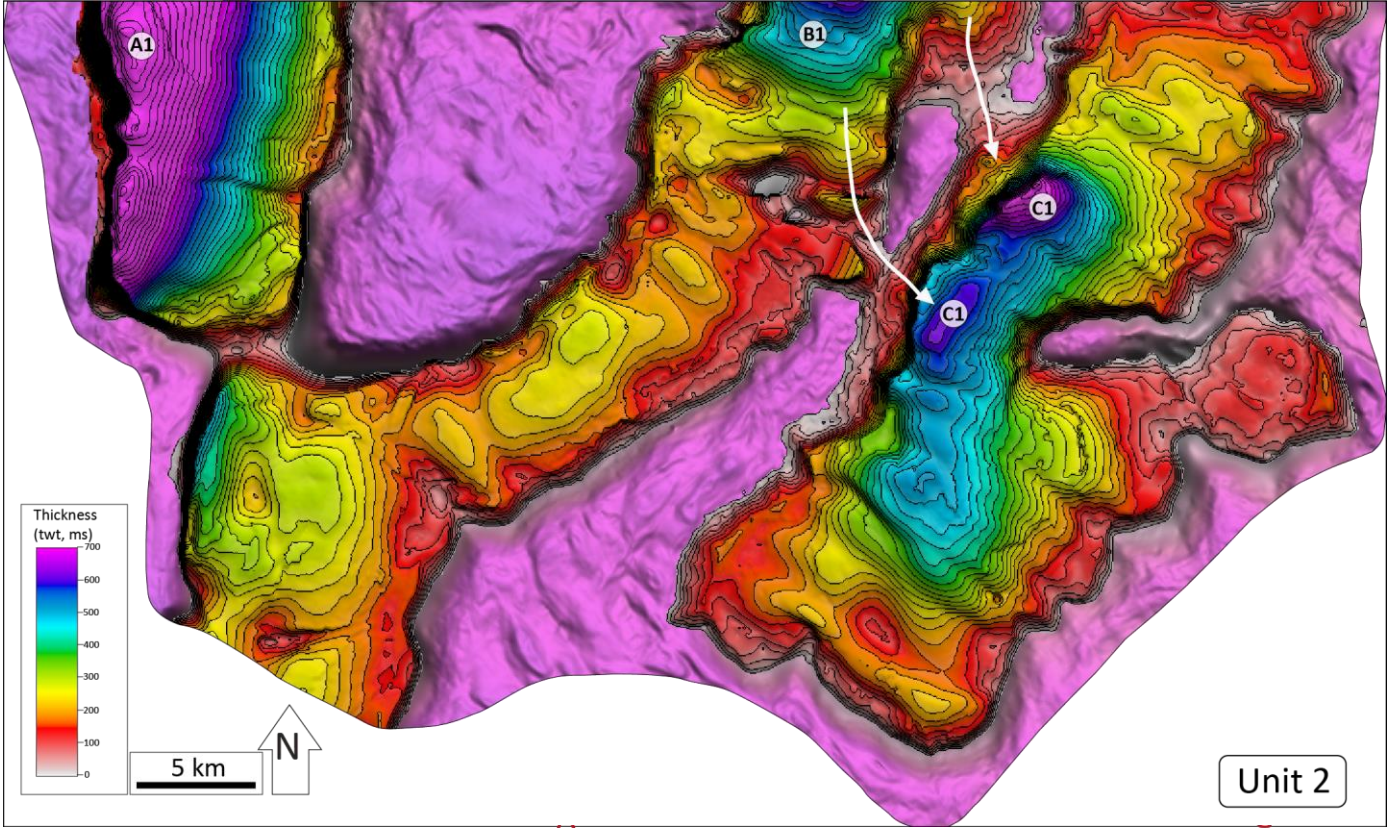
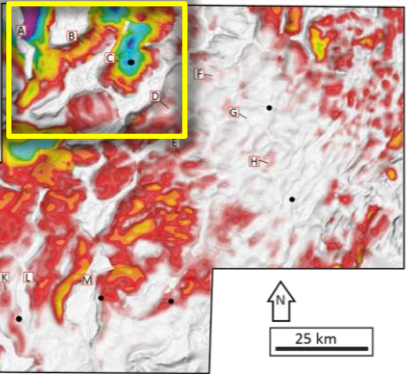
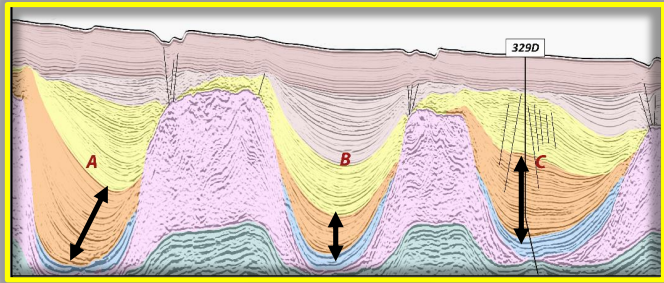
dominated units



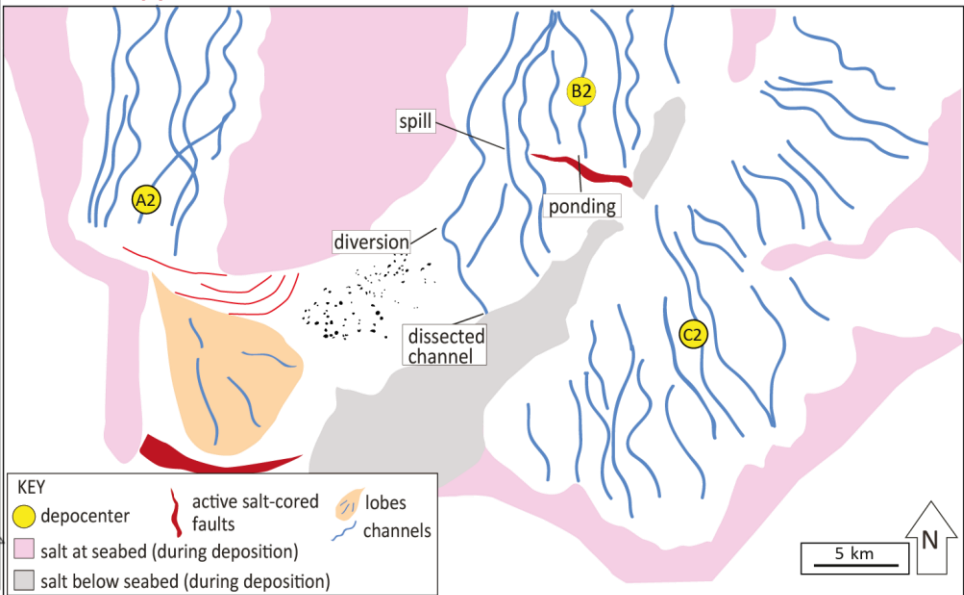
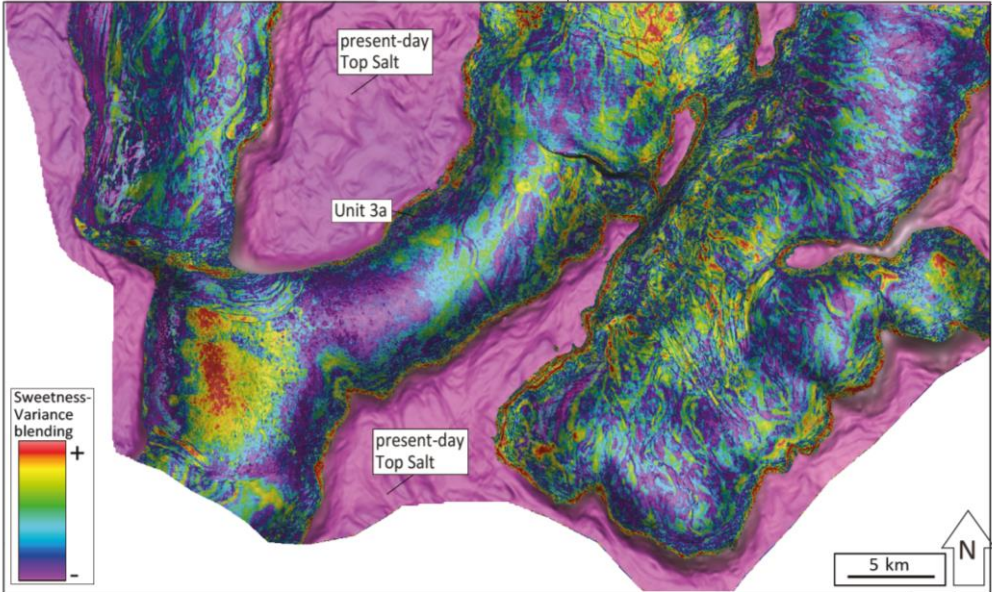
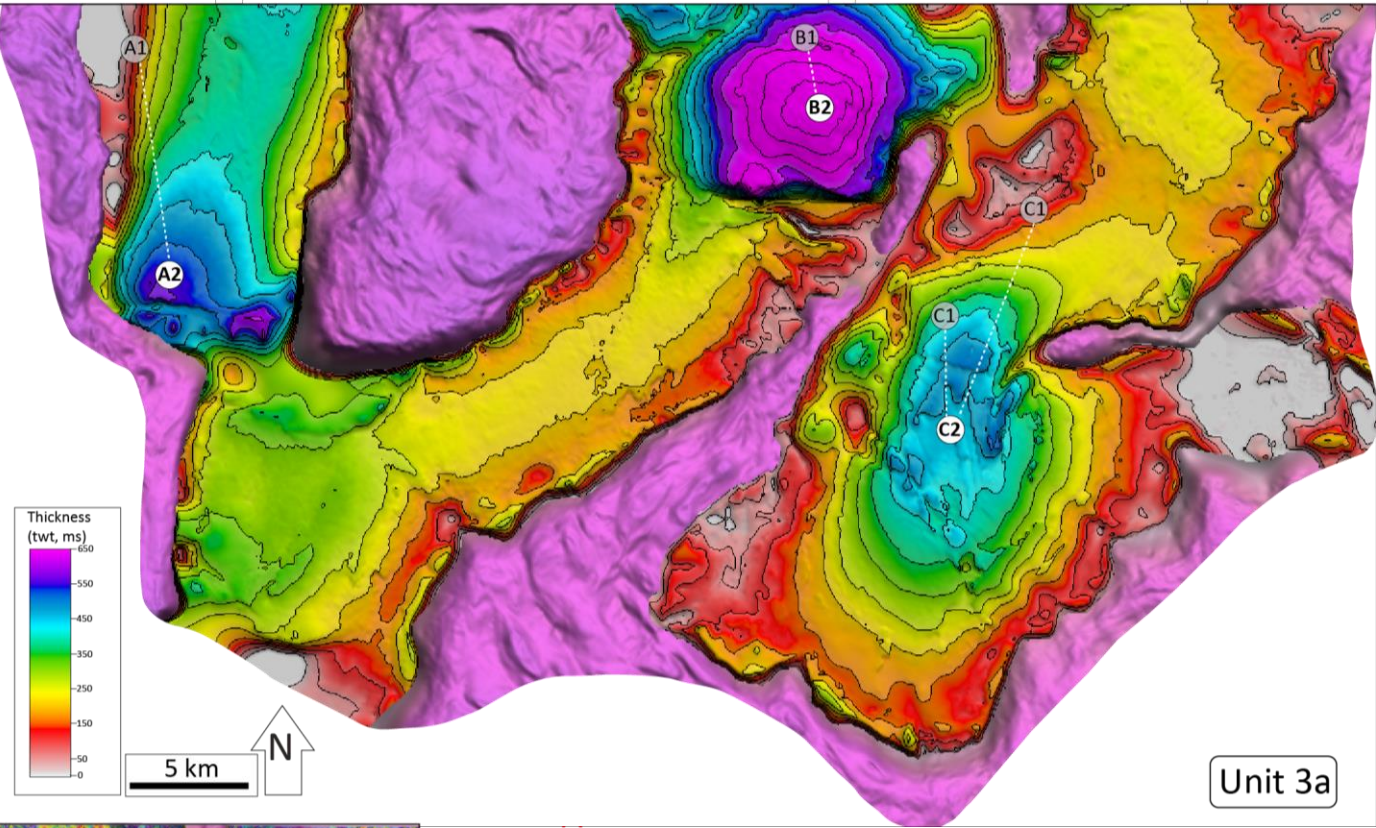
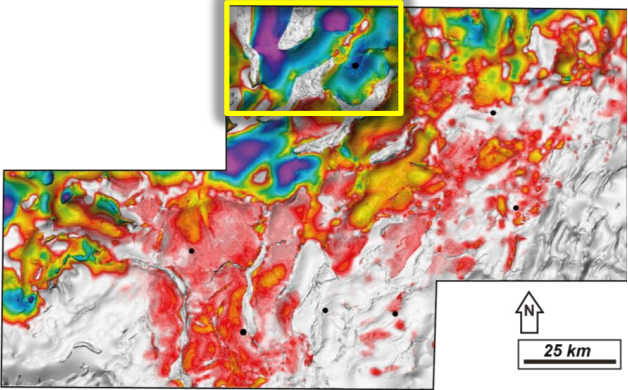
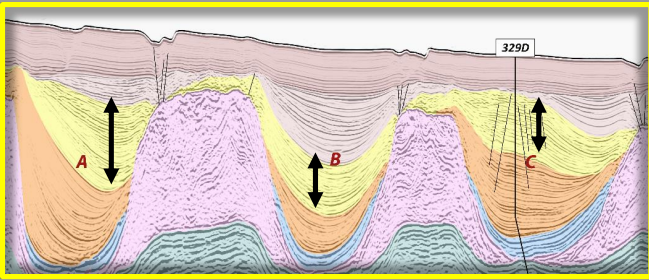
Minibasins seismic facies and depositional elements



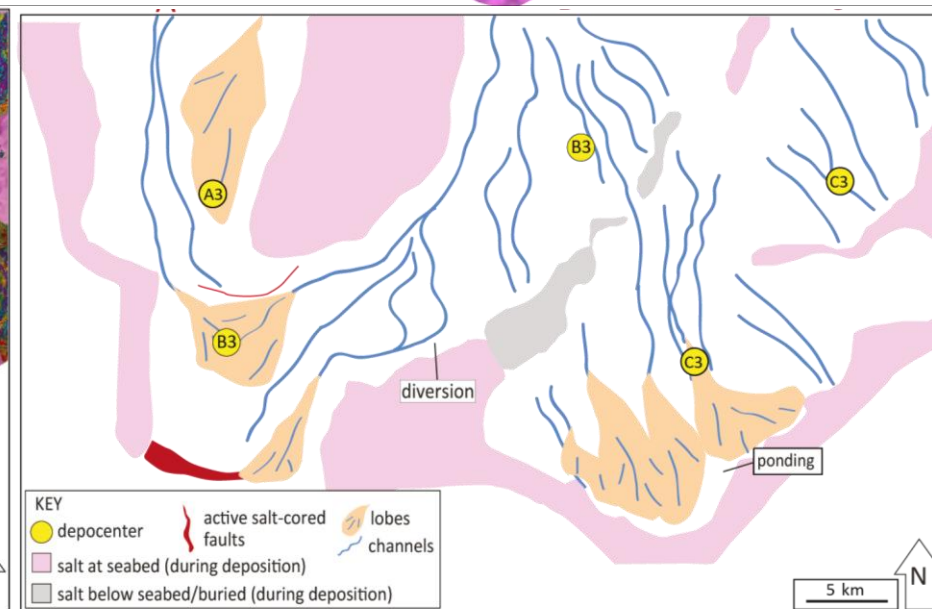
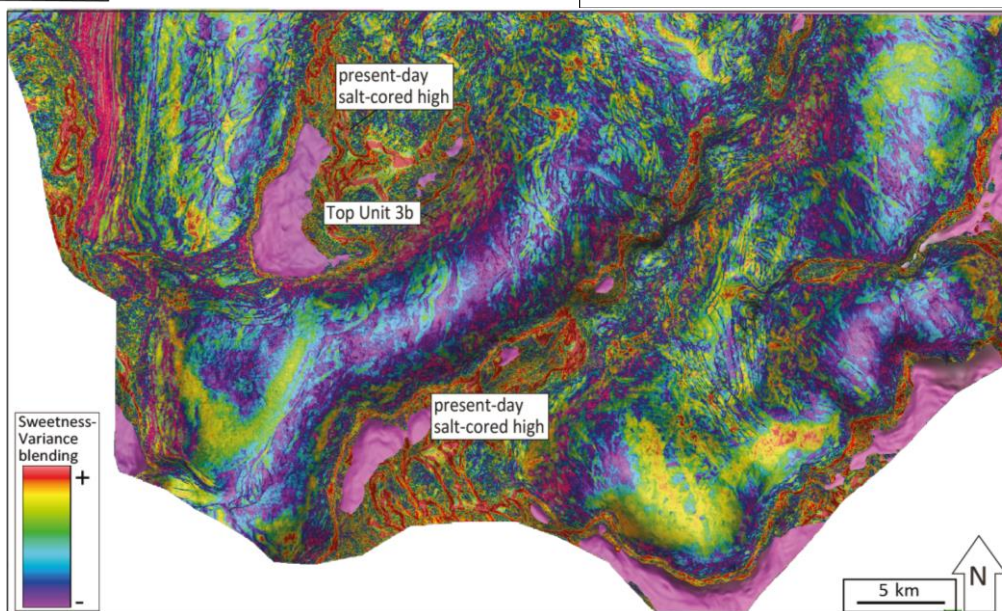
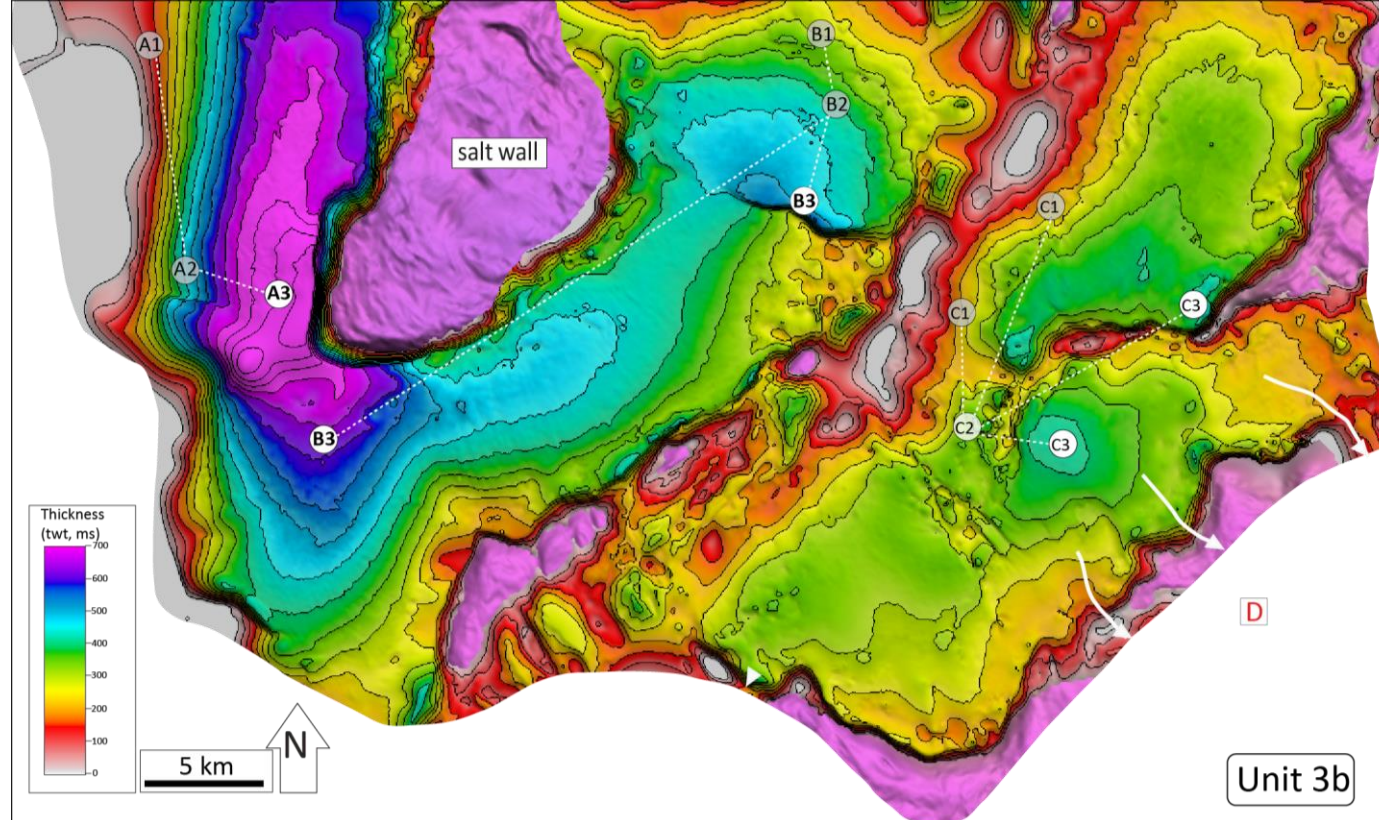
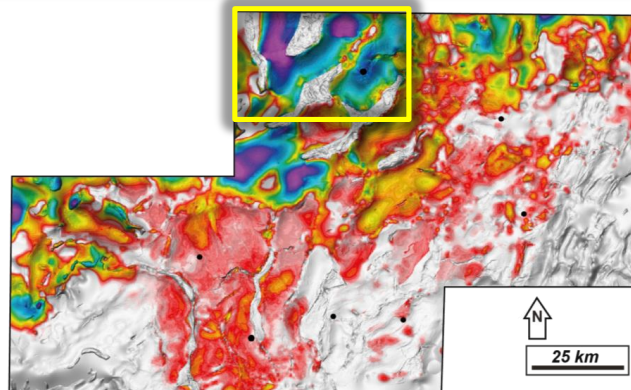
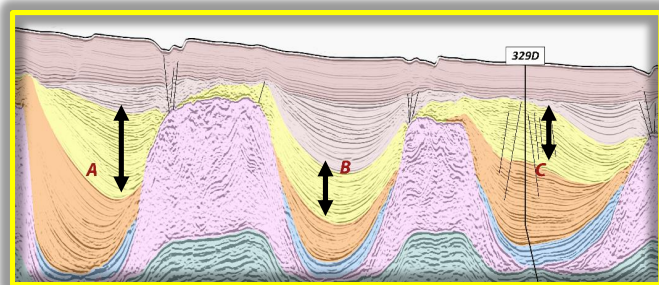
Phase 1



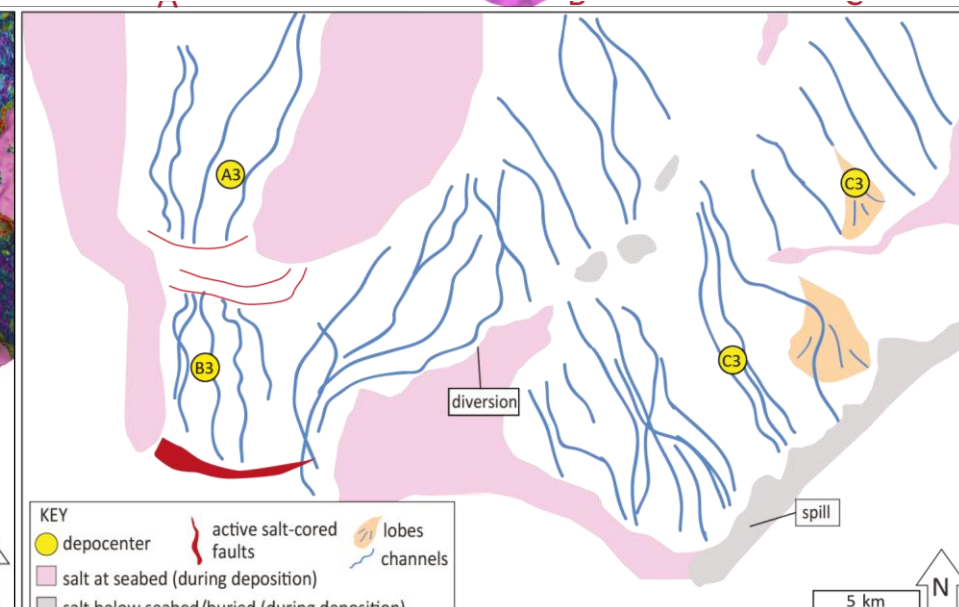
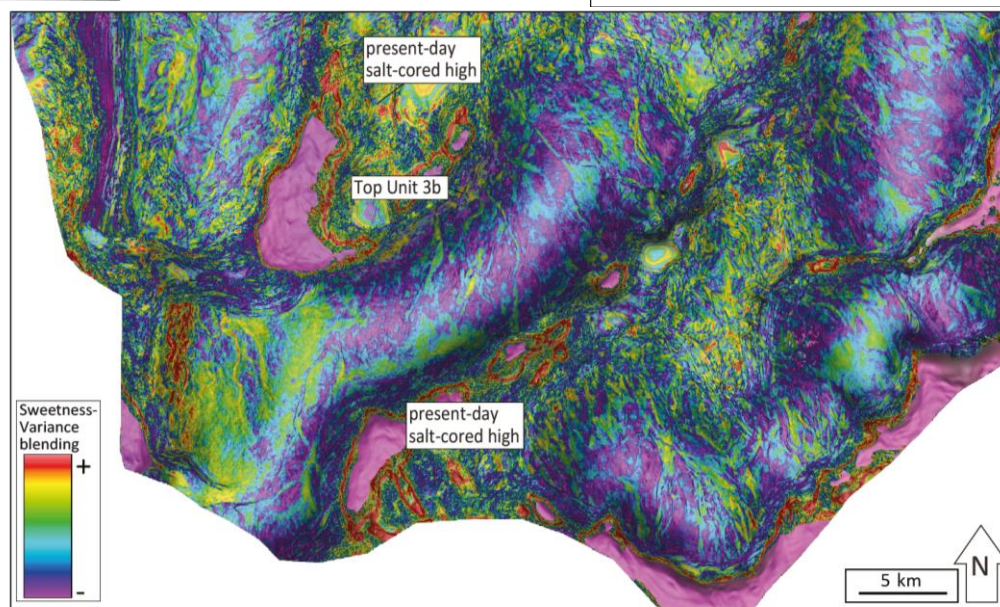
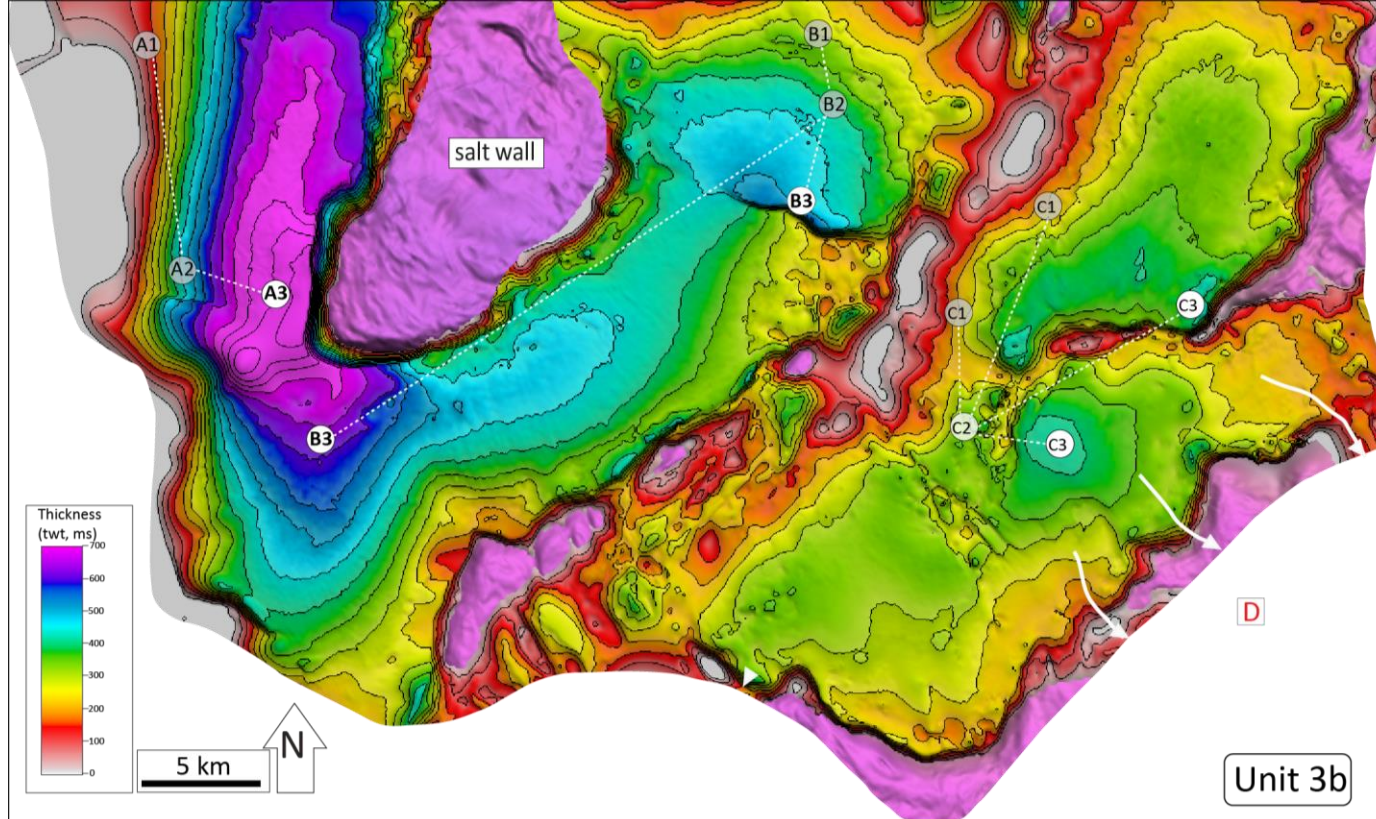
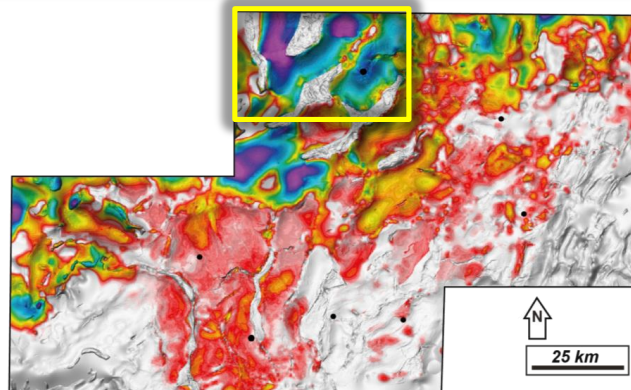
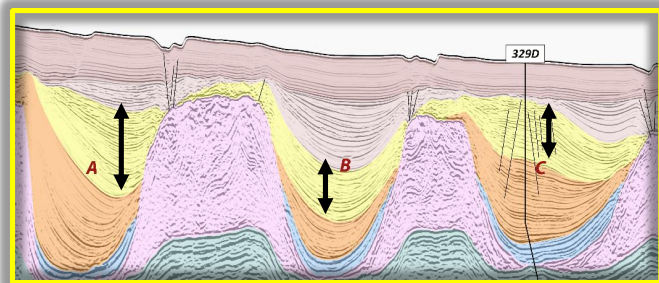
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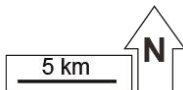
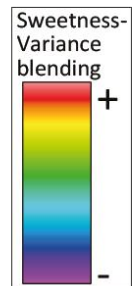
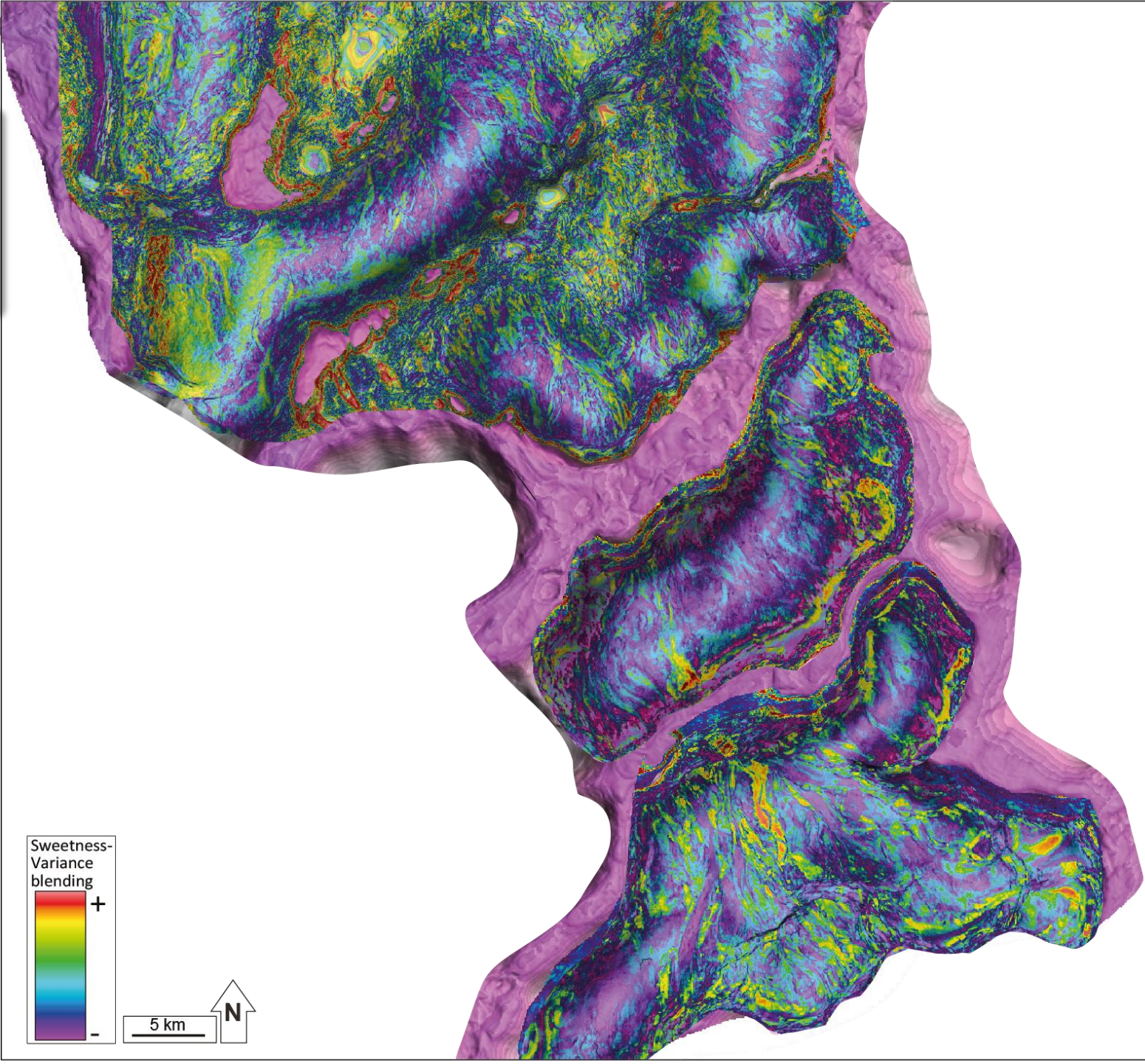
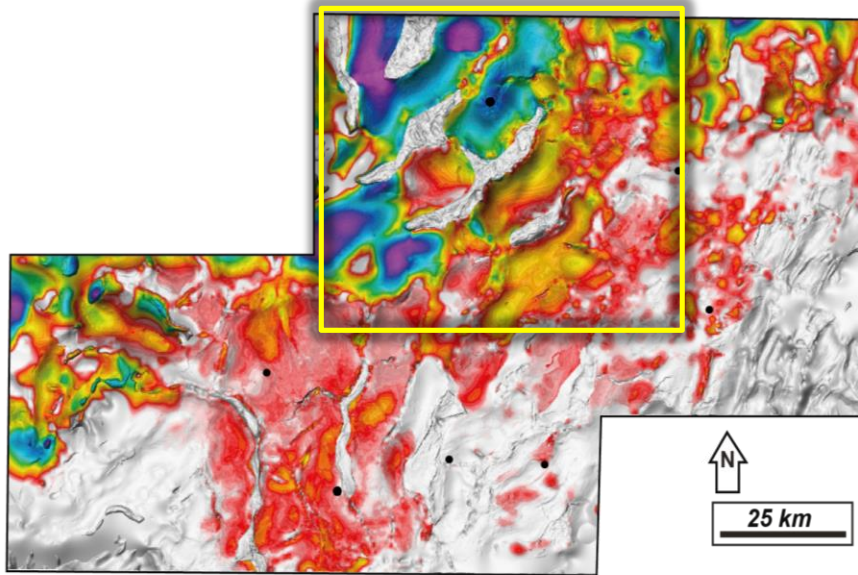
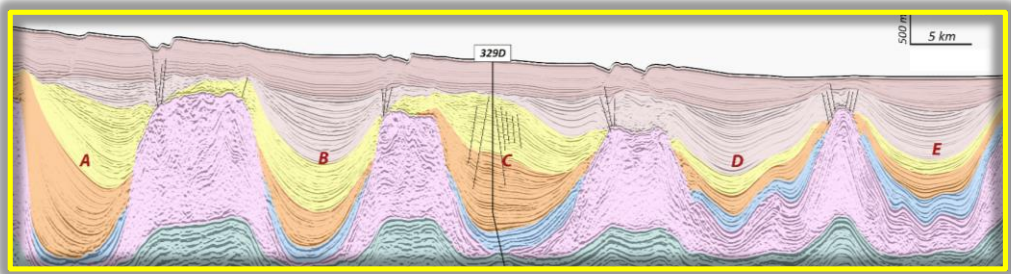
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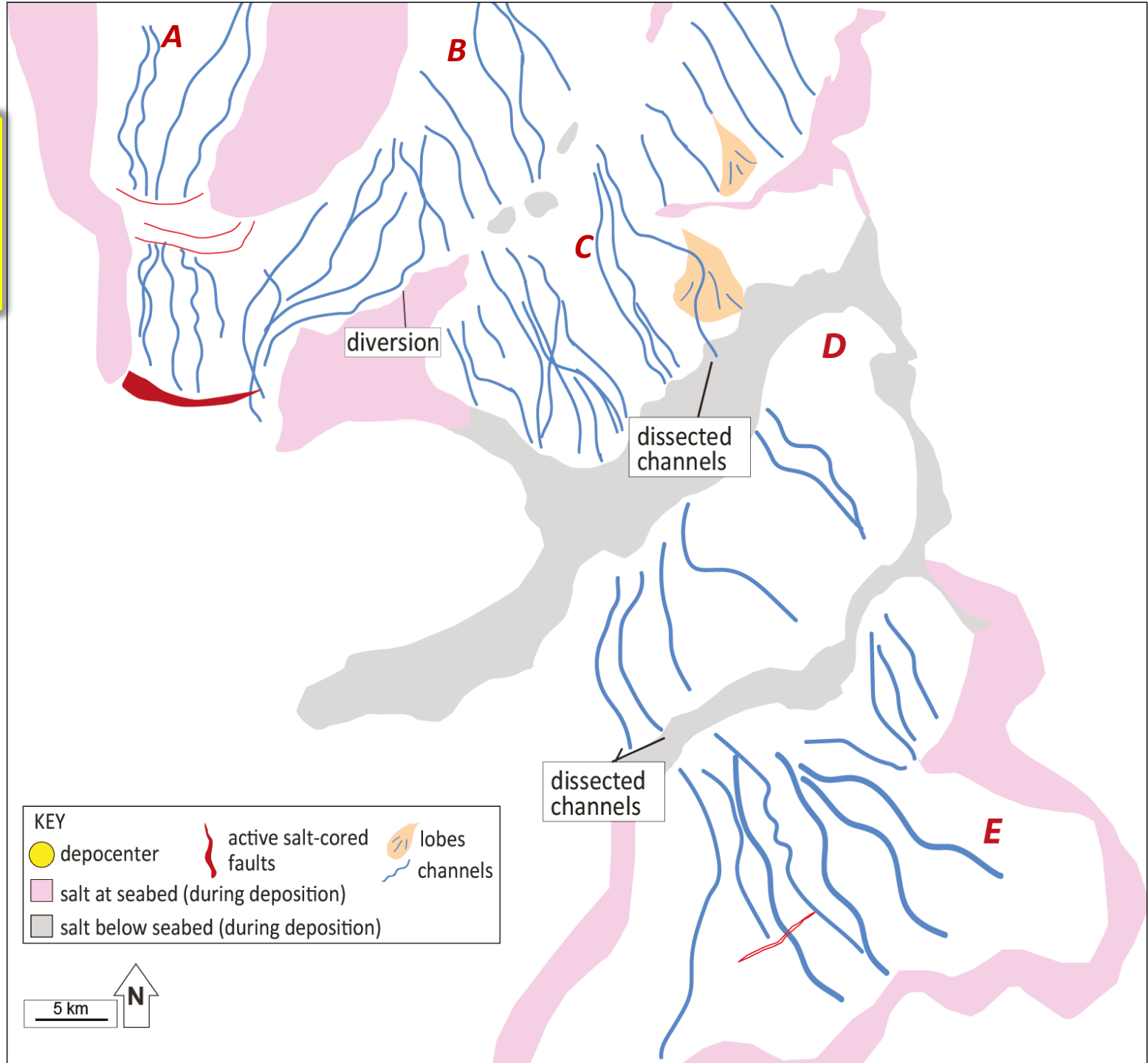
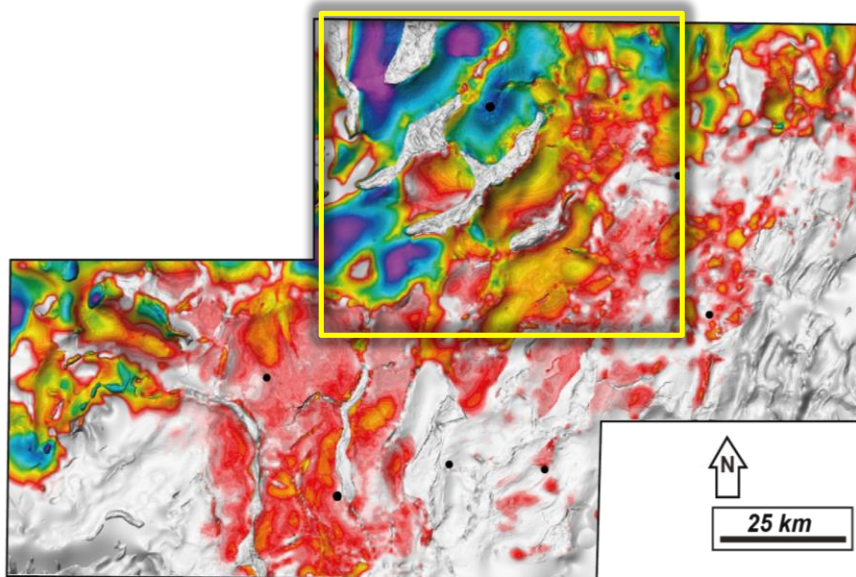
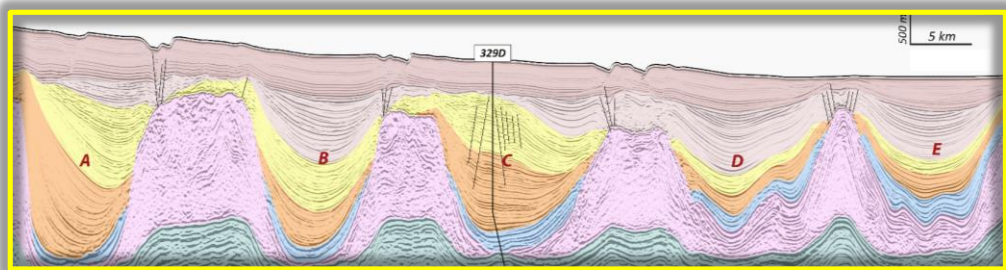
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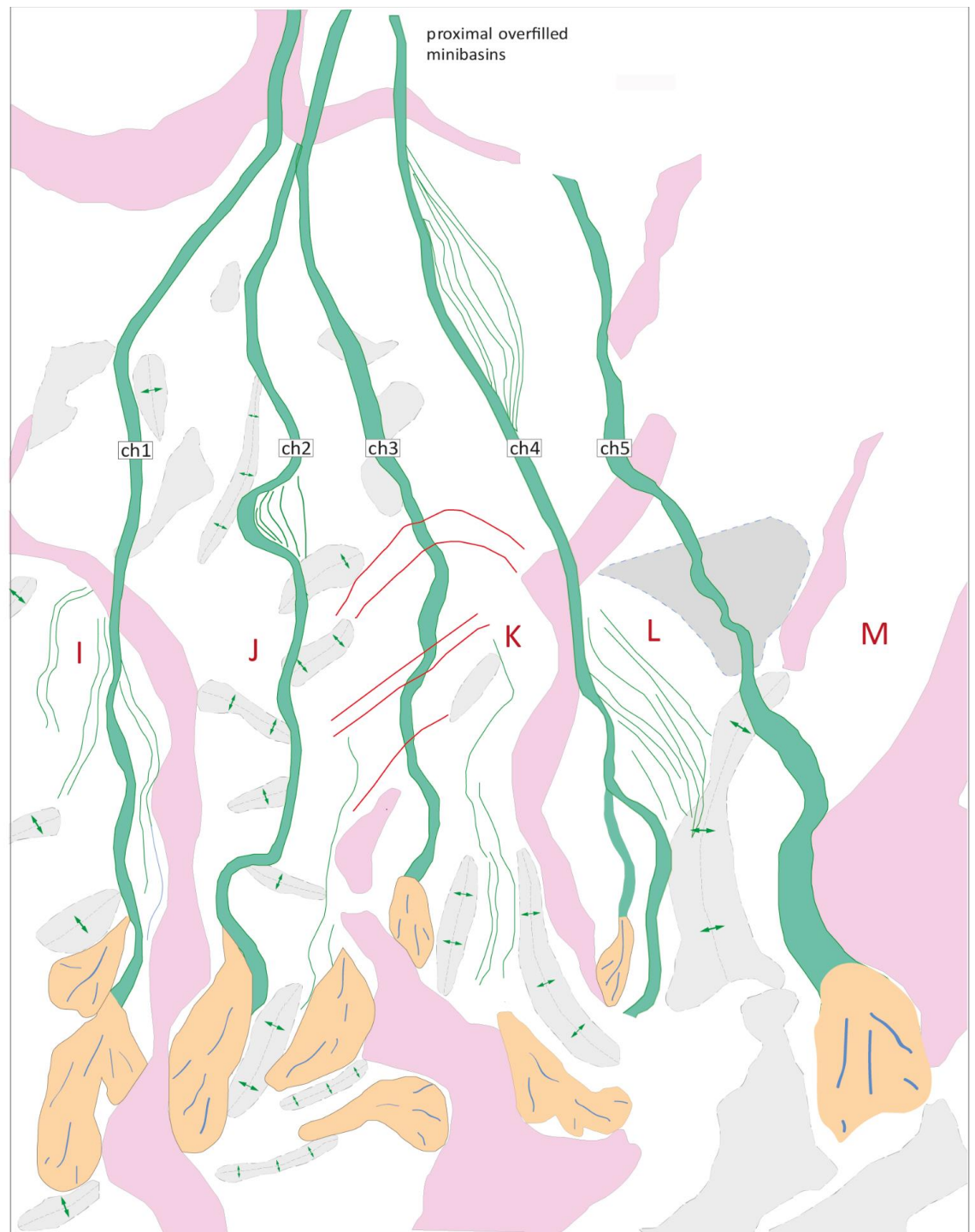
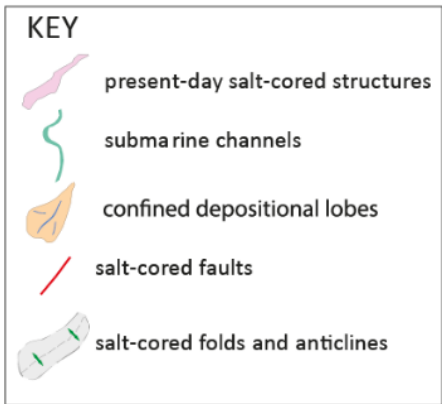
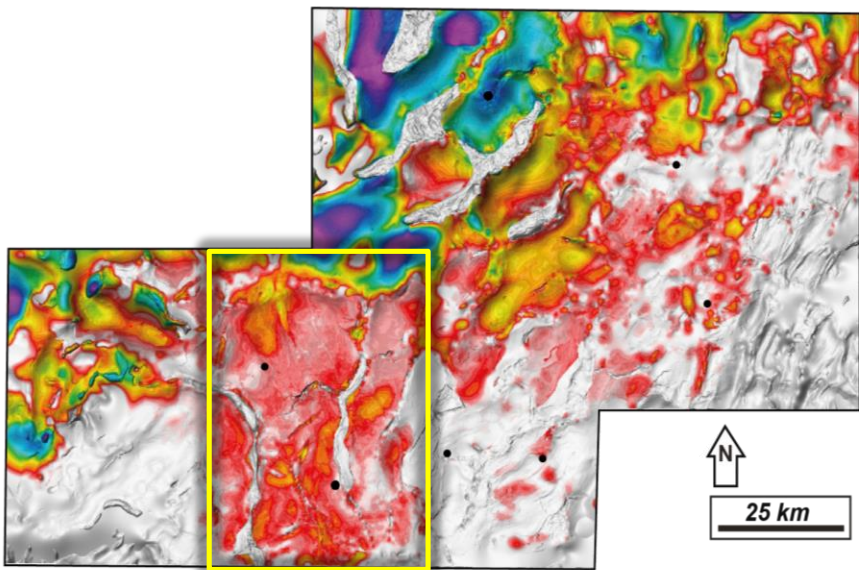
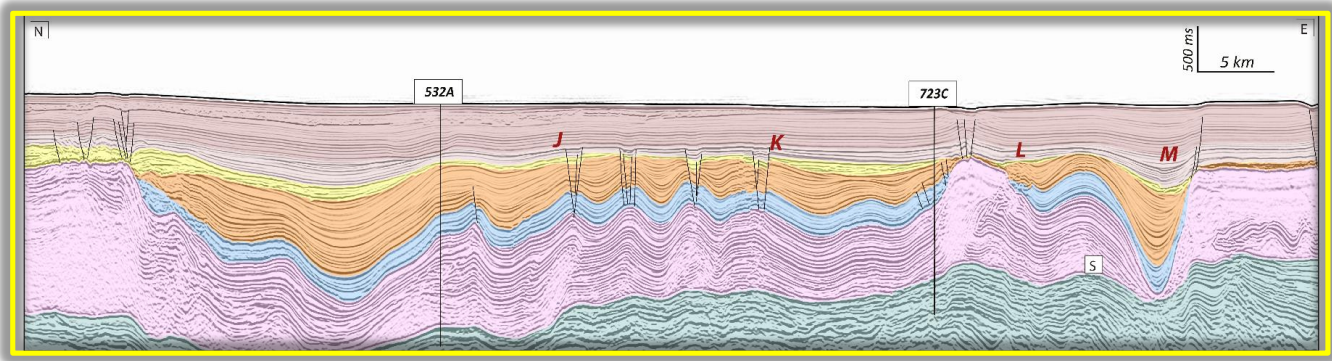
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Phase 2

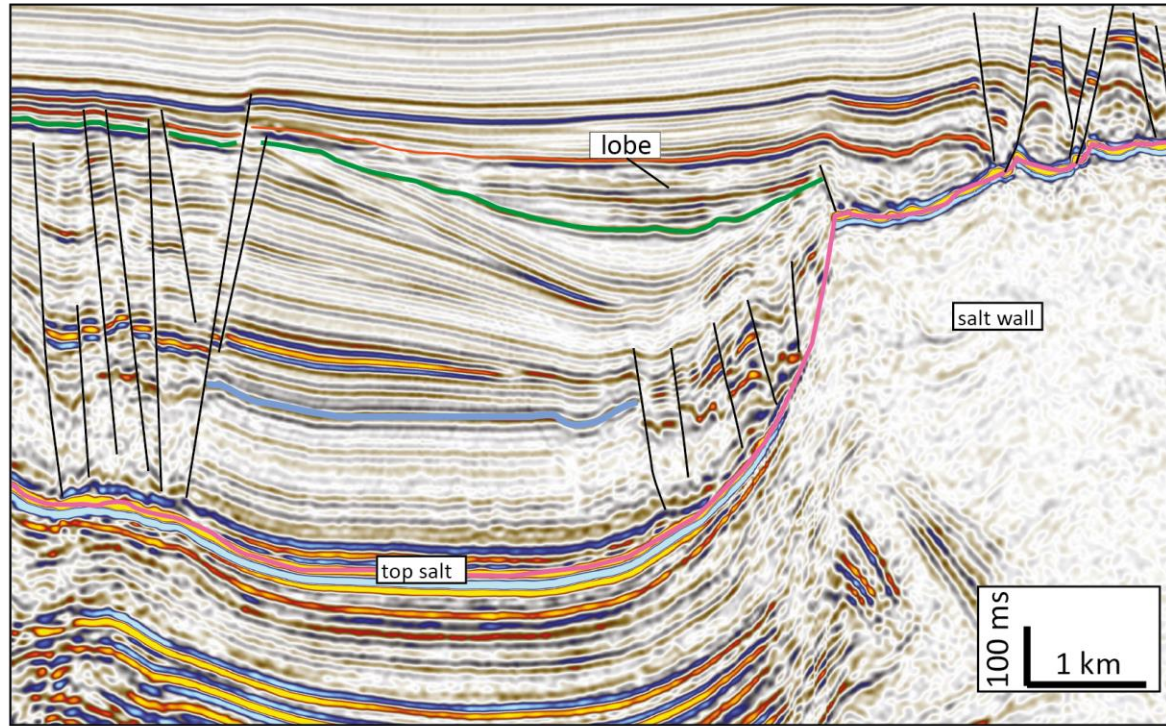


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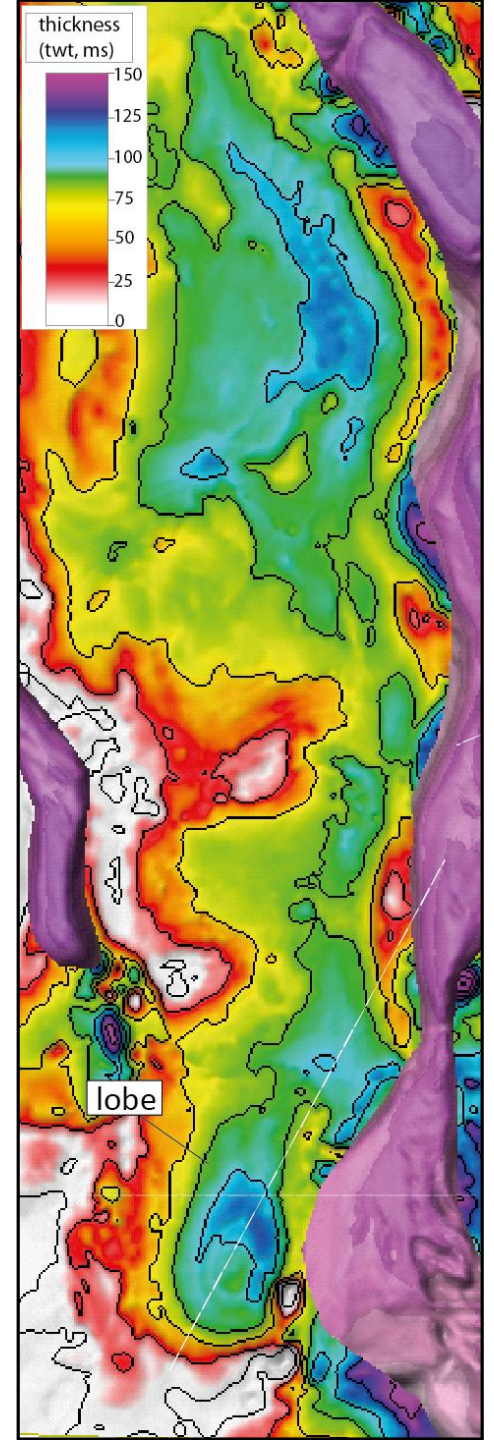
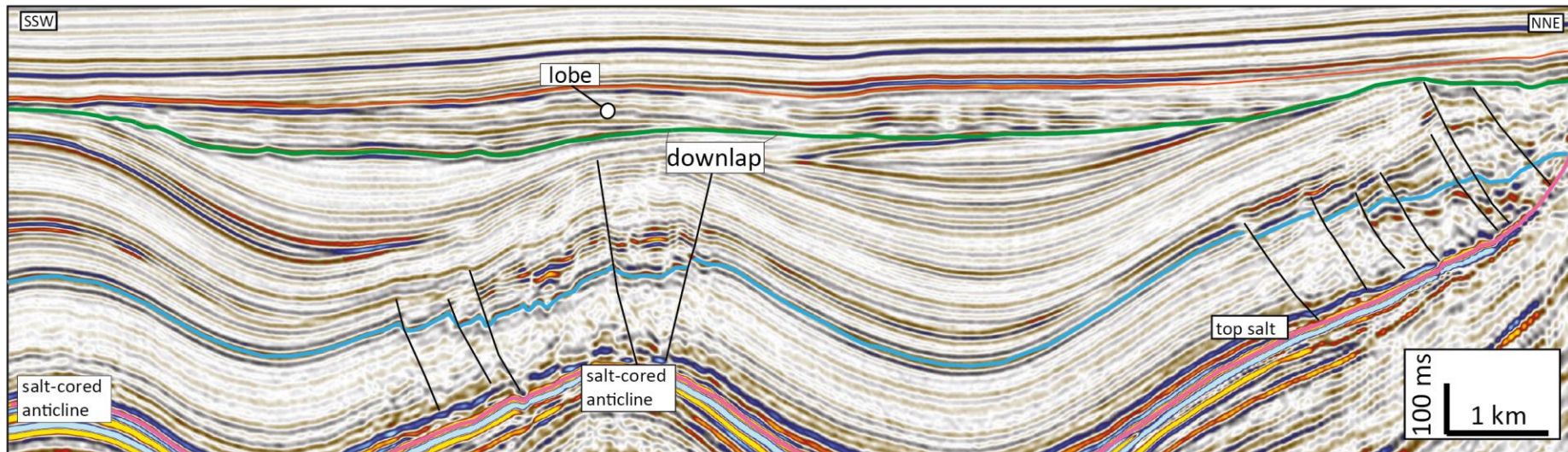


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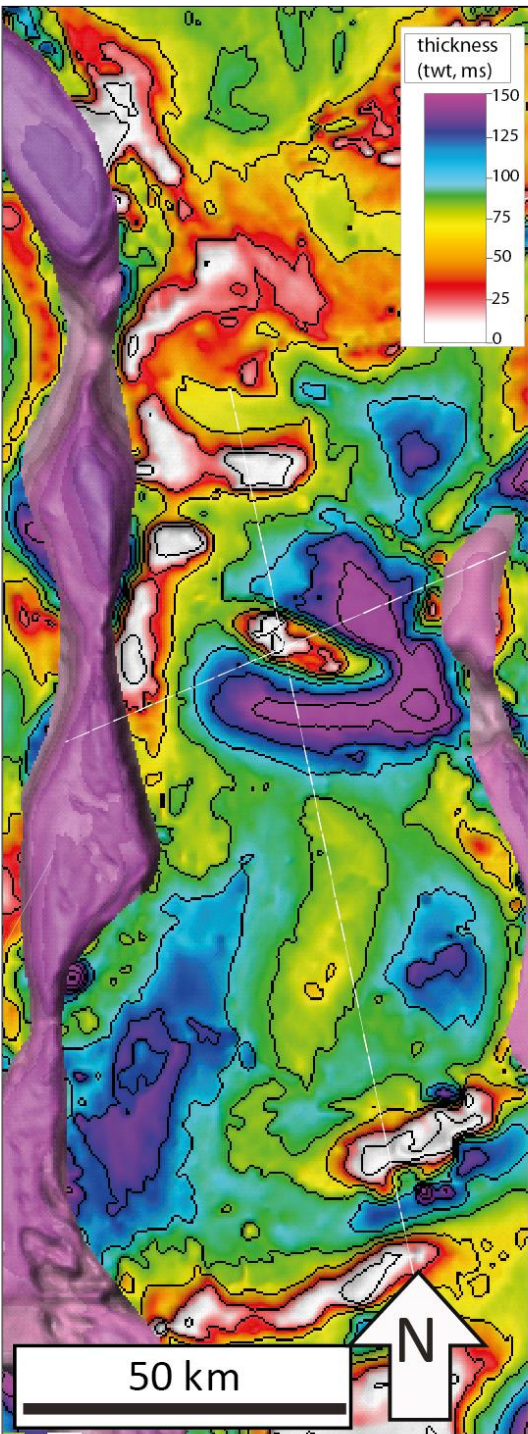
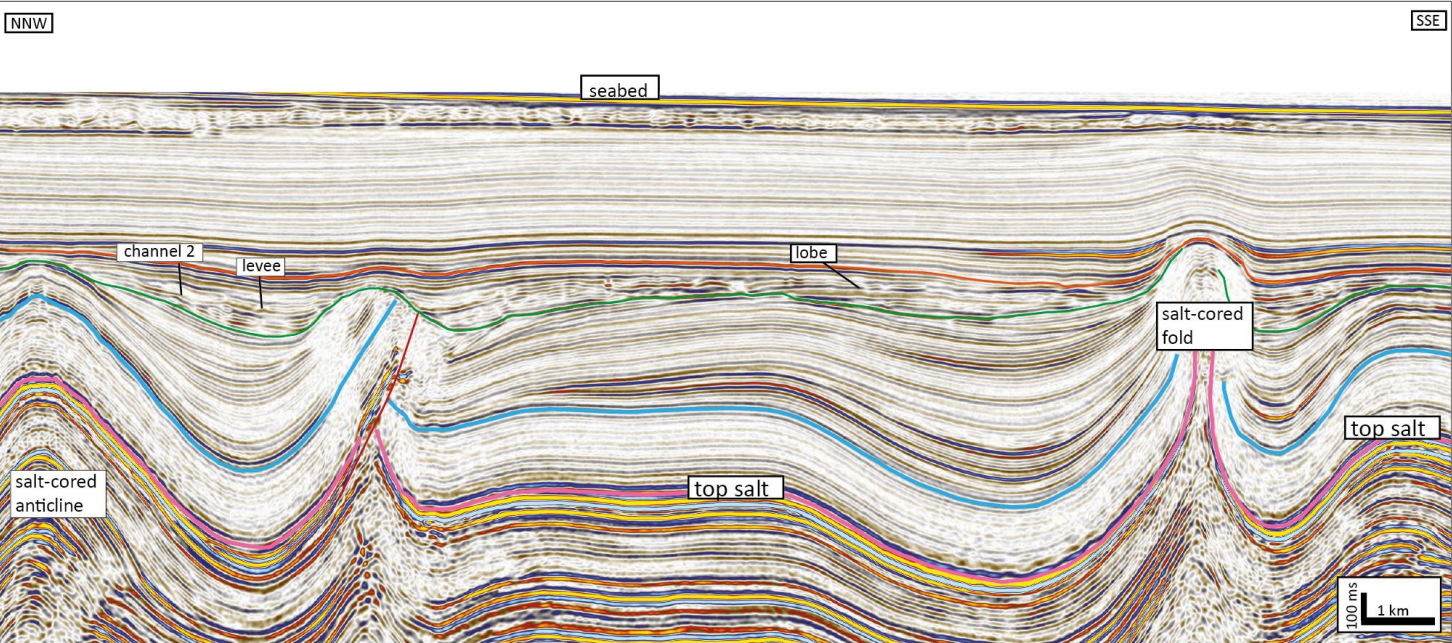
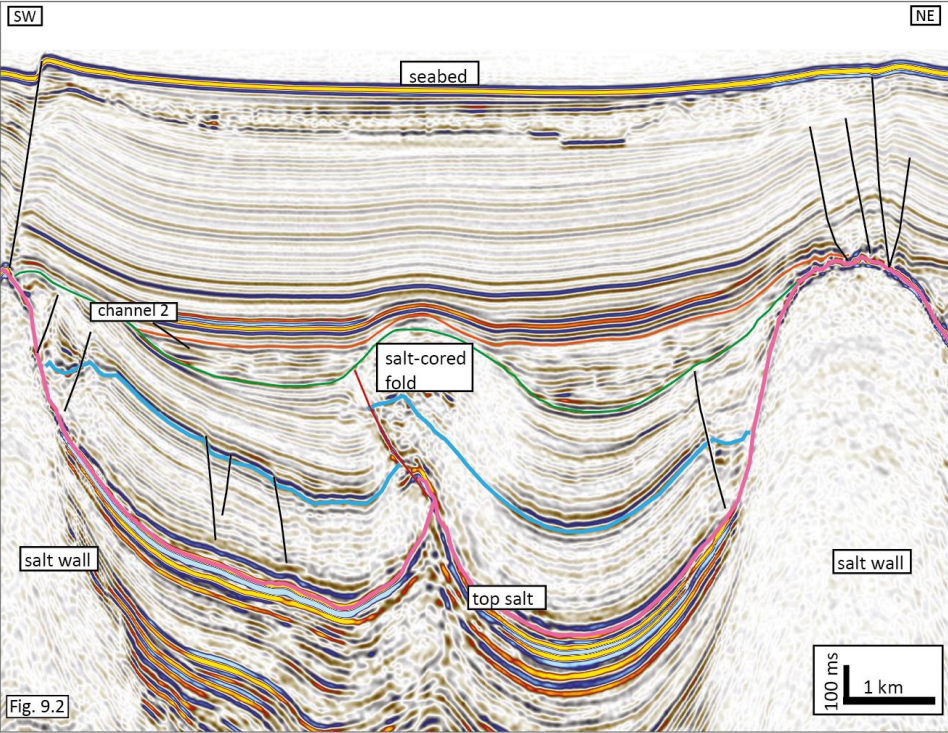
Lateral and frontal confinement
of depositional lobes



Minibasin I

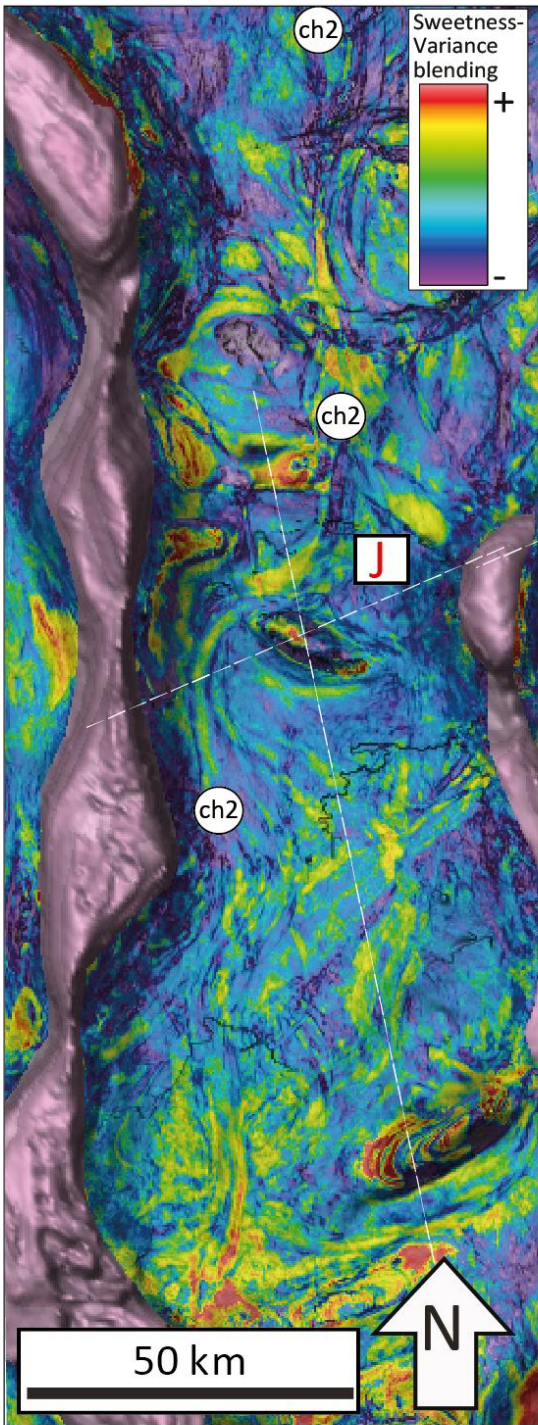
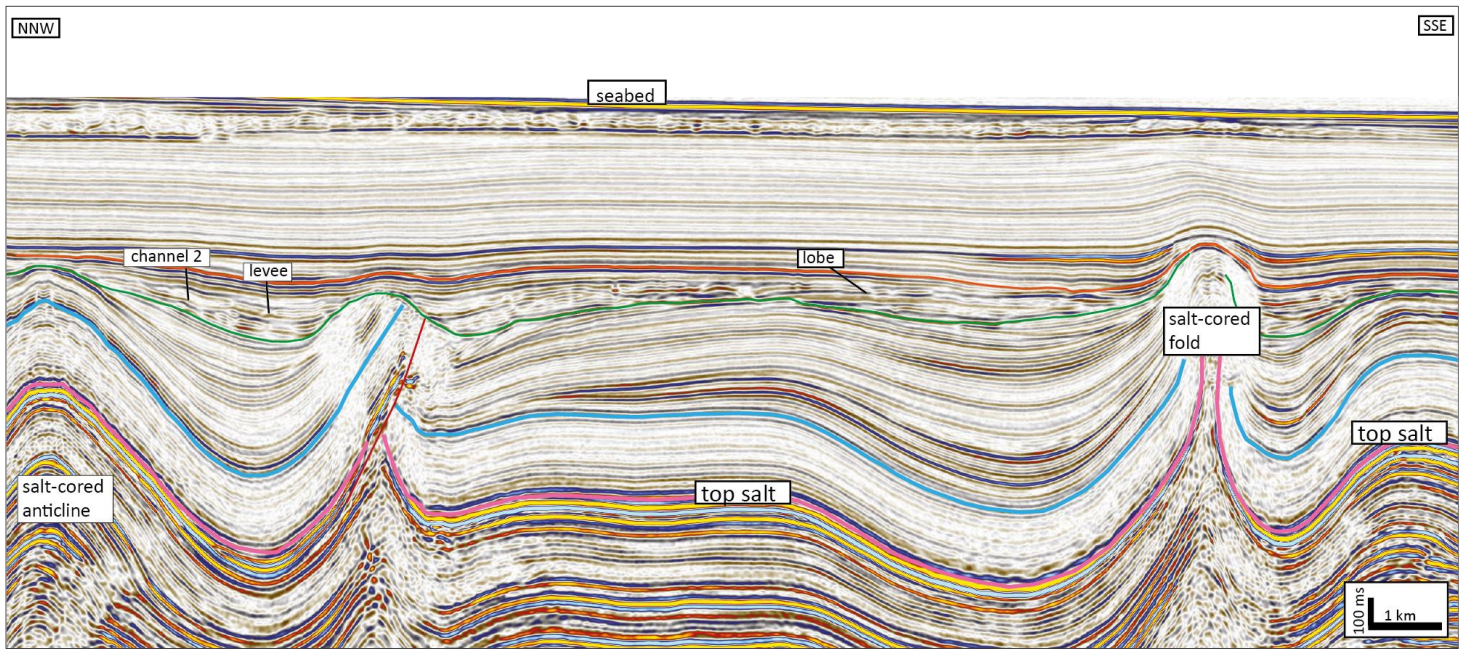
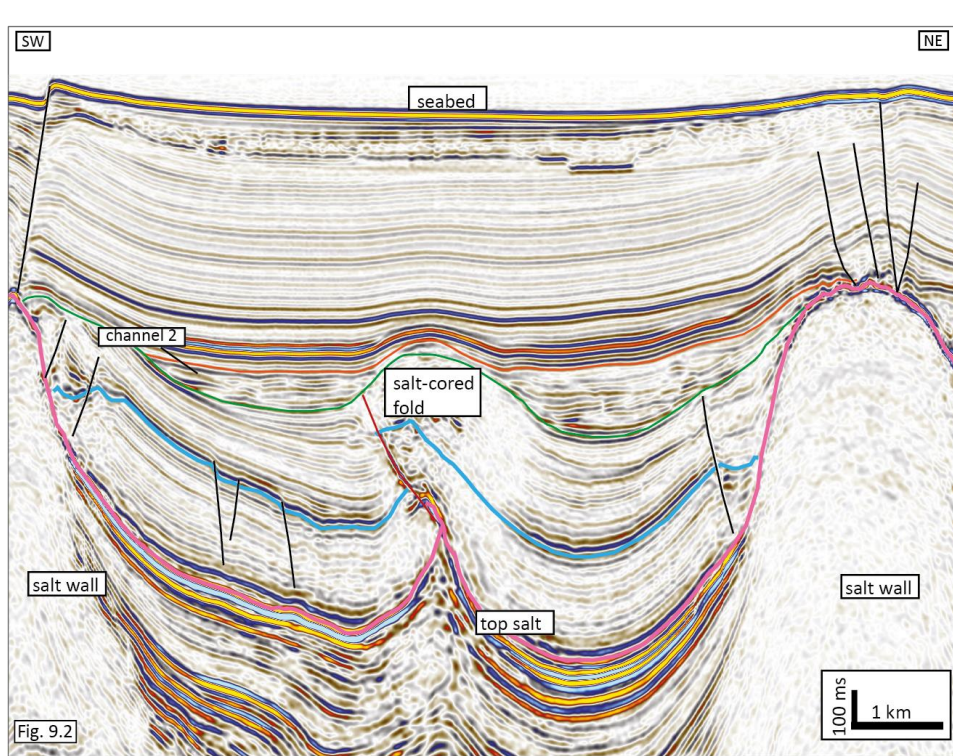
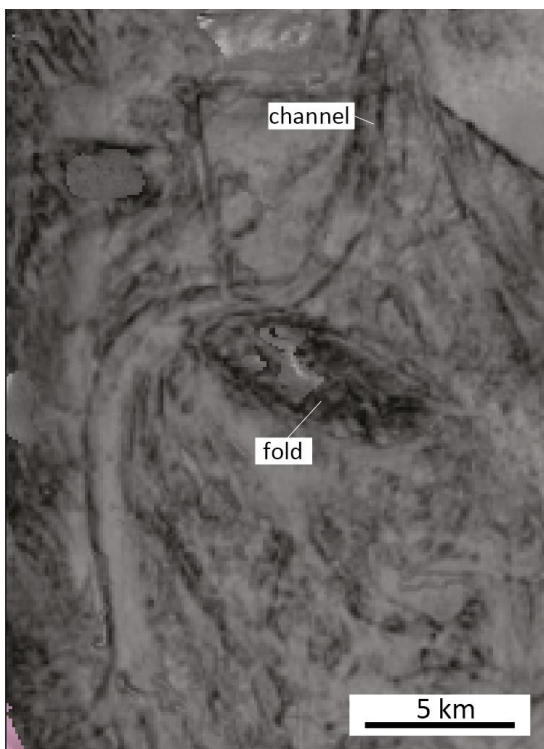


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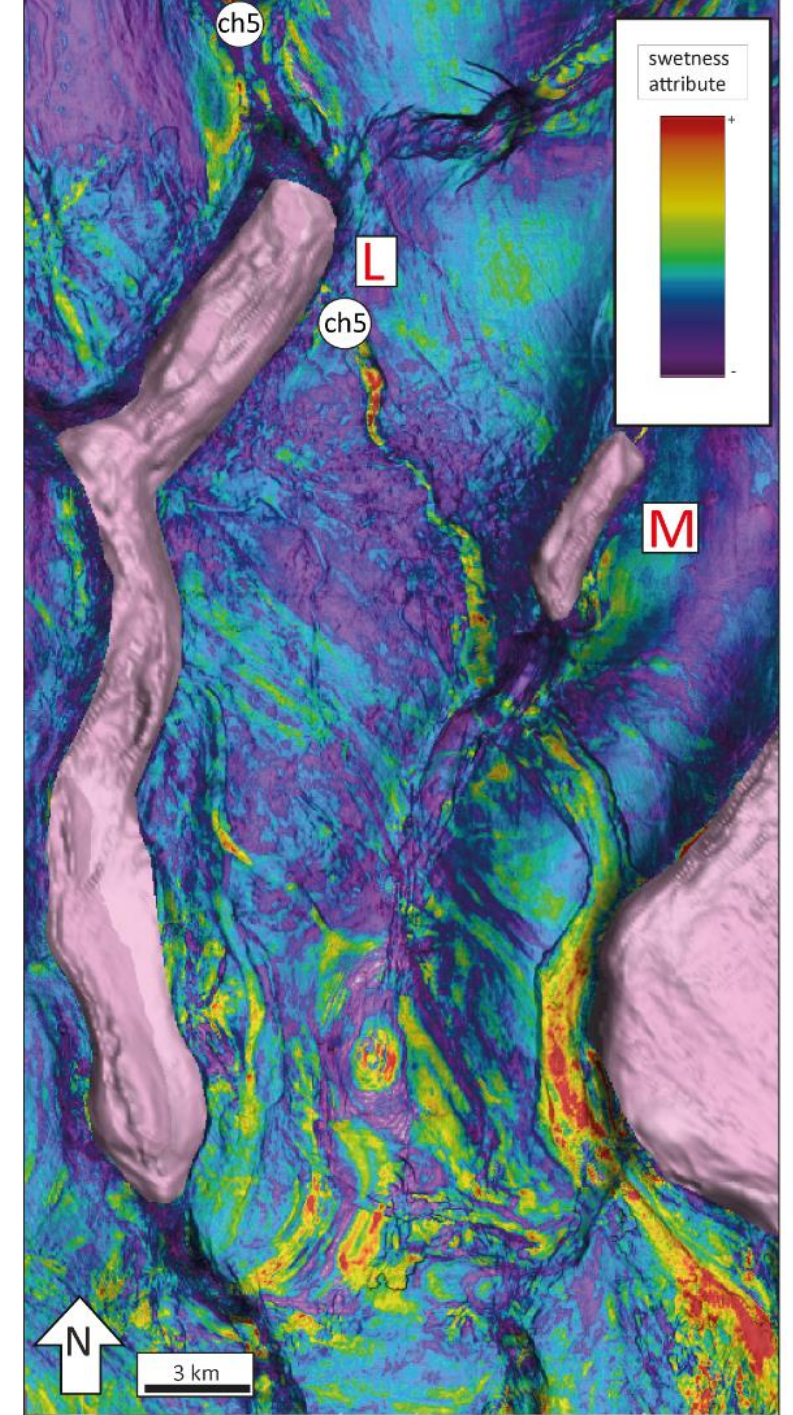
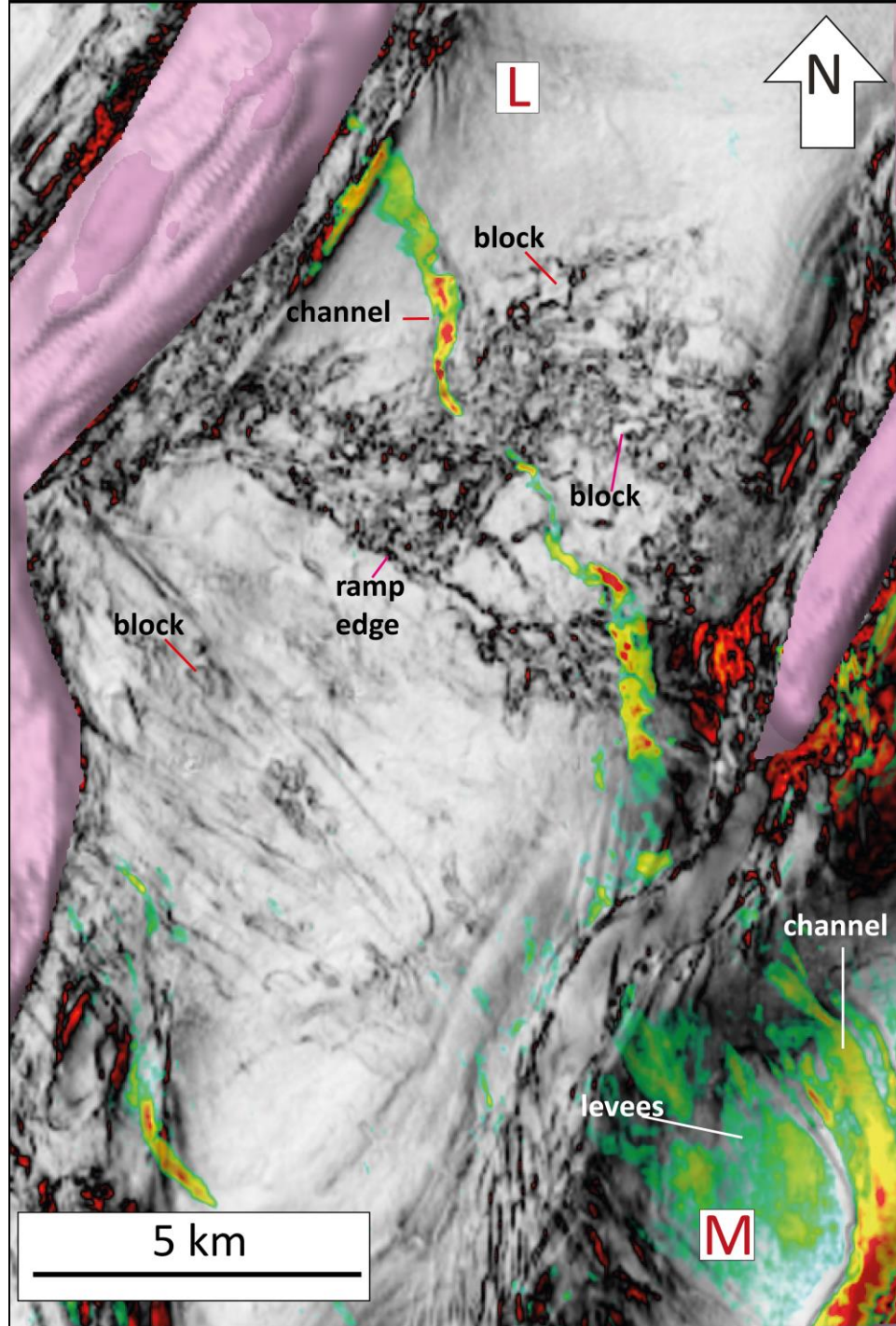
Phase 2

Local diversion
around intra-
minibasin folds

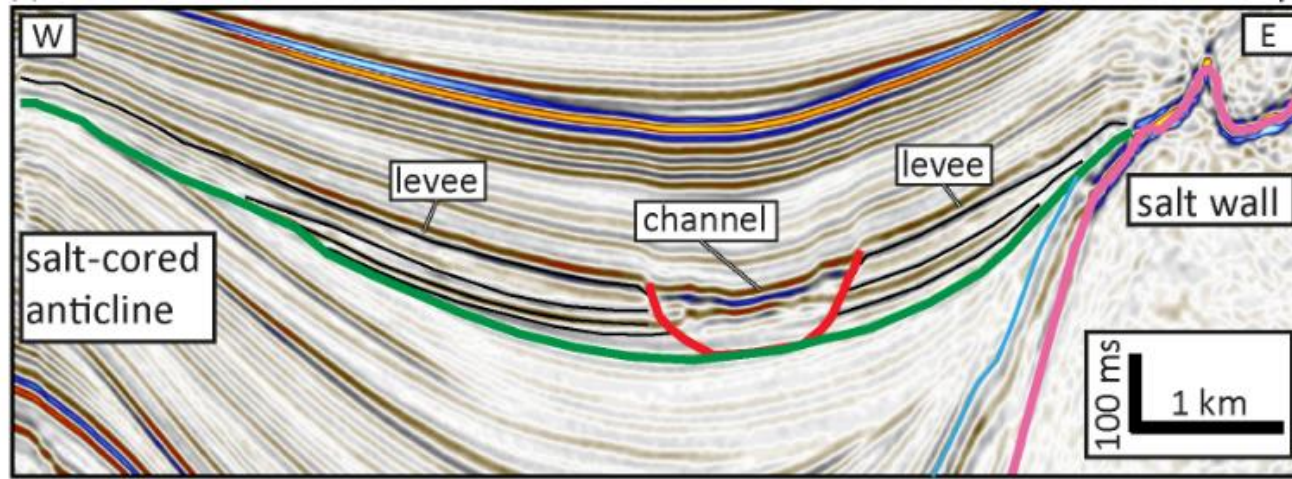


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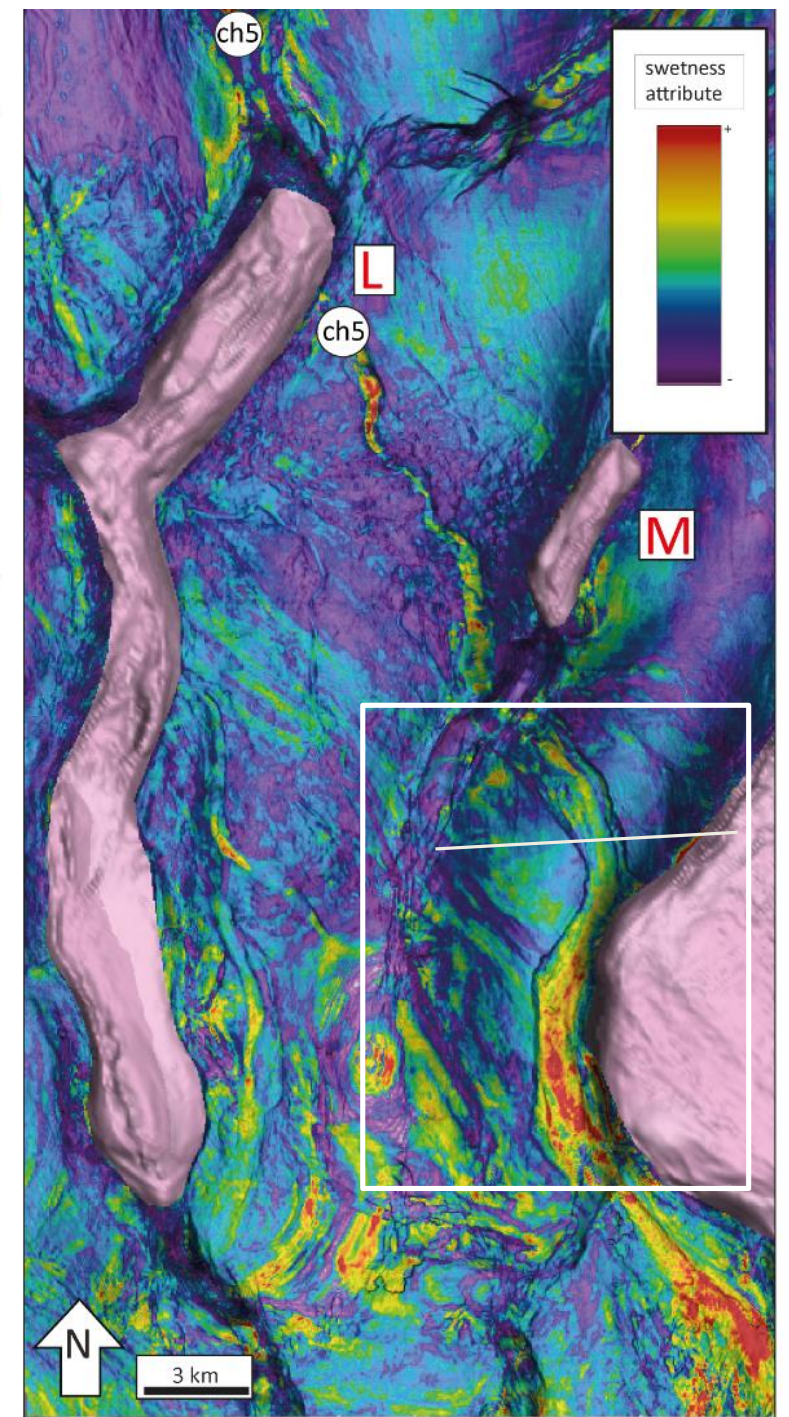
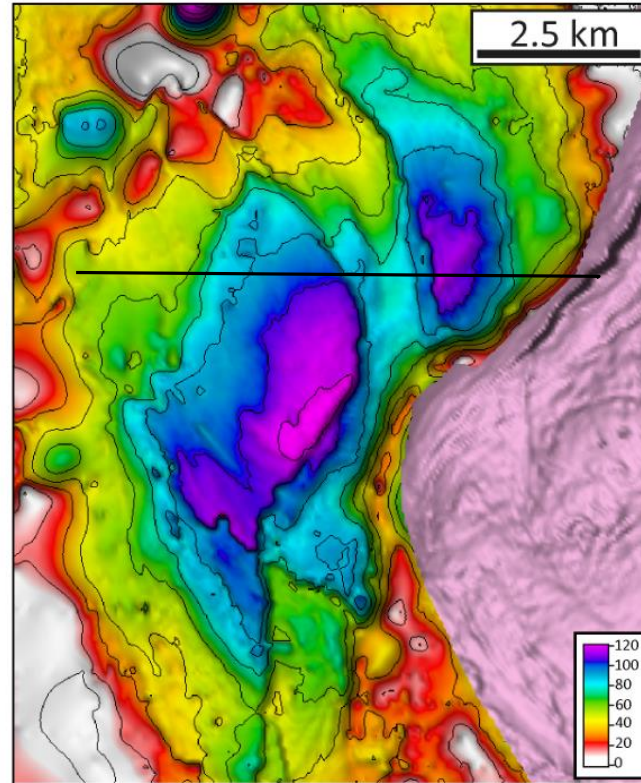
Changes in channel geometry between Minibasins L and M



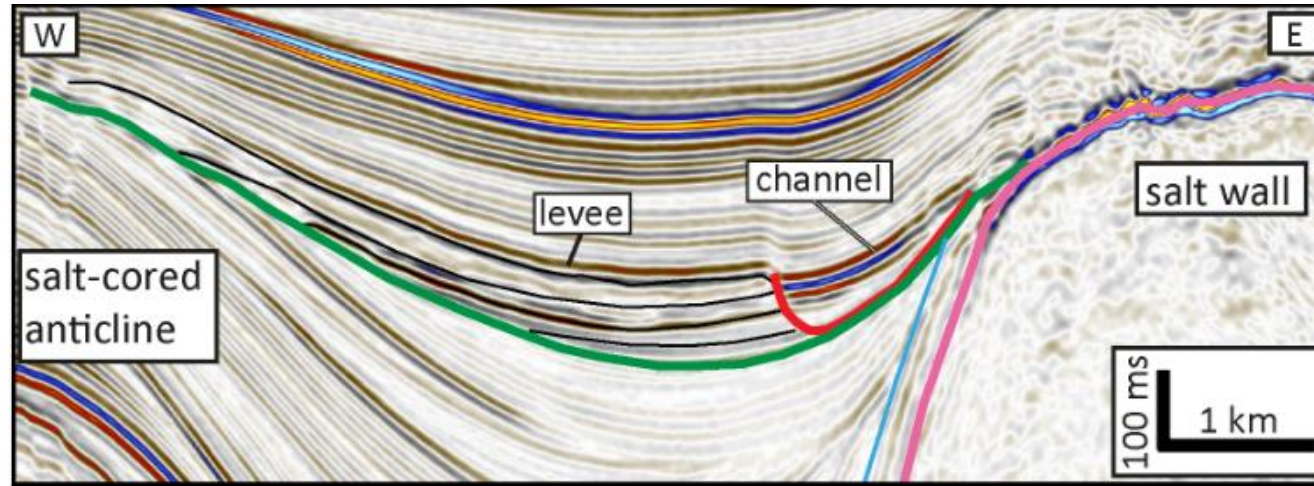
Phase 2



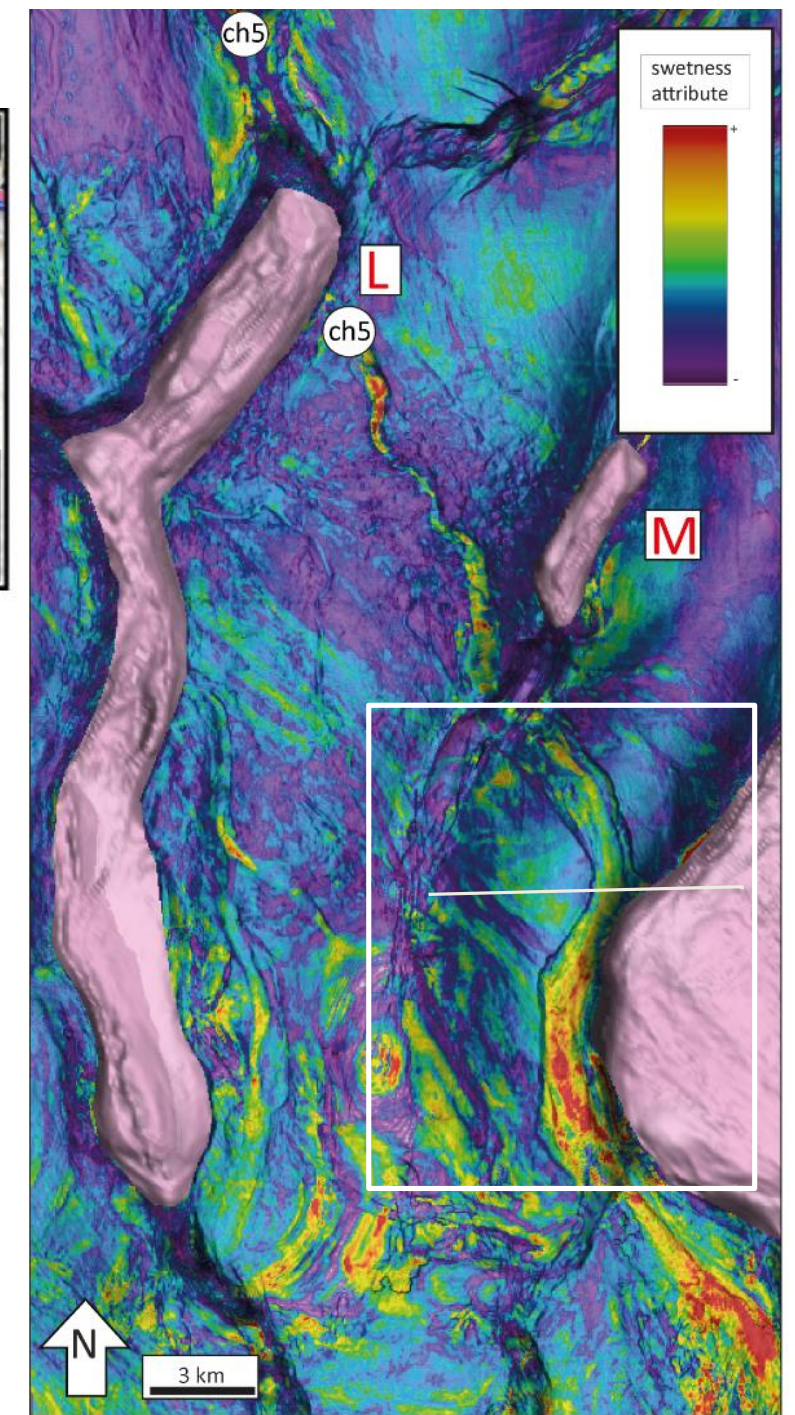
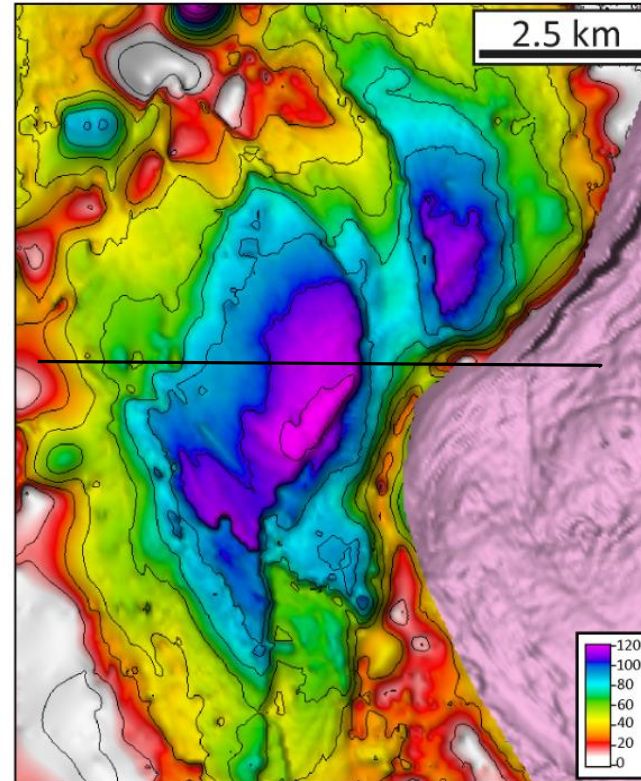
Levees onlap onto and are rotated on the limbs of the salt-cored-anticline



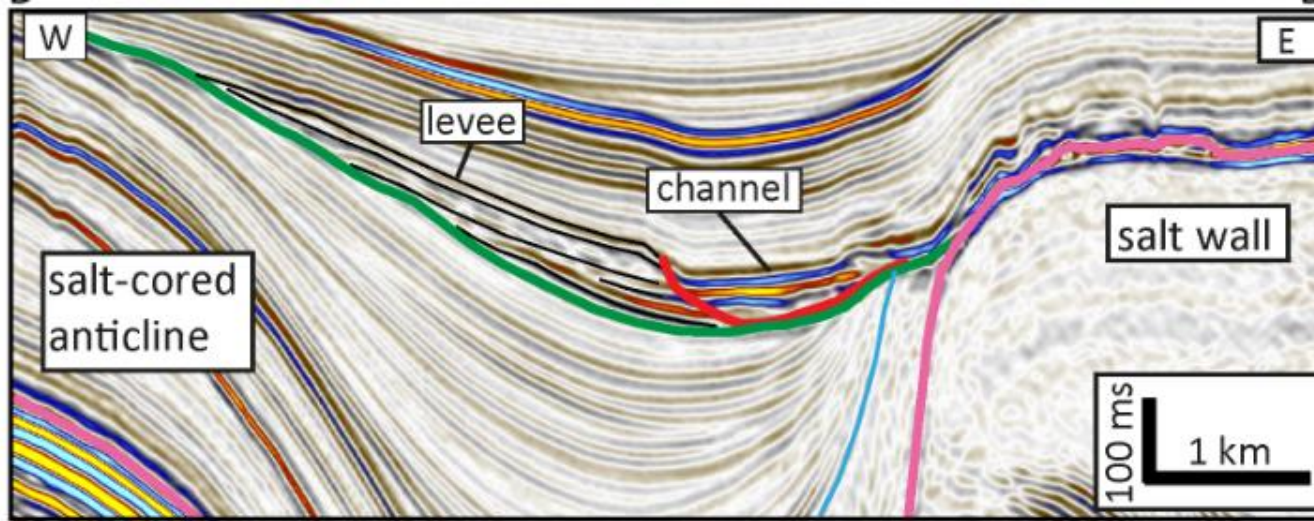
Phase 2



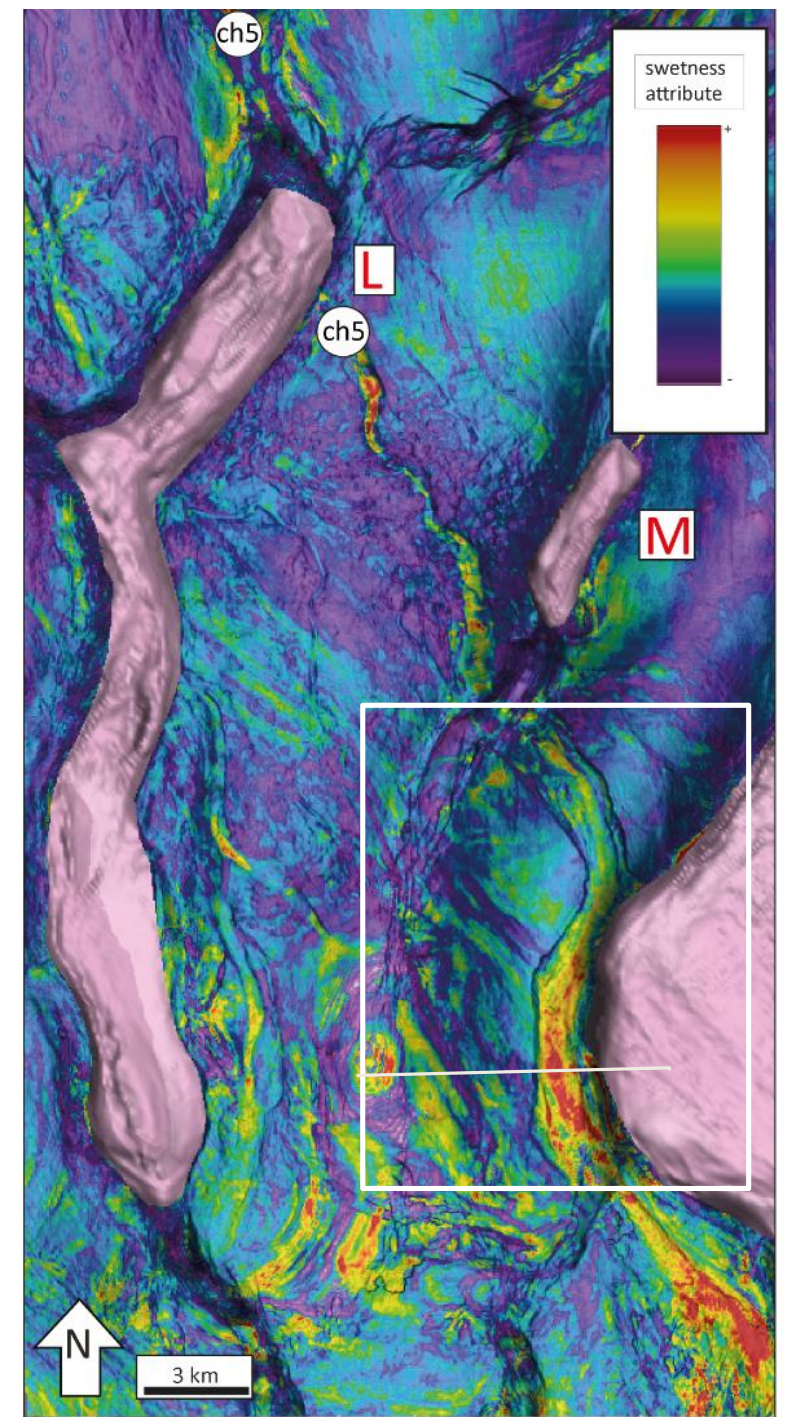
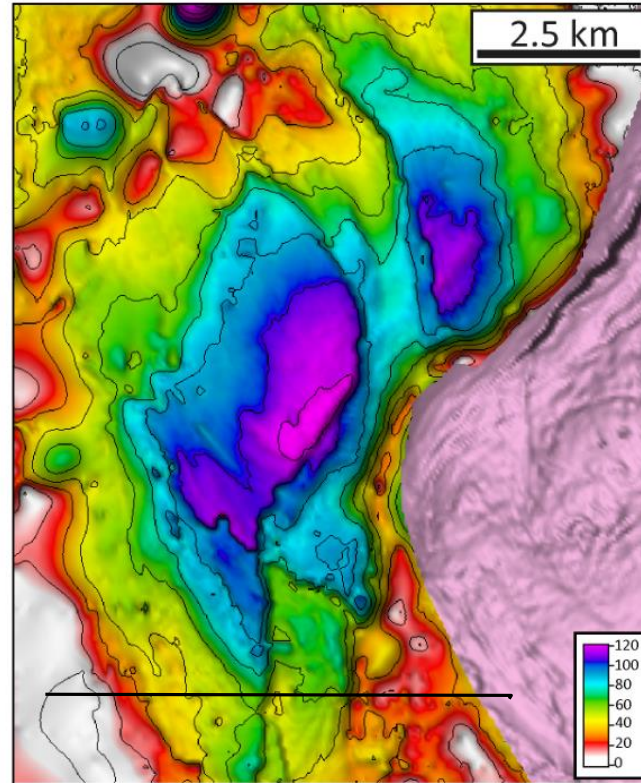
Levees onlap onto and are rotated on the limbs of the salt-cored-anticline



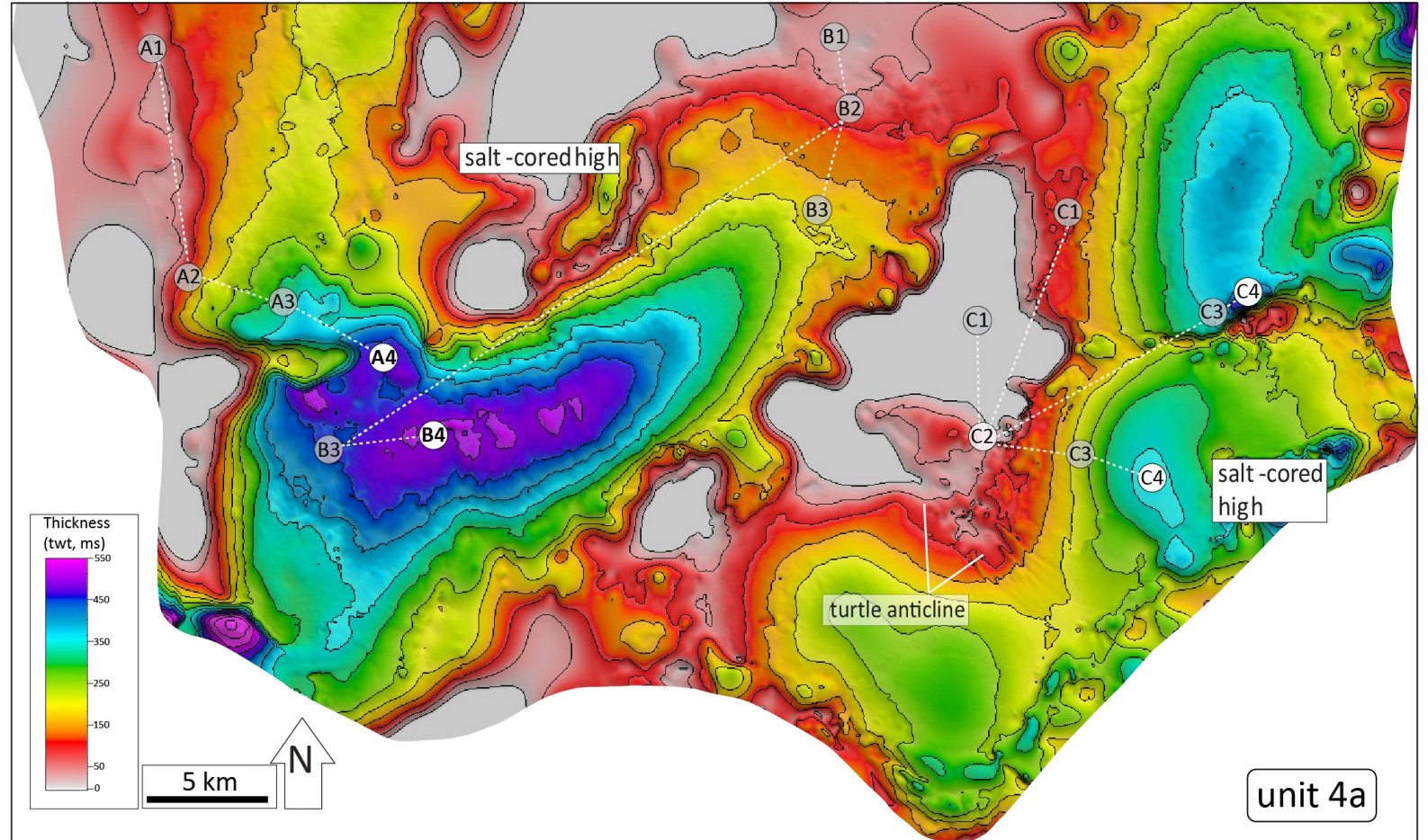
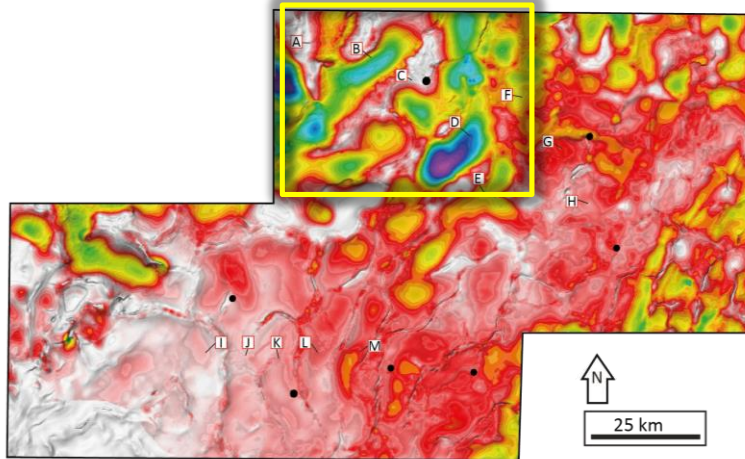
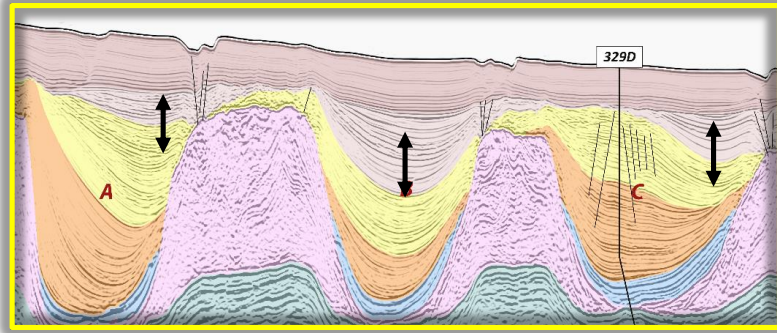
Phase 2



Levees onlap onto and are rotated on the limbs of the salt-cored-anticline

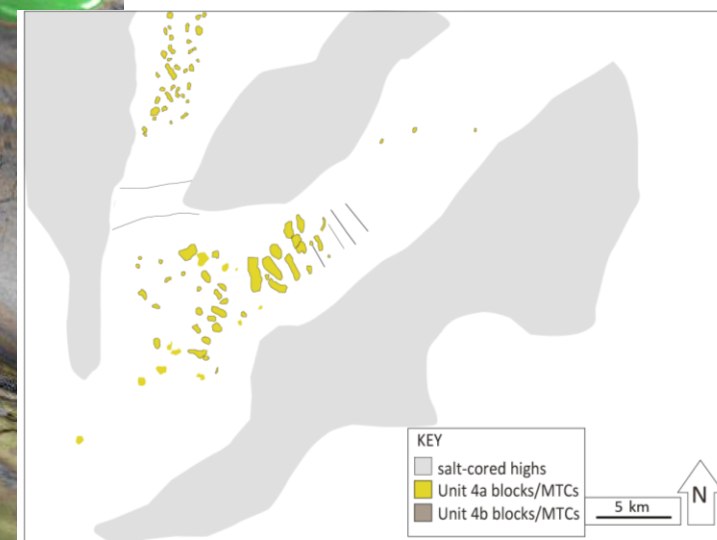
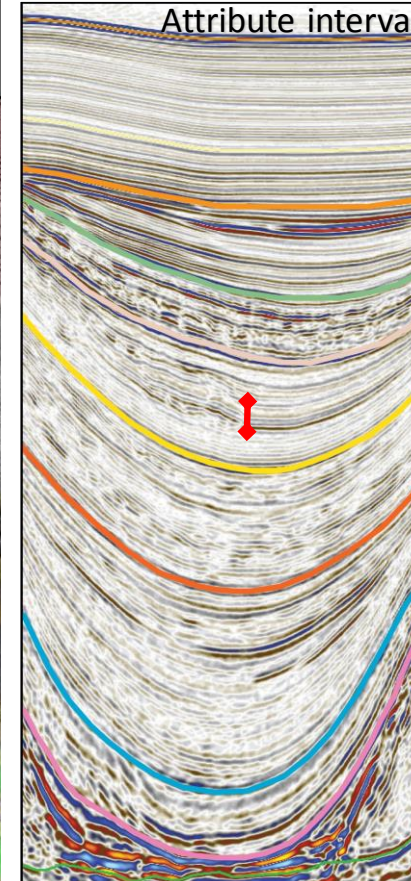
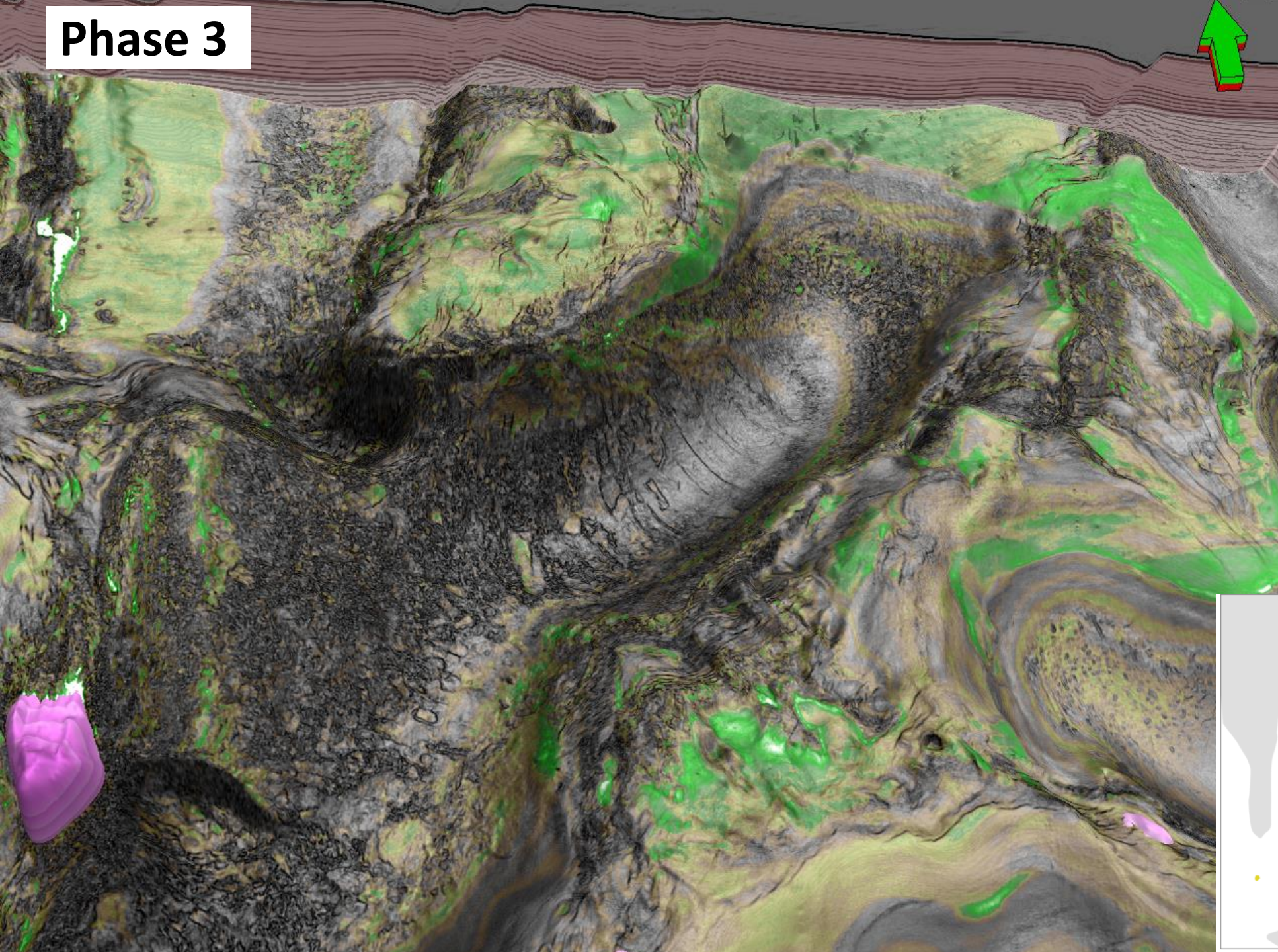


Phase 3

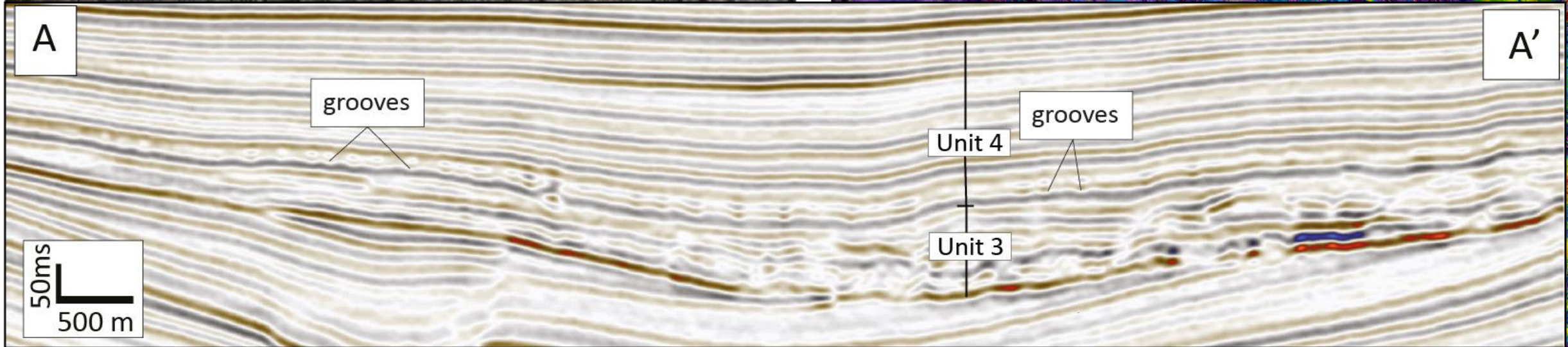
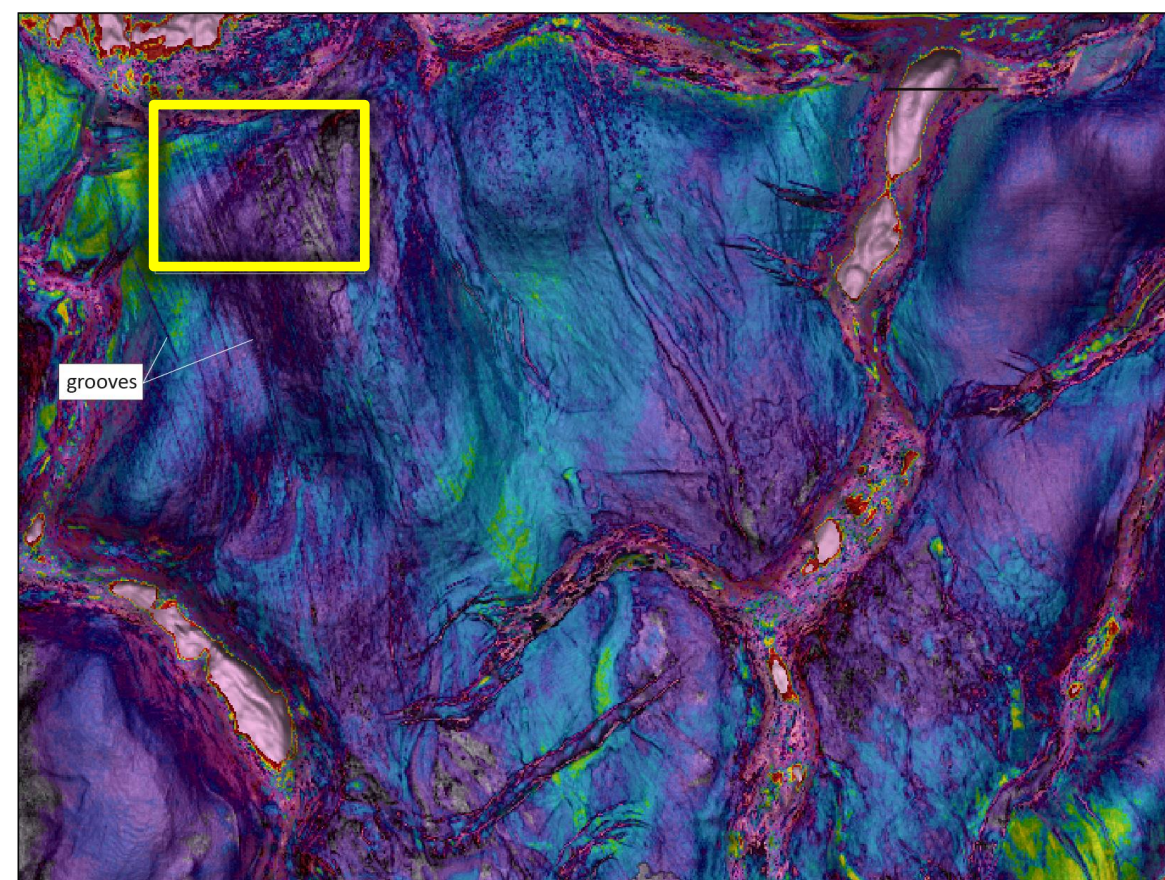
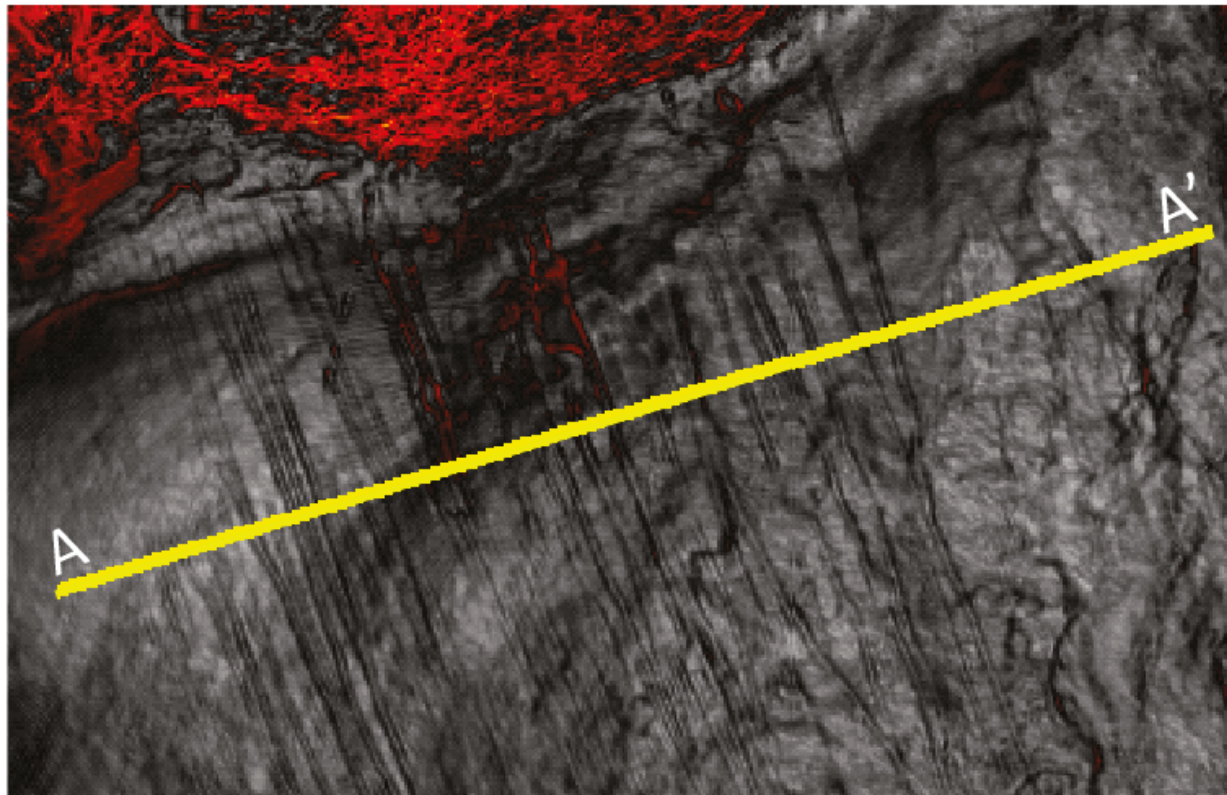


- Proximal minibasin are still actively subsiding
- Cessation of clastic deposition with channels and lobes
- Initiation of widespread MTC emplacement

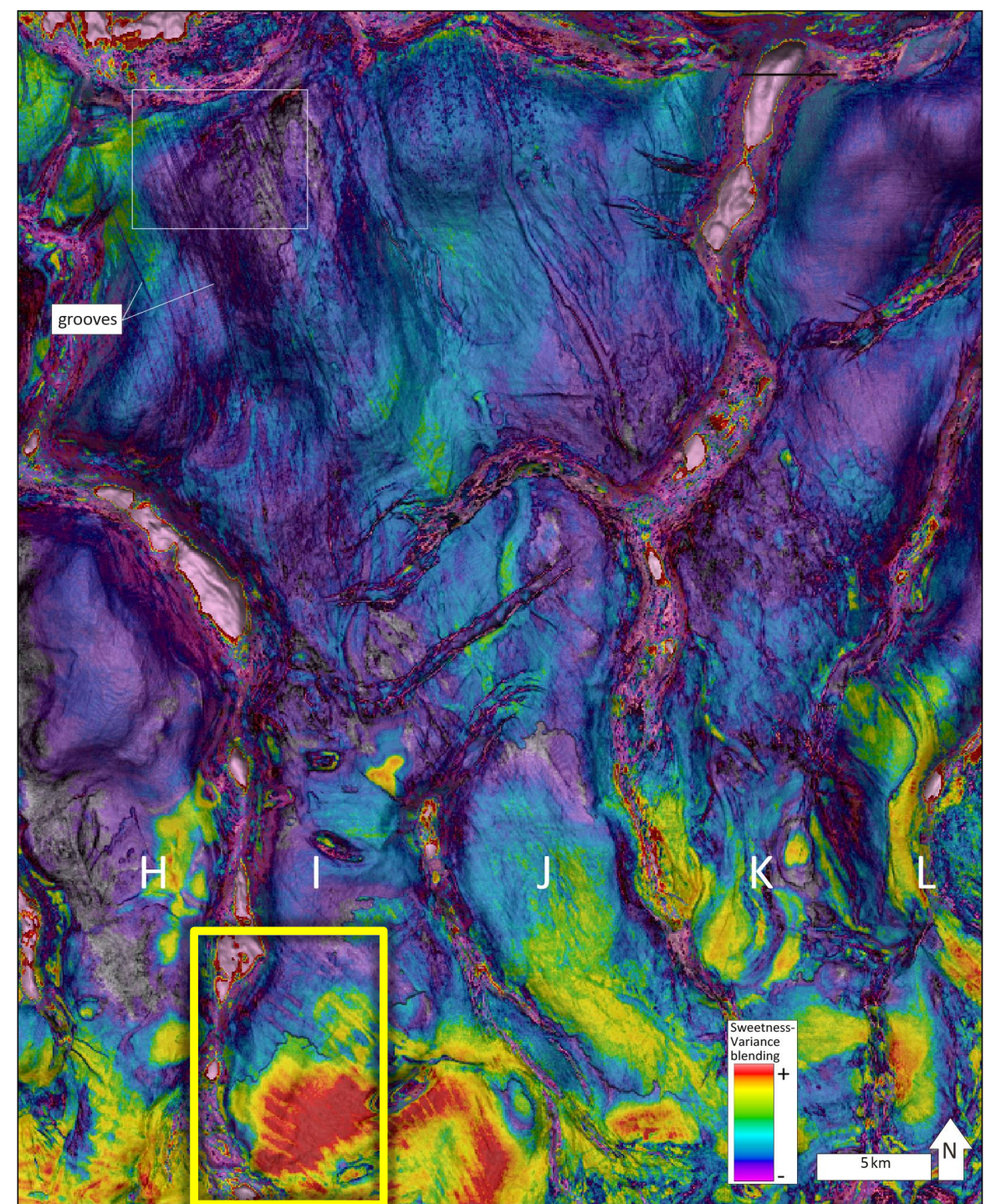
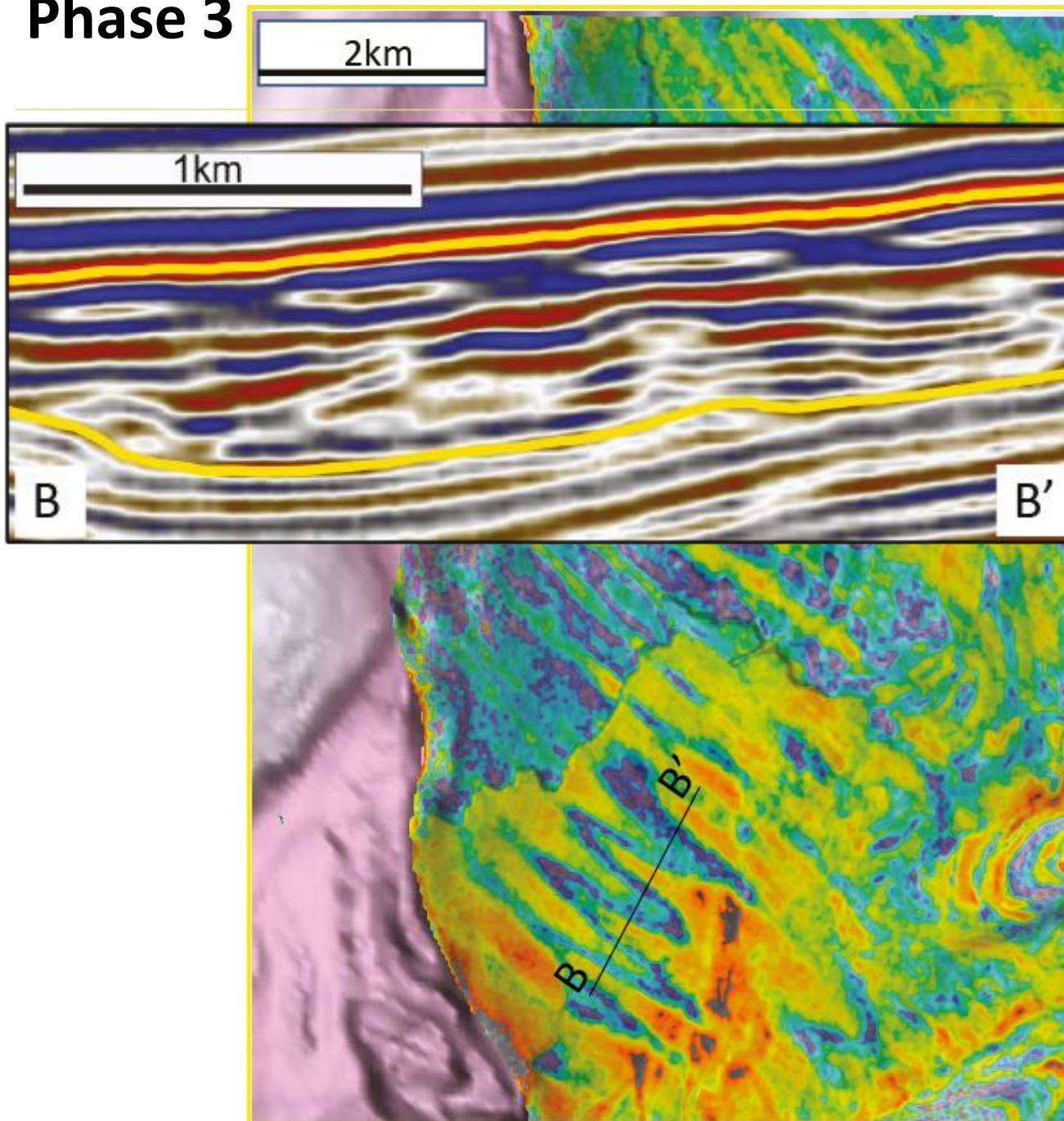
Phase 3



Phase 3

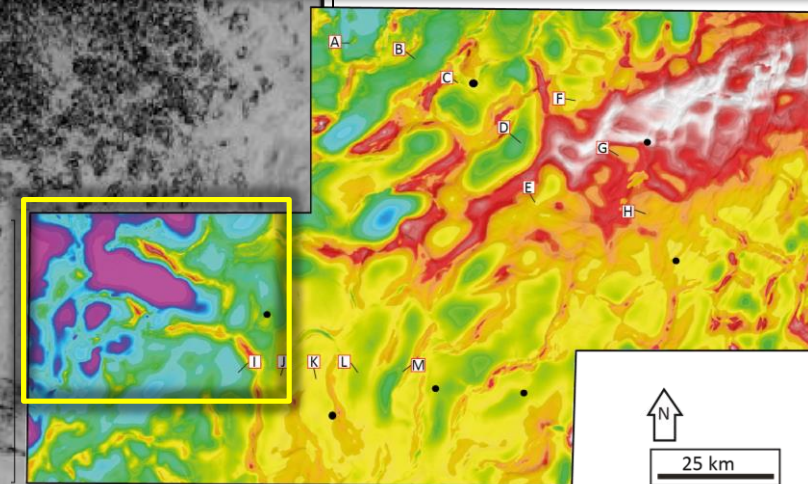
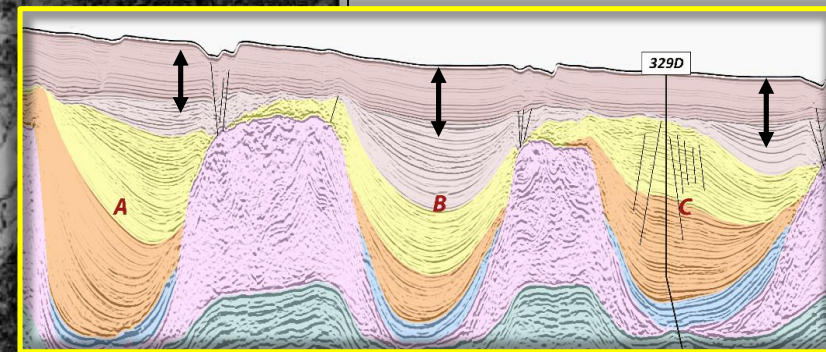


Phase 3

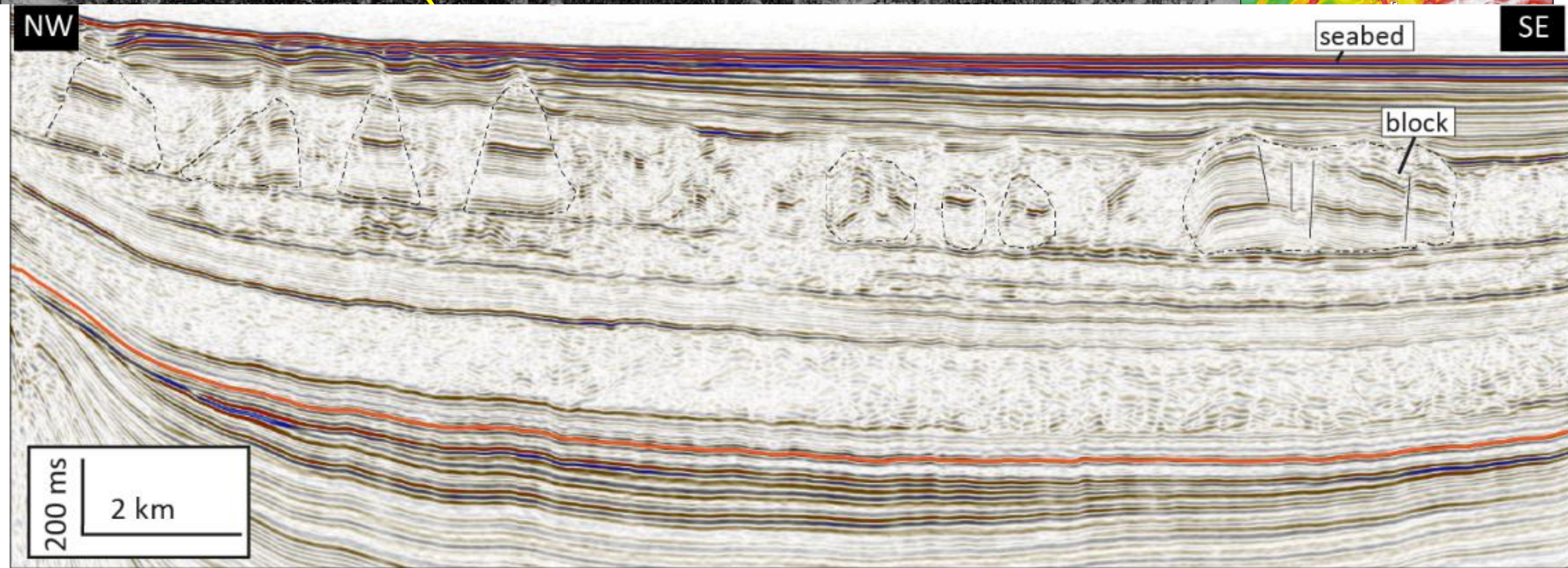
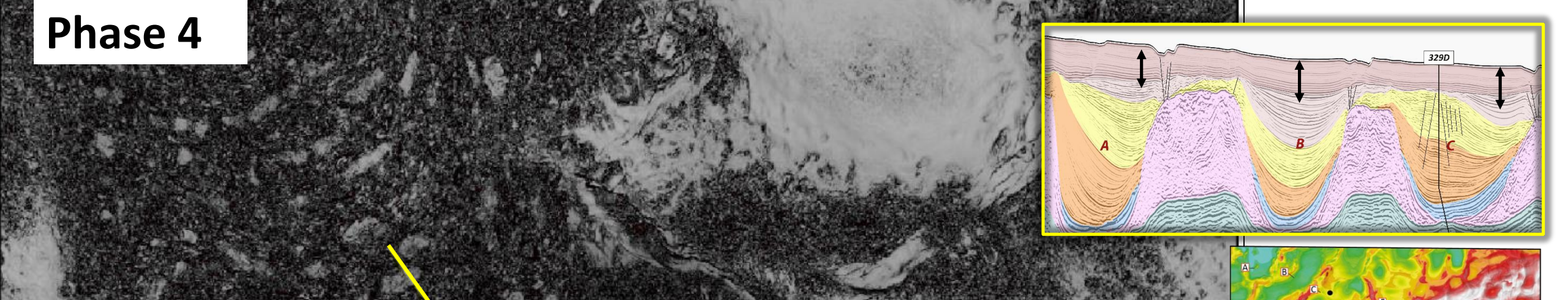


Phase 4

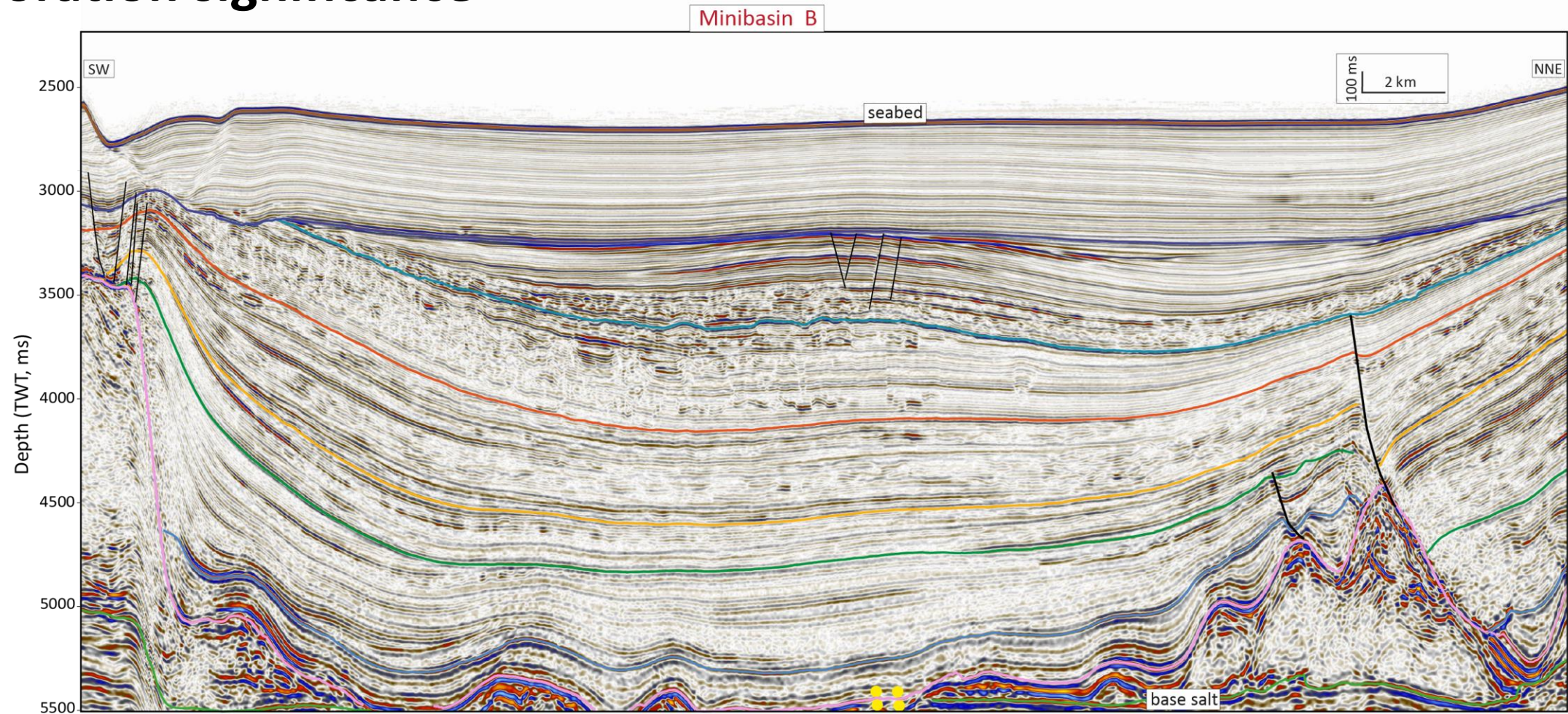
clasts



Phase 4



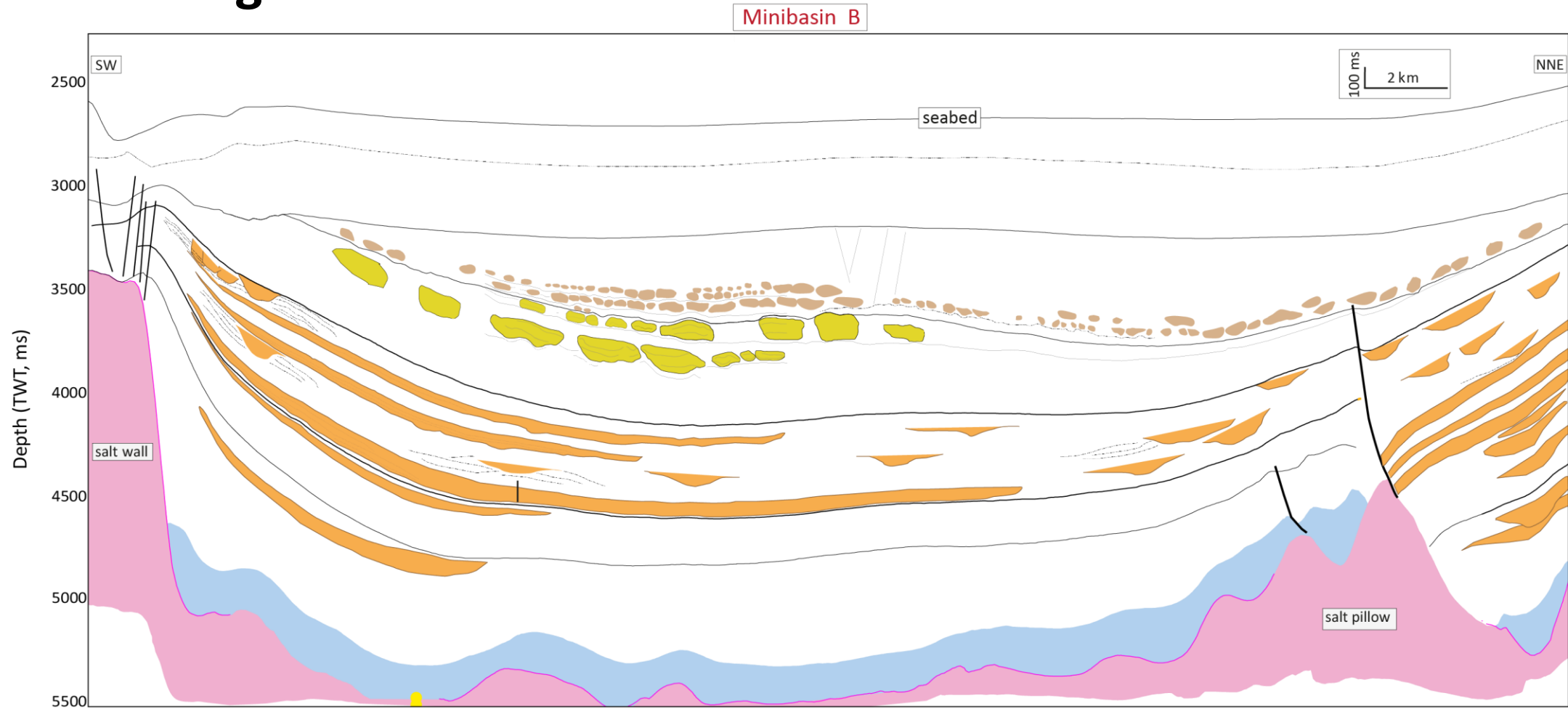
Exploration significance



Salt-related controls led to:

- Changes in the geometry and distribution of deep-water depositional elements
- Development of potential structural and stratigraphic trapping (fault-block traps, onlap, turtle anticlines)

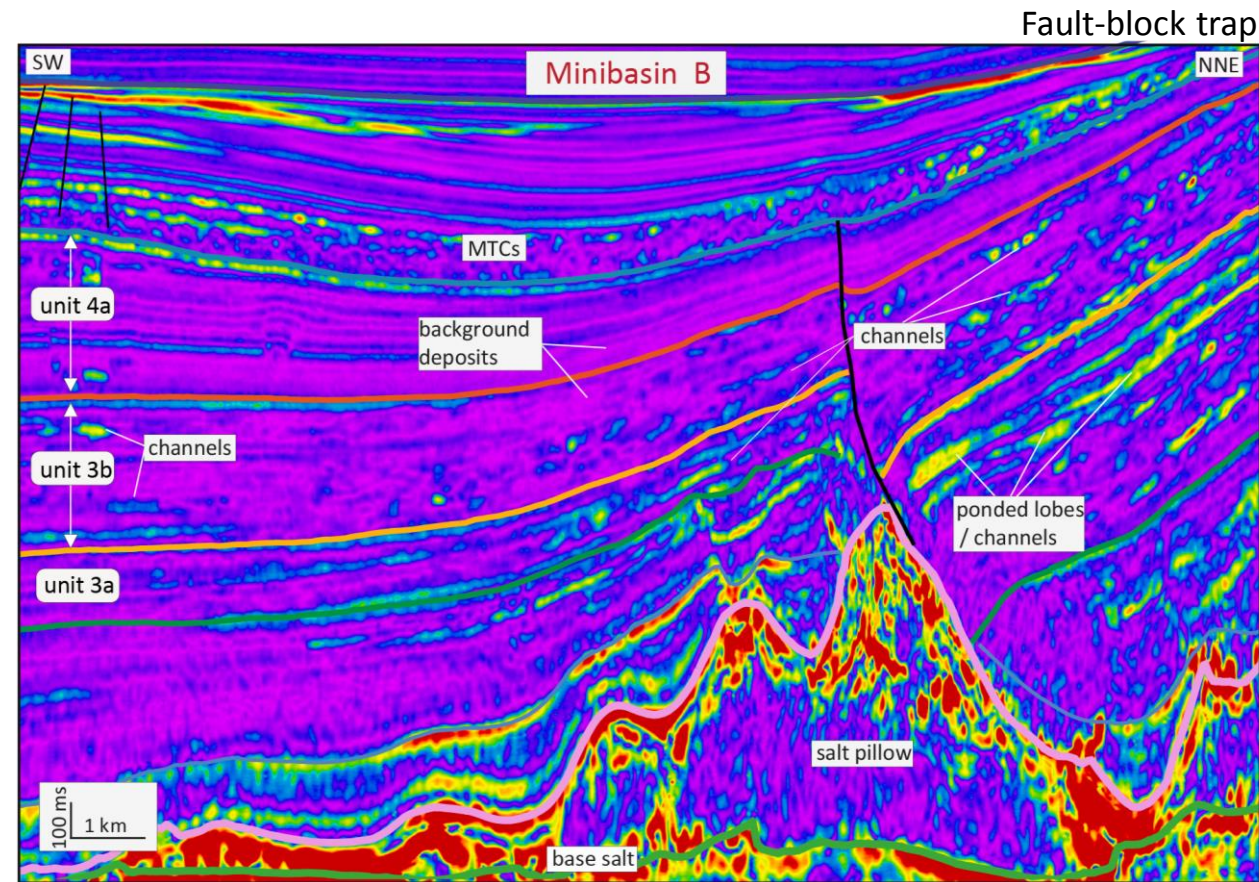
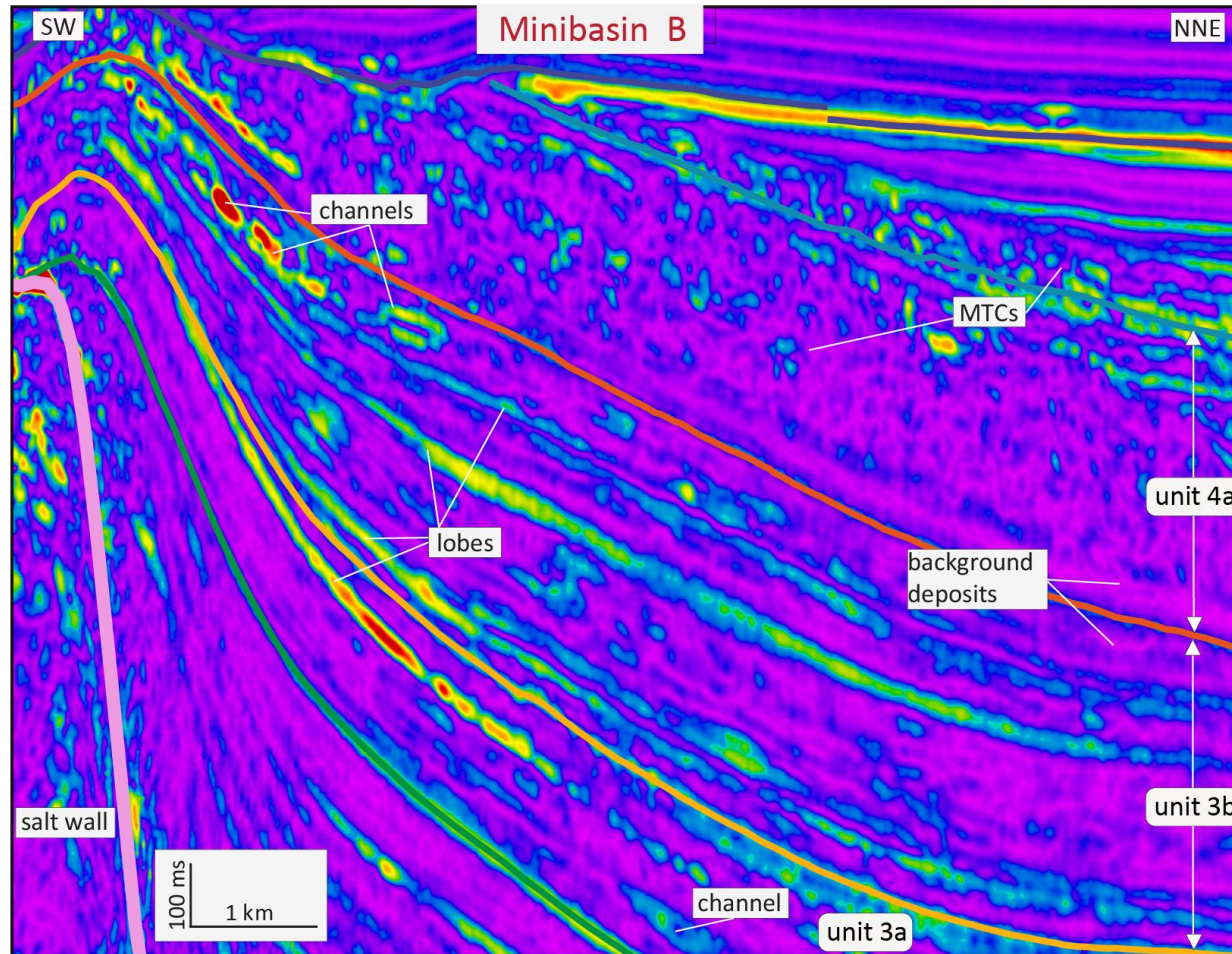
Exploration significance



- Reservoir-prone units: channels, lobes and to a lesser-extent levees
- Seals: Background deposits such as slope mudstone, salt and mud-rich MTCs
- Key risks: Migration due to the thick, very low permeability salt. Welding can facilitate migration.
- Risks associated to MTCs.

Exploration significance

Pinch-out towards salt-cored highs



Take-away message:

The post-salt sequence in central deep-water Santos Basin may have exploration potential,

Distal analogues of the Merluza field in the Santos Basin and the Campanian and Maastrichtian deposits in the Roncador field in the Campos Basin.