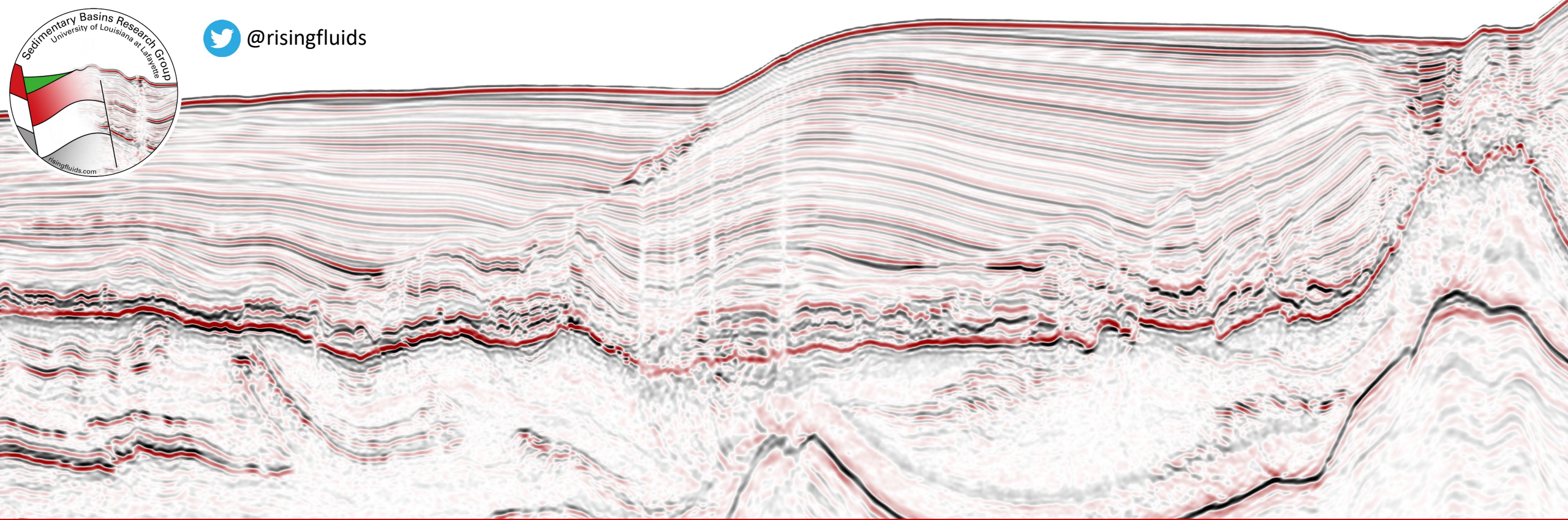


 @risingfluids

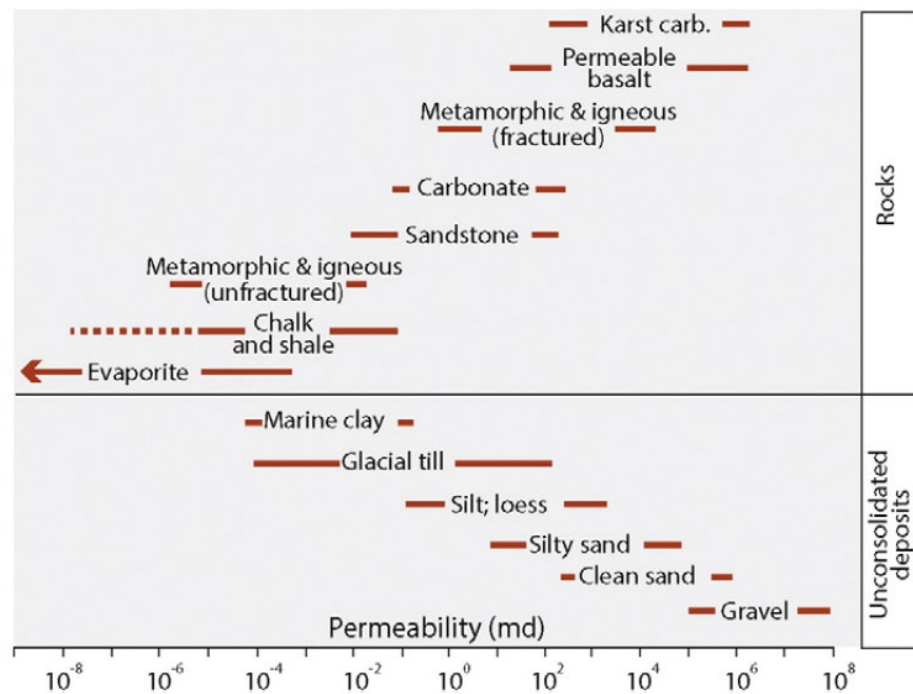


Leaky salt: pipe trails record the history of cross-evaporite fluid escape in the Northern Levant Basin, Eastern Mediterranean

Davide Oppo, Sian Evans, Christopher A-L. Jackson, David Iacopini, SM Mainul Kabir, Vittorio Maselli



Cross-evaporite fluid escape – Why we care?



Warren, 2017

- Salt acts as seals for fluids
 - Hydrocarbon reservoirs and CO₂ storage
 - Potentially a good seal for nuclear waste storage sites
- Salt commonly forms excellent membrane and hydraulic seals due to extremely low permeability
 - Allows volumetrically significant sub-salt accumulations

Recent research shows that salt is not a perfect seal

Tectonic evolution, excessive overpressure, and interaction with pore fluids can reduce or destroy the sealing capacity of salt

Cross-evaporite fluid escape – Why we care?

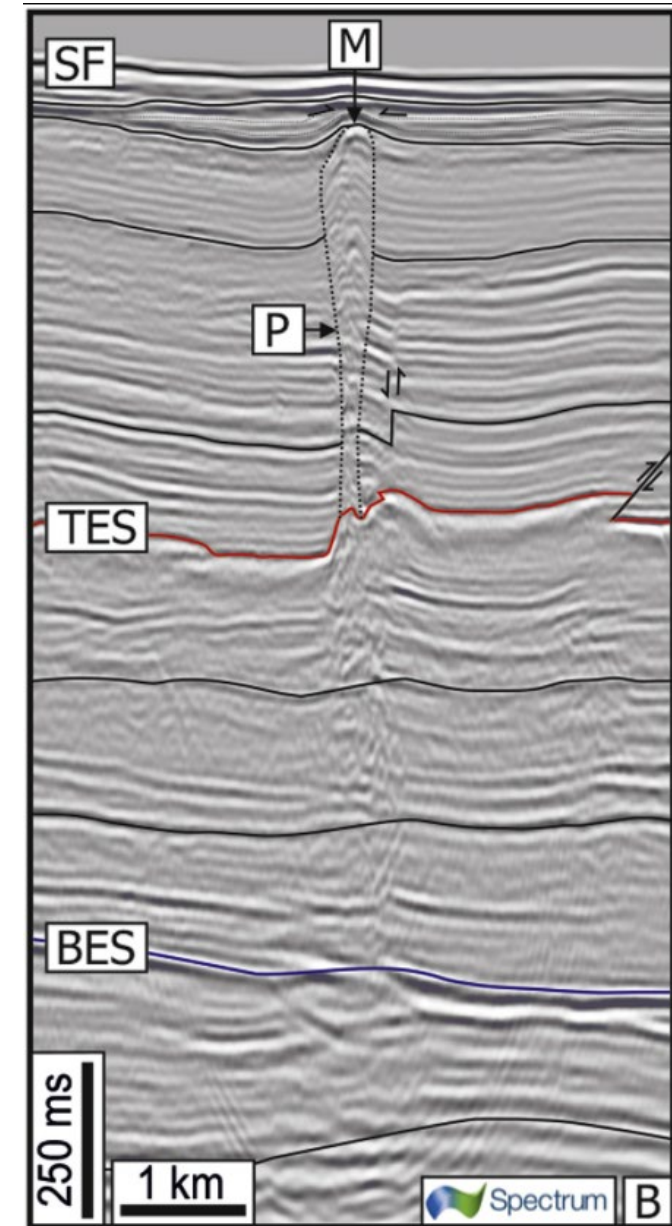
Mainly studied in mature salt basins → extensive salt tectonics

Lack of high-quality outcrops and subsurface datasets of sufficient extent and quality

- 3D relationship between large salt structures, their overburden, and related fluid flow features

Seismic data has also only relatively recently been able to resolve relatively small fluid escapes features

Processes and products of cross-evaporite fluid escape remain poorly understood in the history of a salt basin not yet influenced by mature halokinesis



Bertoni et al., 2017

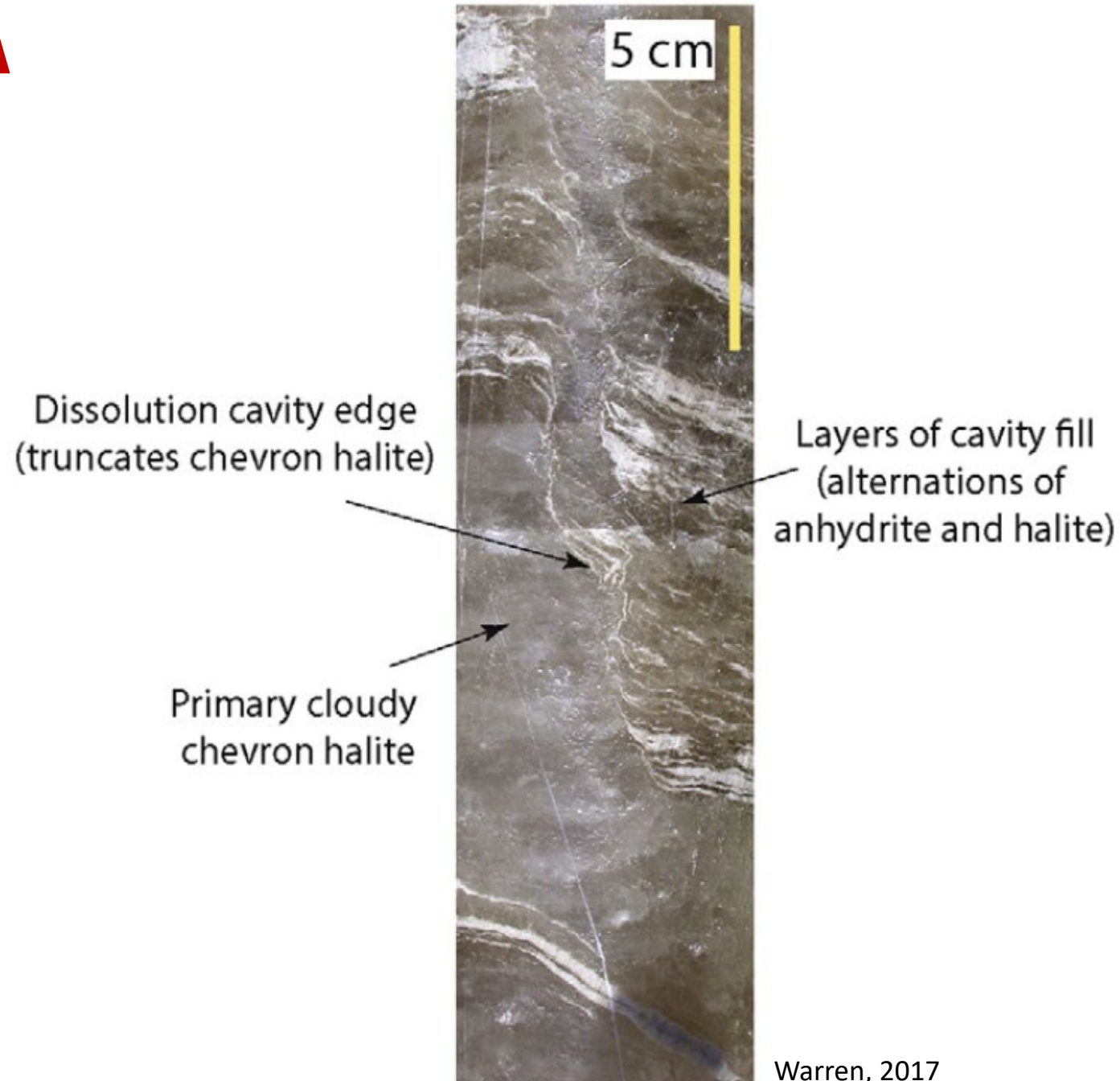
Why we have fluid escape?

Fluid escape through evaporite seals is difficult:

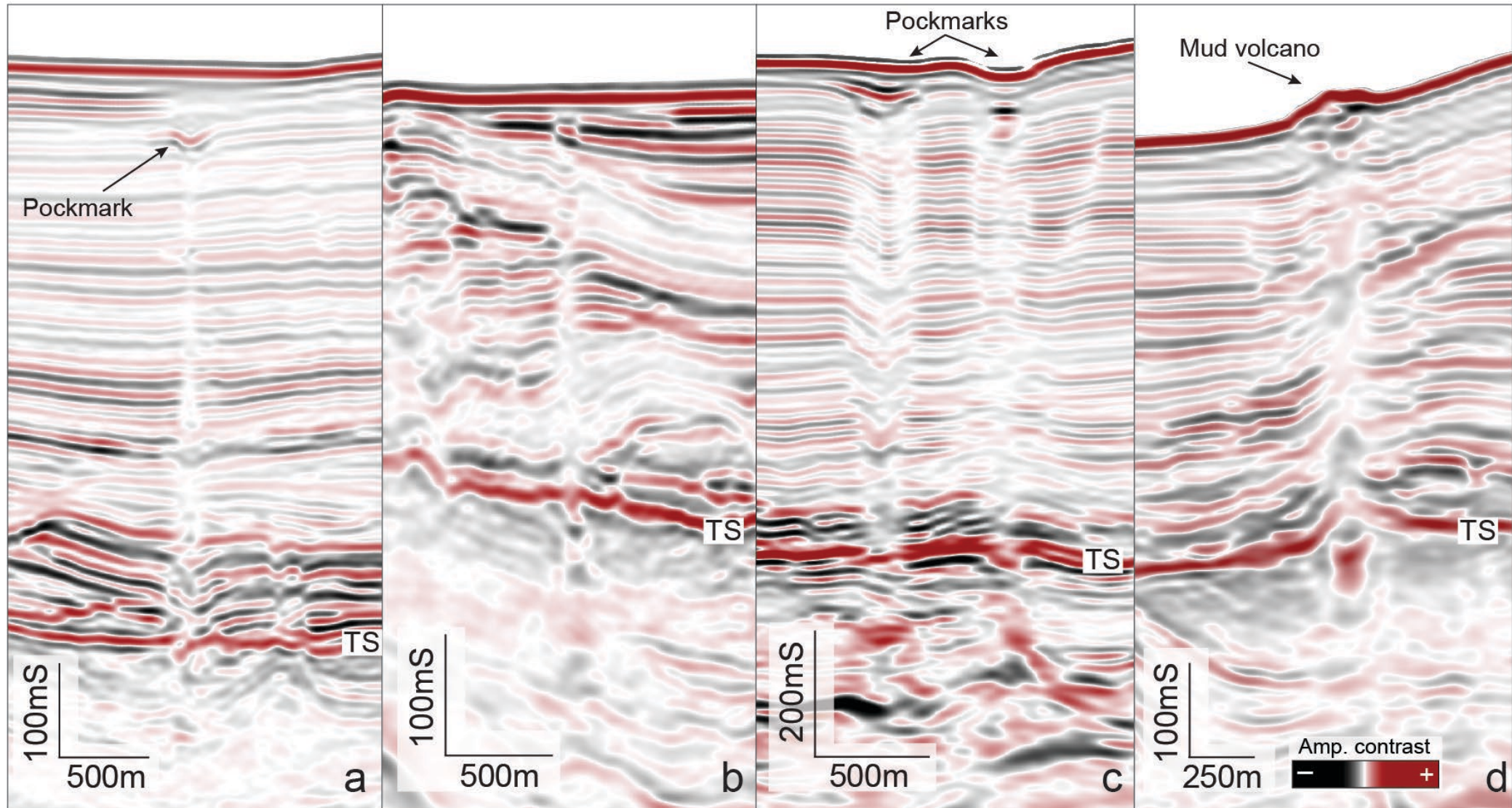
- Salt ability to maintain seal integrity
- Salt flows under stress
- Salt quickly re-anneals fractures

However:

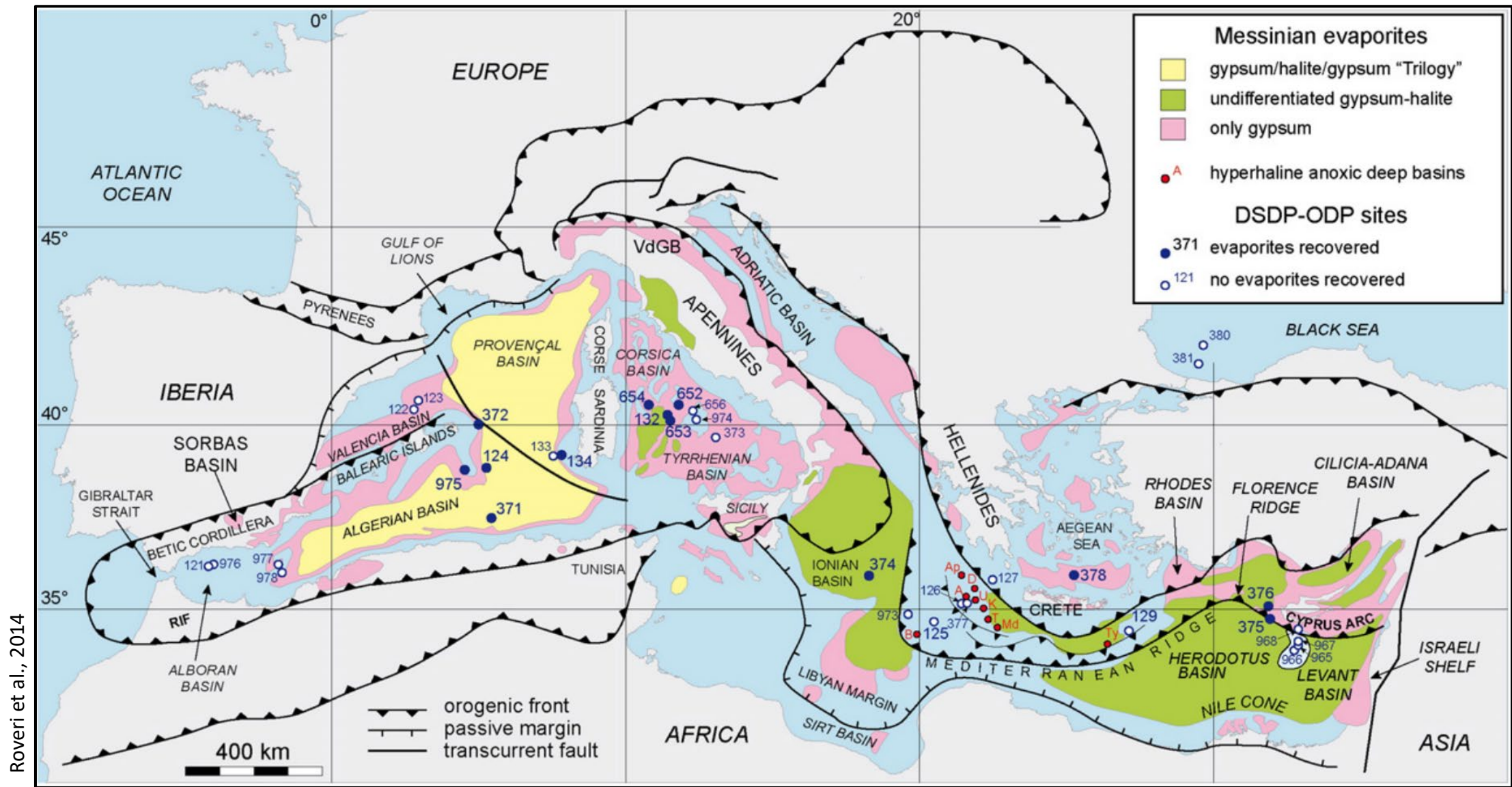
- Salt welding
- Faulting
- Salt dissolution
- Overpressure-related hydrofracturing



What fluid escape pipes are?



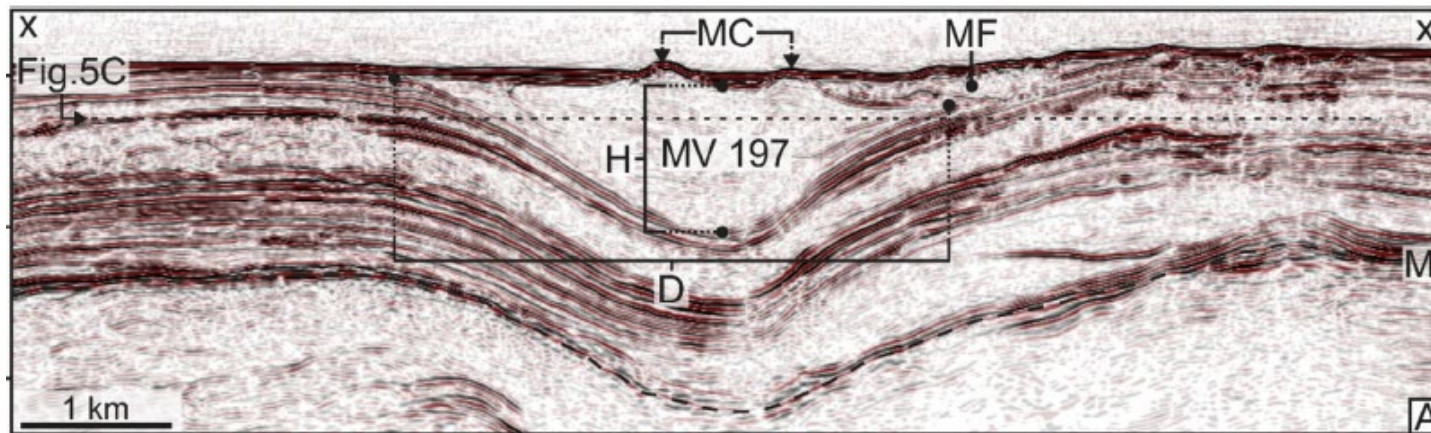
Messinian Salinity Crisis – the birth of a salt giant!



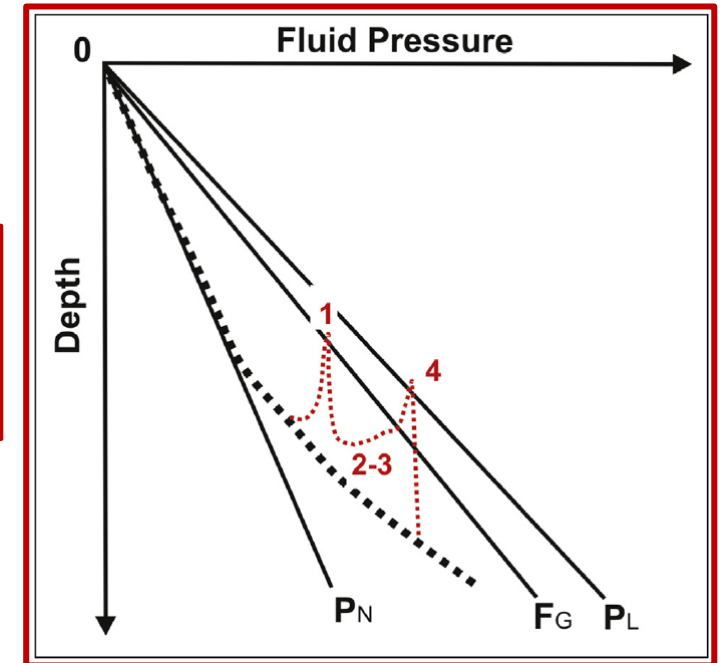
Why did fluid expulsion form in the East Med?

- Messinian Salinity Crisis
- Faults
- Dissolution
- Disequilibrium compaction

1. rapid water unloading
- 2-3. rapid deposition of thick salt
4. rapid water loading



Kirkham et al, 2017



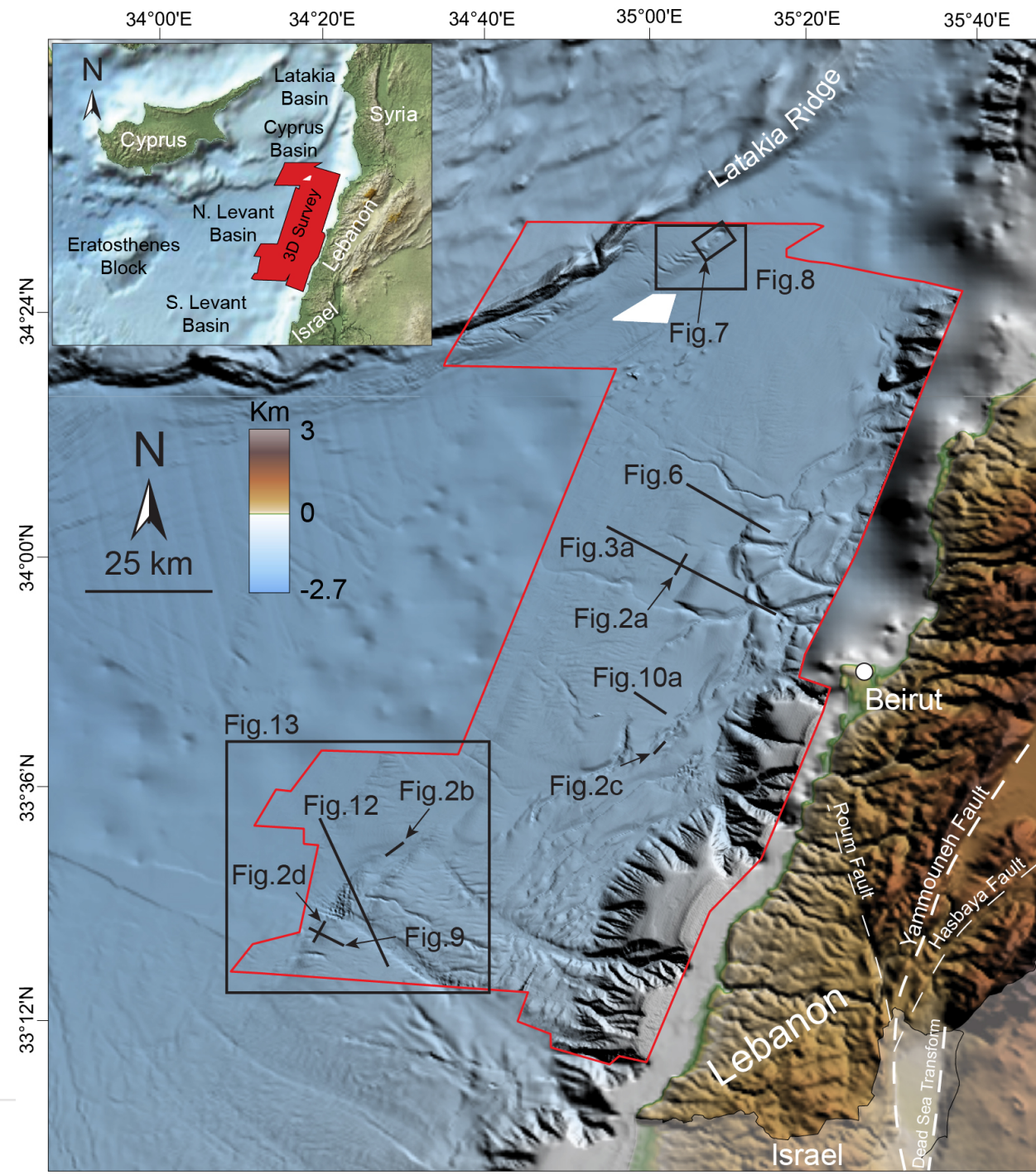
Bertoni & Cartwright, 2015

Levant Basin – East Med, new frontier

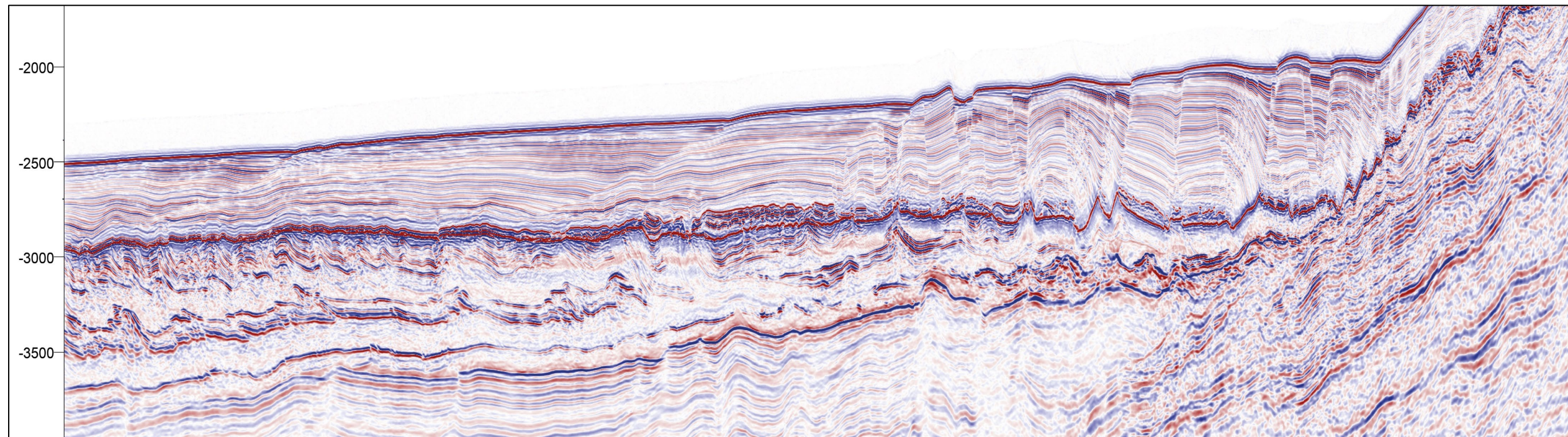
- Shaped by the collision of the African and Eurasian plates
- At the end of the Messinian the Levant Fracture System onshore Lebanon and Israel **gradually uplifted the eastern margin of Levant Basin**

The rate of uplift was not constant:
higher rates during the Late Miocene-Pliocene and Late Pleistocene

- Uplift and tilting, as well as differential loading, led to **gravity-driven salt tectonics**



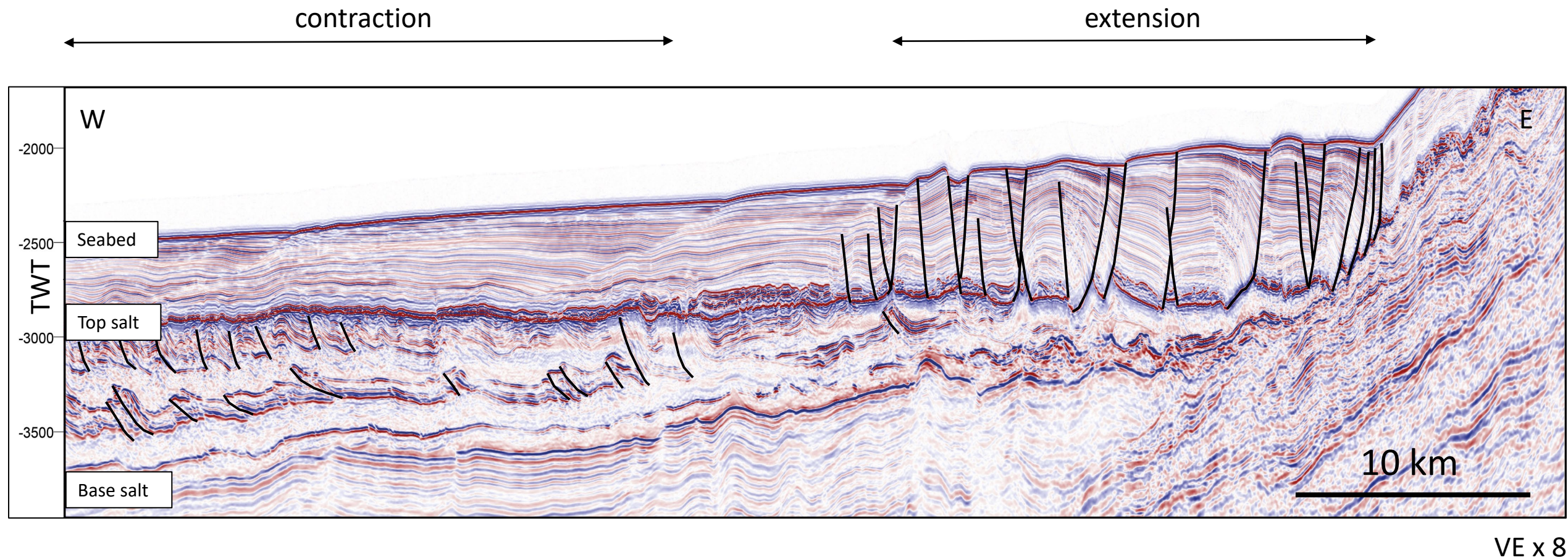
Salt tectonics



Modif. from S. Evans

Dr. Davide Oppo

Salt tectonics

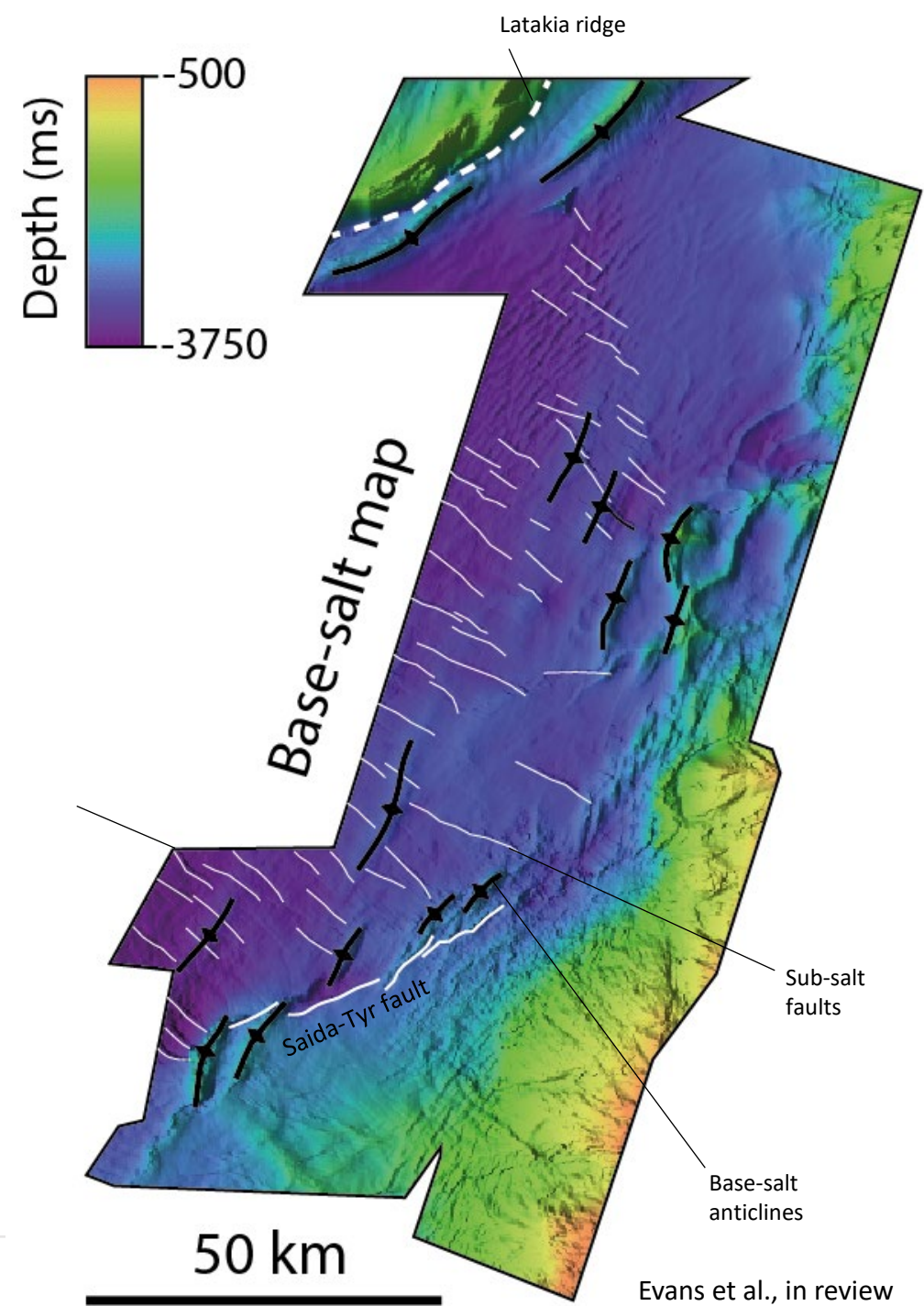


Modif. from S. Evans

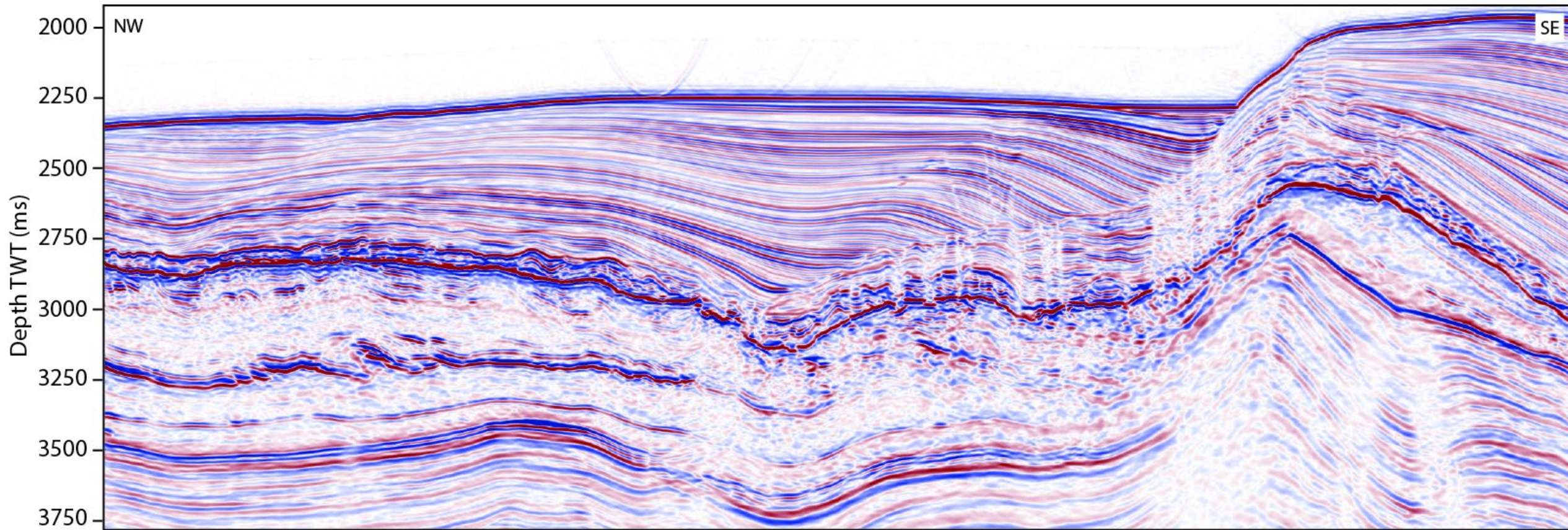
Structure map

Folding and thrusting led to NE-trending anticlines

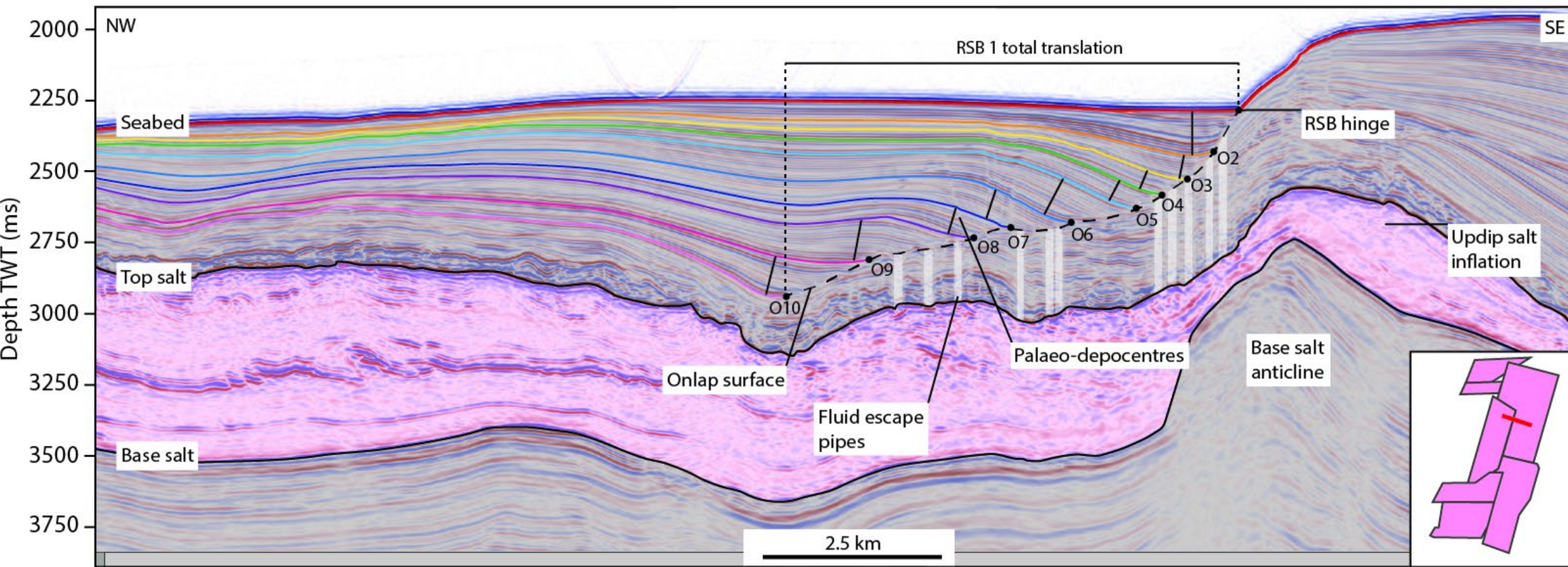
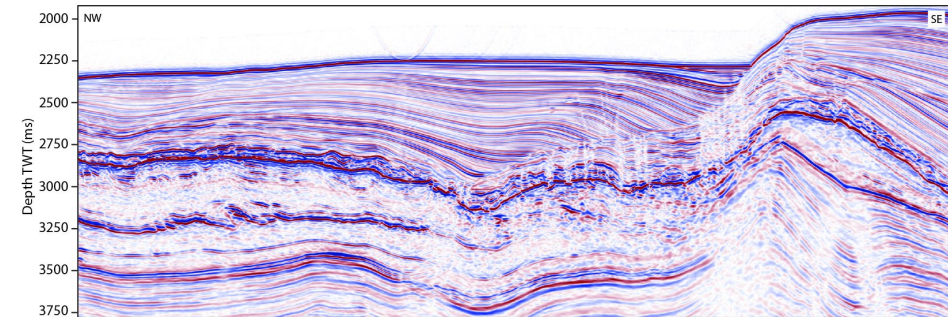
Oligo-Miocene sedimentary units have been deformed prior to, or at the onset of, the MSC



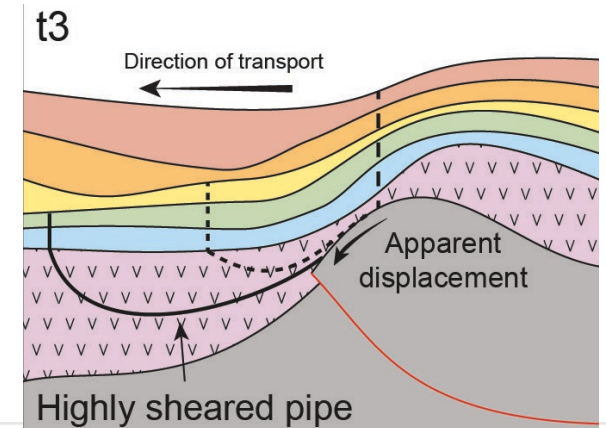
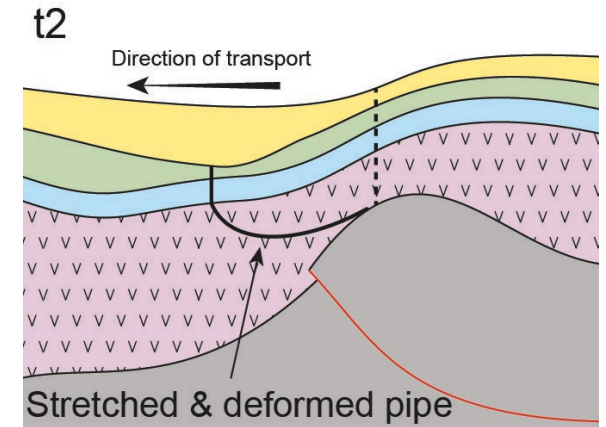
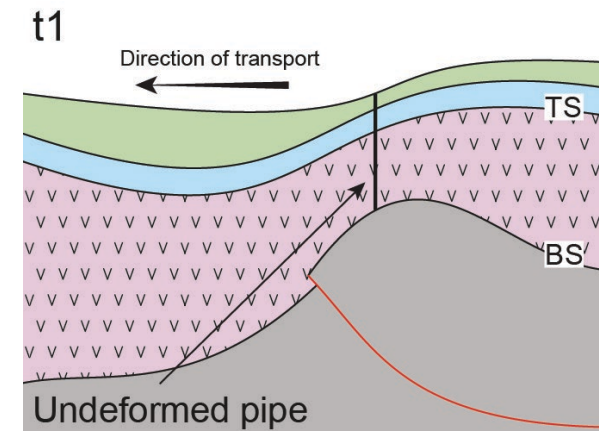
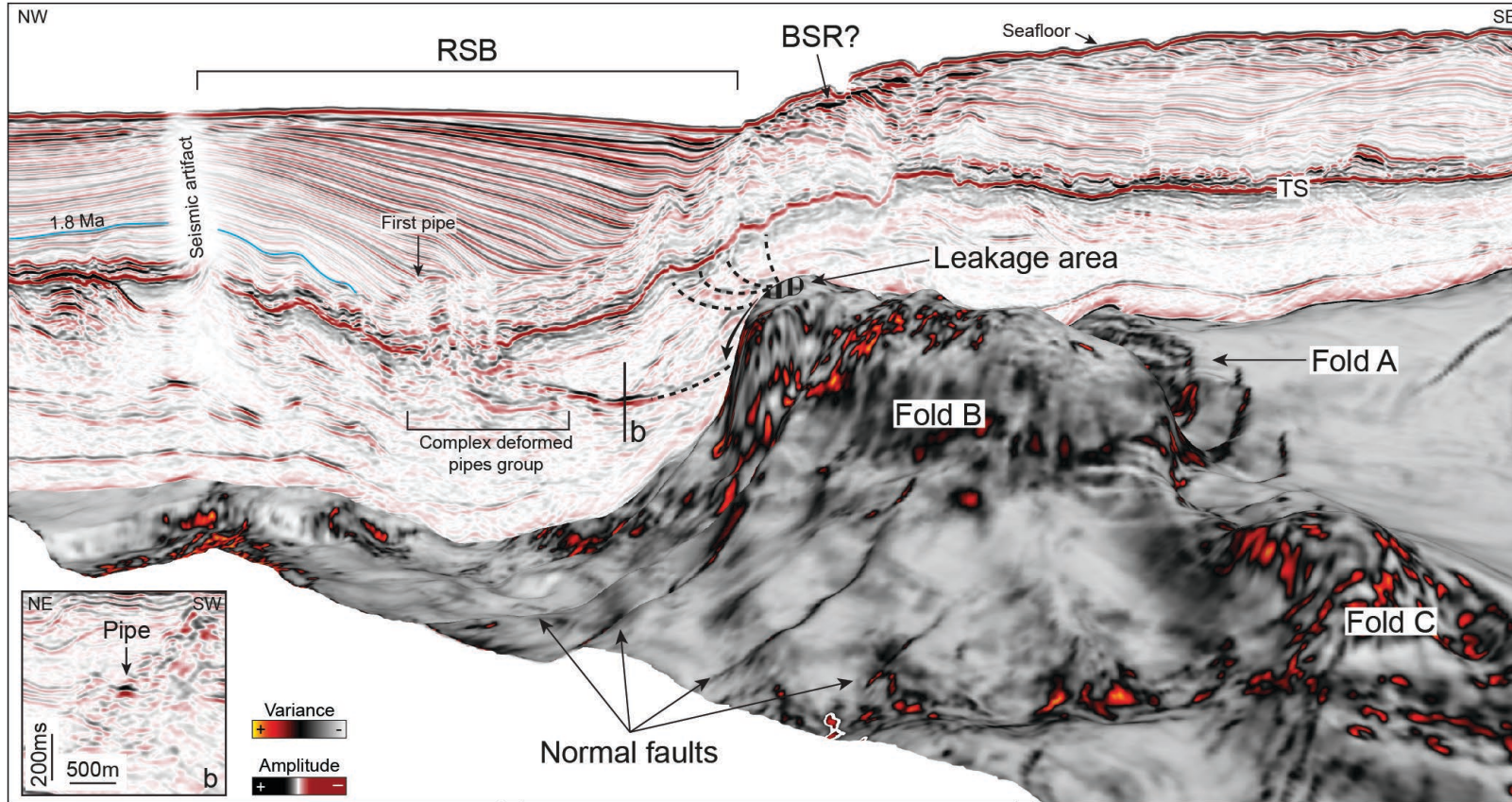
Ramp Syncline Basins

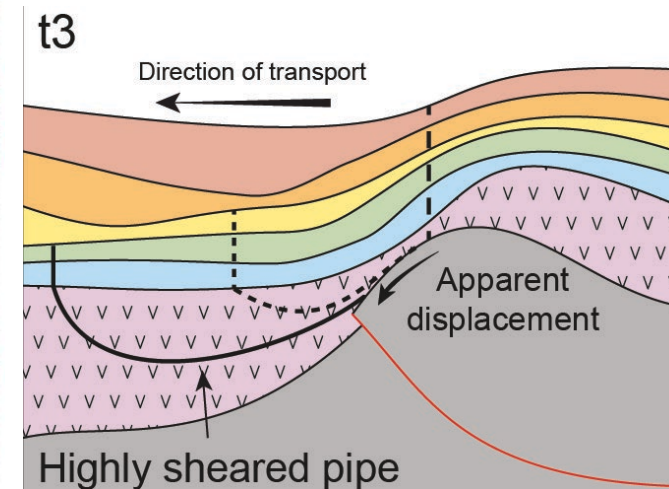
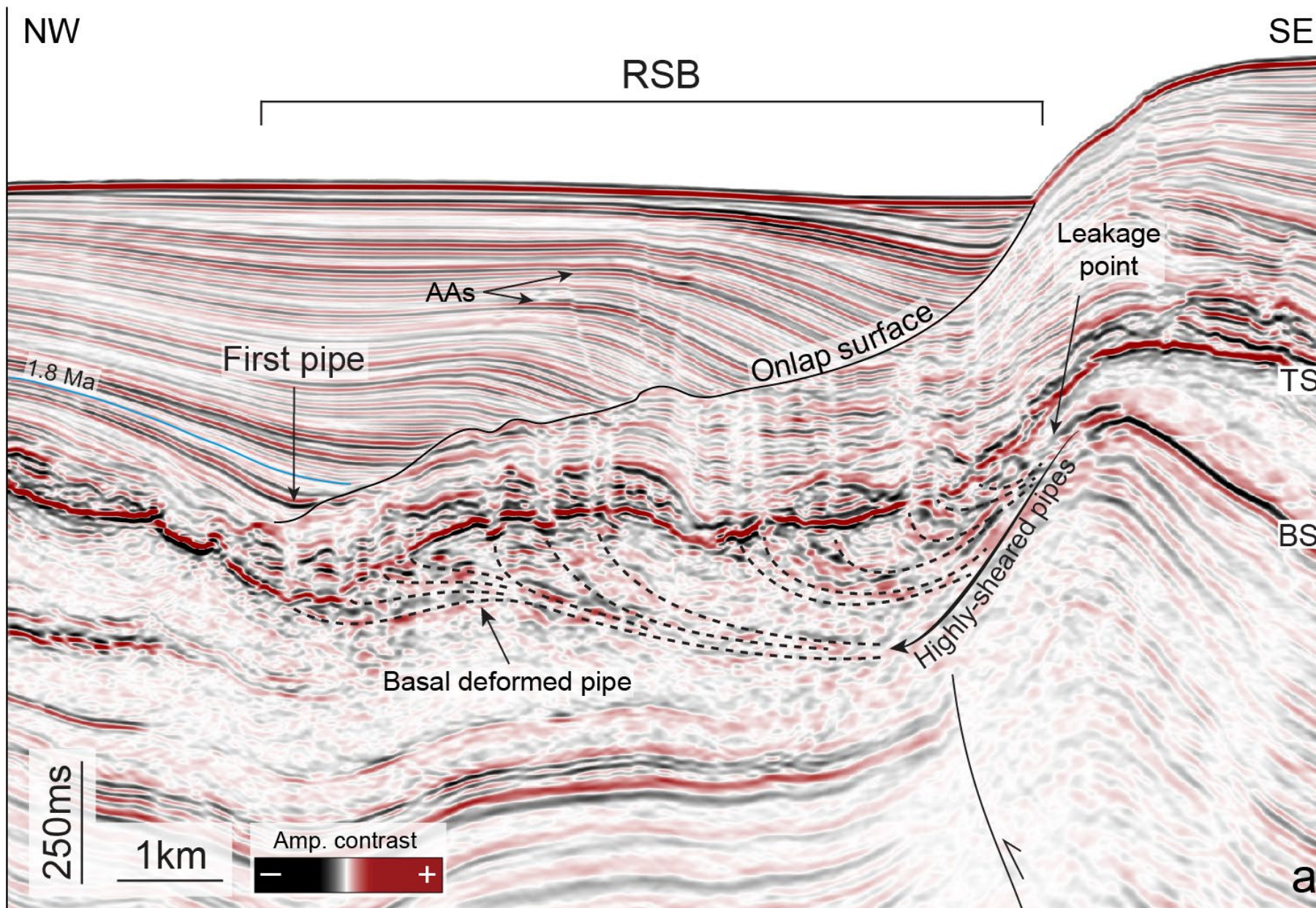


Ramp Syncline Basins

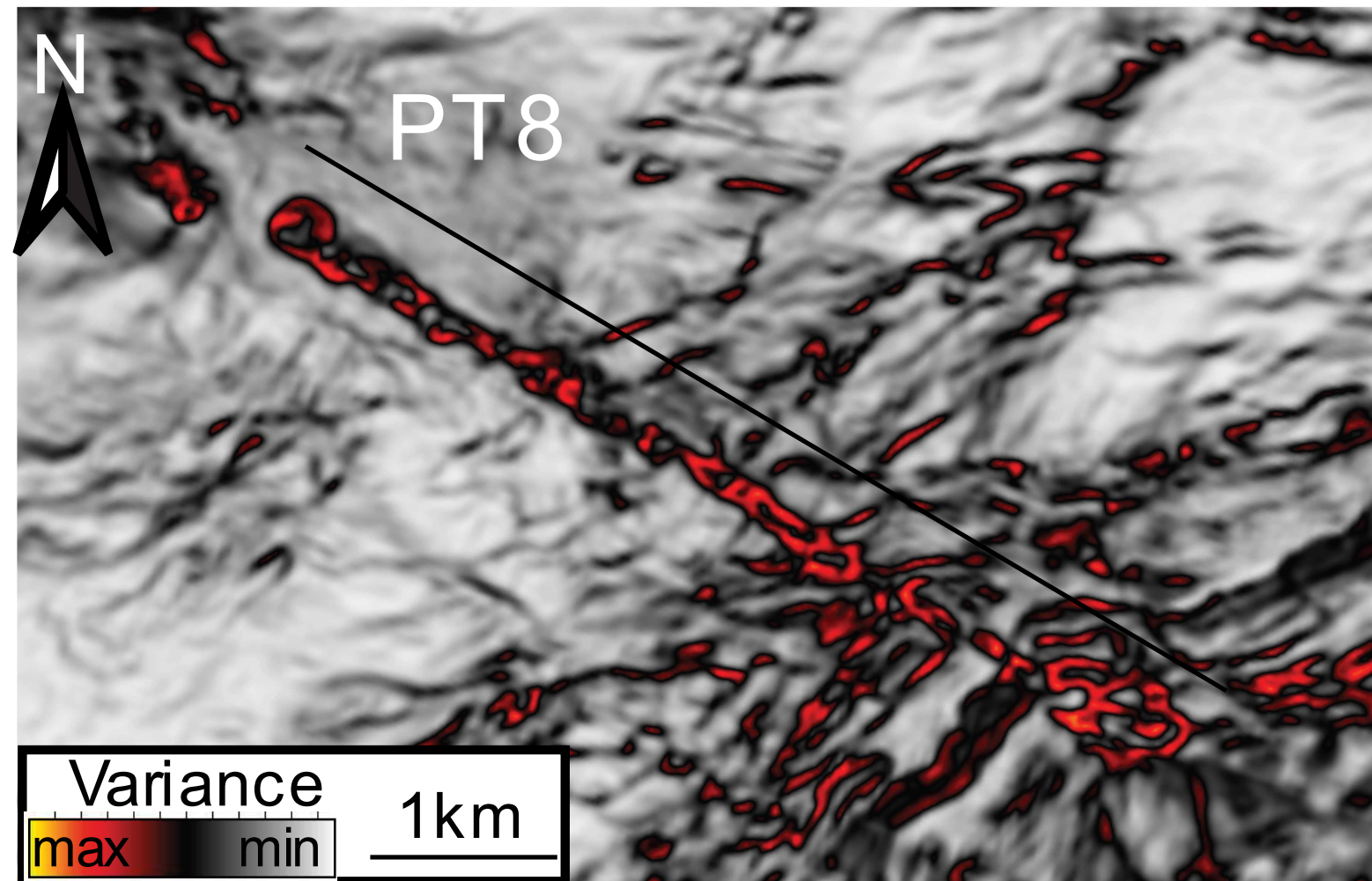
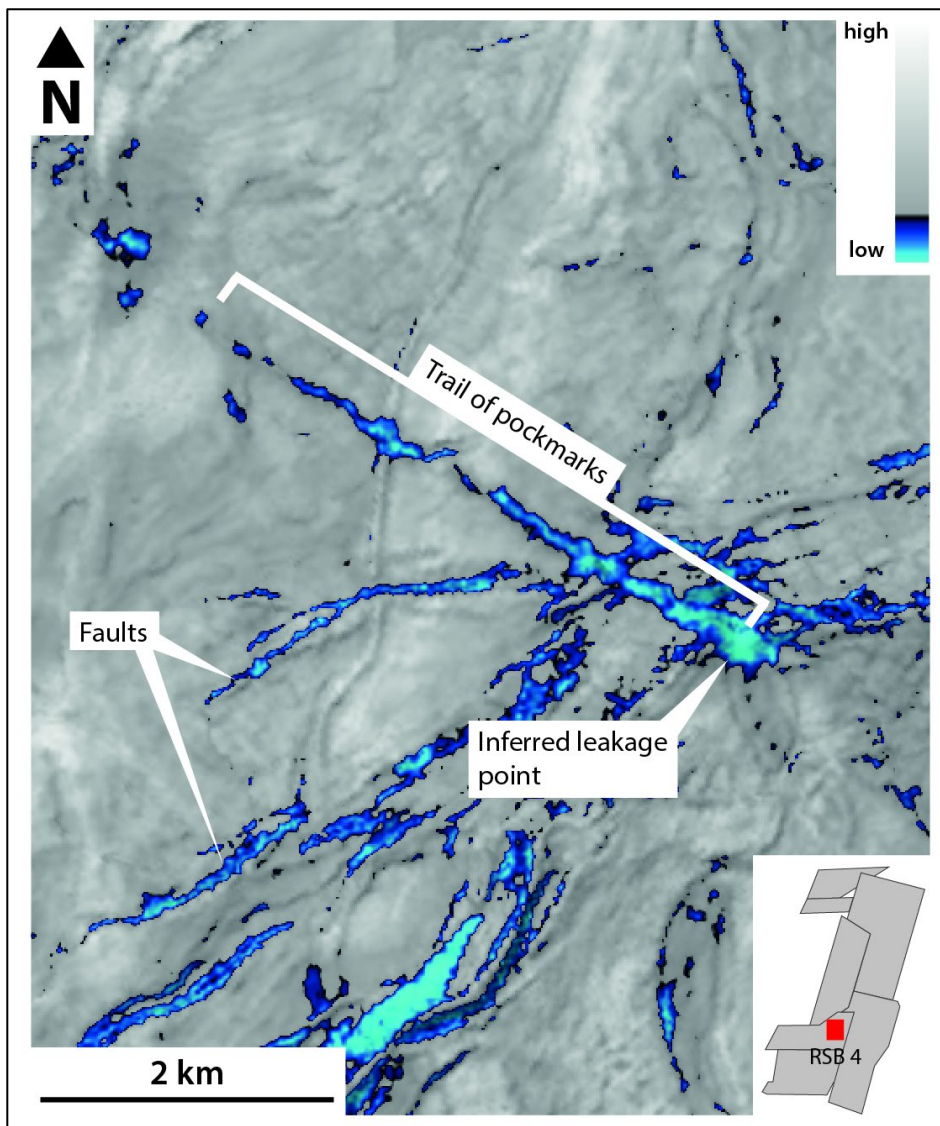


Fluid escape pipes & RSBs

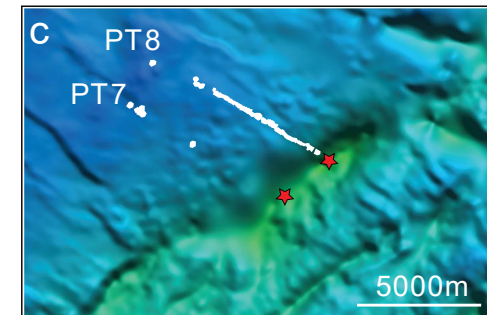
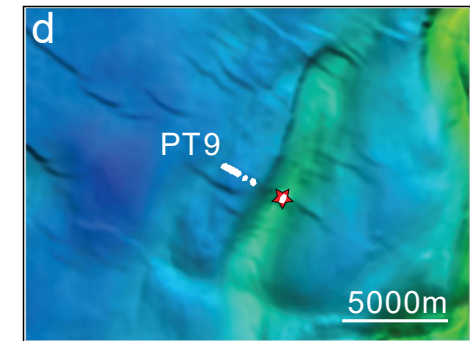
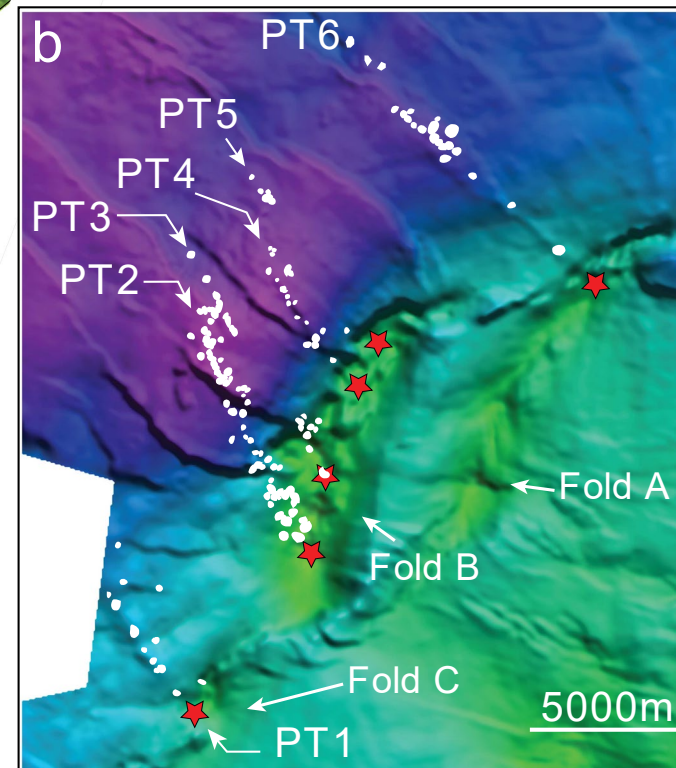
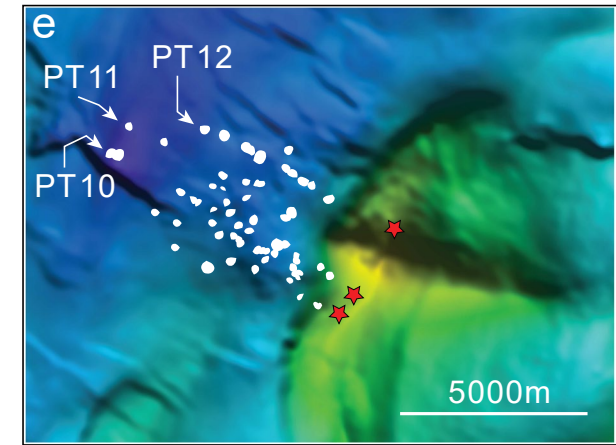
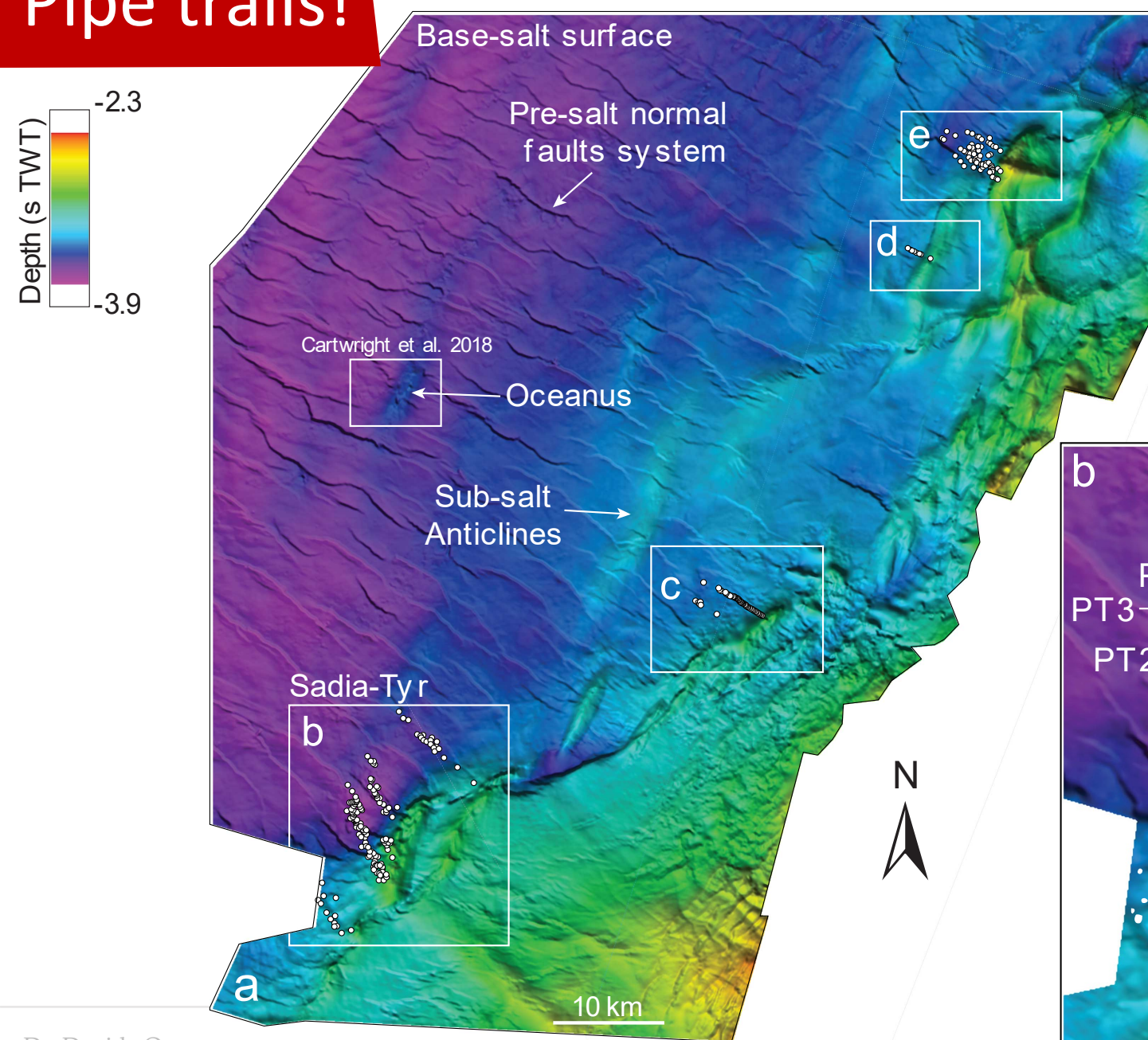




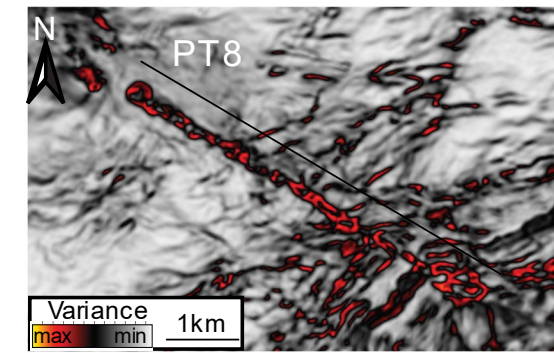
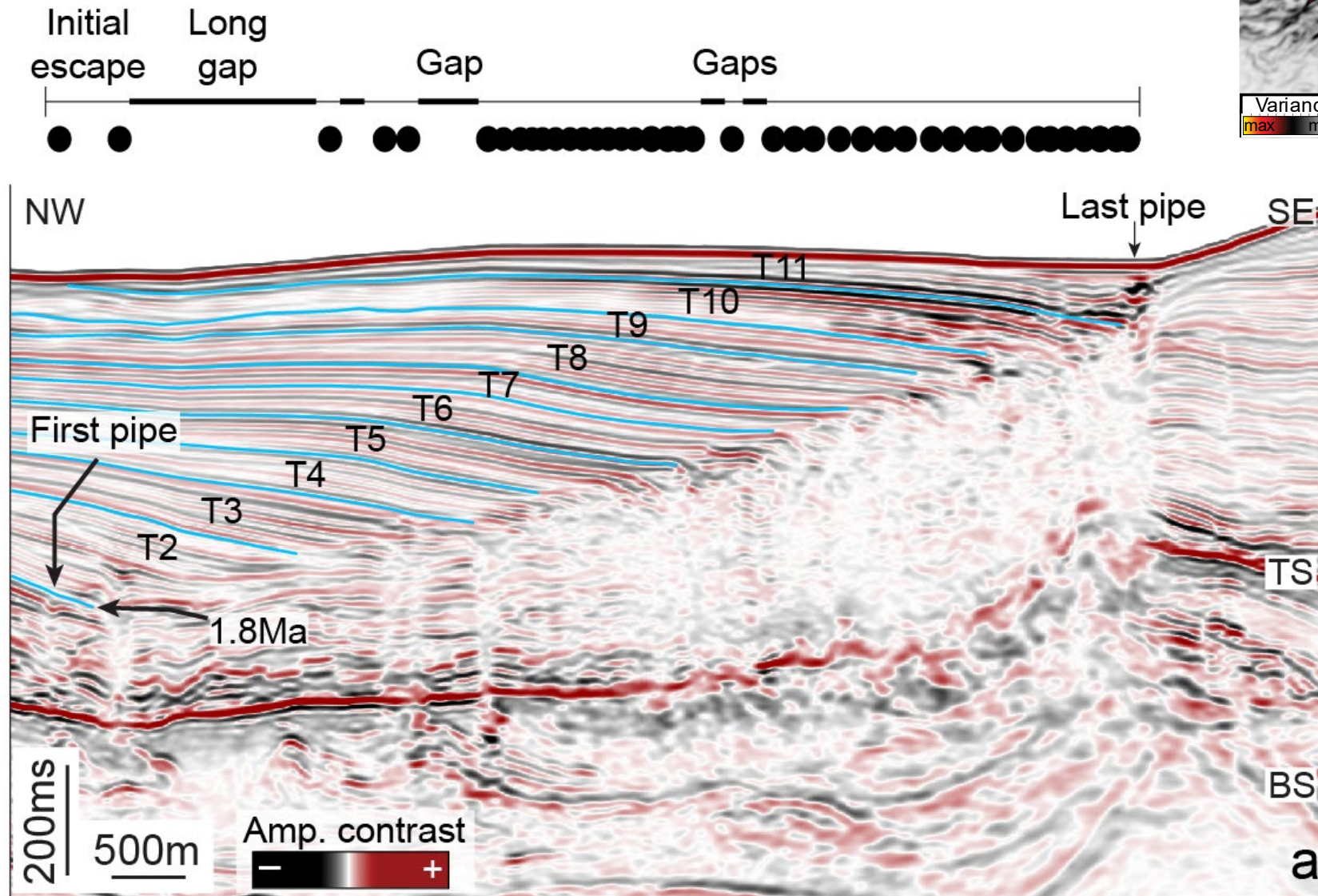
Pipe trails!



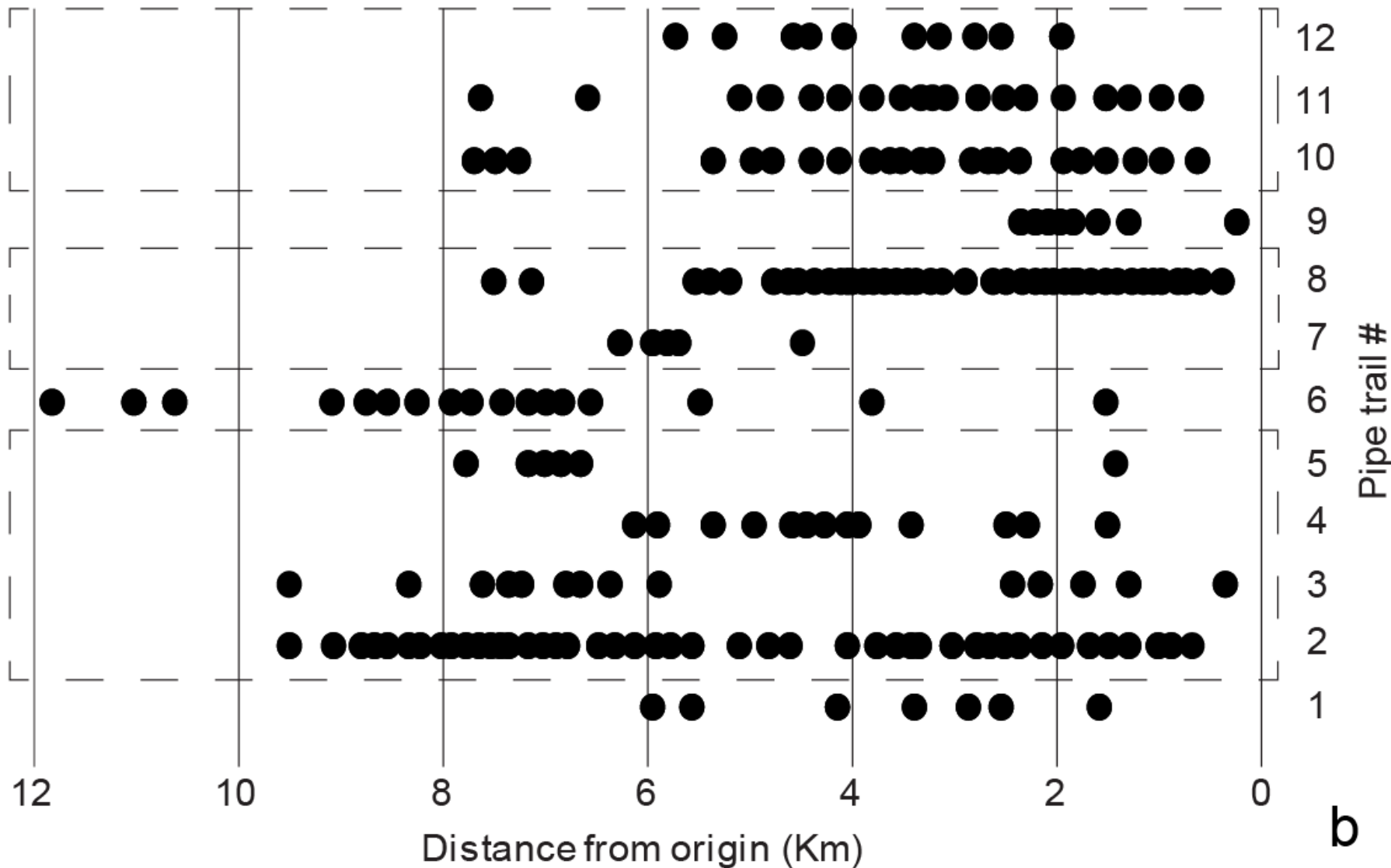
Pipe trails!



Pipe mapping within each trail



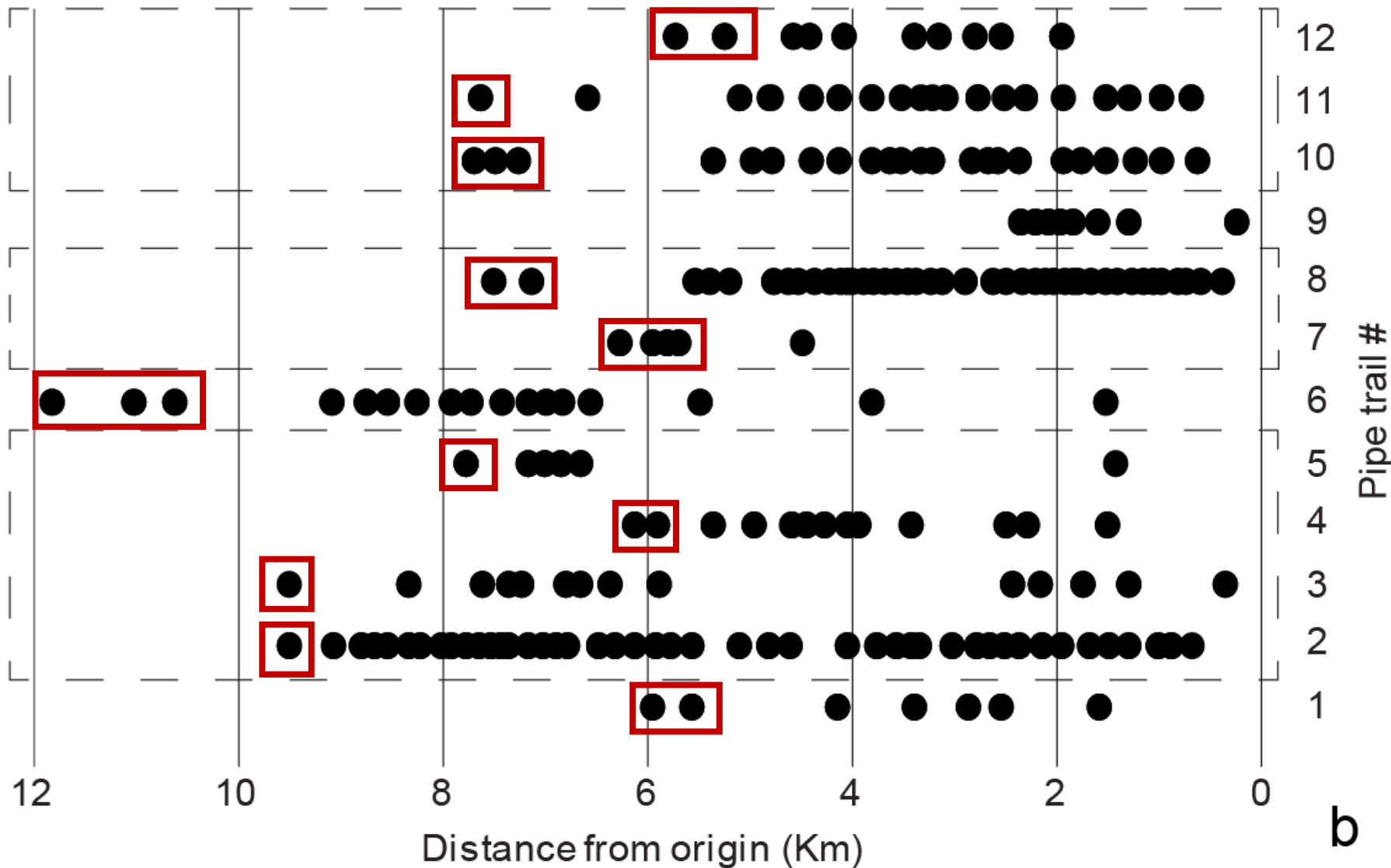
Pipe mapping - All trails



- First-order distribution:

A small but well-defined cluster of closely spaced (<1 km) pipes, or a single pipe, is separated from younger features by a c. 1 km gap.
- Younger pipes are more widely dispersed along the trail length

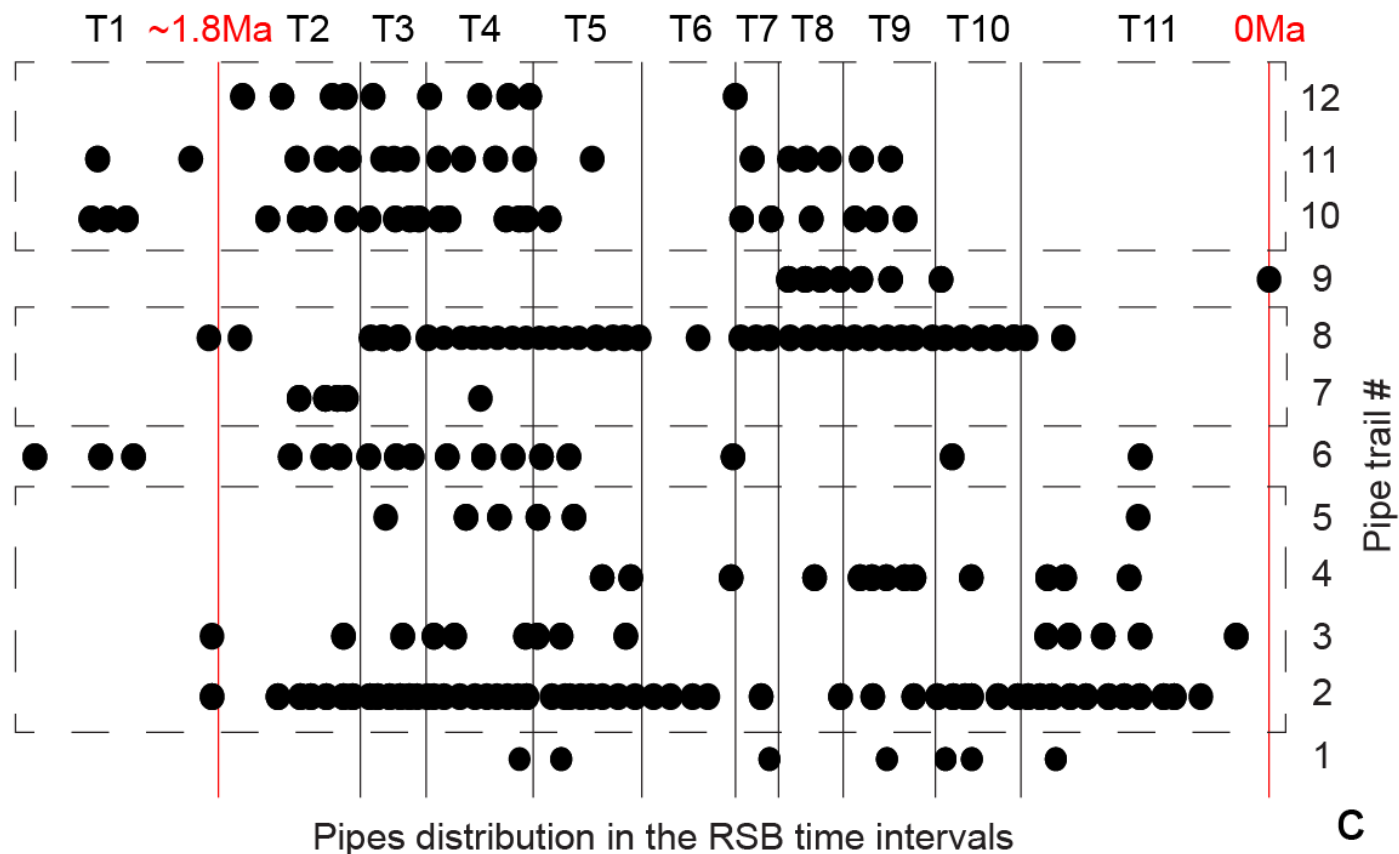
Pipe mapping - All trails



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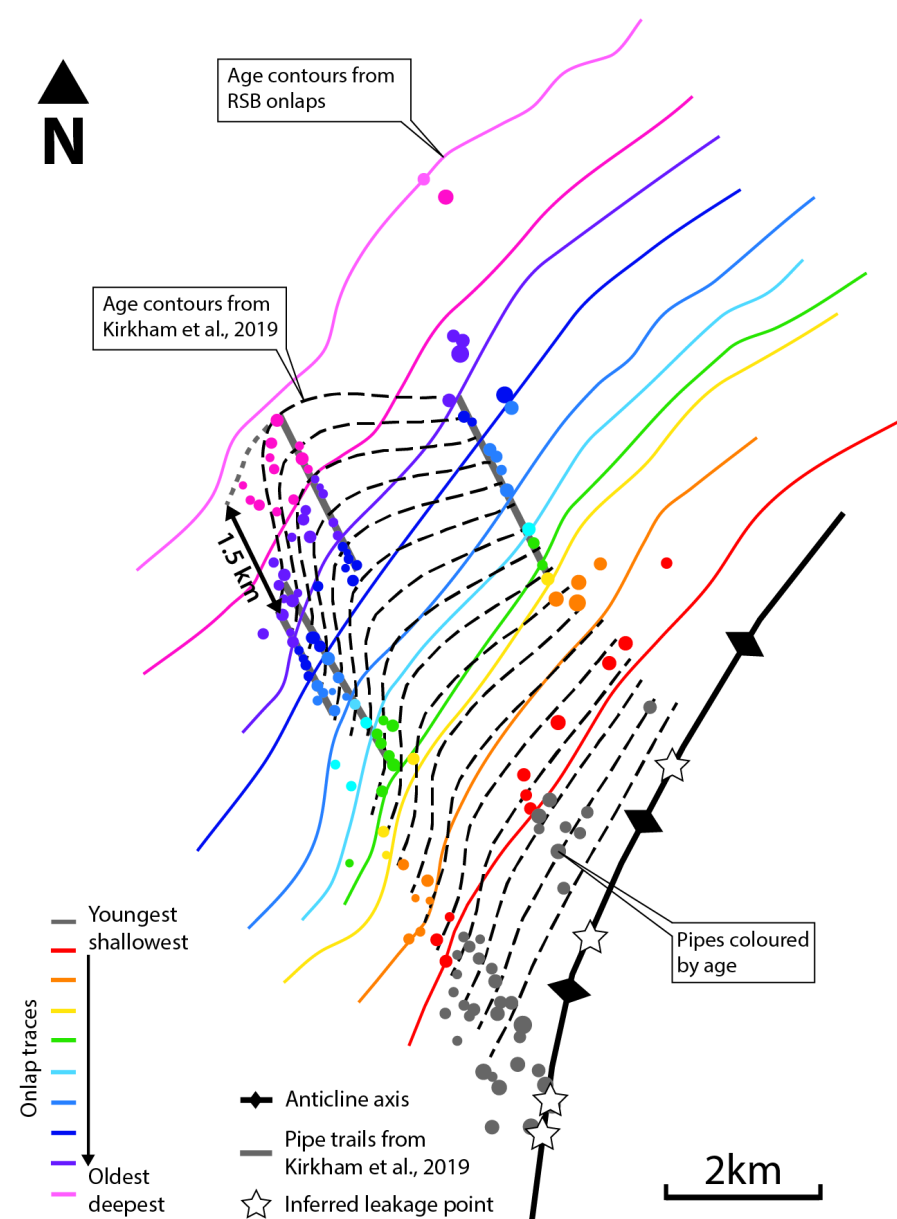
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When did the pipes form?



Can we date the pipes in the trails?
Not really (YET!)

But... we can date (relatively) the sediments in the RSB!

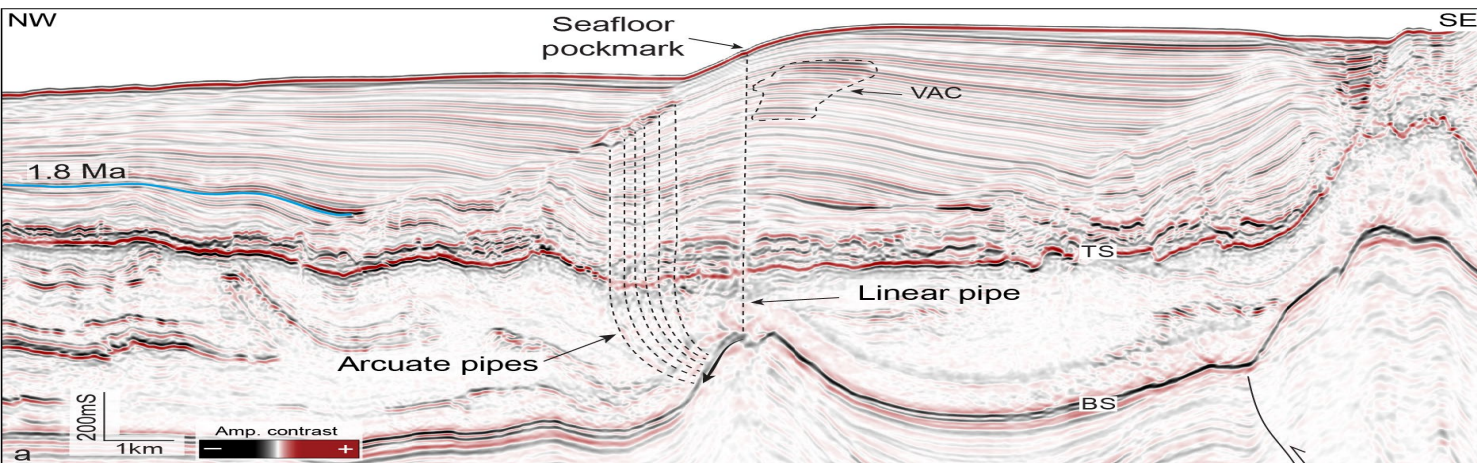
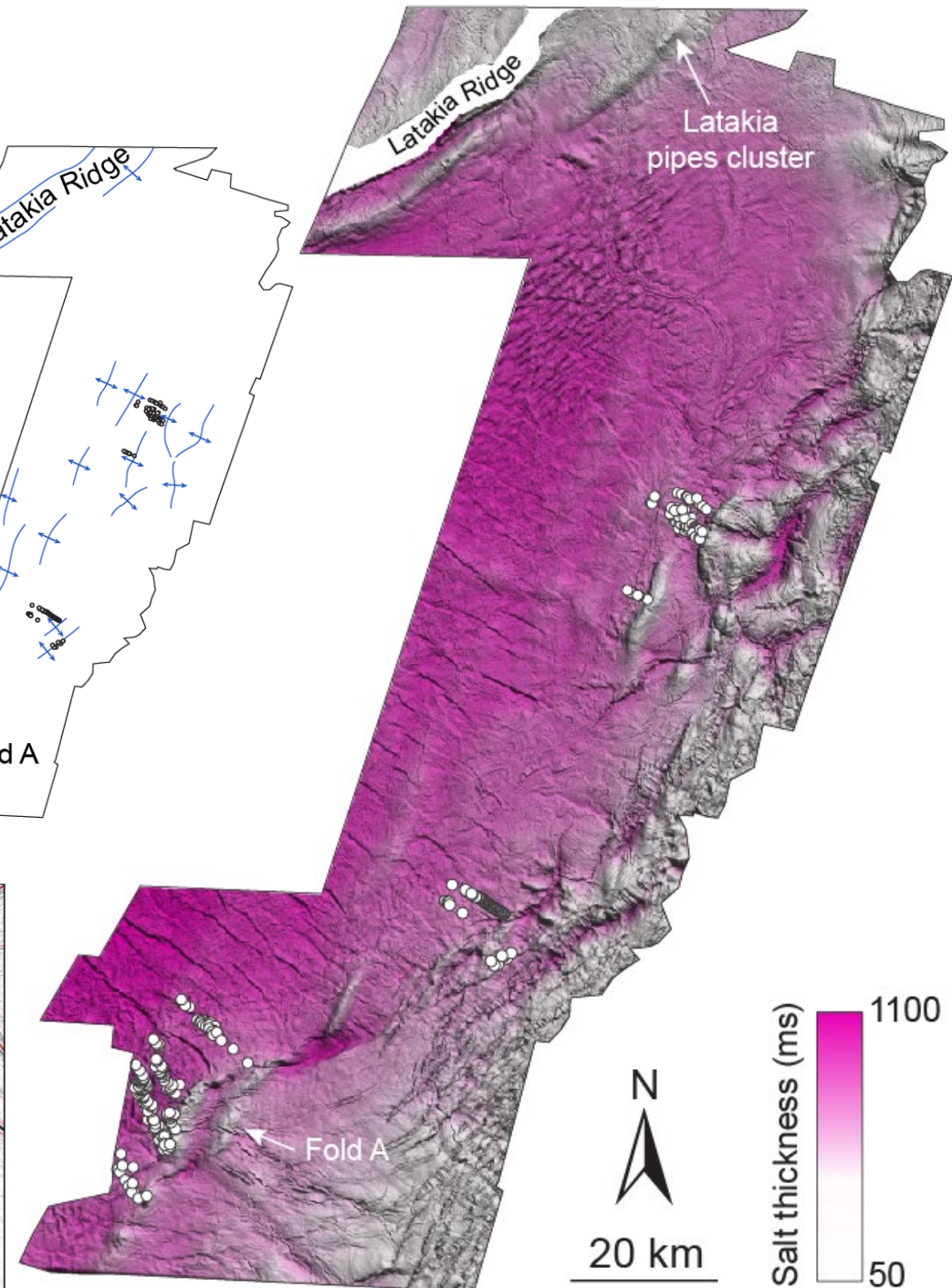
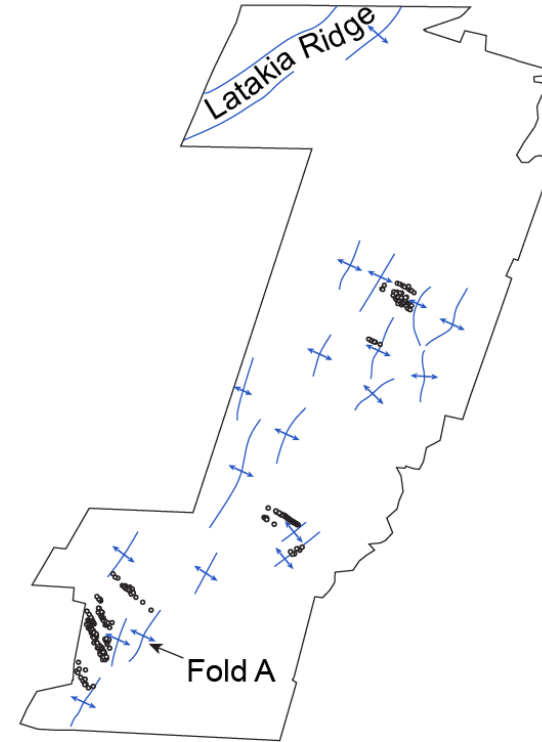


Evans et al, 2020

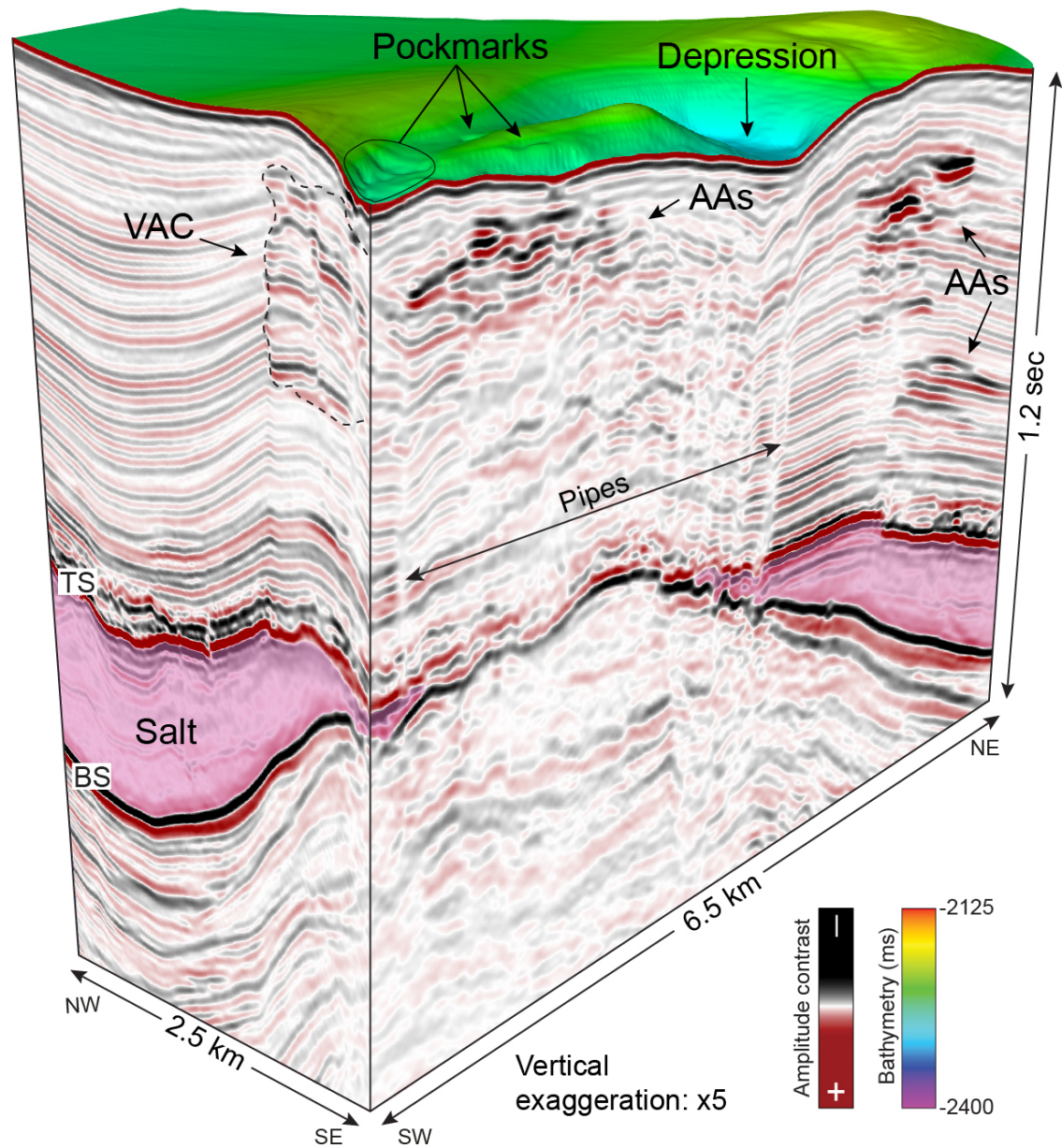
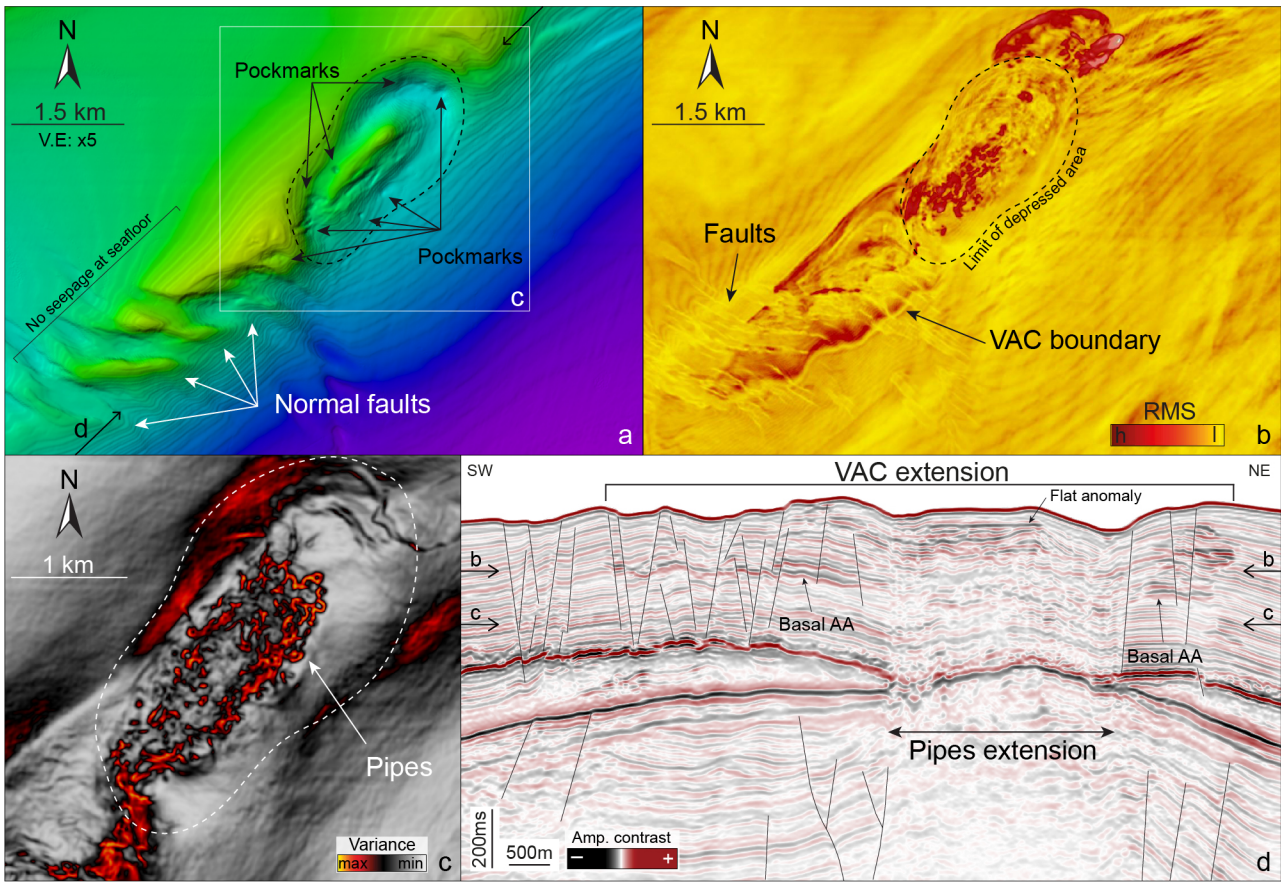
Where did the pipes form?

Pipes form only on top of prominent anticlines where the salt is thinner

These anticlines act as 4-way-dip closure hydrocarbon traps that allow extensive fluid accumulation, increasing the potential for overpressure generation and hydrofracturing.

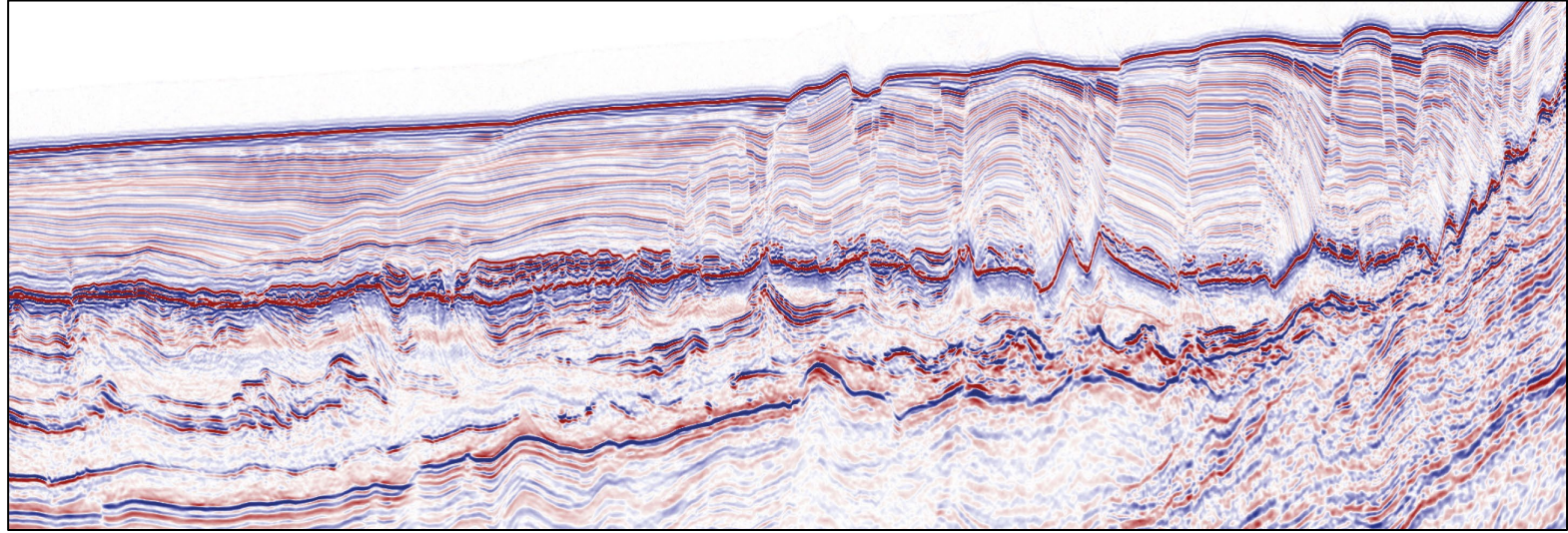


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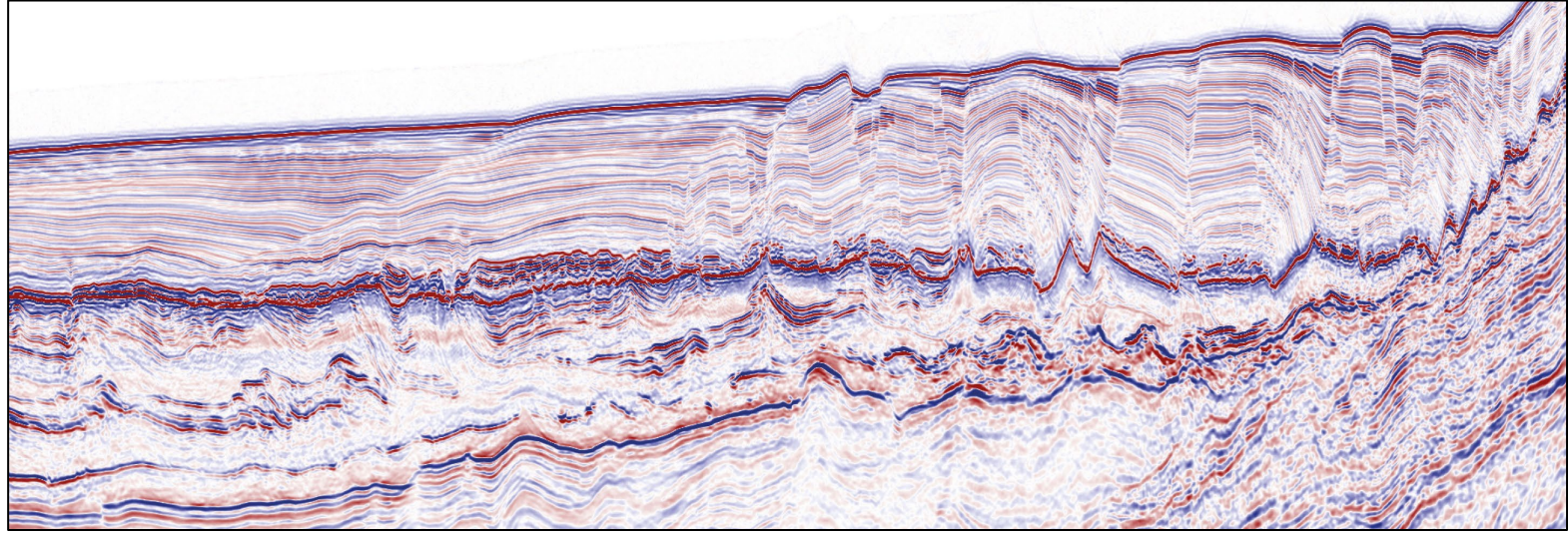
Looking for a trigger...

Thin-skinned extension detaches within the top of salt and does not crosscut the evaporite layer.



Looking for a trigger...

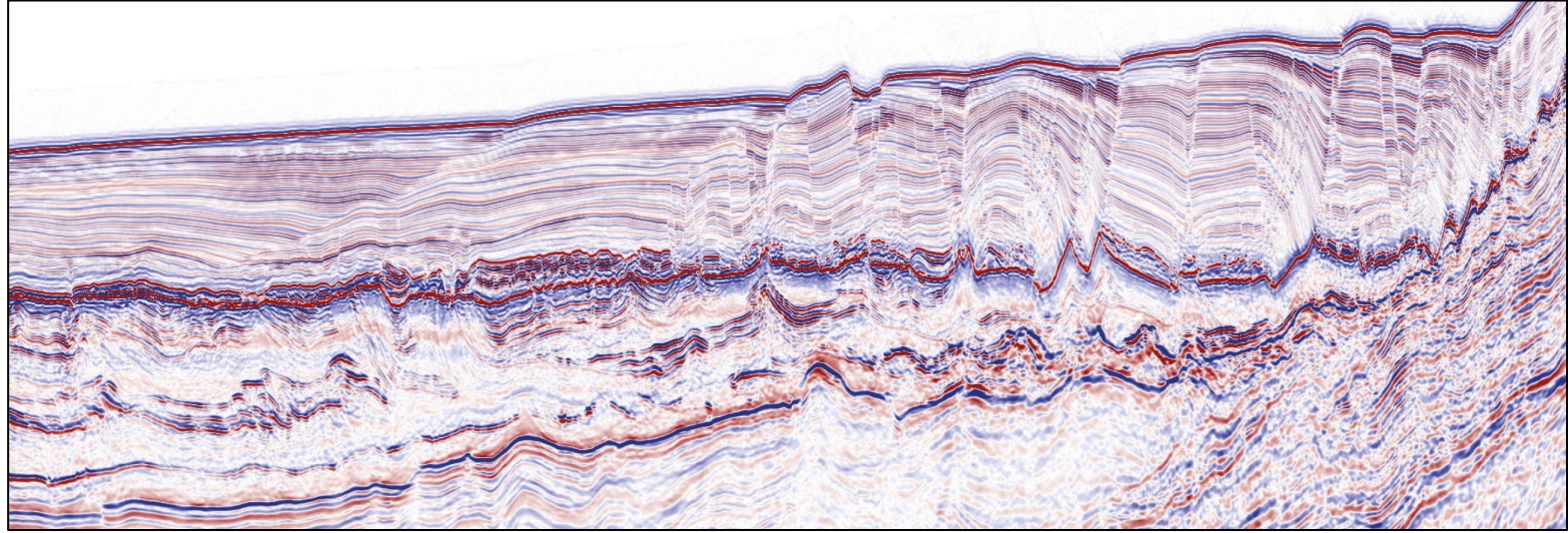
~~Thin-skinned extension detaches within the top of salt and does not crosscut the evaporite layer.~~



Oldest fluid escape pipes formed during Late Pliocene/Early Pleistocene, thus postdating the end of the MSC by >2 Myr. This lag suggests that the MSC did not create sufficient overpressure within the sub-salt traps to reach the near-lithostatic level necessary to fracture the overlying salt.

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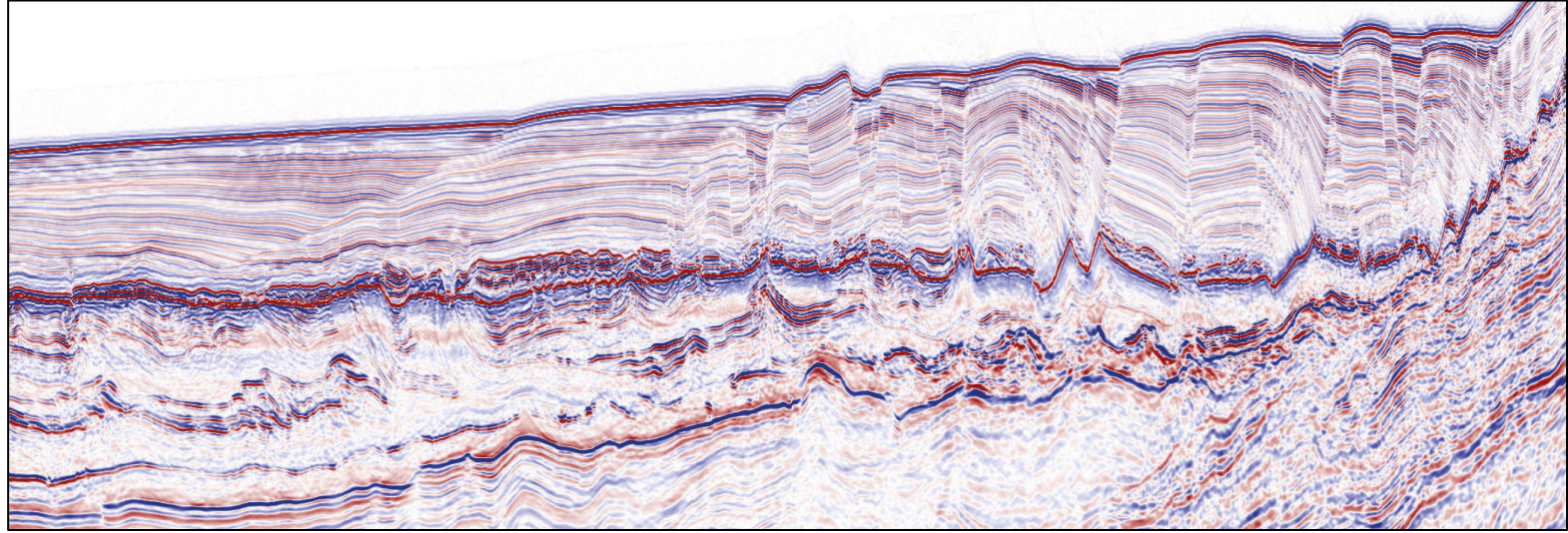


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The start of pipe formation and the main phase of salt movement are nearly simultaneous, but pipe formation is independent from salt tectonics.

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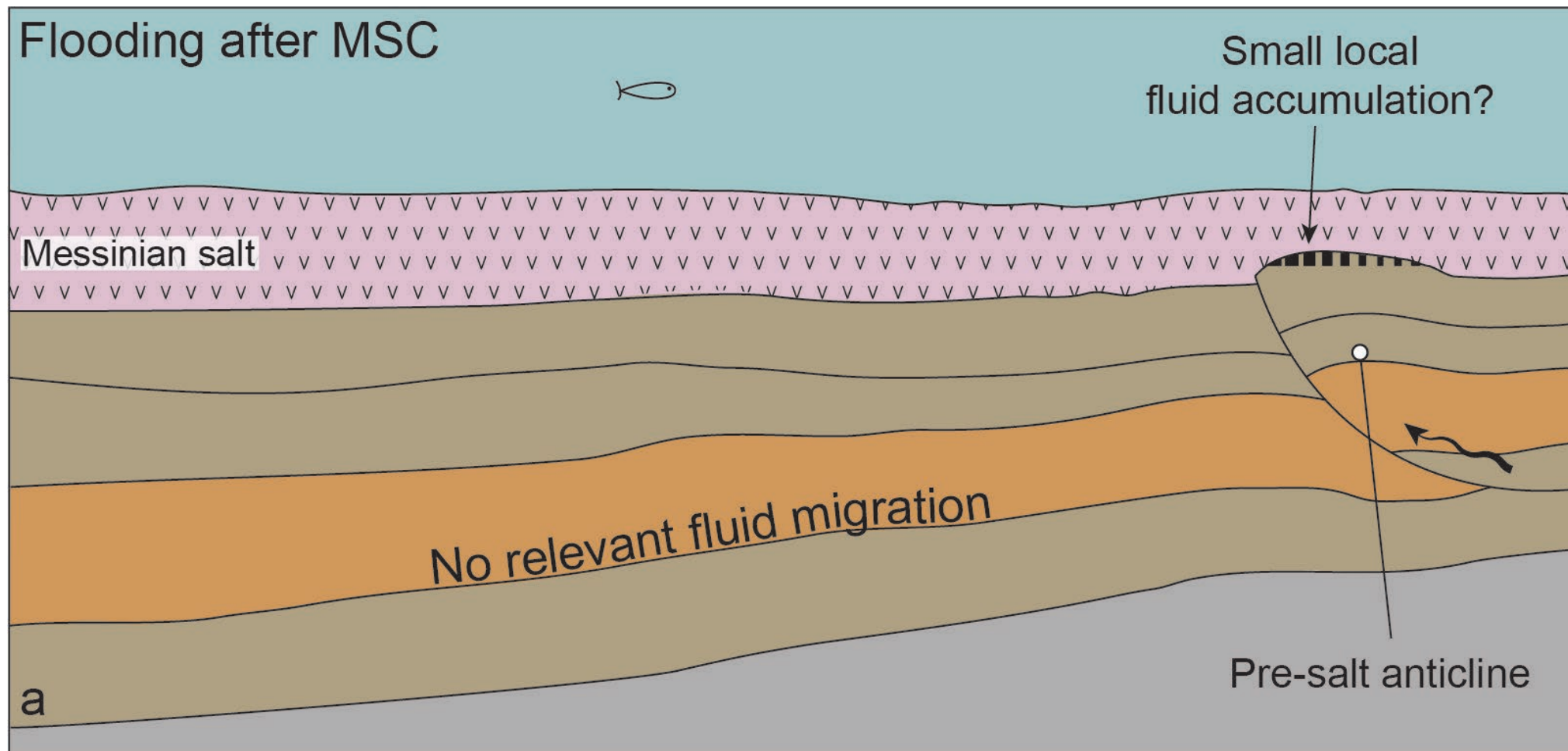
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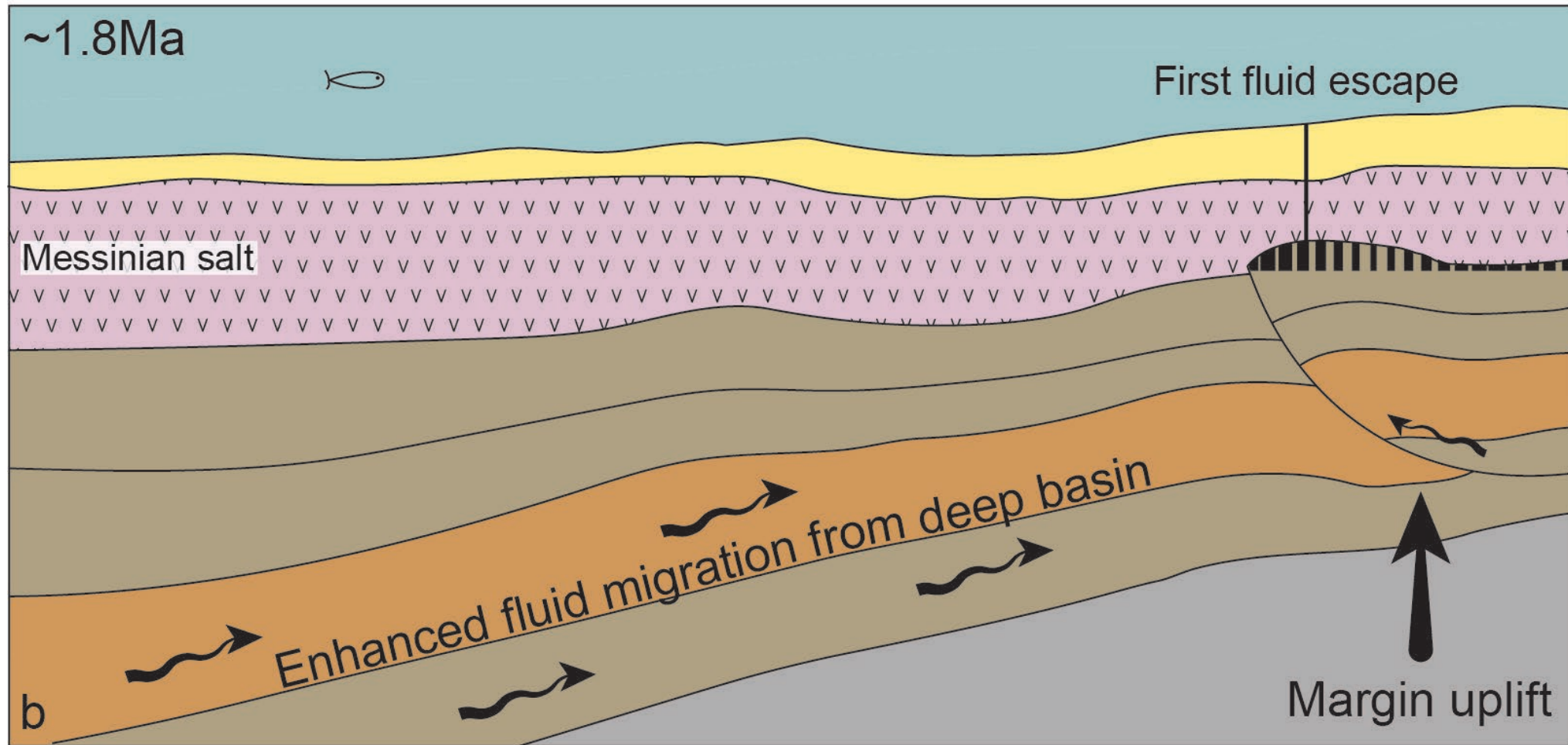
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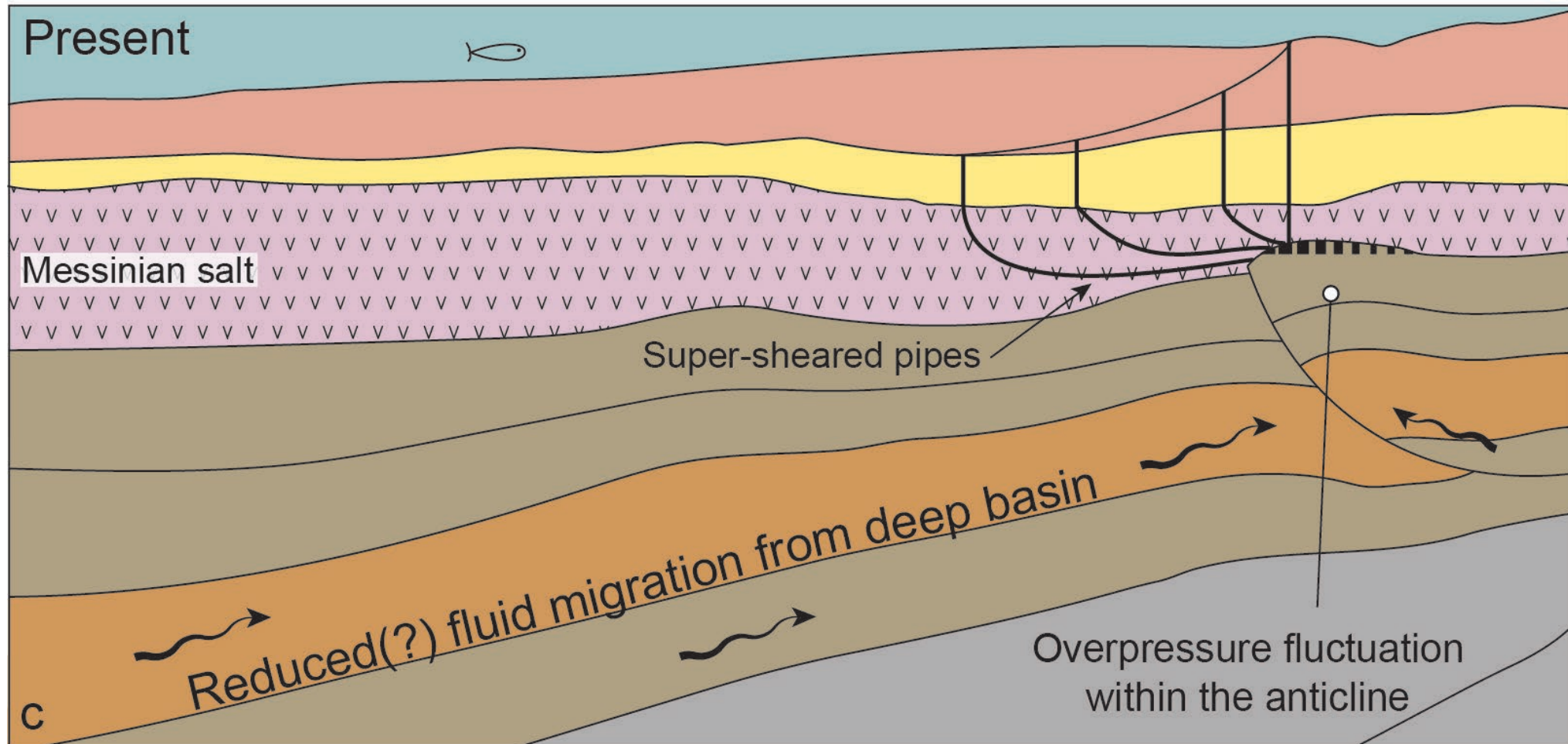


Why did the pipes form?

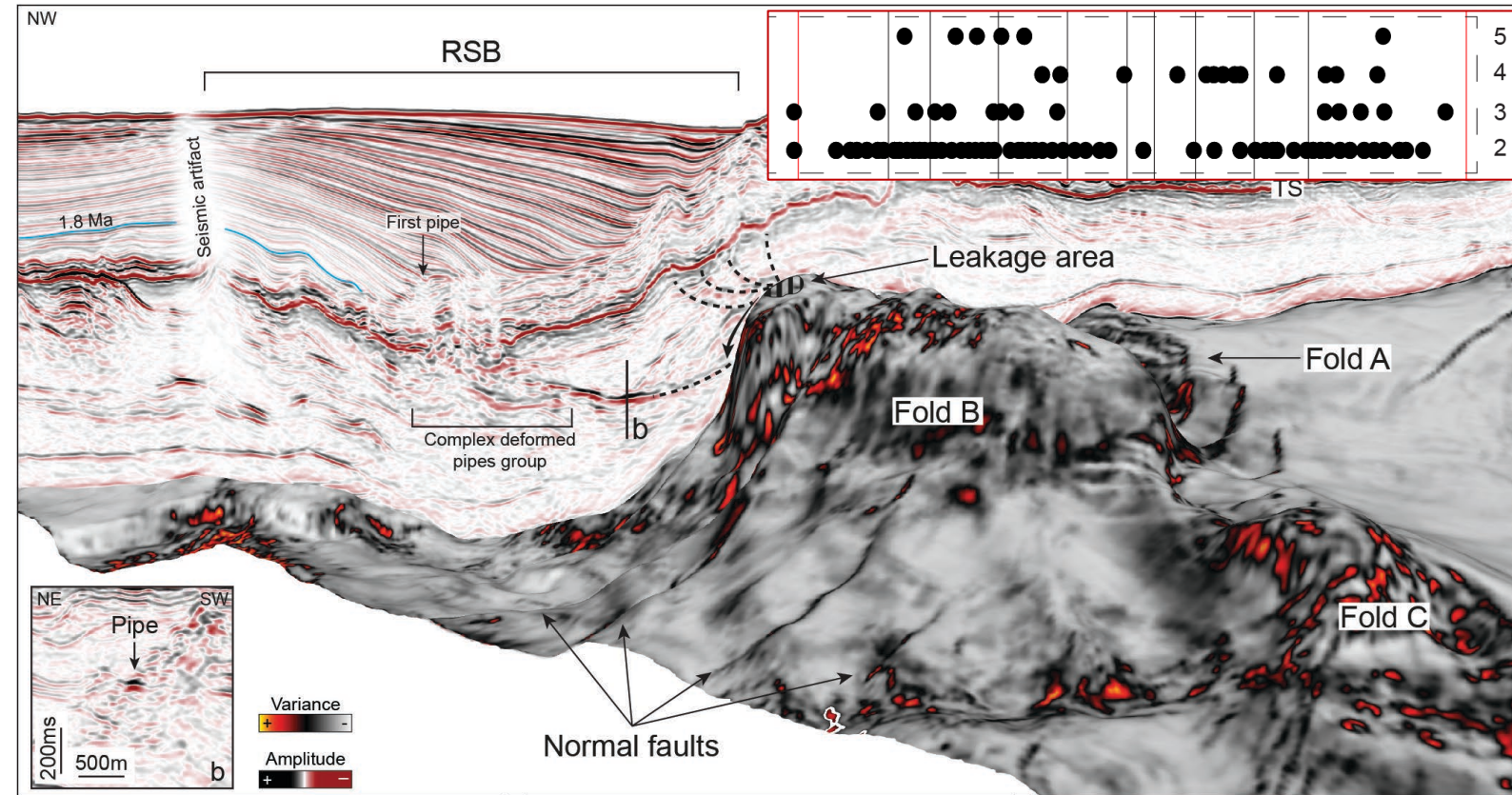
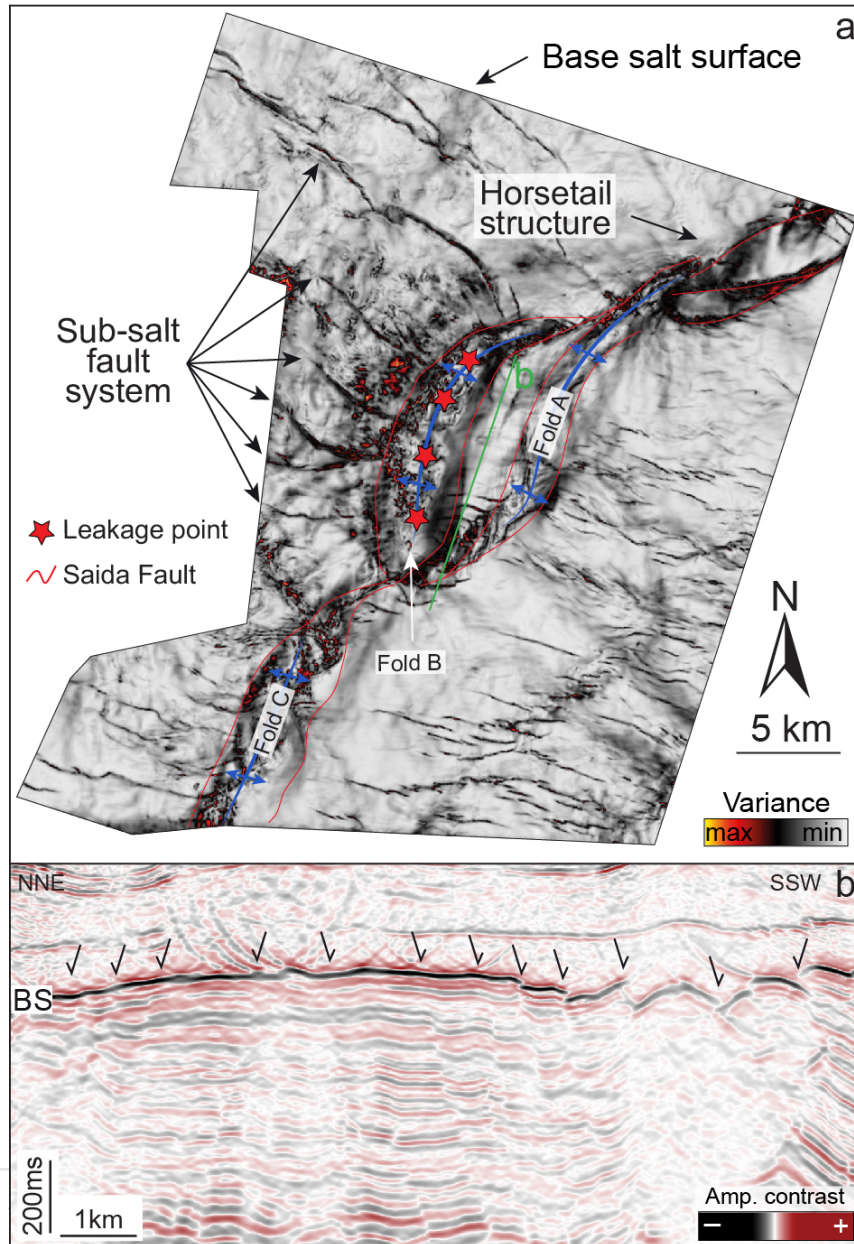


Uplift is a key agent for transferring overpressure towards shallower, more proximal successions

Why did the pipes form?



Local independence and compartmentalization?



- Rate of hydrocarbon production
- Efficiency of migration from the source rocks
- Trap size and geometry
- Reservoir porosity and permeability
- Salt characteristics

Take away

Highly active regional petroleum system able to generate large volumes of hydrocarbons over a relatively long time span

Diffuse fluid expulsion since the Late Pliocene/Early Pleistocene, which **peaked in the Late Pleistocene**.

The initial pipe formation is asynchronous across the basin despite concentrating within a narrow time interval coincident with the **main uplift of the eastern sector of the basin**

We interpret the uplift as the main event leading to cross-evaporite fluid escape in this region of the Eastern Mediterranean

Local dynamics of fluid migration and overpressure buildup over-imposed on the controls acting at a regional scale

- 1) the pipes location is strongly controlled by the structural arrangement of the sub-salt units
- 2) the cyclicity of overpressure and fluid charge/discharge is dependent on the individual structures.

Our study shows that the causes of cross-evaporite fluid escape can be multiple, vary over time, act in synergy, and have different impacts in the various areas of salt giant basins.

Do you want to know more?

Taking the pulse of salt-detached gravity gliding in the eastern Mediterranean



This is a Preprint and has not been peer reviewed. This is version 1 of this Preprint.

4 Taking the pulse of salt-detached gravity 5 gliding in the eastern Mediterranean

6 Sian L. Evans^{1*}, Christopher A.-L. Jackson¹ and Davide Oppo²

7 ¹ Basins Research Group (BRG), Department of Earth Science & Engineering, Imperial College
8 London, UK

9 ² Sedimentary Basins Research Group, School of Geosciences, University of Louisiana at La



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RESEARCH ARTICLE

Leaky salt: pipe trails record the history of cross-evaporite fluid escape in the northern Levant Basin, Eastern Mediterranean

[Davide Oppo](#) , [Sian Evans](#), [David Iacopini](#), [SM Mainul Kabir](#), [Vittorio Maselli](#), [Christopher A-L. Jackson](#)

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