Basins Research Group

Imperial College London

The truth about Triassic salt tectonic models for the Northern North Sea

Christopher A-L. Jackson

Basins Research Group (BRG), Department of Earth Science & Engineering, Imperial College, Prince Consort Road, London, SW7 2BP, UK

thanks also to Mike Hudec (UT Austin) for discussions regarding Triassic salt tectonics

Data:

PGS CGG DISKOS NORWEGIAN PETROLEUM DATA Statoil

Triassic Park (FORCE)
Friday 20th October 2017
Stavanger, Norway

Software:
Schlumberger

Talk Outline

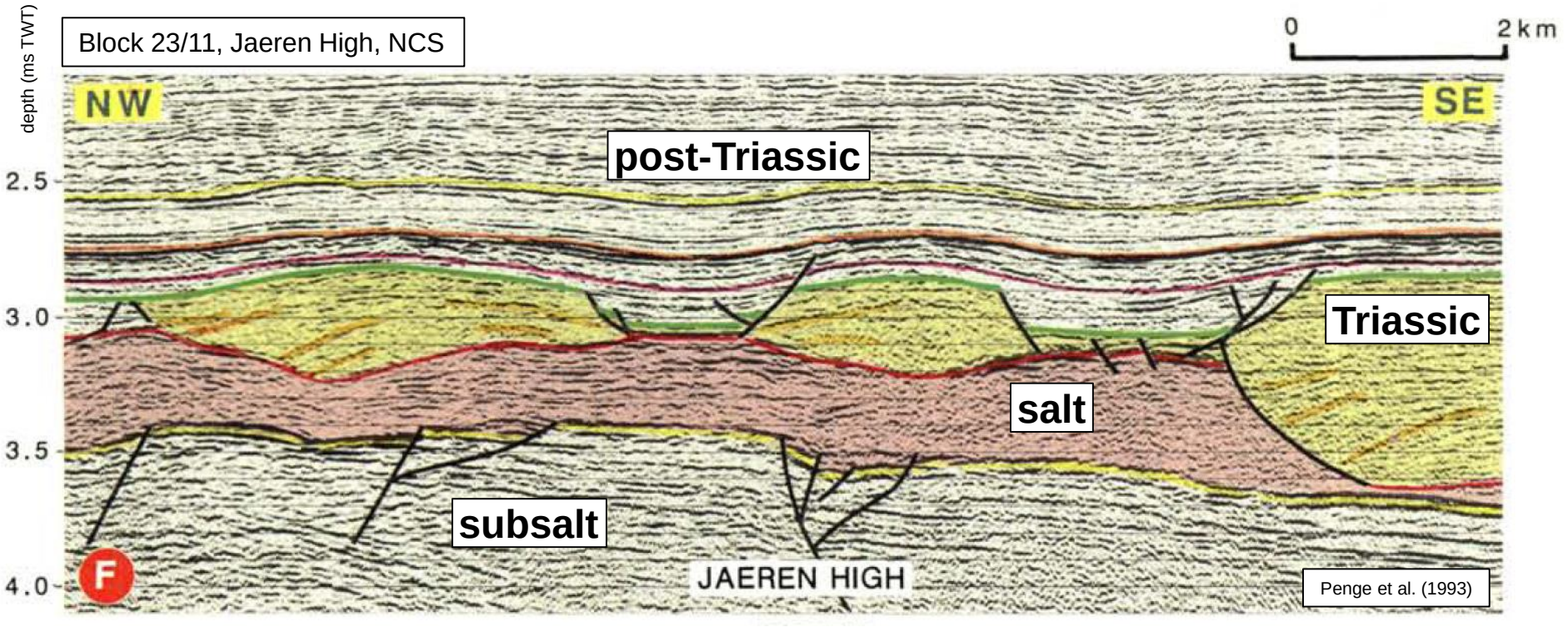
Imperial College London

- Provide an overview of Triassic salt-tectonic models for the Northern North Sea
- Outline the implications of model choice for reservoir development, trapping style, and basin-scale structural style and kinematics
- Test models using observations from published and unpublished datasets

“In the case of Triassic salt-tectonic models for the Northern North Sea, I call to the stand Penge et al. (1993) and Hodgson et al. (1993)…”

Rift-Raft Salt Tectonics

Imperial College London

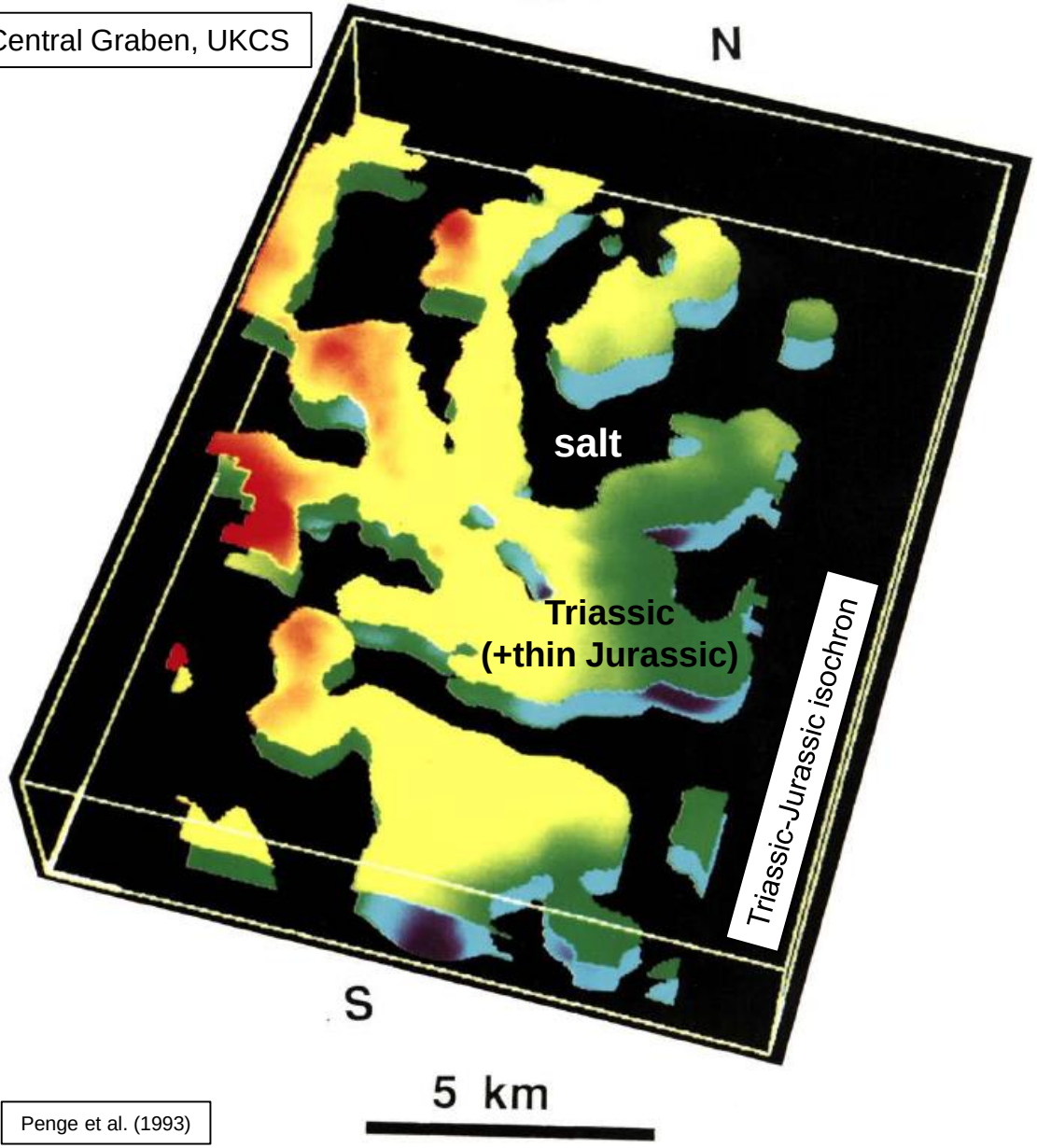


- Fault-bound blocks of Triassic above salt
- Thin salt below blocks; thick salt (reactive diapirs) between blocks
- Largely 2D profiles; few map-view images showing salt geometry
- Limited information on detailed Triassic stratigraphic architecture

Rift-Raft Salt Tectonics

Imperial College London

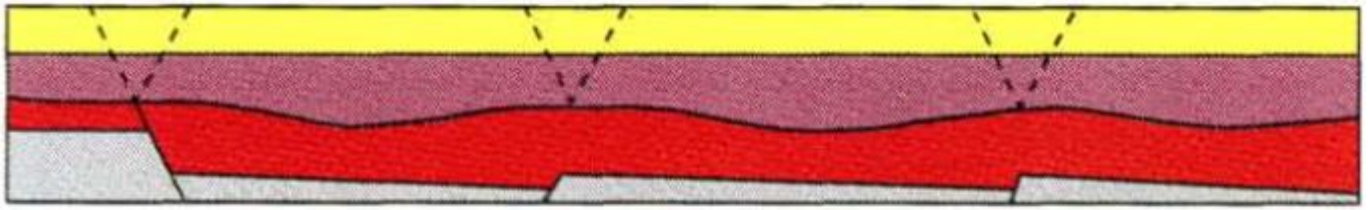
East Central Graben, UKCS



Penge et al. (1993)

Rift-Raft Salt Tectonics

Imperial College London



extension

brittle cover

increasing extension

ductile cover
(e.g. boudinage)

Ductile Sedimentary Unit
Upper } Competent Unit
Lower

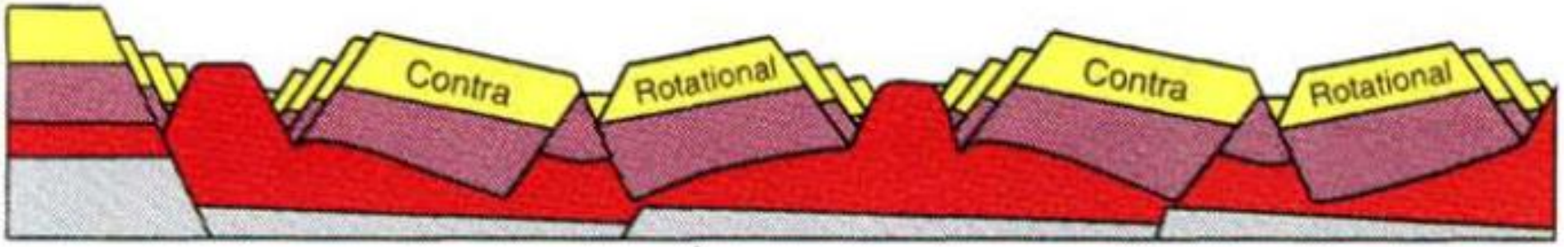
Salt
Pre-salt

Penge et al. (1993)

(Some) Diagnostic Criteria?

Imperial College London

- Triangular-shaped salt diapirs
- Inward-dipping fan of normal faults younging upwards towards diapir crest
- Structural attenuation of overburden towards diapir flank
- Oldest overburden broadly tabular
- True stratigraphic onlap absent
- Elongate salt walls and minibasins trend normal to slope
- **Widespread depositional systems later cut by normal faults and diapirs...**

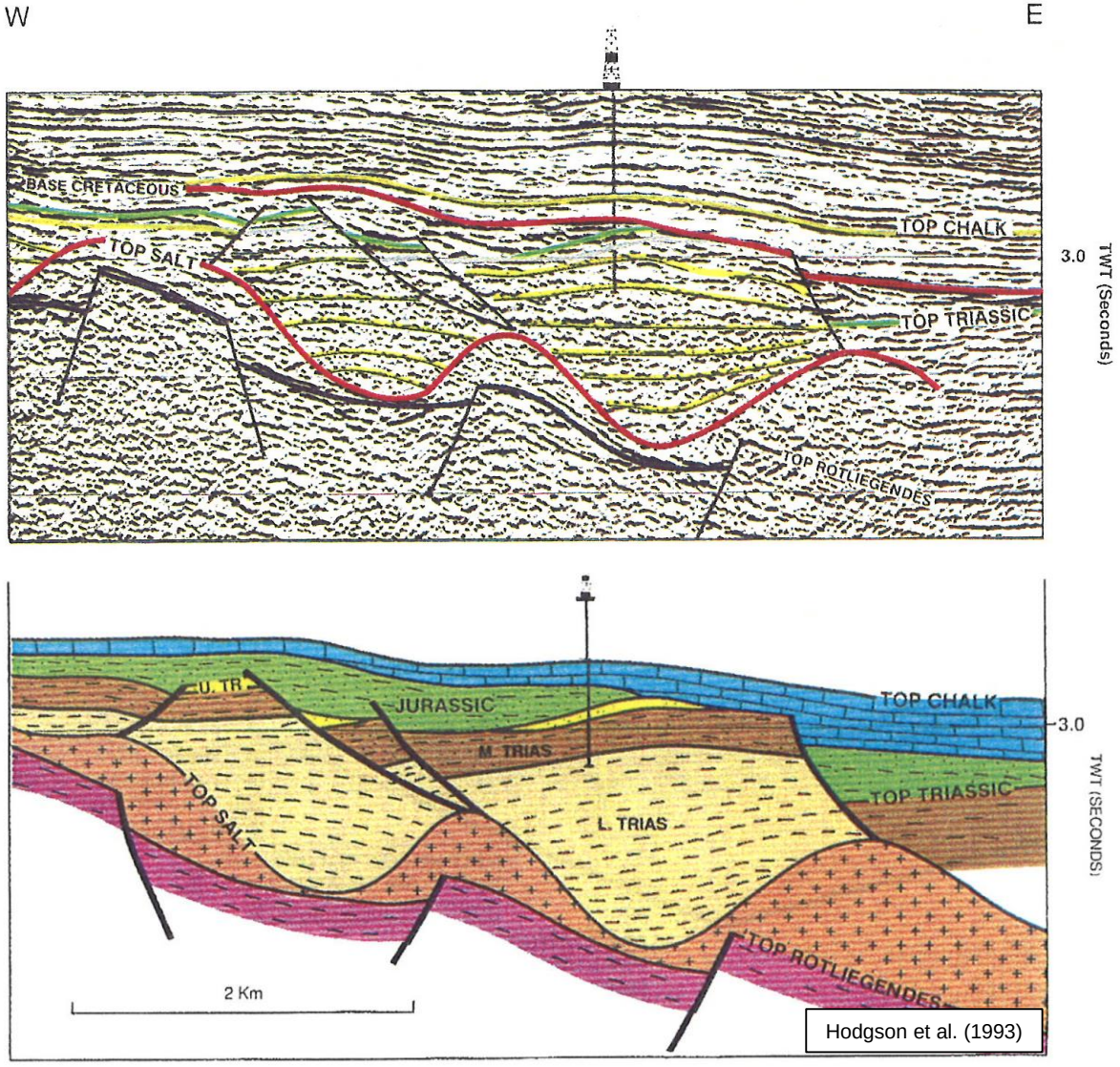


Passive Diapirism

Imperial College London

Eastern Trough, Central Graben, UKCS

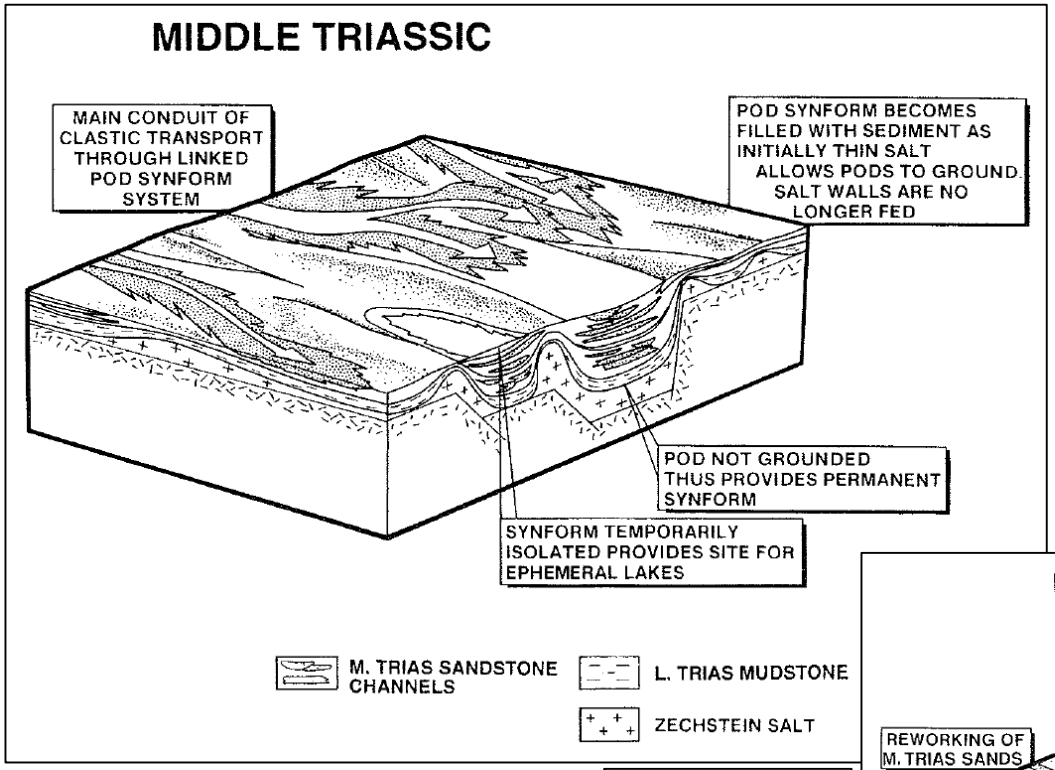
Conceptual model



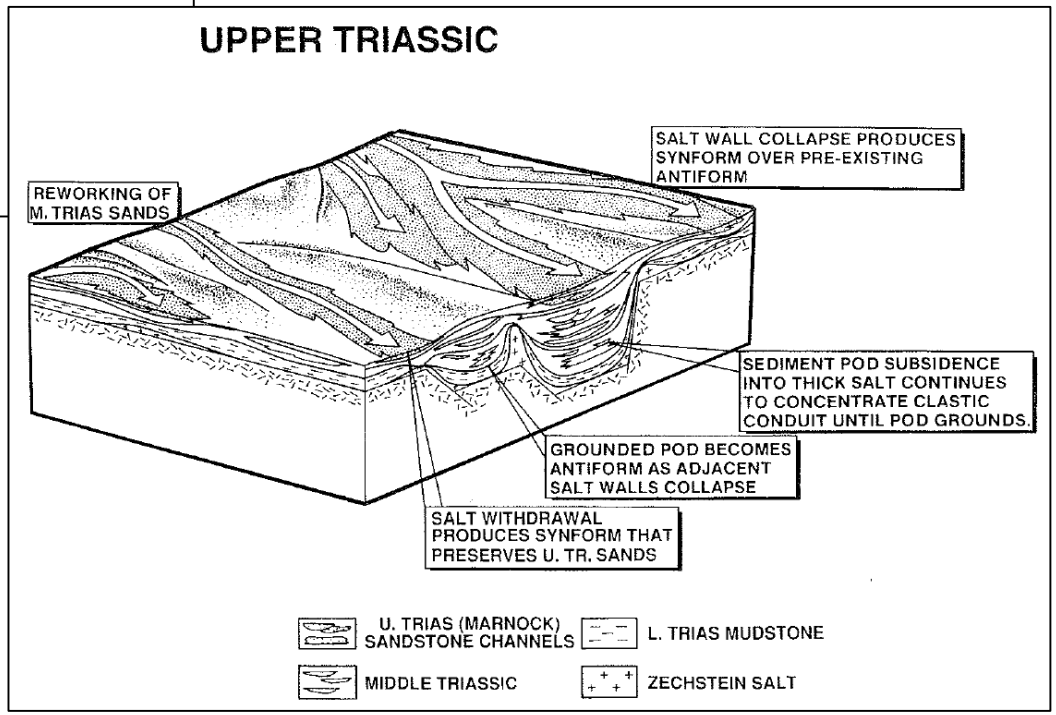
Hodgson et al. (1993)

Passive Diapirism

Imperial College London



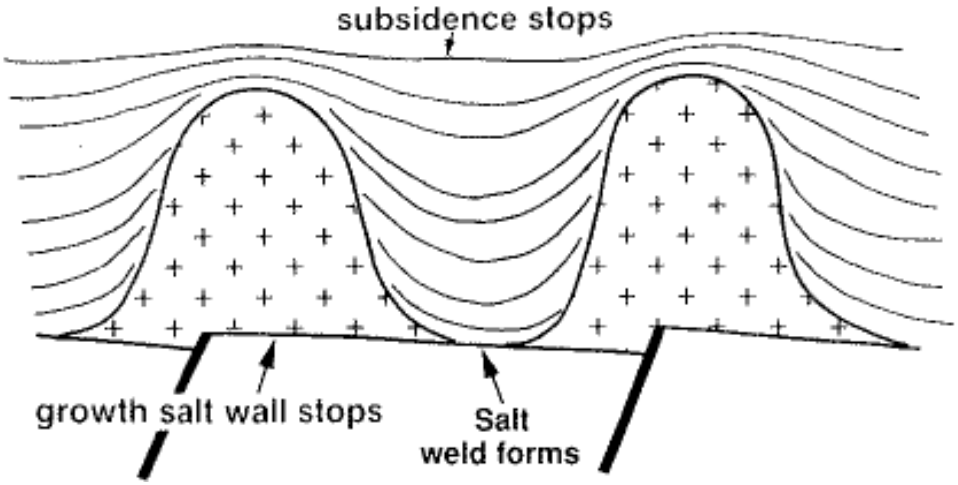
Hodgson et al. (1993)



(Some) Diagnostic Criteria?

Imperial College London

- Diapirs have rounded crests
- Minibasins only gently folded; faulting generally absent
- Thickness changes in earliest/deepest minibasin fill
- Irregular minibasin shapes and distributions
- Stratigraphic onlap occurs near minibasin base and persists though minibasin-fill
- **Depositional systems restricted to minibasin centre...**

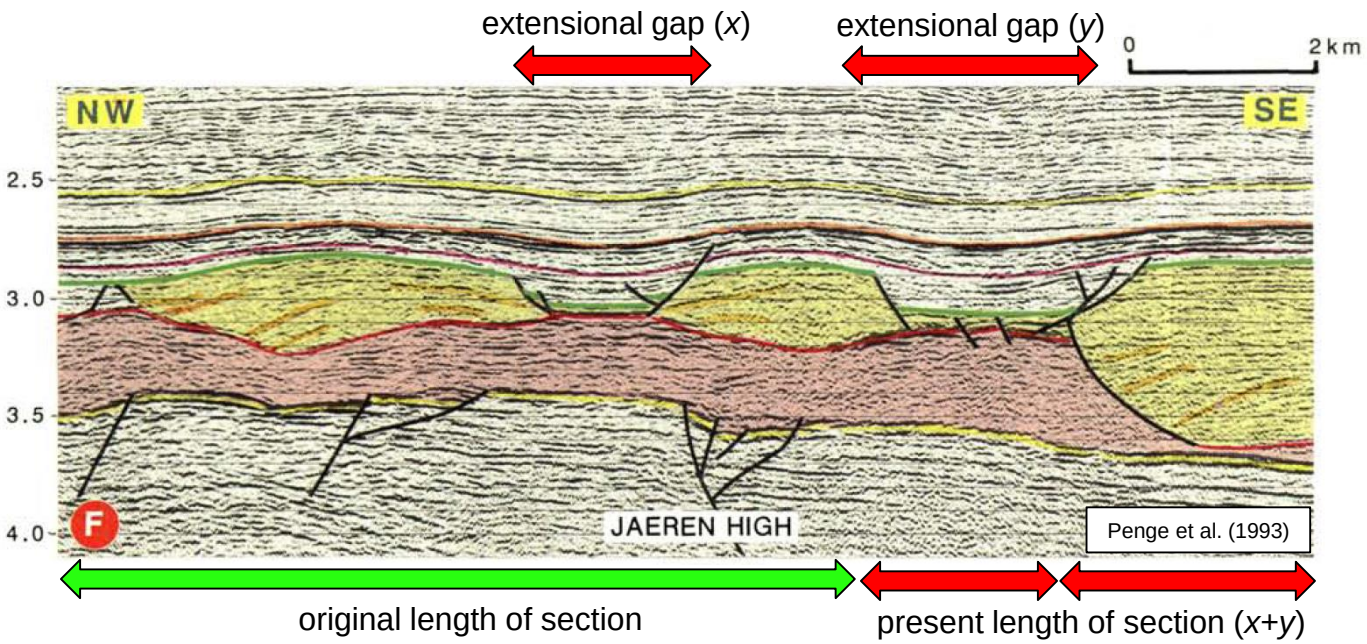


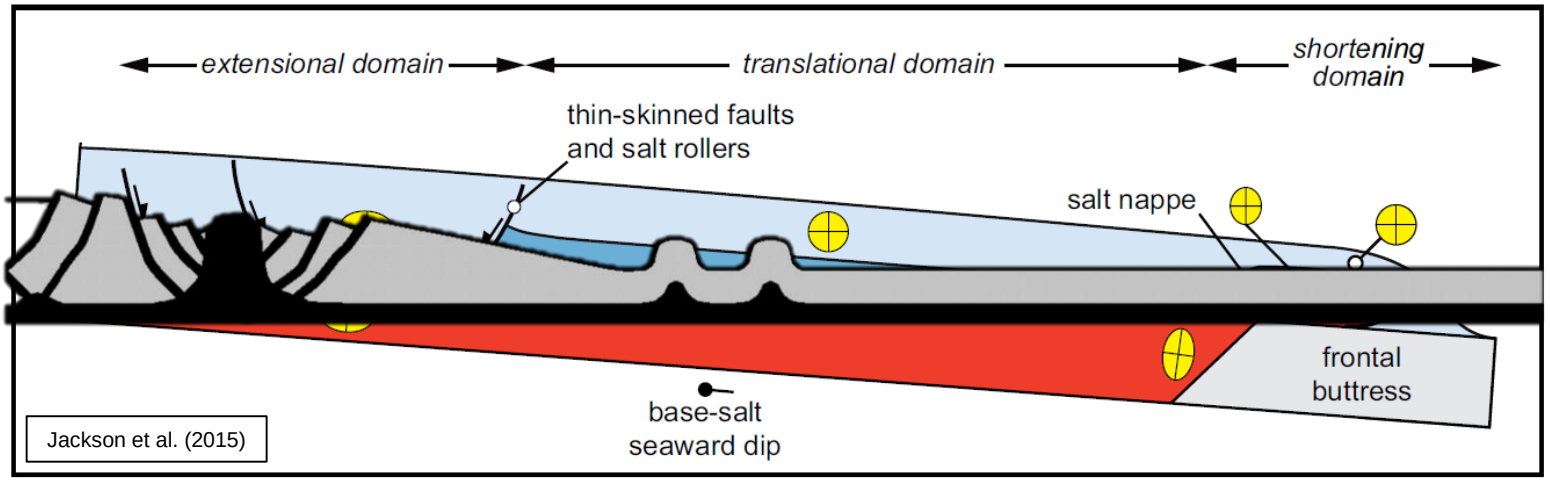
so, does it matter which model we choose…?

Structural Implications

Imperial College London

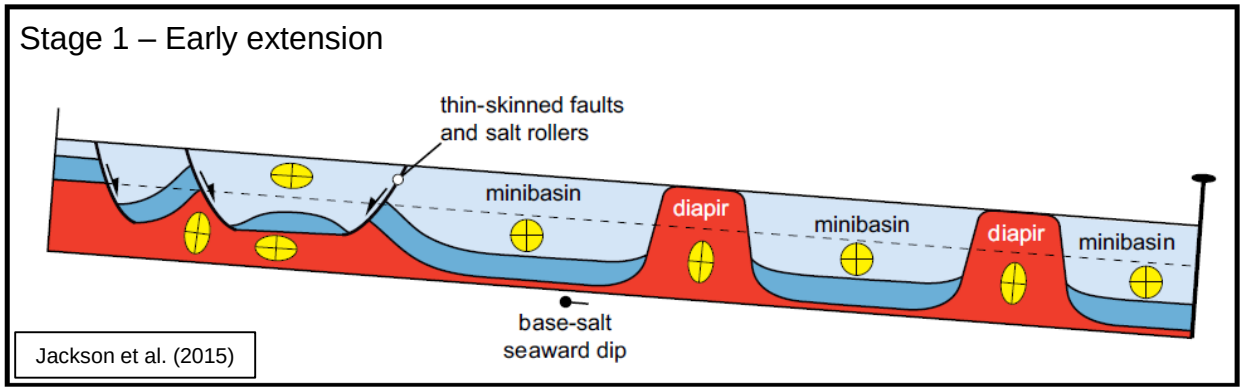
The Curse of the Kinematic Requirement…





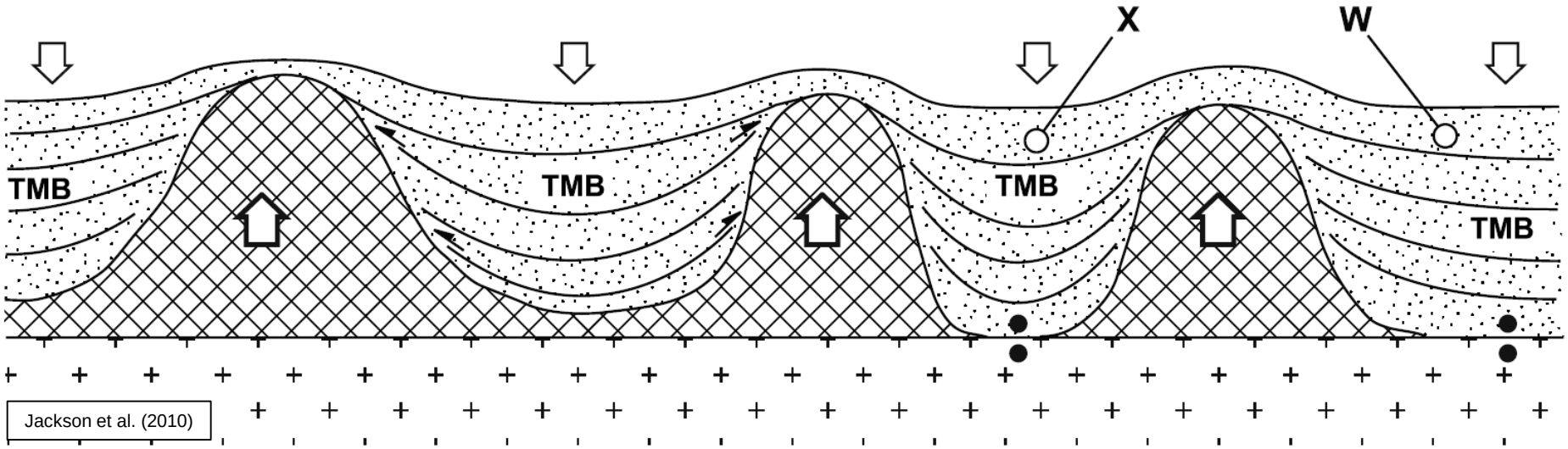
Structural Implications

Imperial College London



Structural Implications

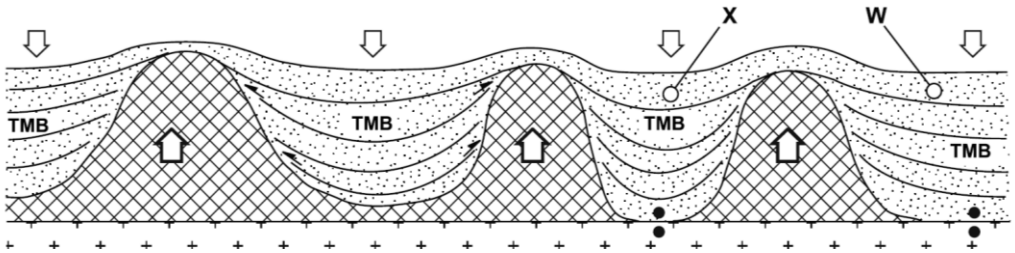
Imperial College London



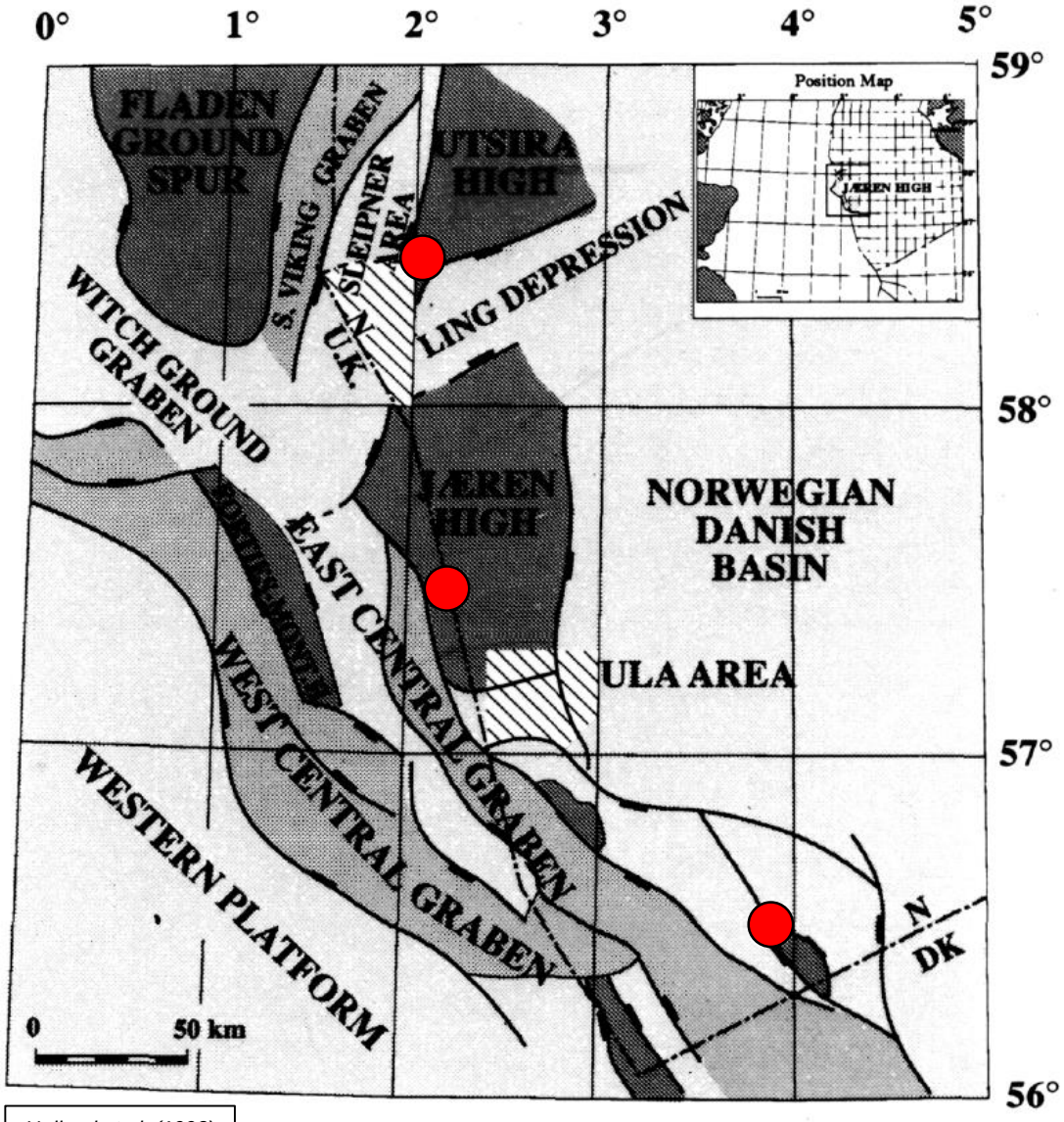
Summary

- **Rift-raft model –** Vertical **and** horizontal overburden motions; kinematically requires complimentary shortening, which should be of: (i) broadly similar age; (ii) similar structural trend; and (iii) of broadly similar magnitude

- **Passive diapirism model –** Predominantly vertical motions; complimentary shortening not kinematically required



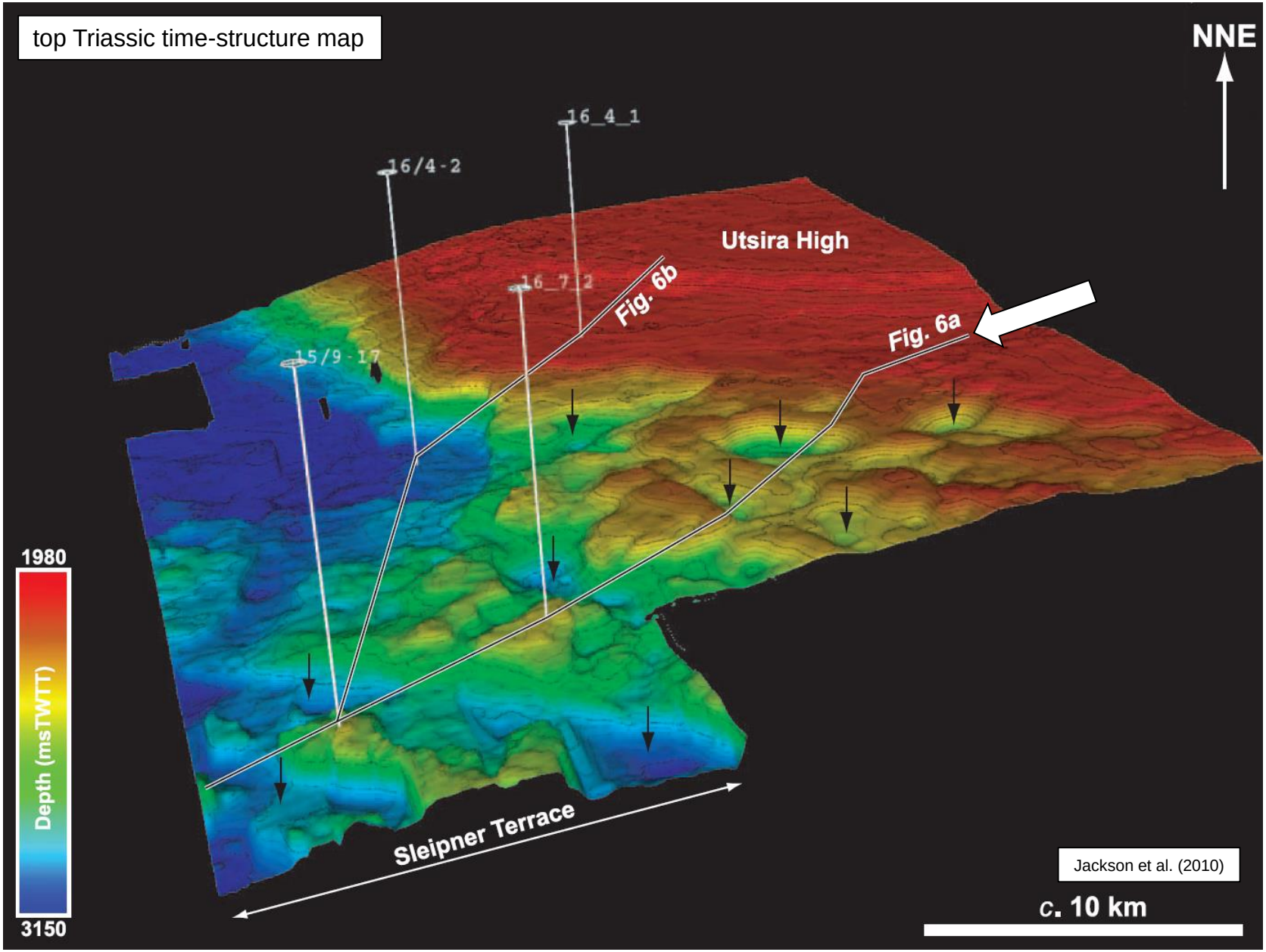
so, what do the data say…?



Høiland et al. (1993)

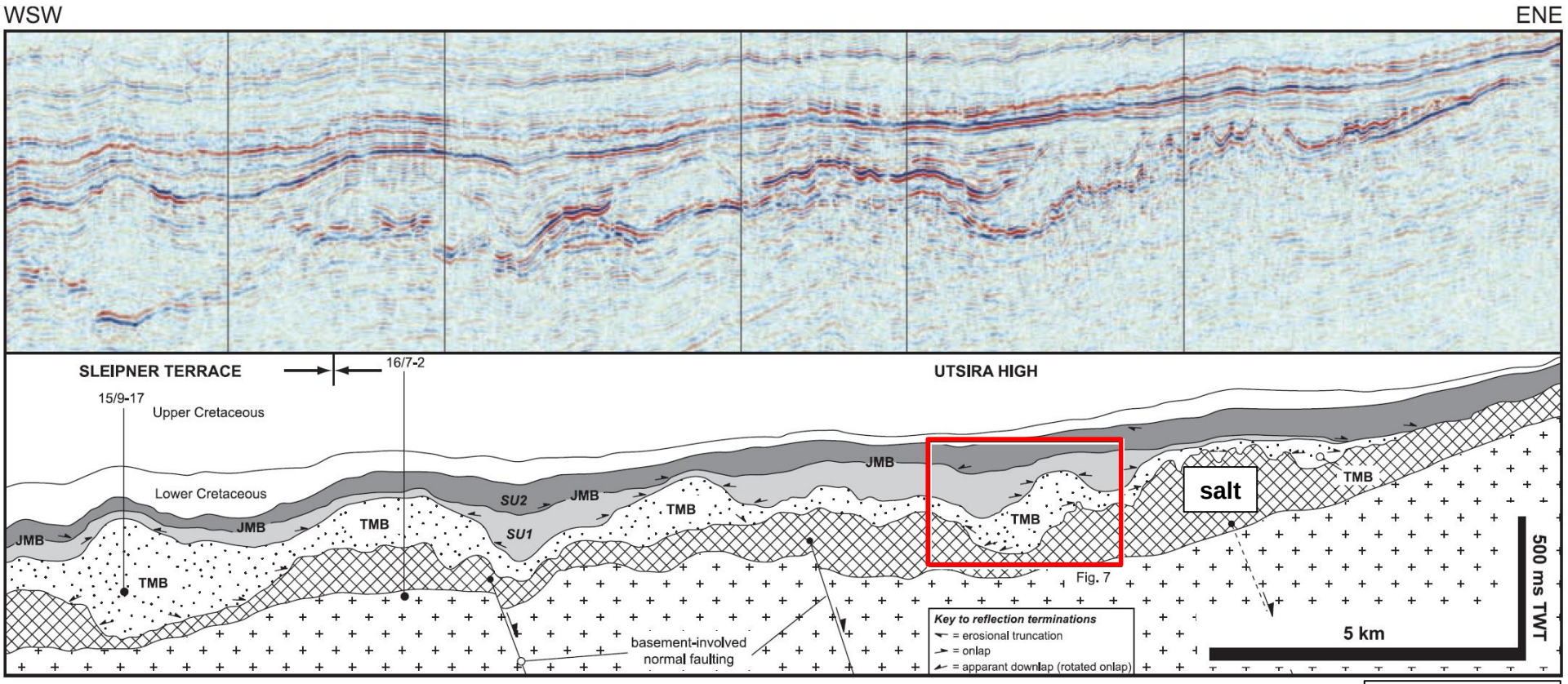
Utsira High

Imperial College London



Utsira High

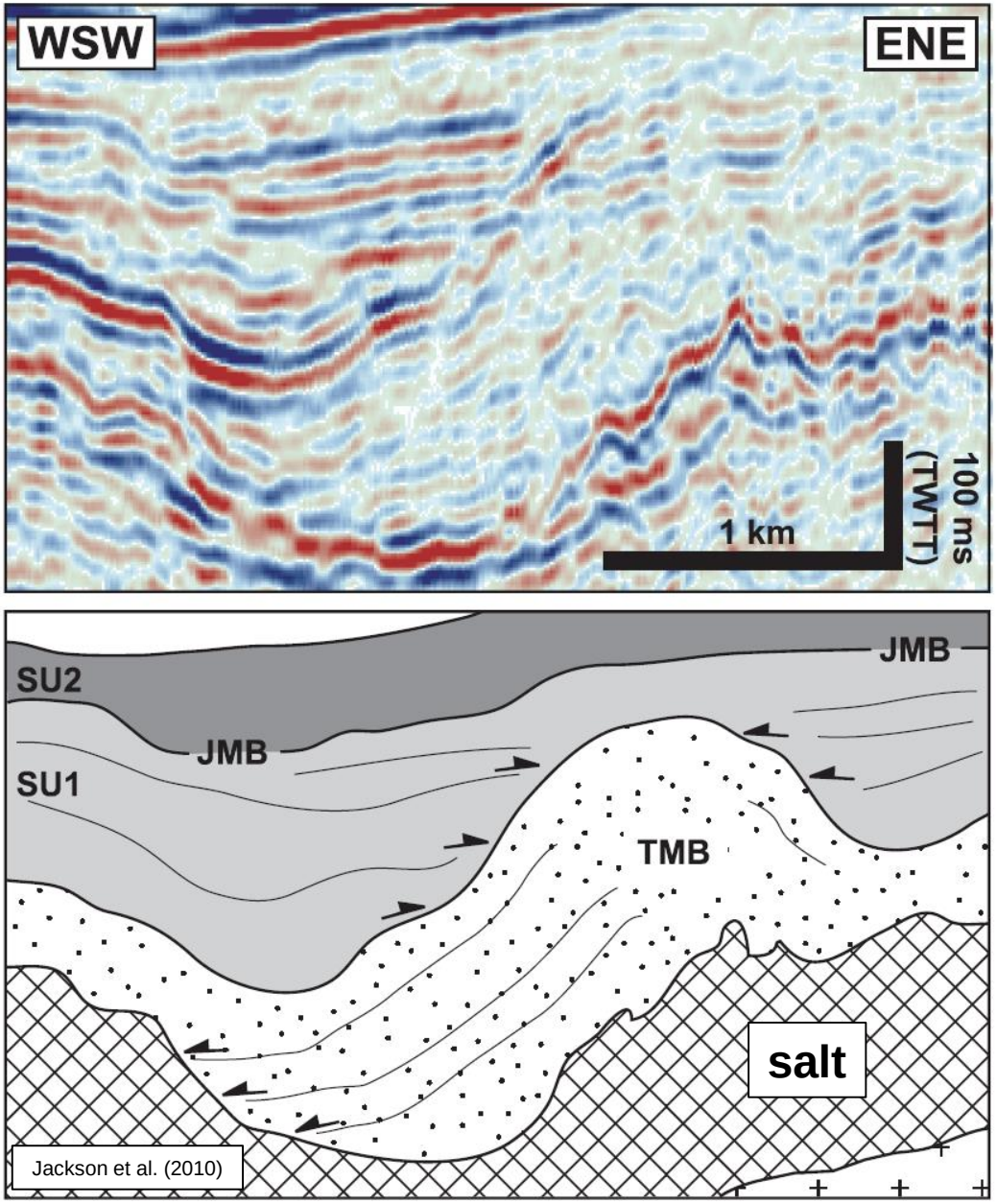
Imperial College London



Jackson et al. (2010)

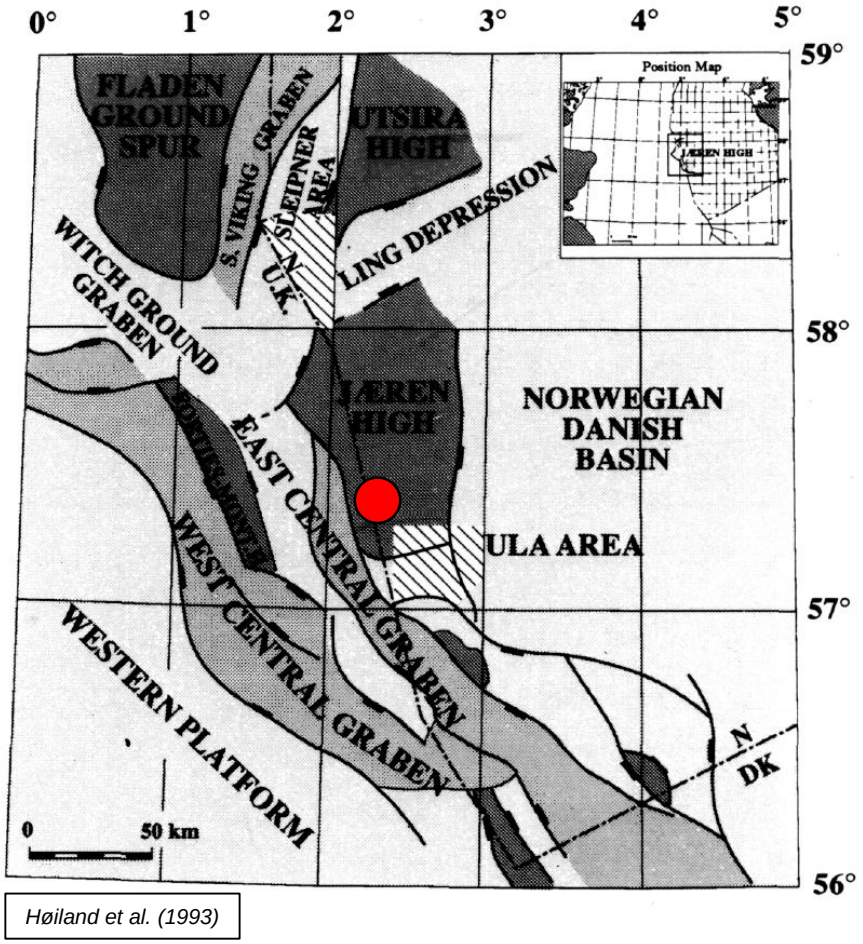
Utsira High

Imperial College London

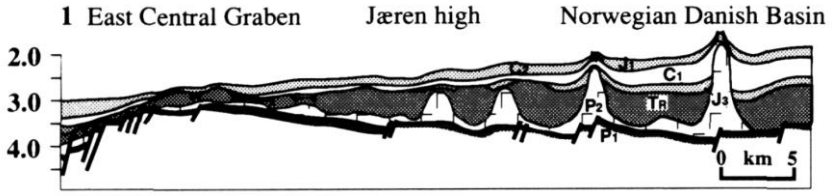


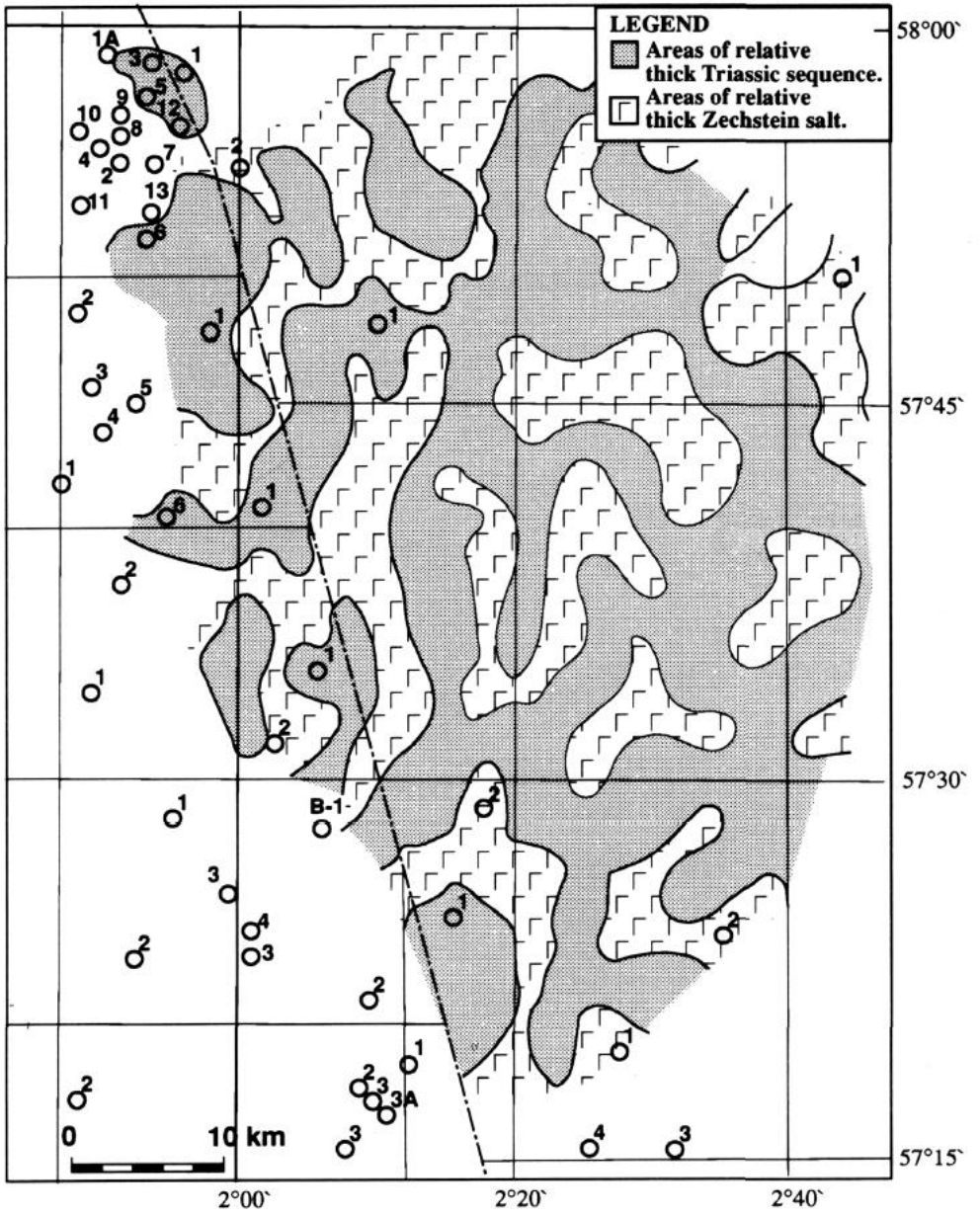
Jæran High

Imperial College London



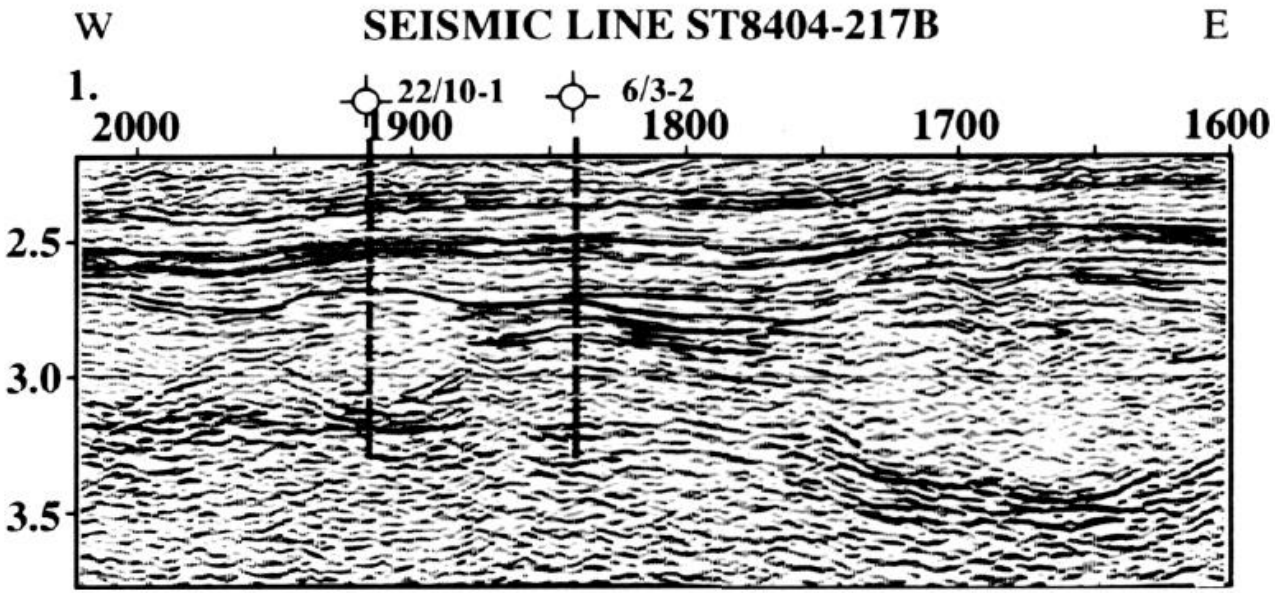
Høiland et al. (1993)

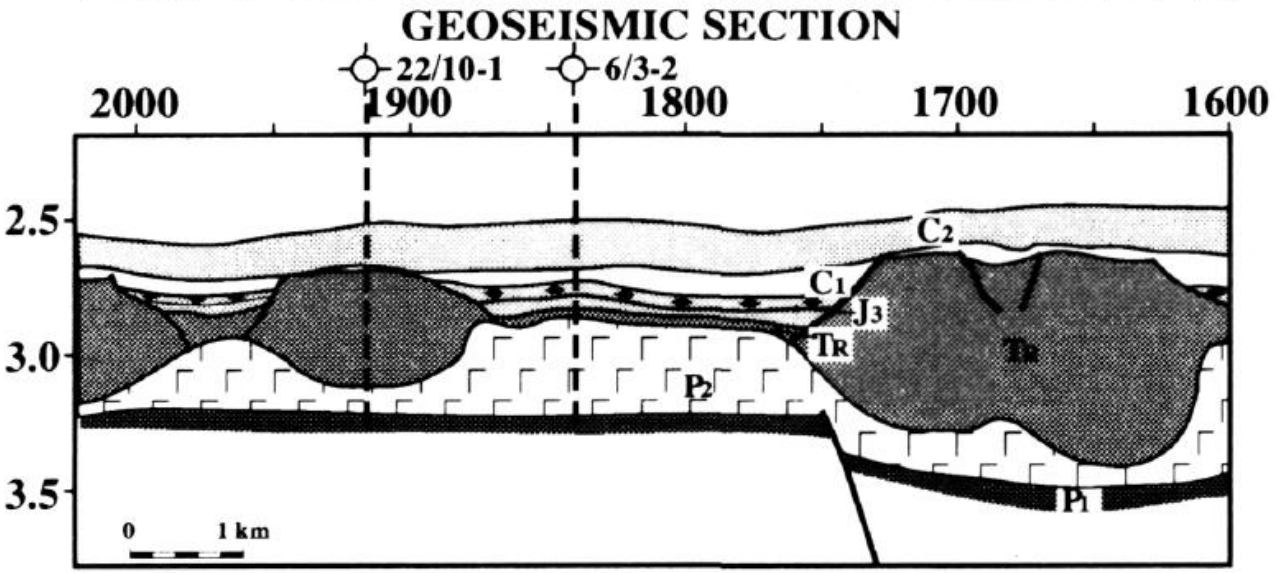


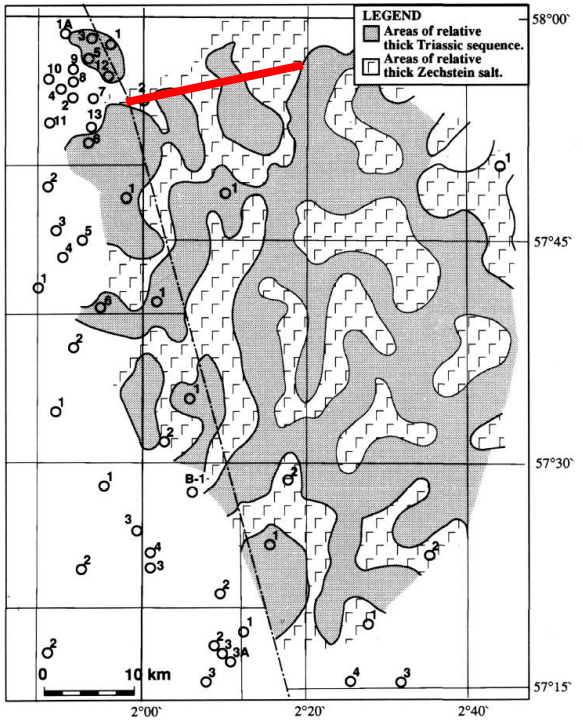


Jæran High

Imperial College London



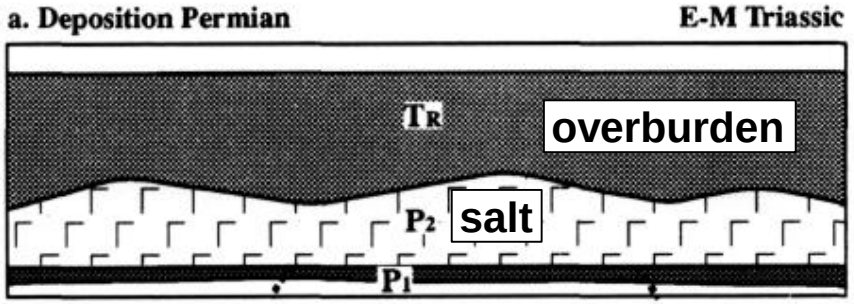


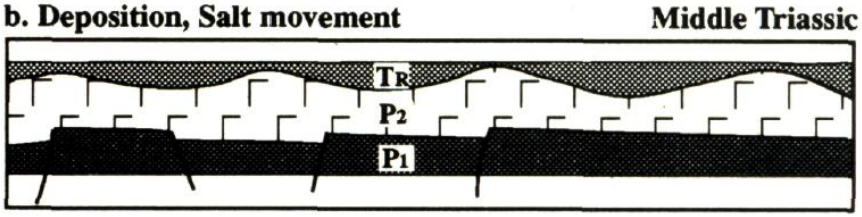


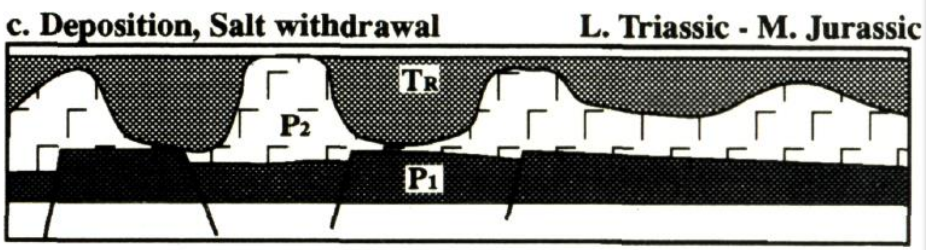
Høiland et al. (1993)

Jæran High

Imperial College London



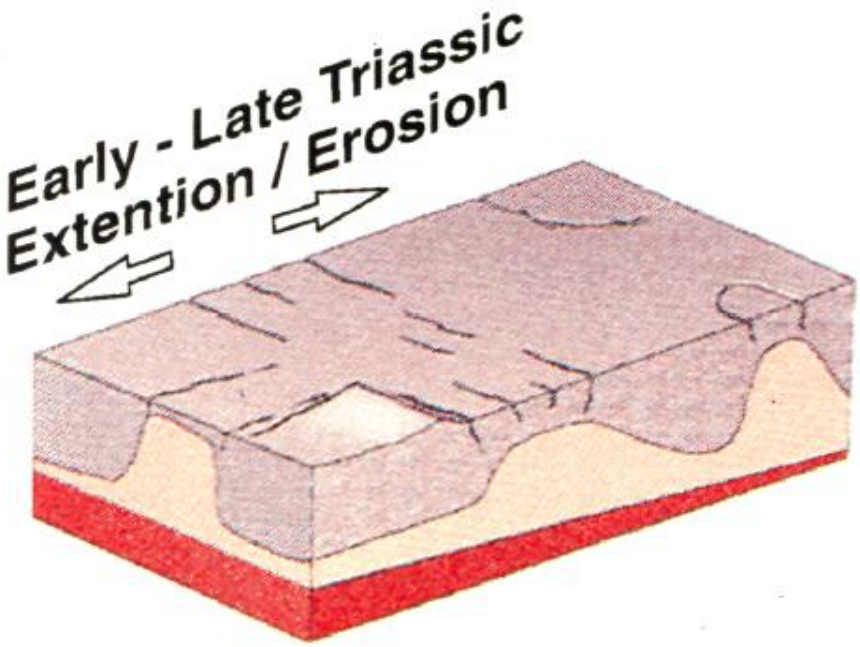


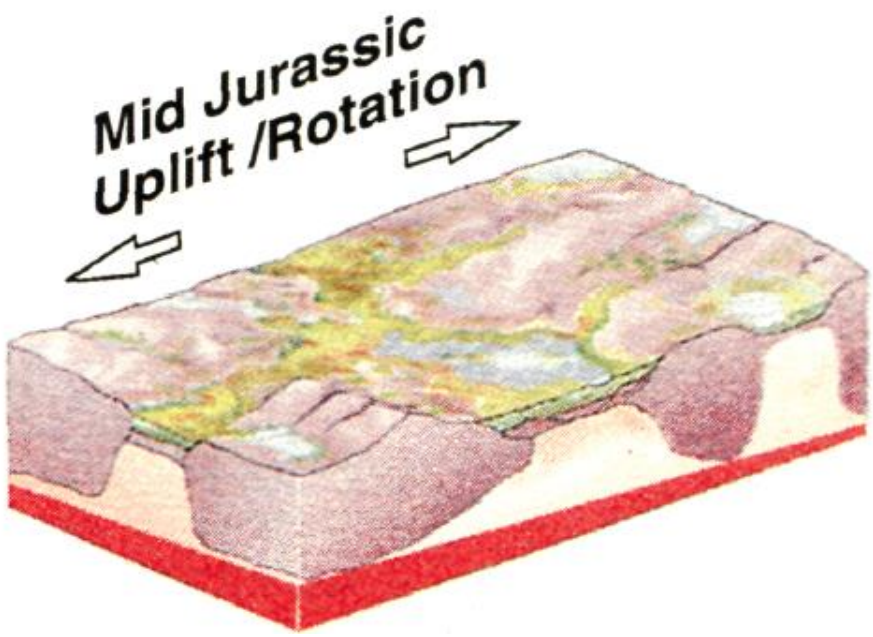


Høiland et al. (1993)

Jæran High

Imperial College London

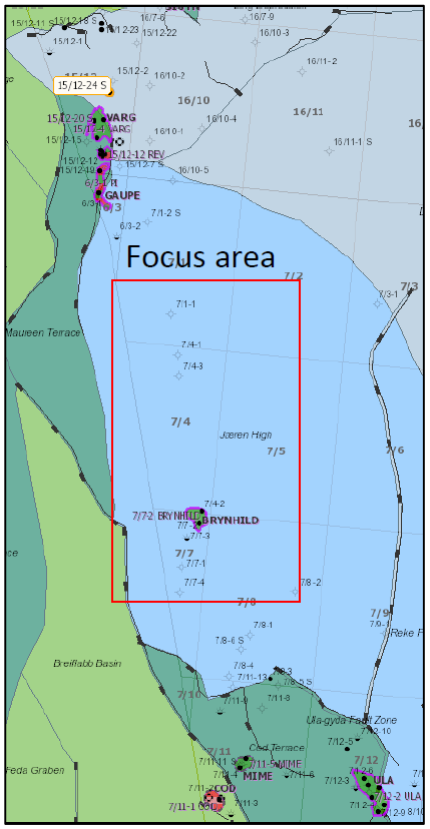


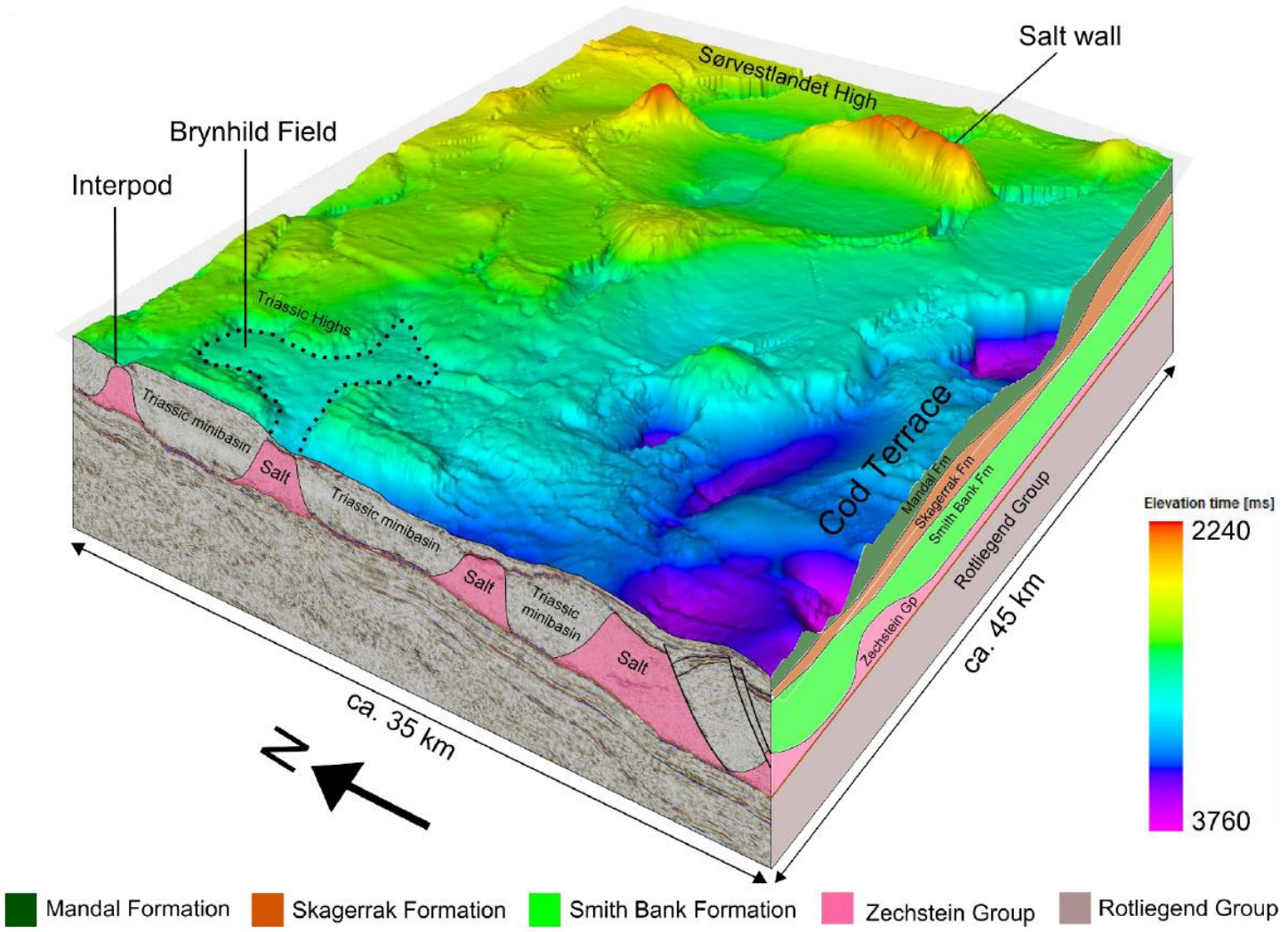


Høiland et al. (1993)

Jæran High

Imperial College London

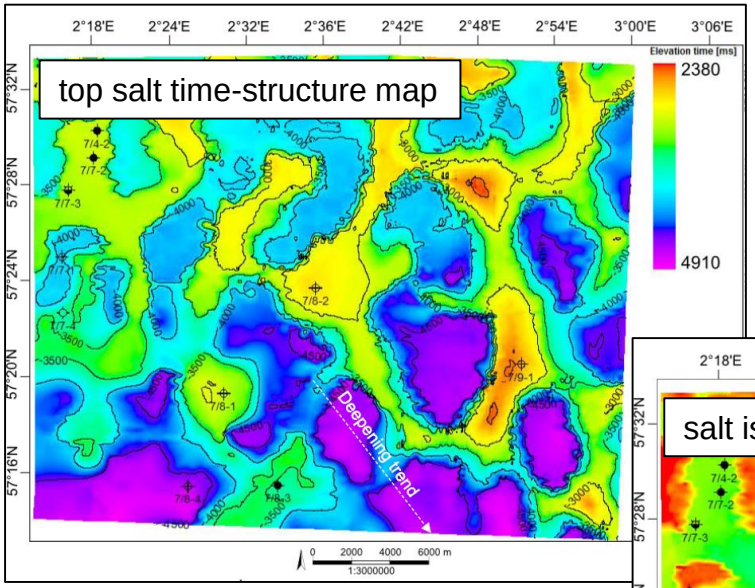




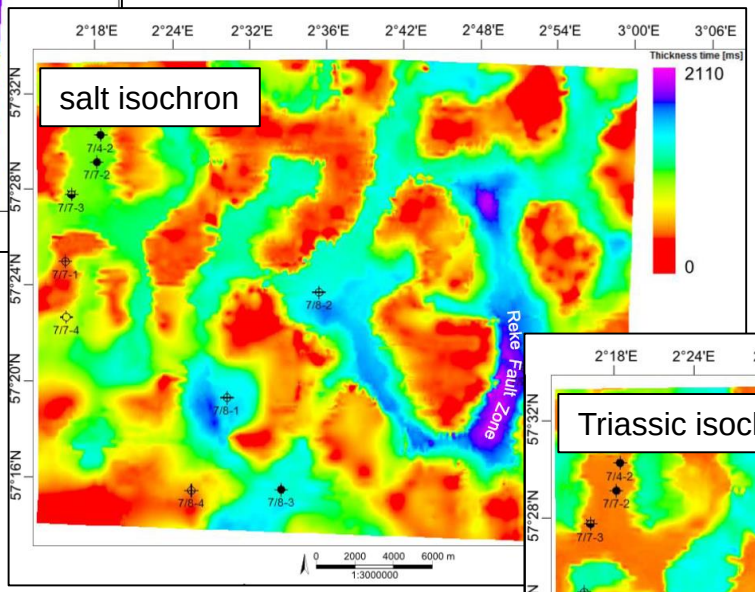
Leong (2015)

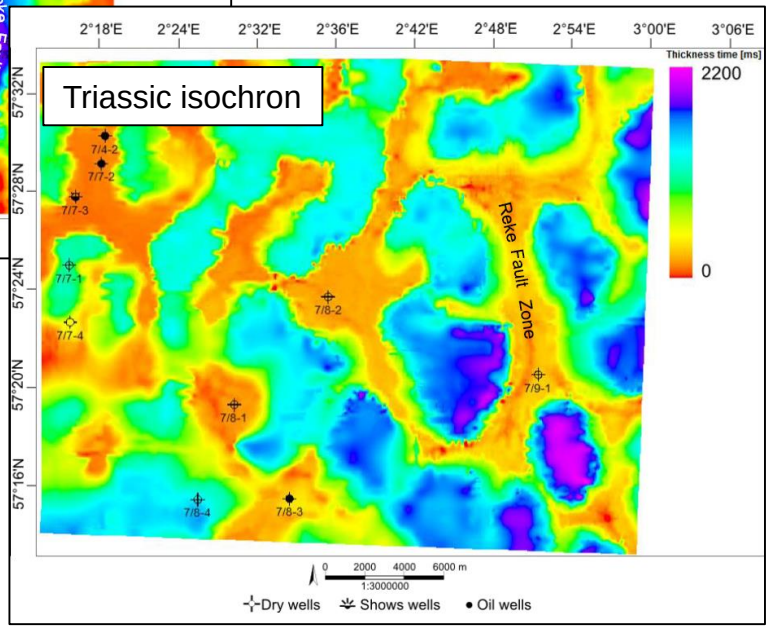
Jæran High

Imperial College London



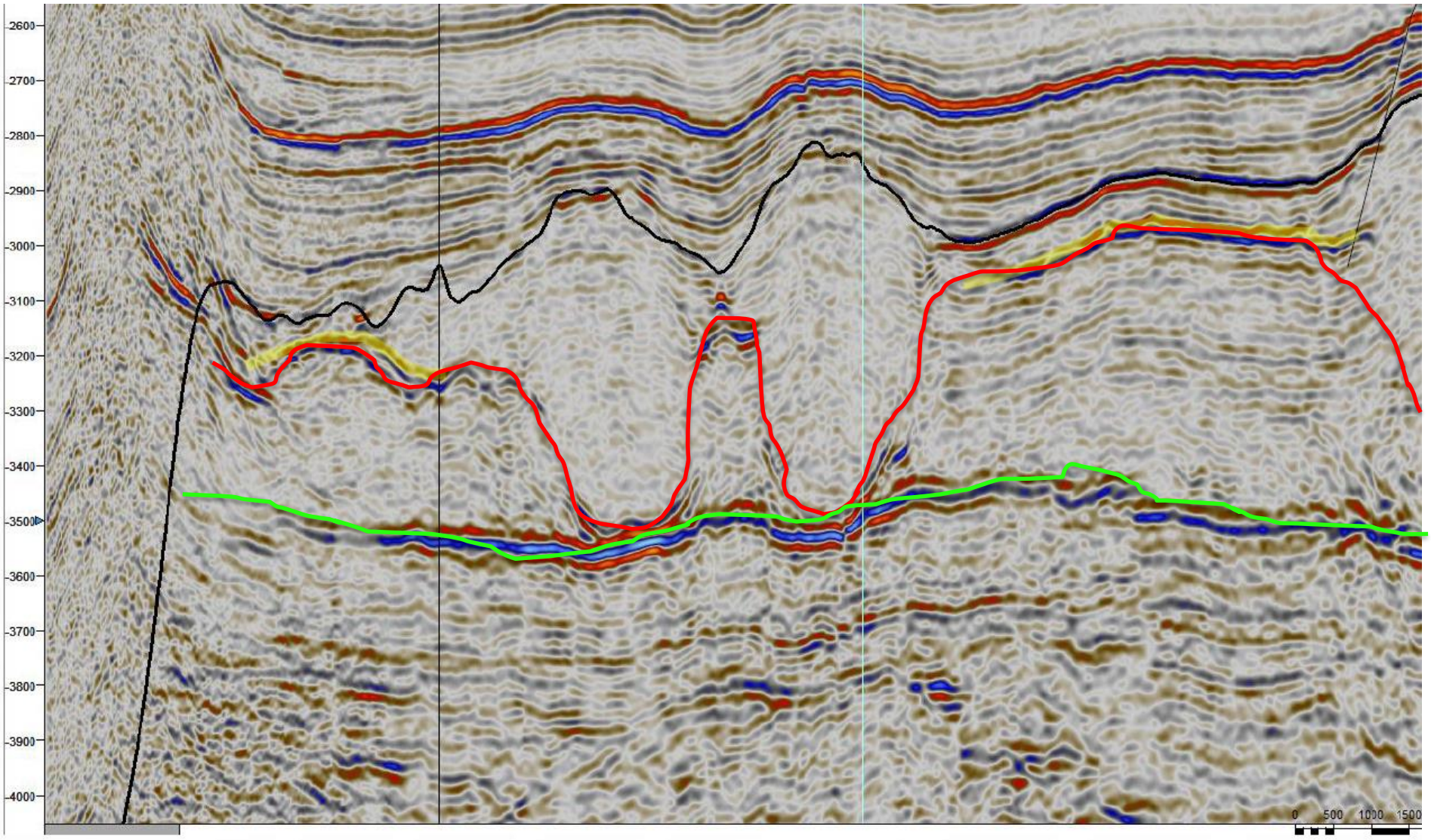
Leong (2015)





Jæran High

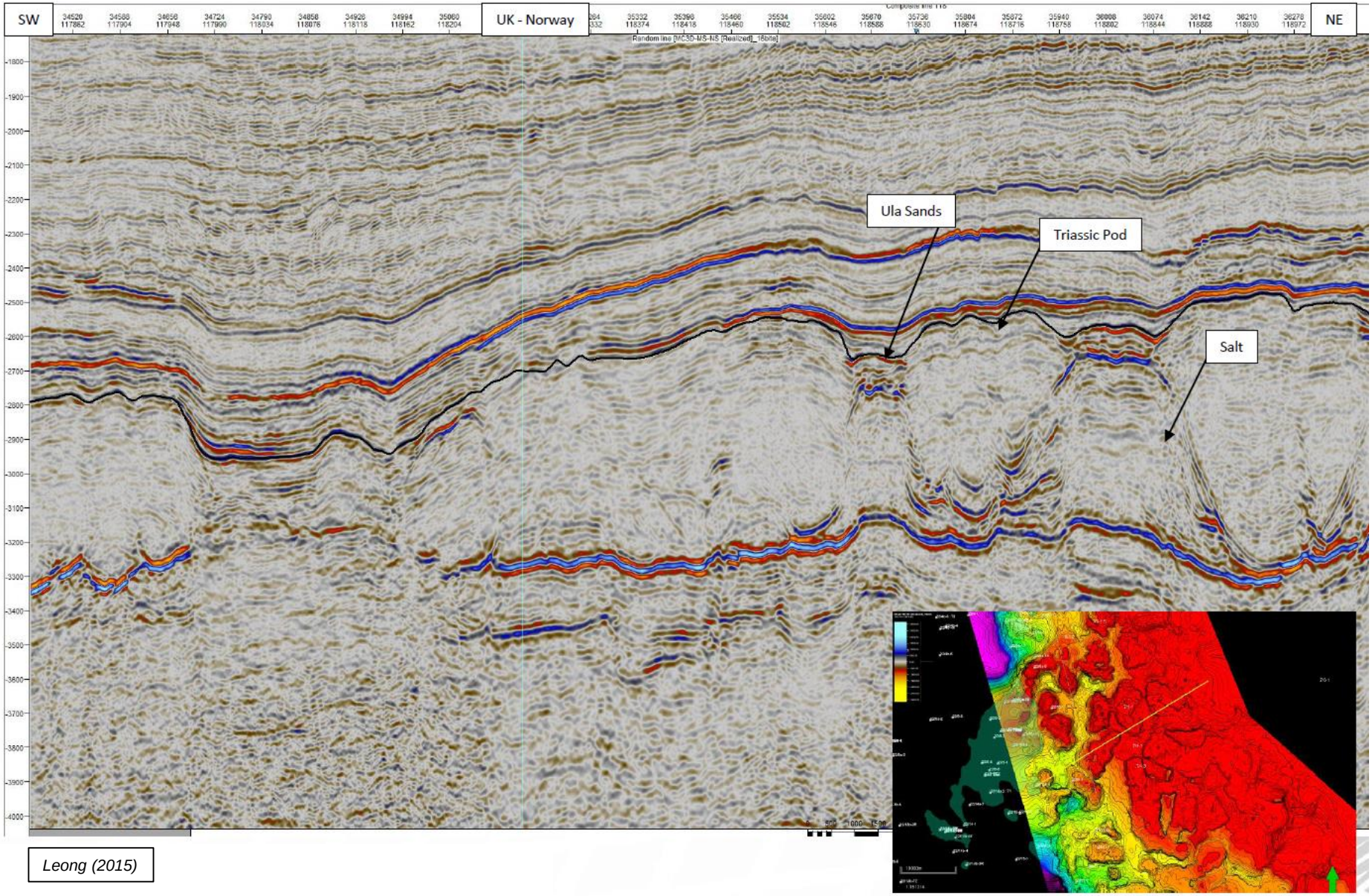
Imperial College London



Leong (2015)

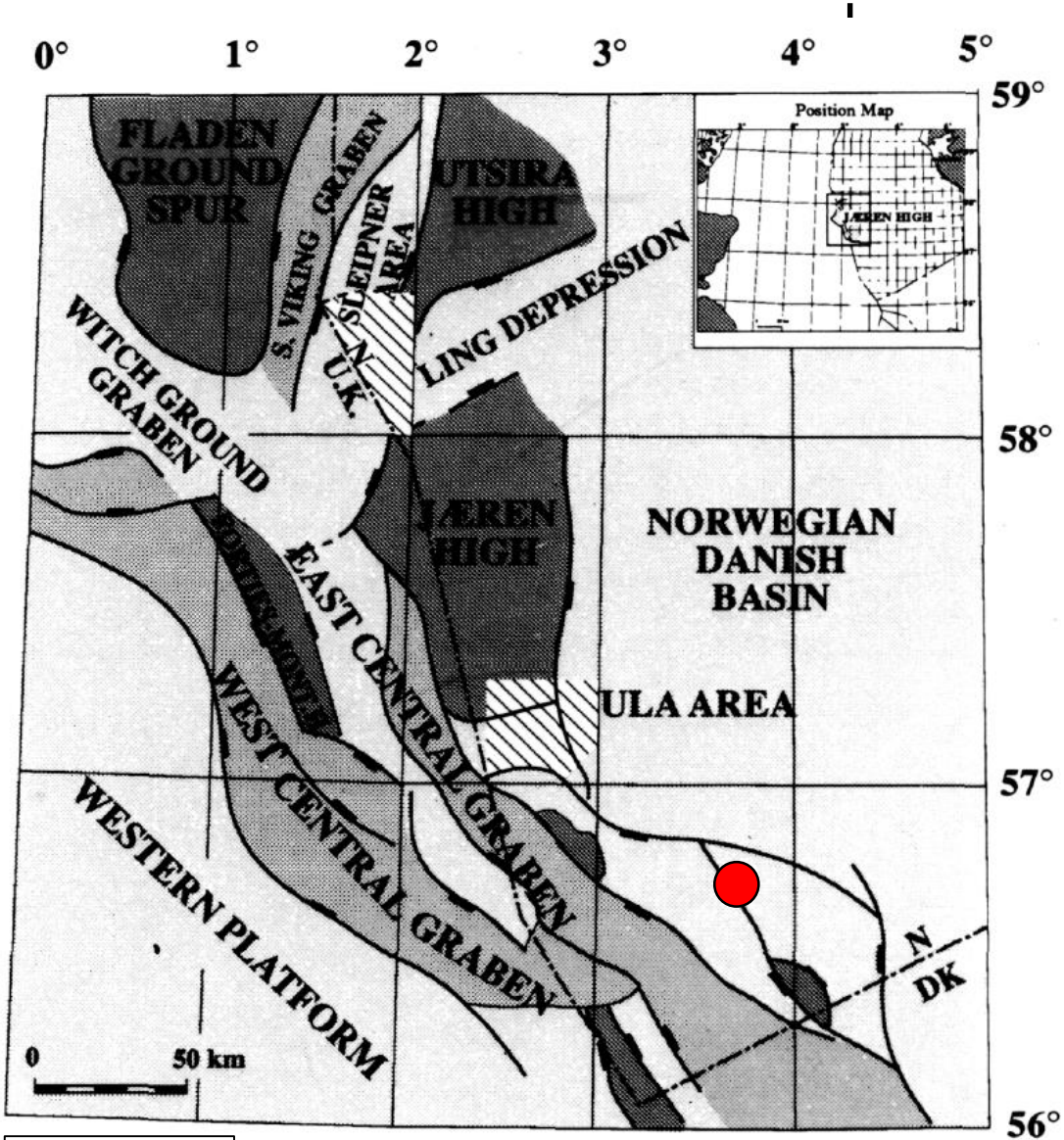
Jæran High

Imperial College London



Leong (2015)

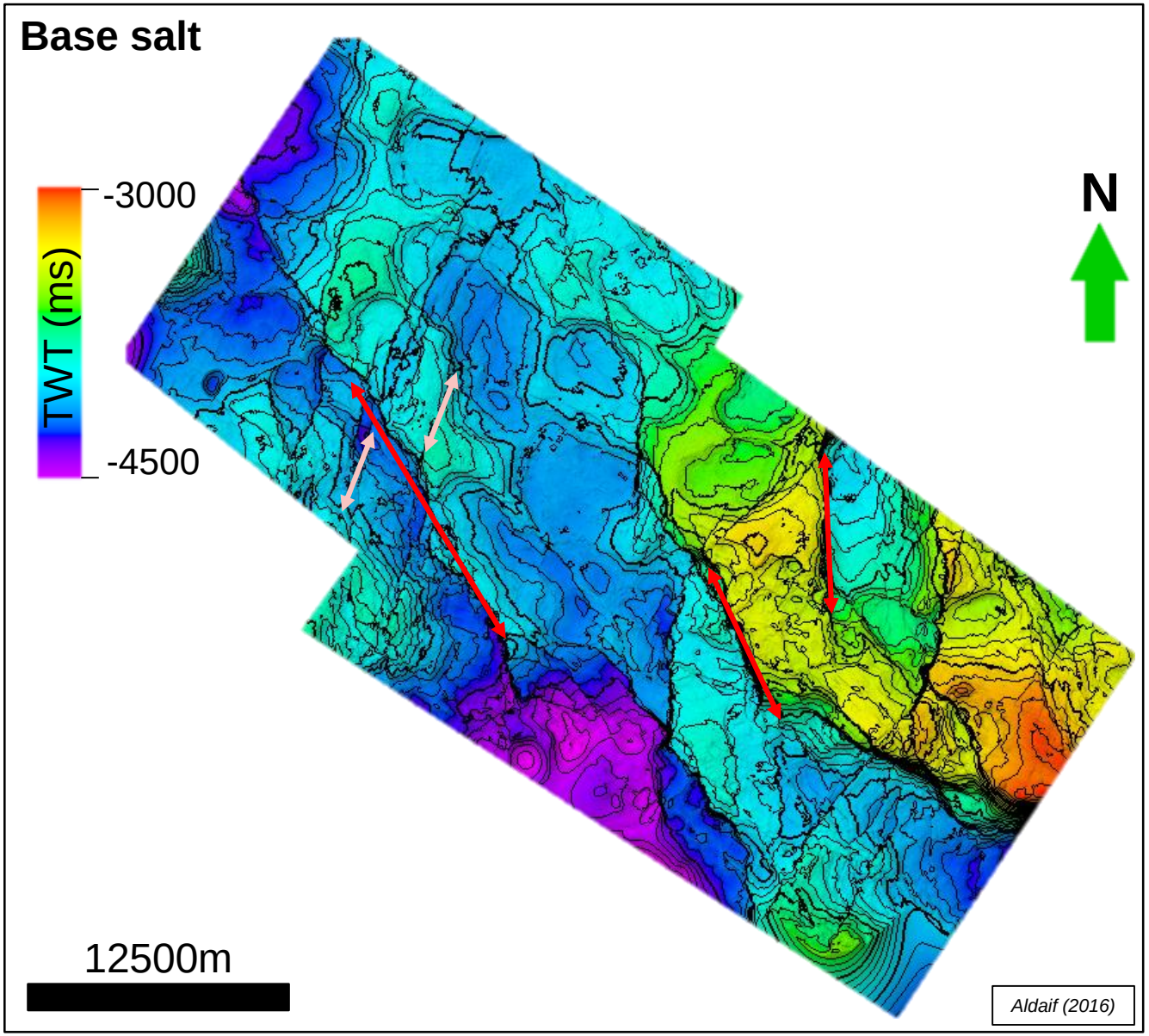
Mandal High



Høiland et al. (1993)

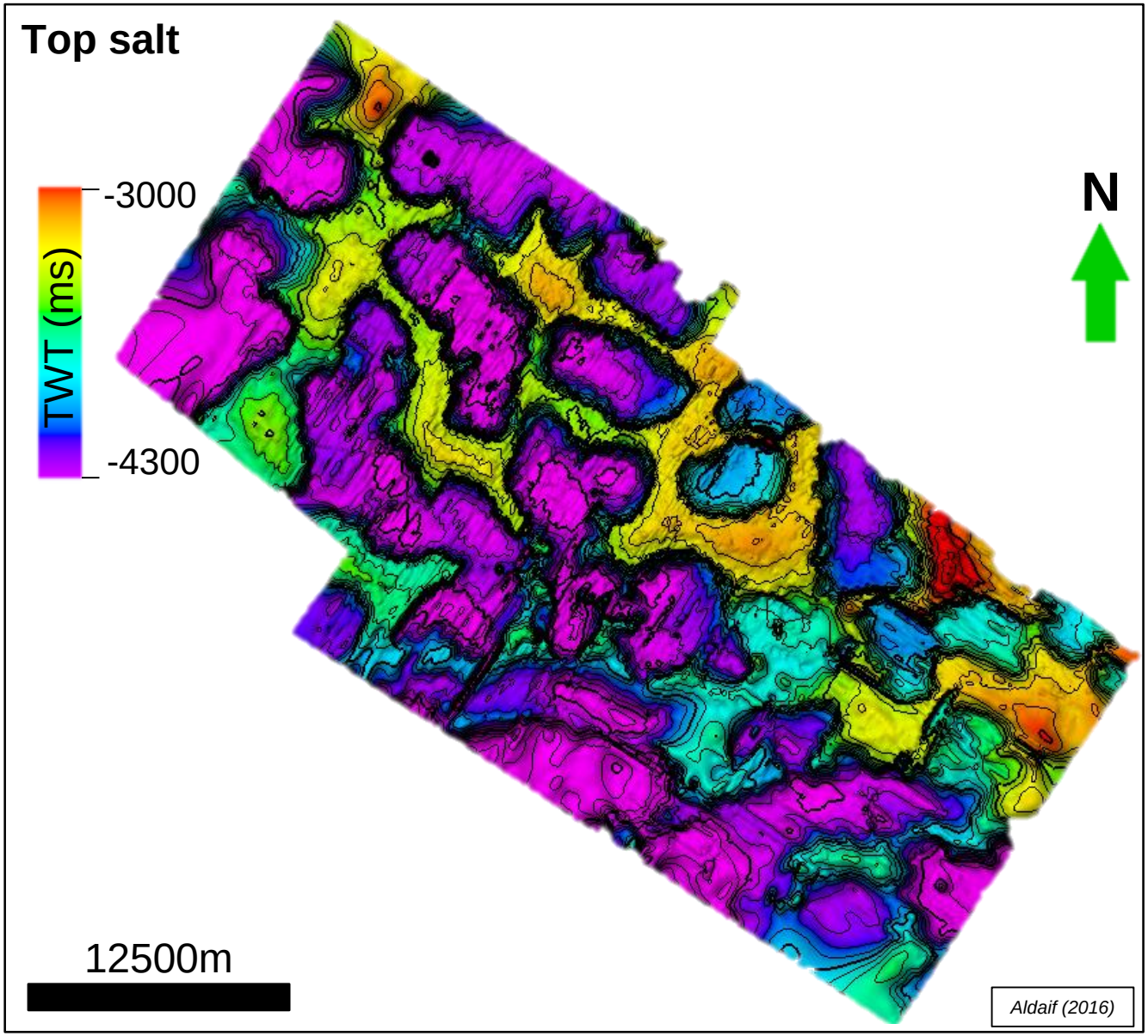
Mandal High

Imperial College London



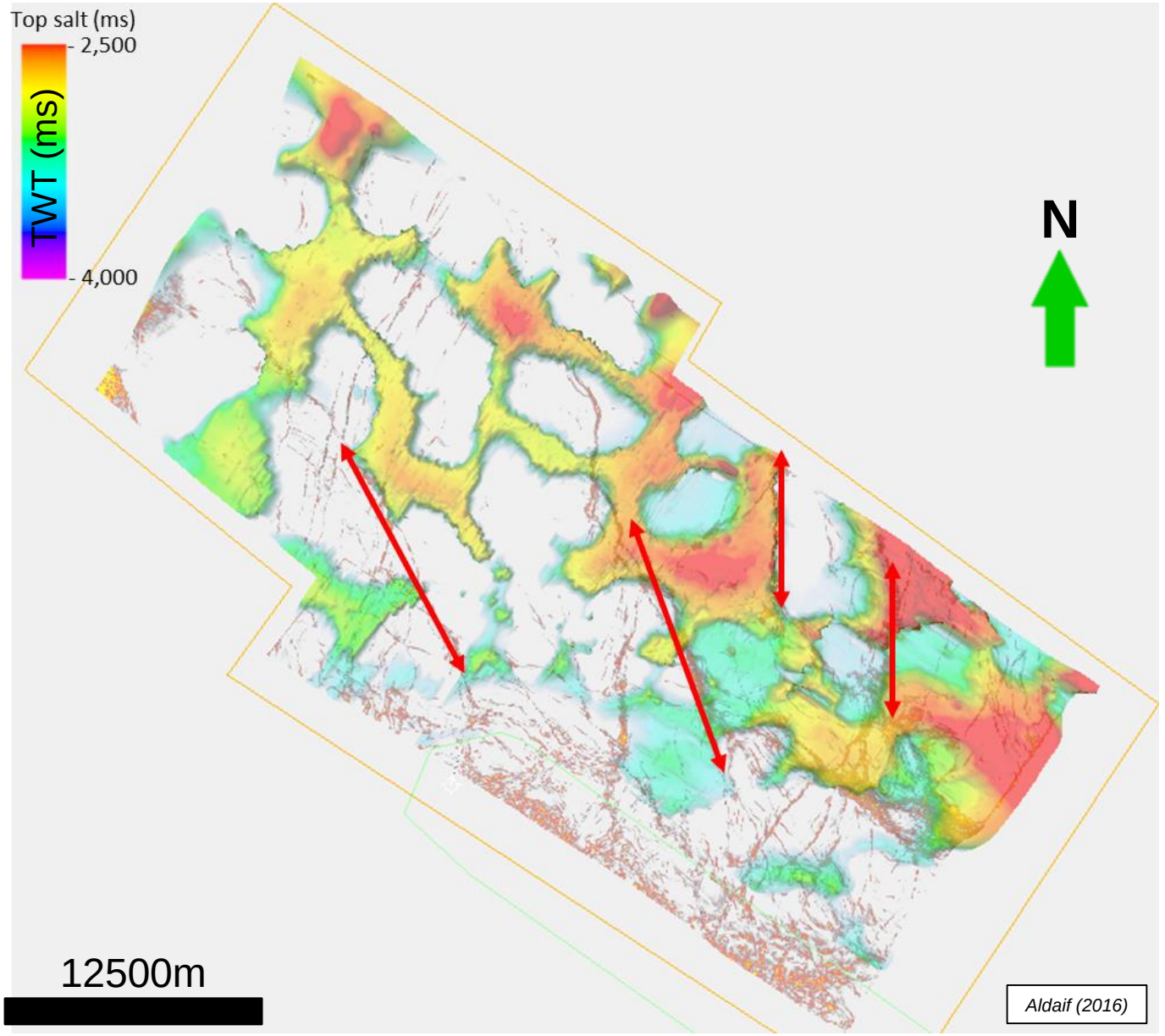
Mandal High

Imperial College London



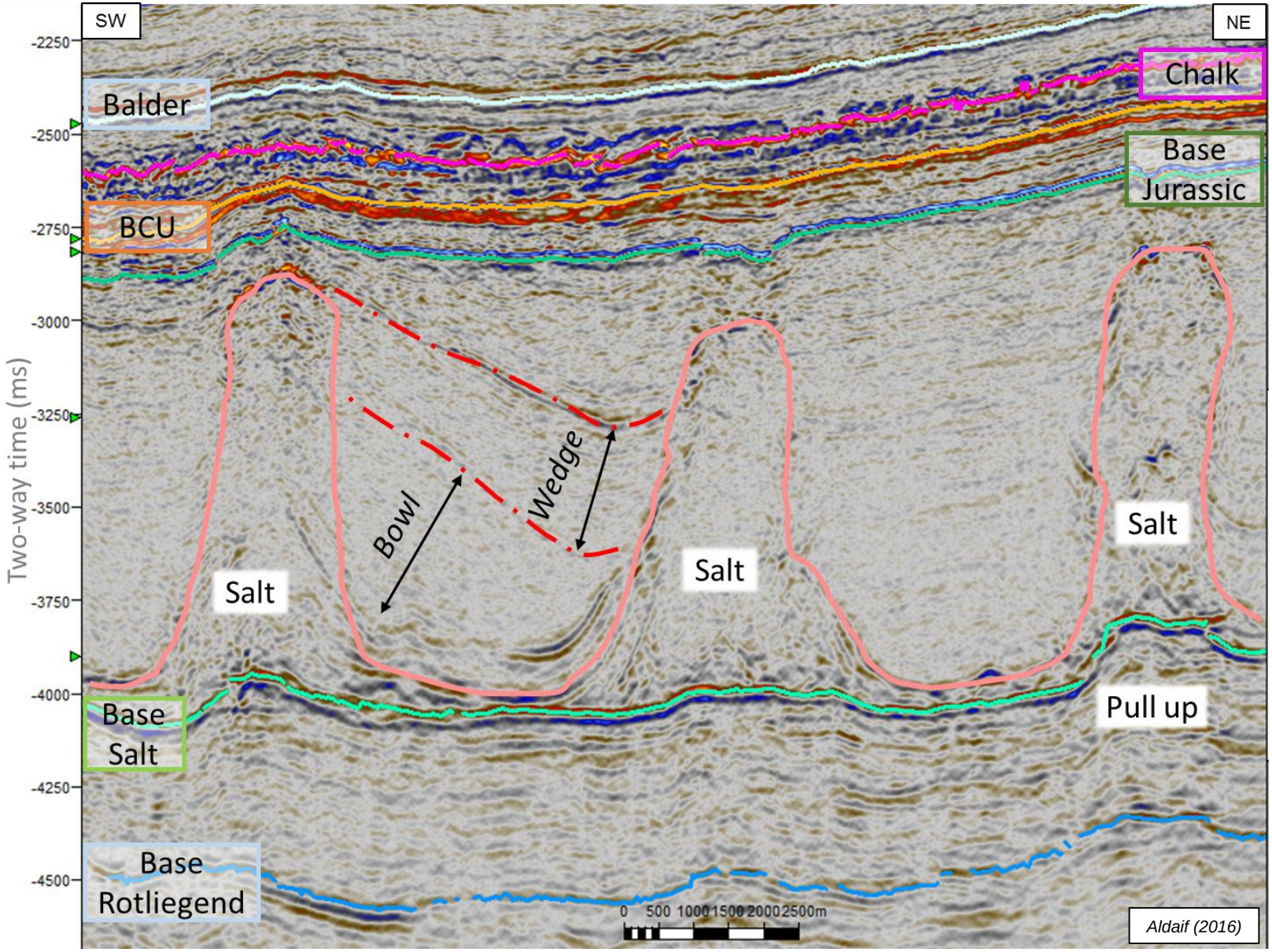
Mandal High

Imperial College London



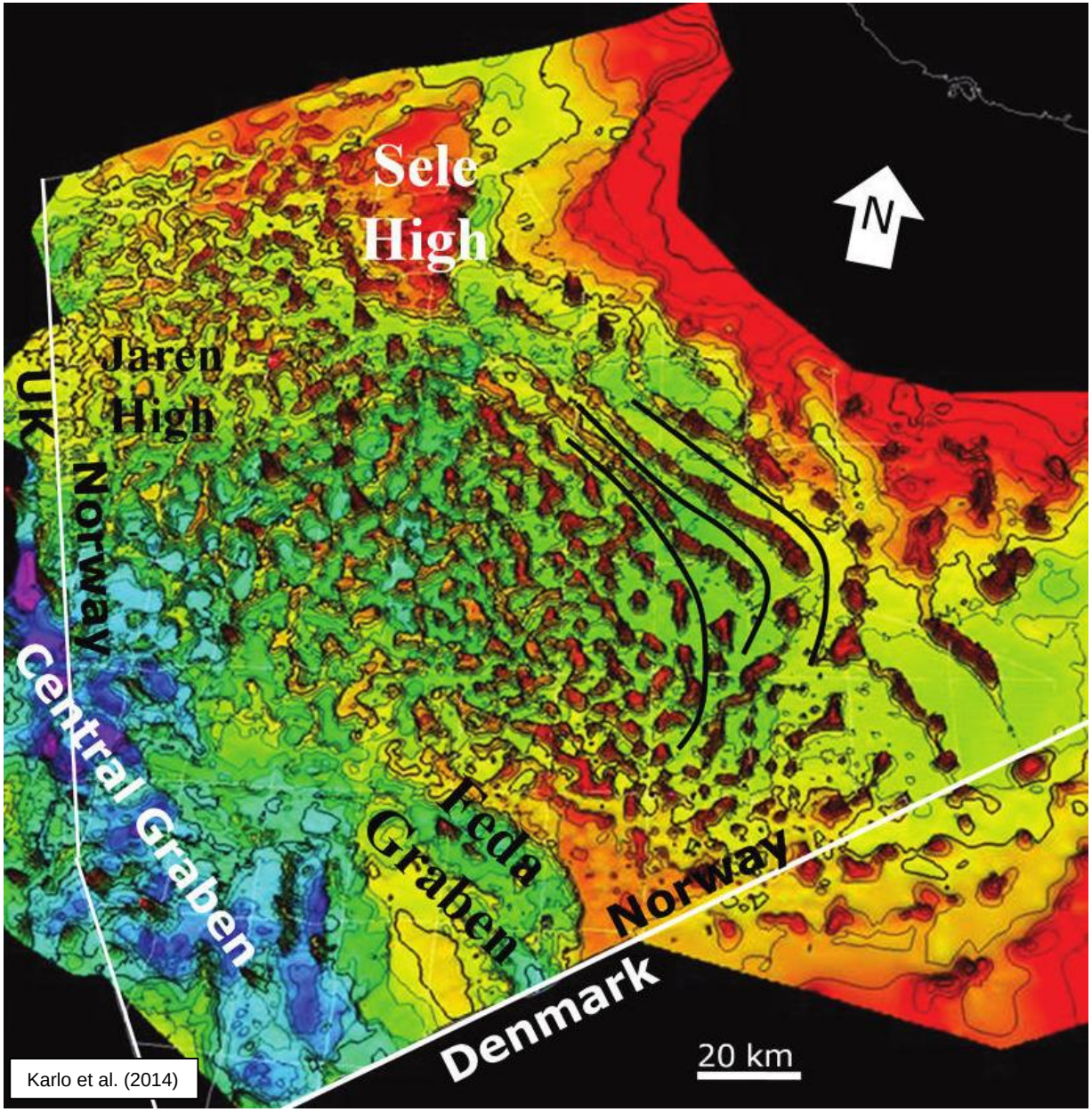
Mandal High

Imperial College London



Regional Observations

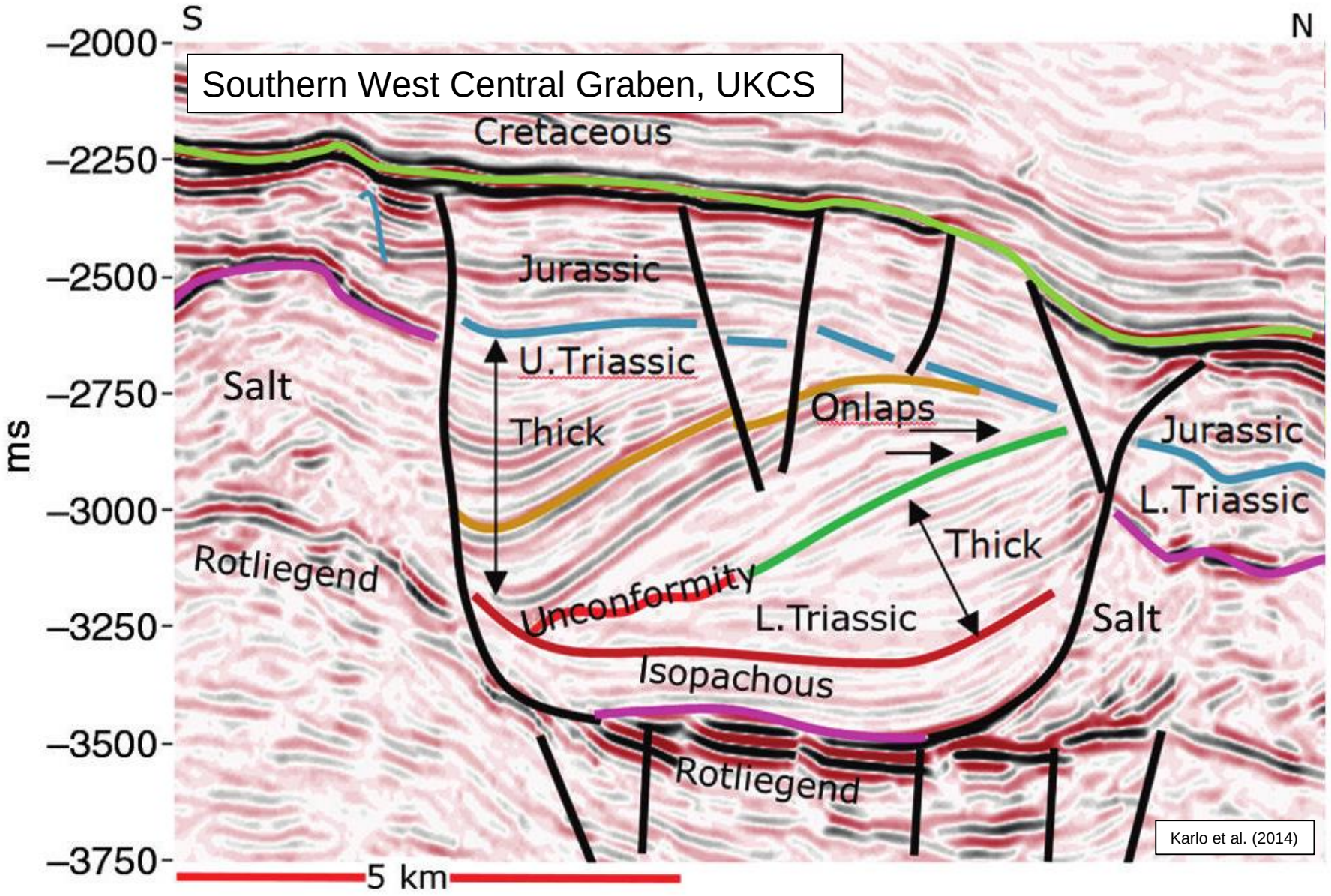
Imperial College London



Karlo et al. (2014)

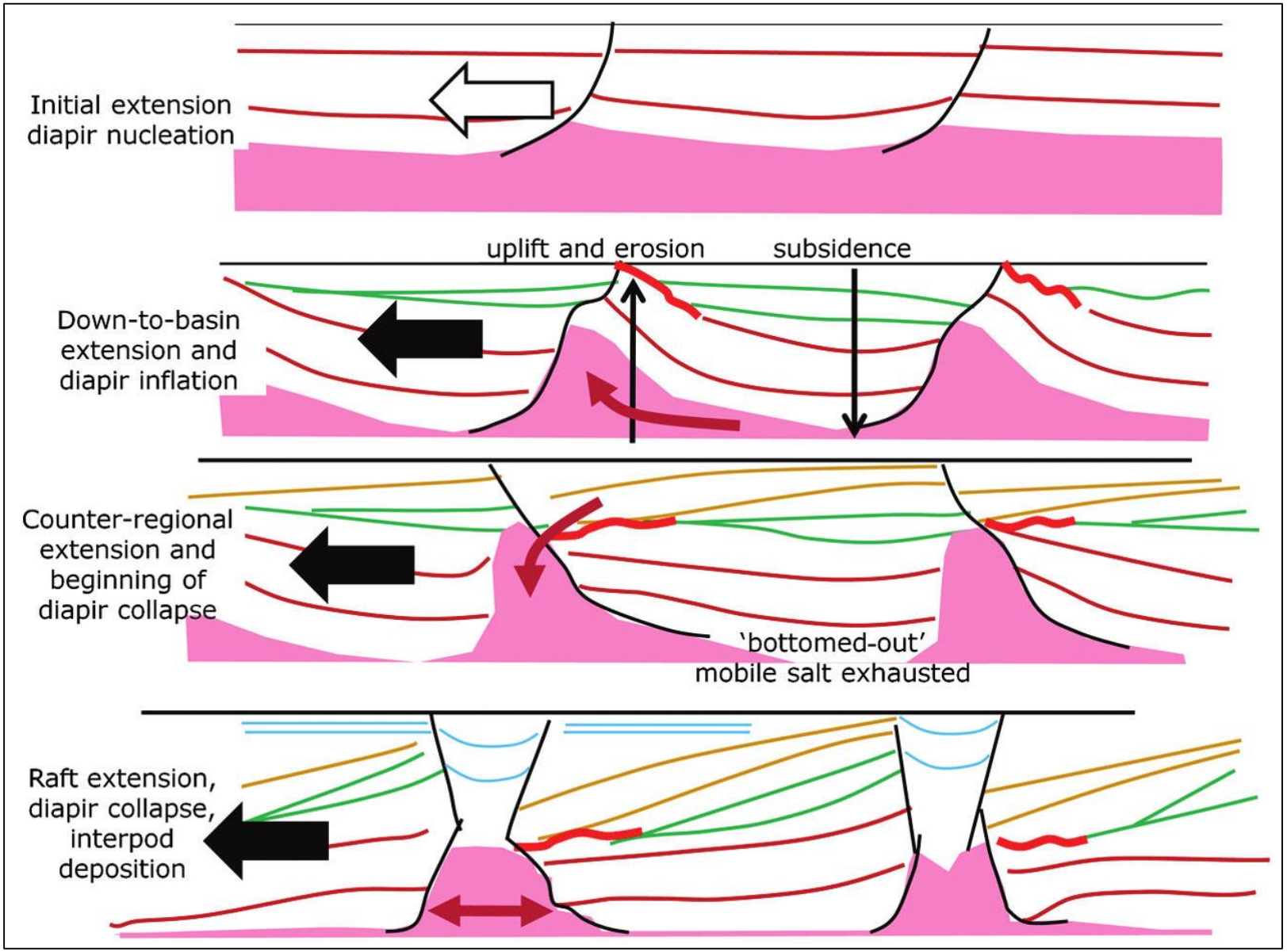
Triassic Seismic Stratigraphy

Imperial College London



Hybrid Salt-Tectonic Models

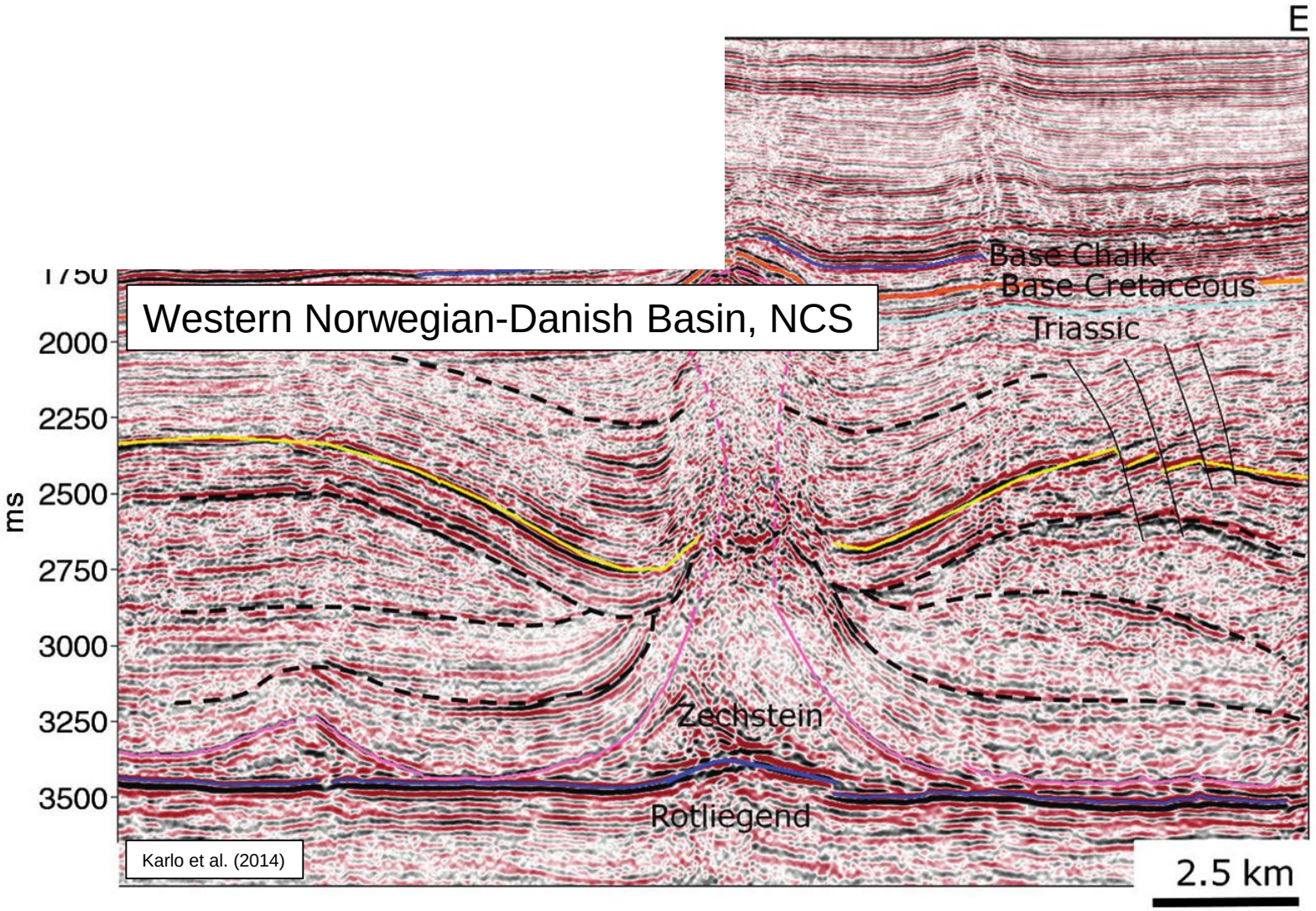
Imperial College London



Karlo et al. (2014)

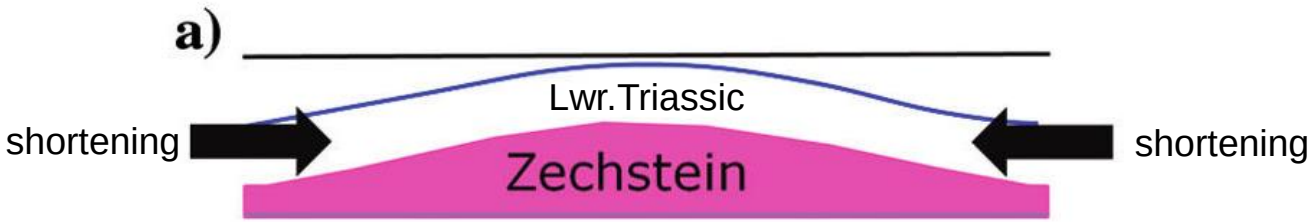
Evidence for Triassic shortening

Imperial College London



Evidence for Triassic shortening

Imperial College London



Karlo et al. (2014)

Data favour the passive diapirism model for Triassic salt tectonics in the Northern North Sea.

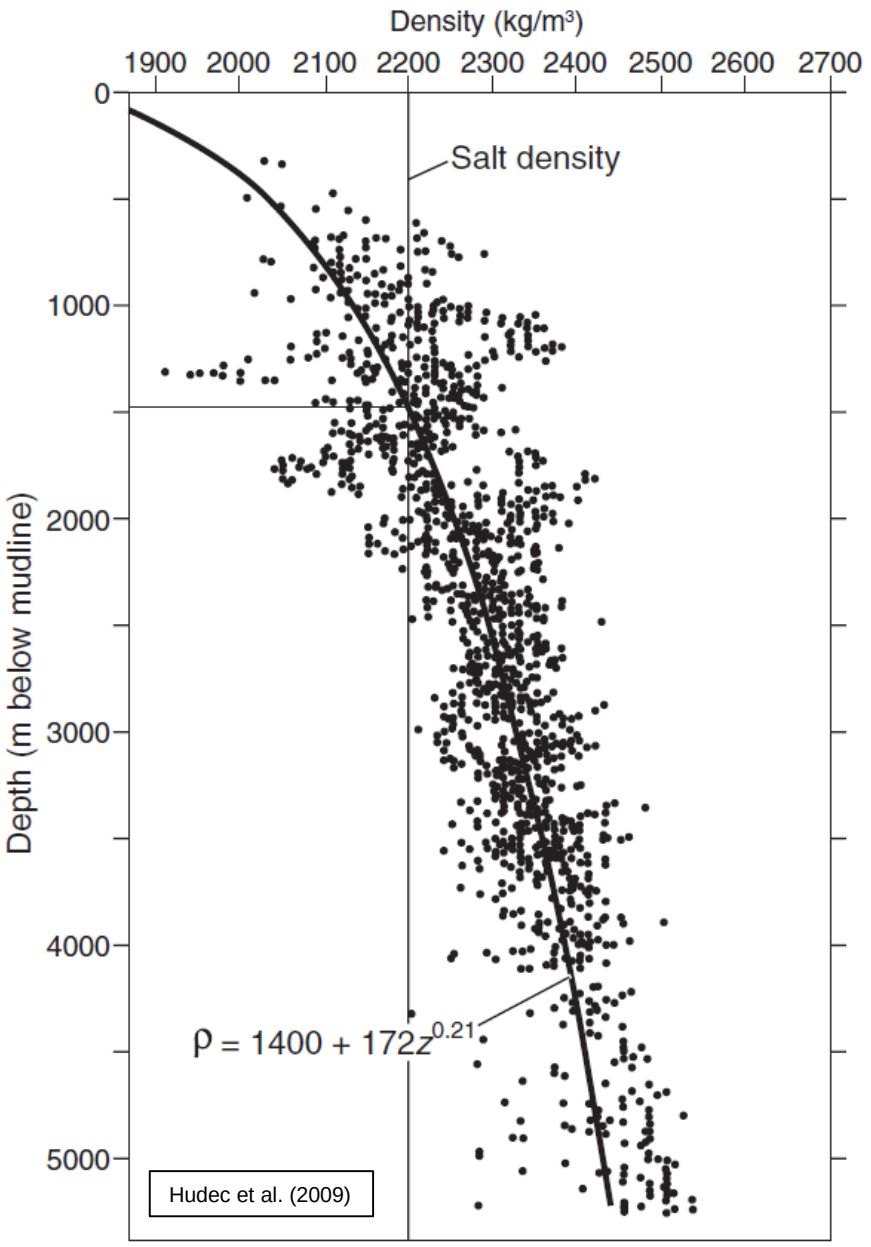
So, we're all good, yes...?

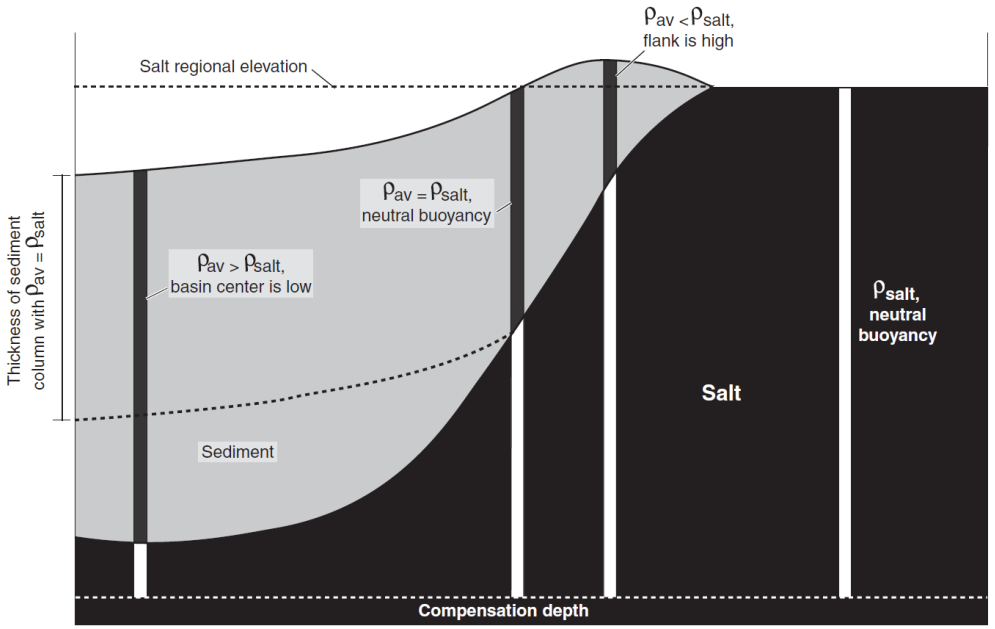
No...

...because of the Mechanical Gremlin...

The ‘Density Paradox’

Imperial College London

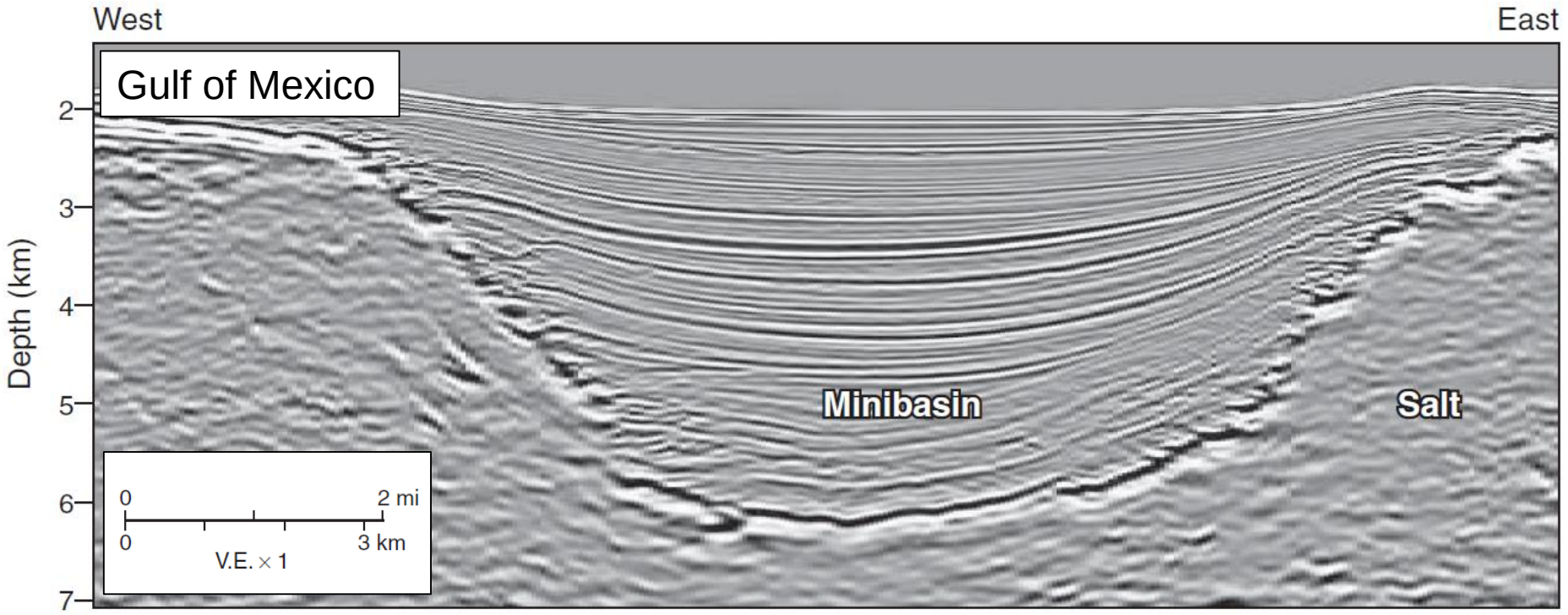




- Overburden sinks into salt due to excess density
- Pure salt density = 2.2 kg/m^3; sediment densities = <2.2 kg/m^3 until several hundred to >1 km thickness
- How to trigger Early Triassic subsidence below such thin overburden?

The ‘Density Paradox’

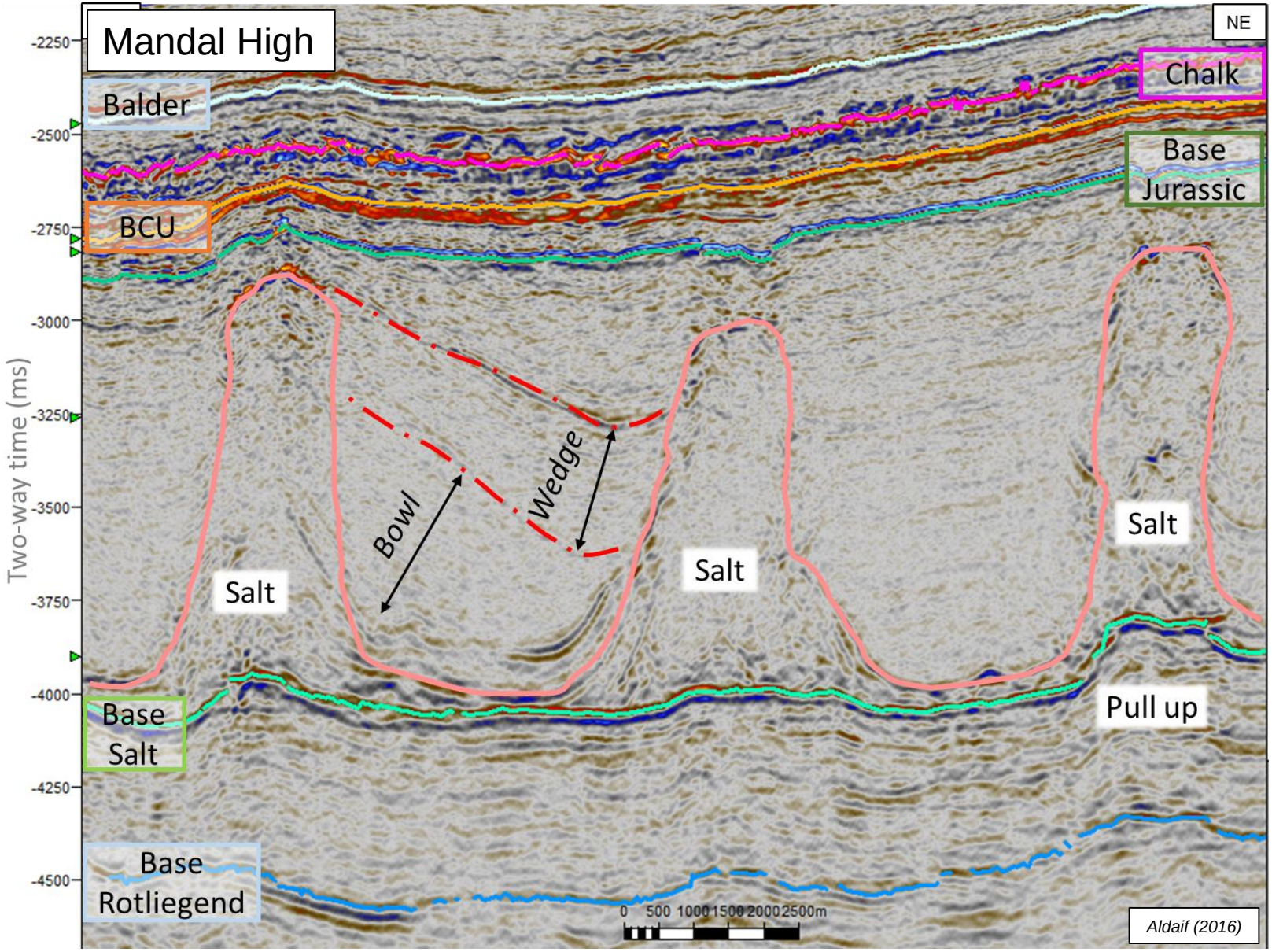
Imperial College London



Hudec et al. (2009)

The ‘Density Paradox’

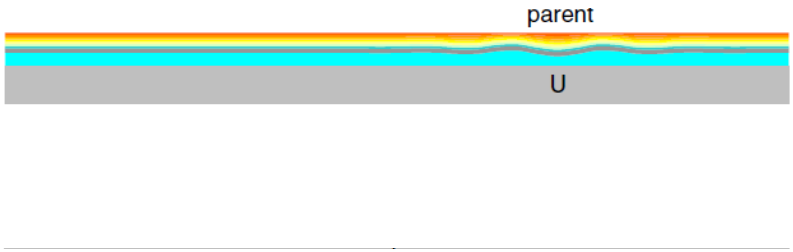
Imperial College London



So, how to trigger passive diapirism...?

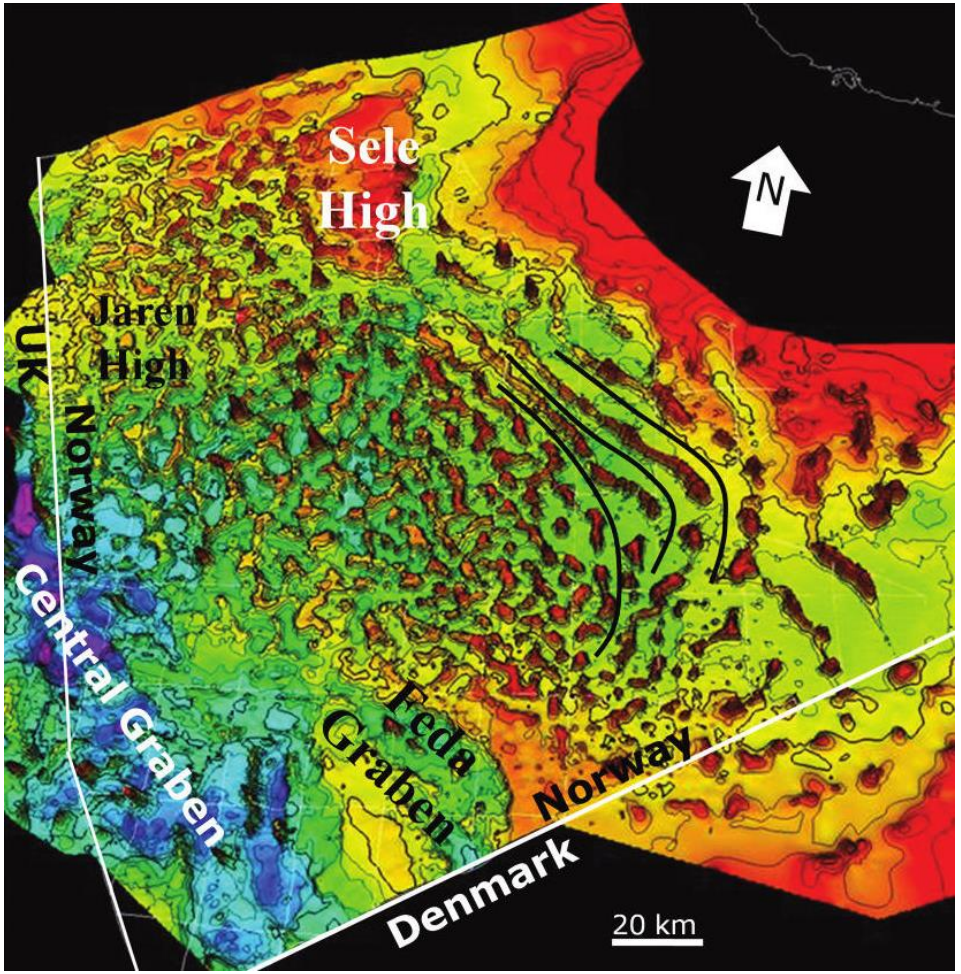
Minibasin Propagation?

Imperial College London



Peel (2014)

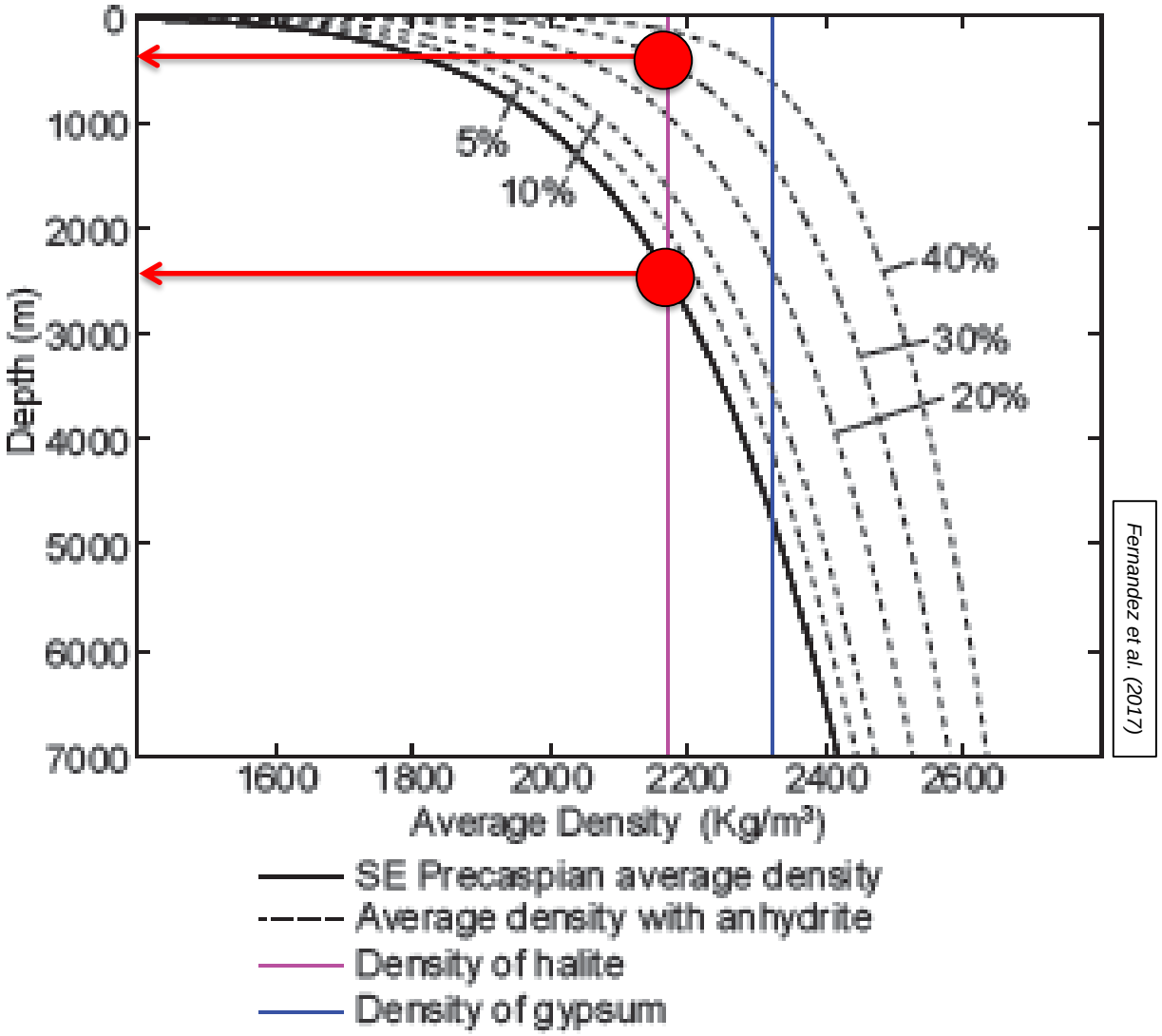
- Minibasin array propagates from dense ‘seed’ (i.e. sediment mound)
- Does not explain plan-view geometries (e.g. polygonal walls or isolated minibasins)...
- Depositional system type providing initial seed/seeds unclear...



Karlo et al. (2014)

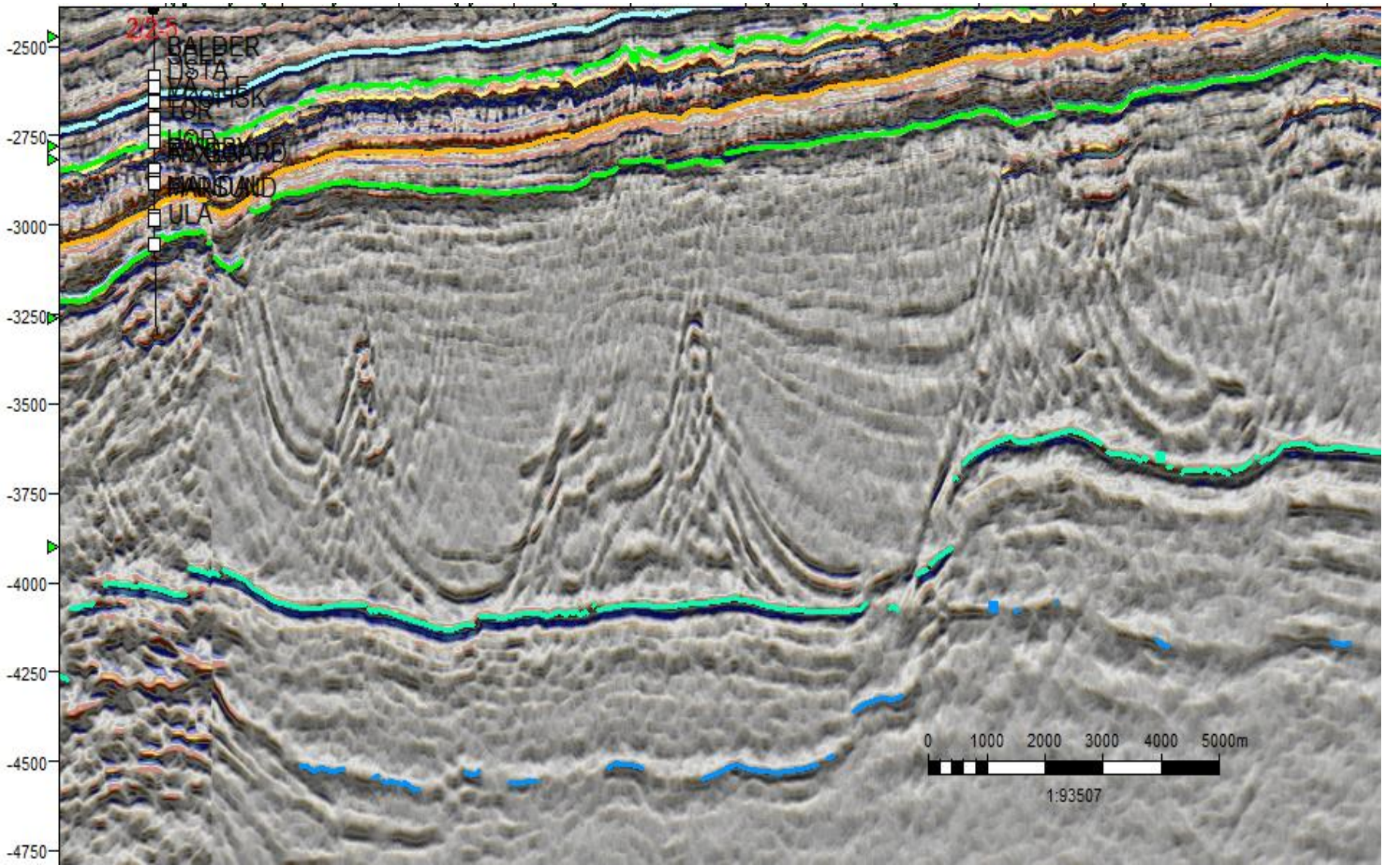
Syn-Salt Density Overturn?

Imperial College London



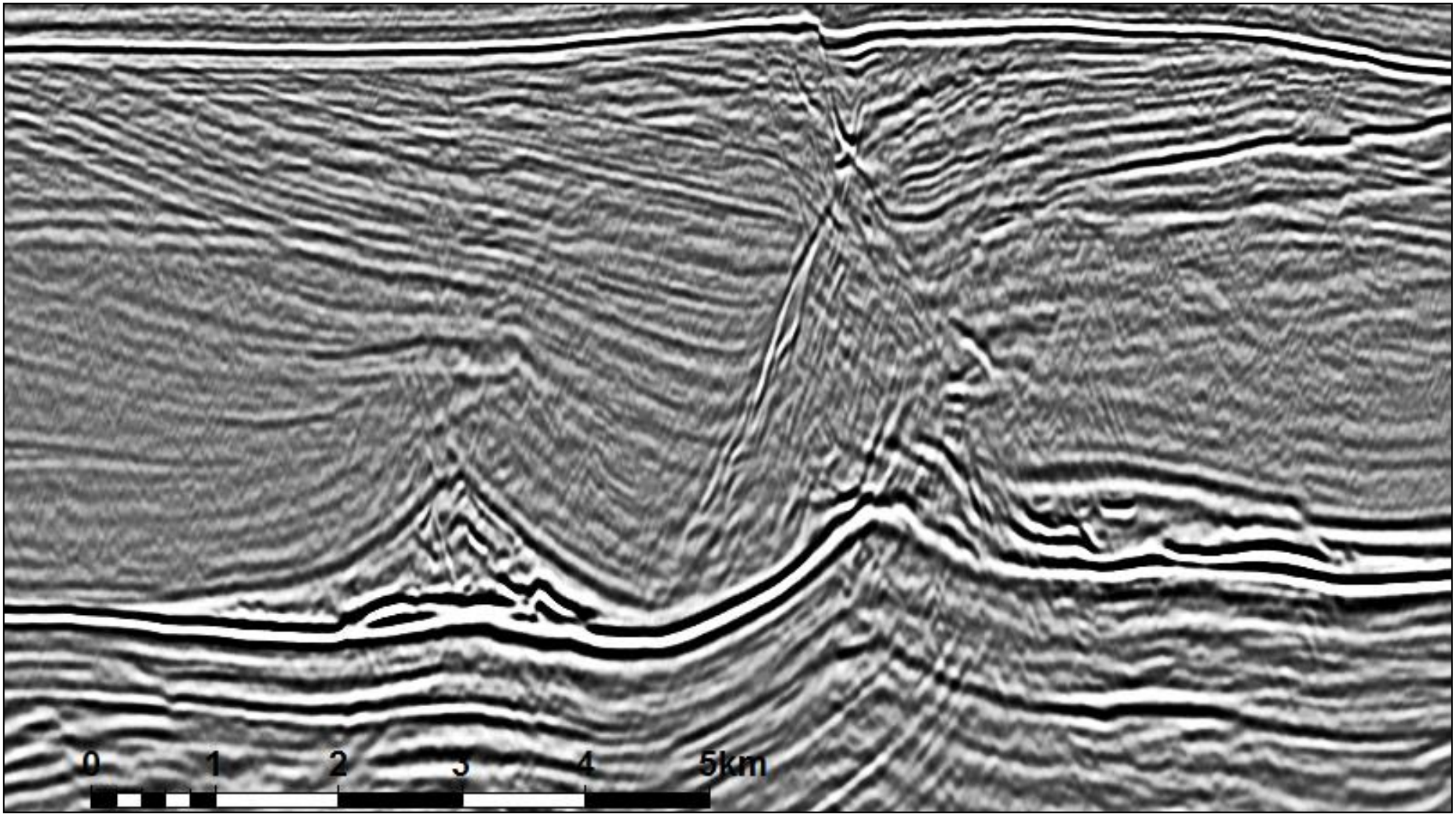
Seismic Evidence for Intrasalt Variability

Imperial College London



Seismic Evidence for Intrasalt Variability

Imperial College London



Conclusions

Imperial College London

- Two end-member models for Triassic salt-tectonics; passive and reactive diapirism
- Diagnostic criteria (or varying strengths) allow model differentiation; model selection has kinematic and exploration consequences
- Seismic reflection-based observations (e.g. onlaps, lack of faulting, lack of coeval contraction) largely support passive diapir model (reactive model may be locally applicable on tilted fault blocks)
- Latest Permian, intrasalt depositional heterogeneity may explain the so-called ‘Density Paradox’