Late Charge problems in the K5 area

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TEP Nederland,
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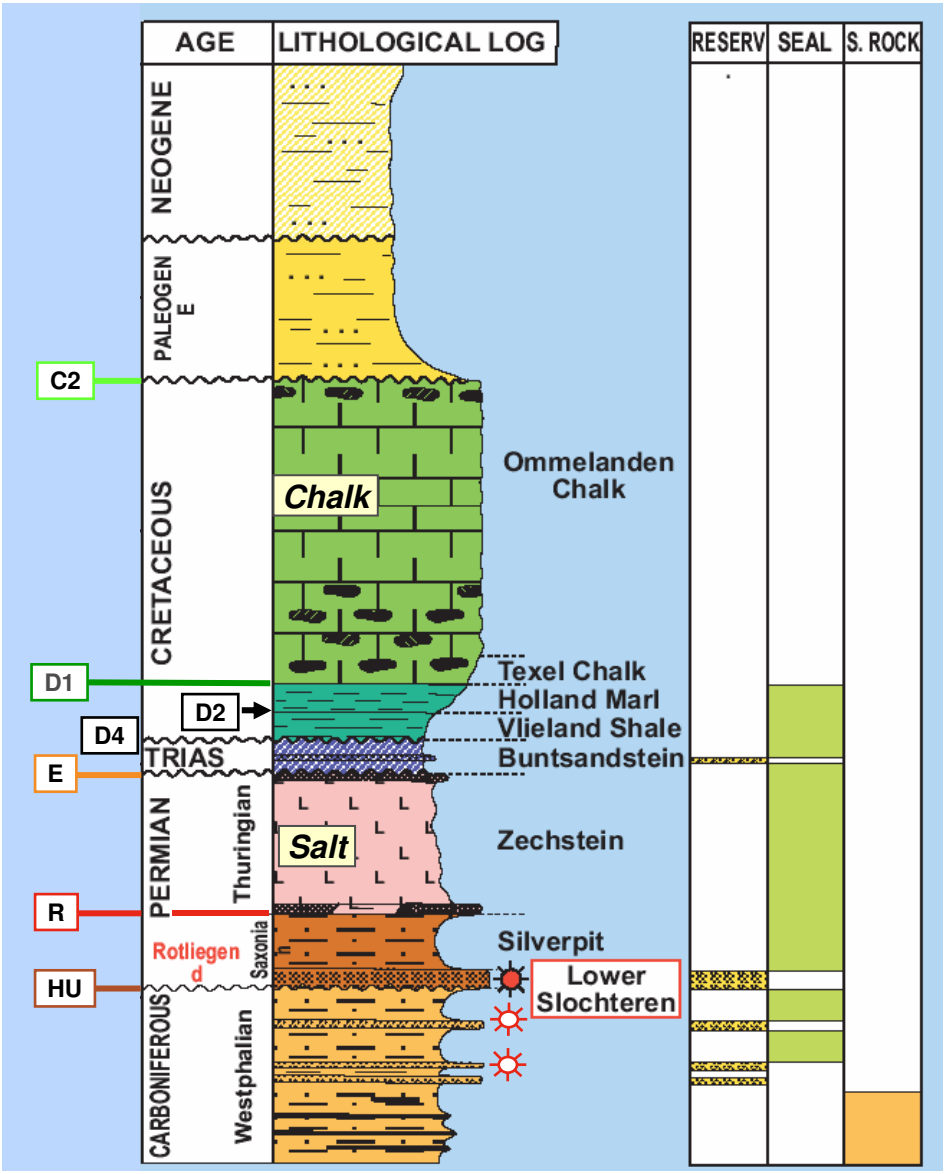
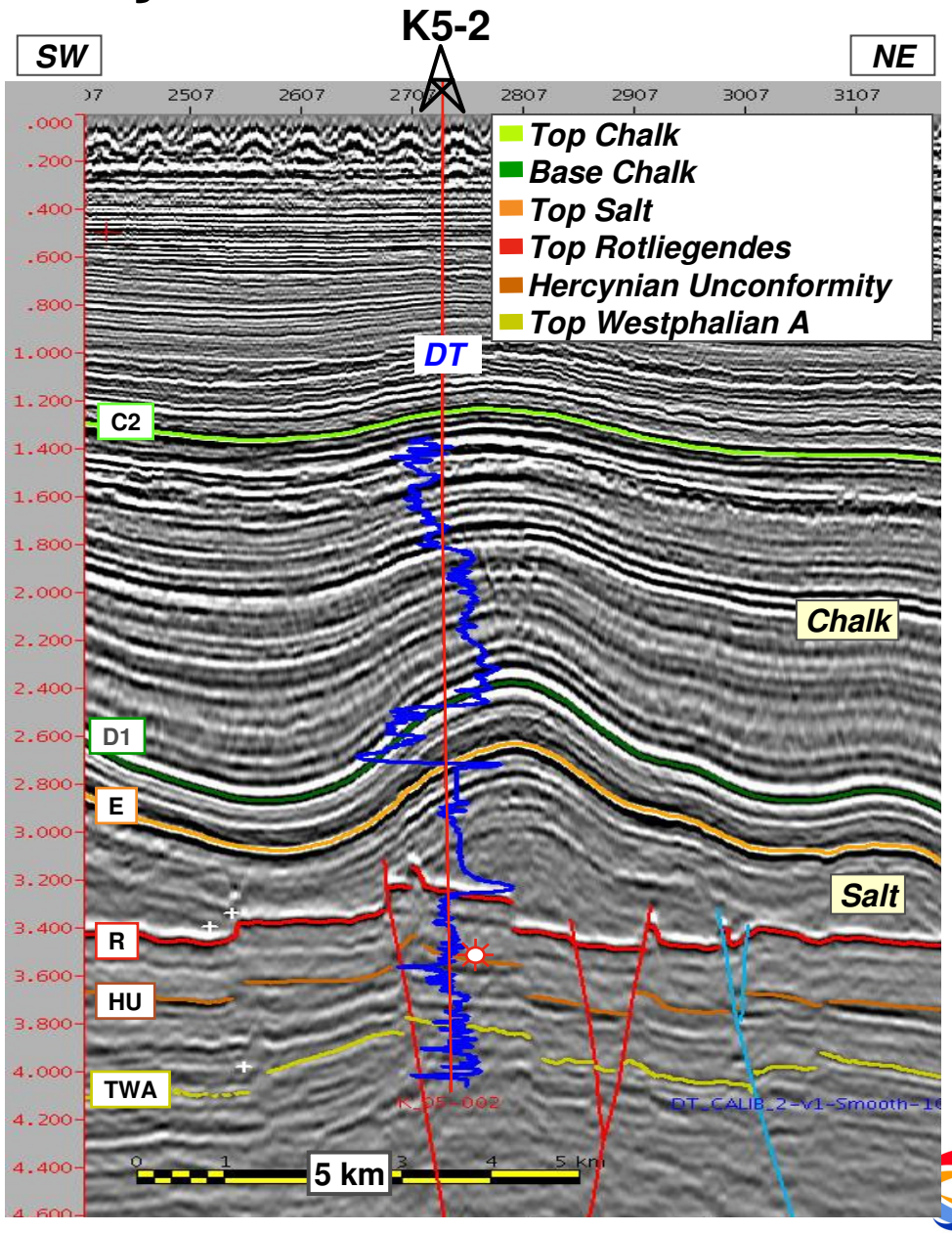
TNO/EBN Workshop Utrecht

Agenda

- Regional context
- K5-13 results and Post Mortem
- Structural Setting K4-K5 area
- Conclusions

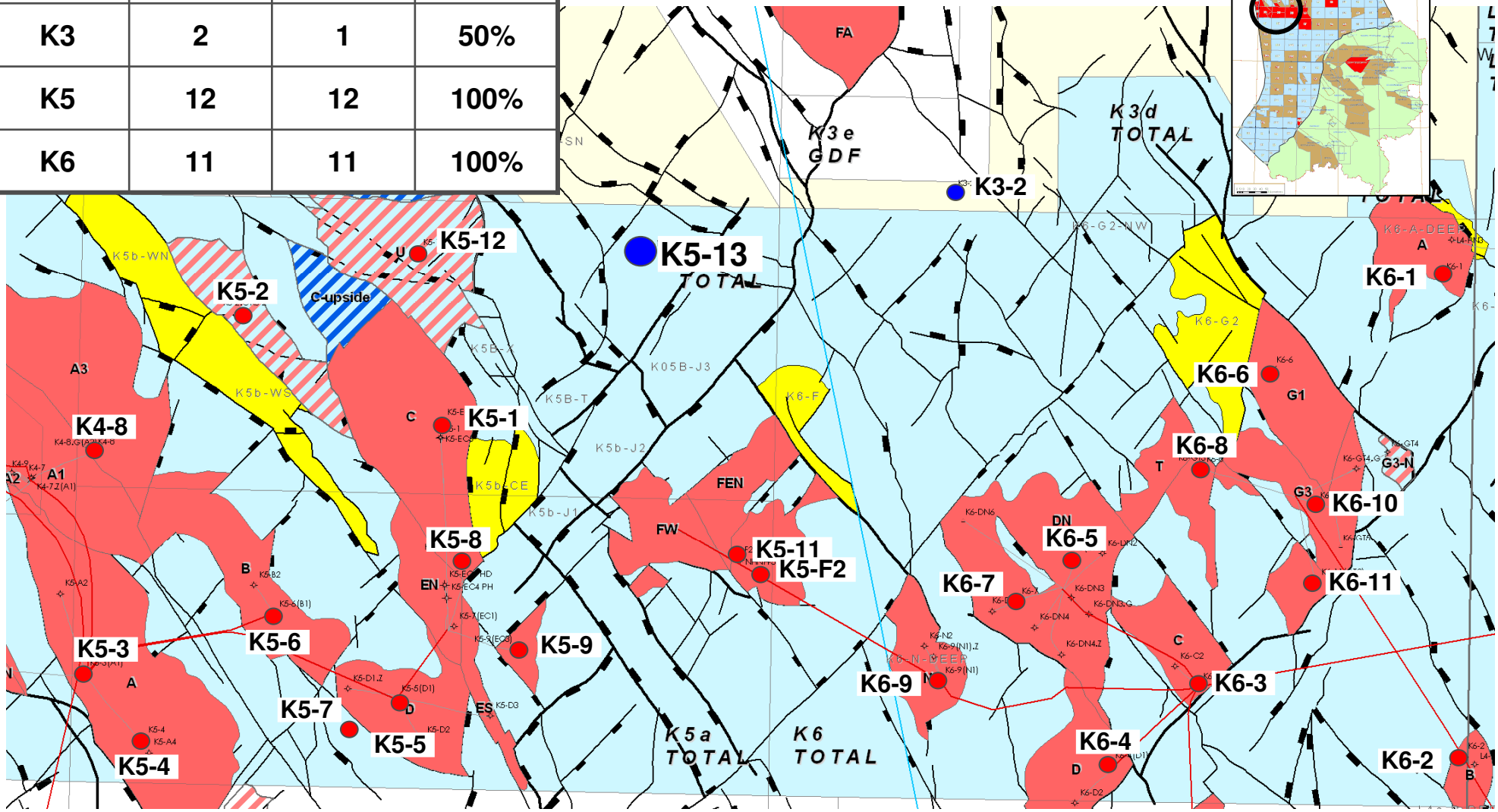
Stratigraphic Column and HC Play in core area



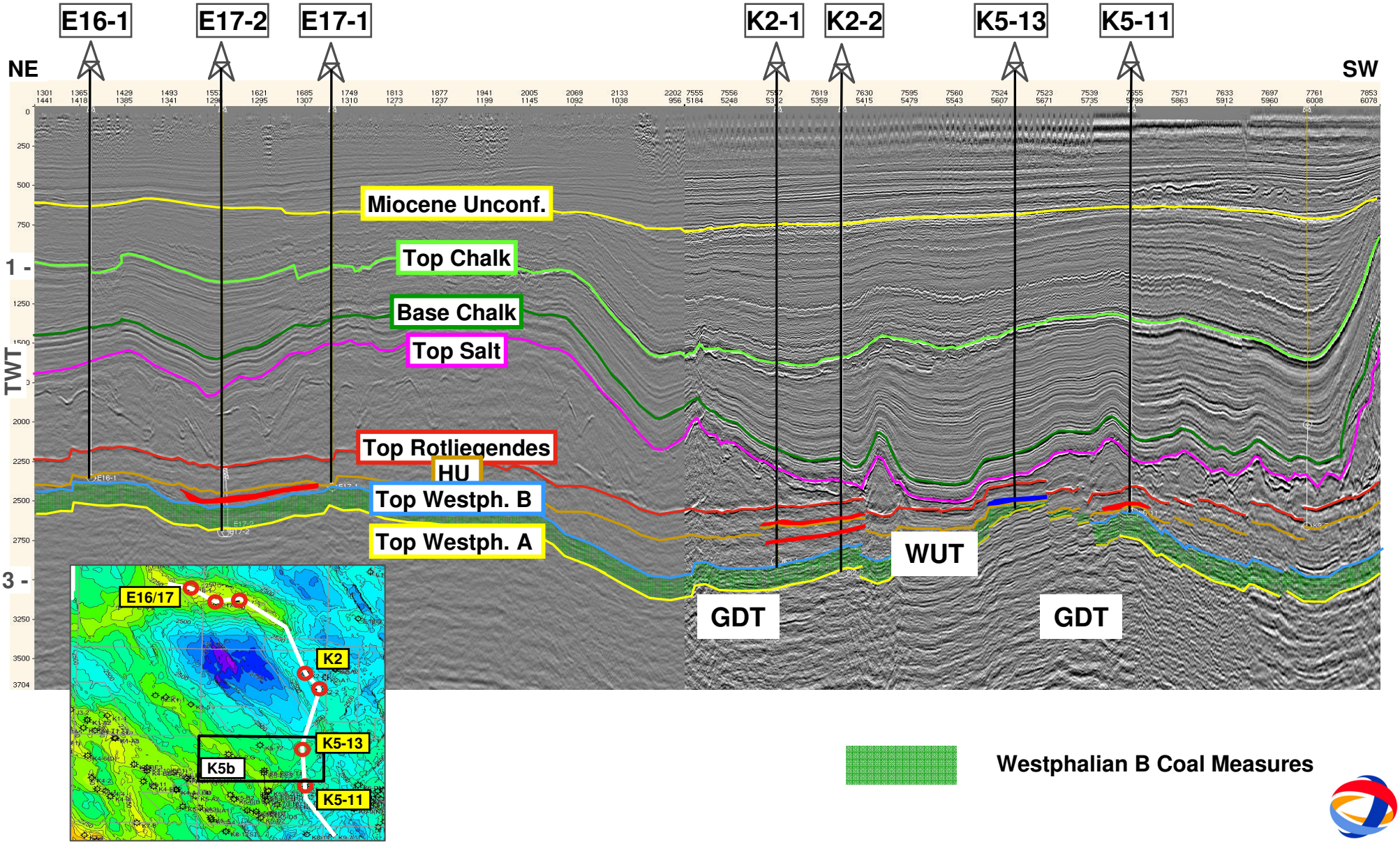


Exploration wells and success rate

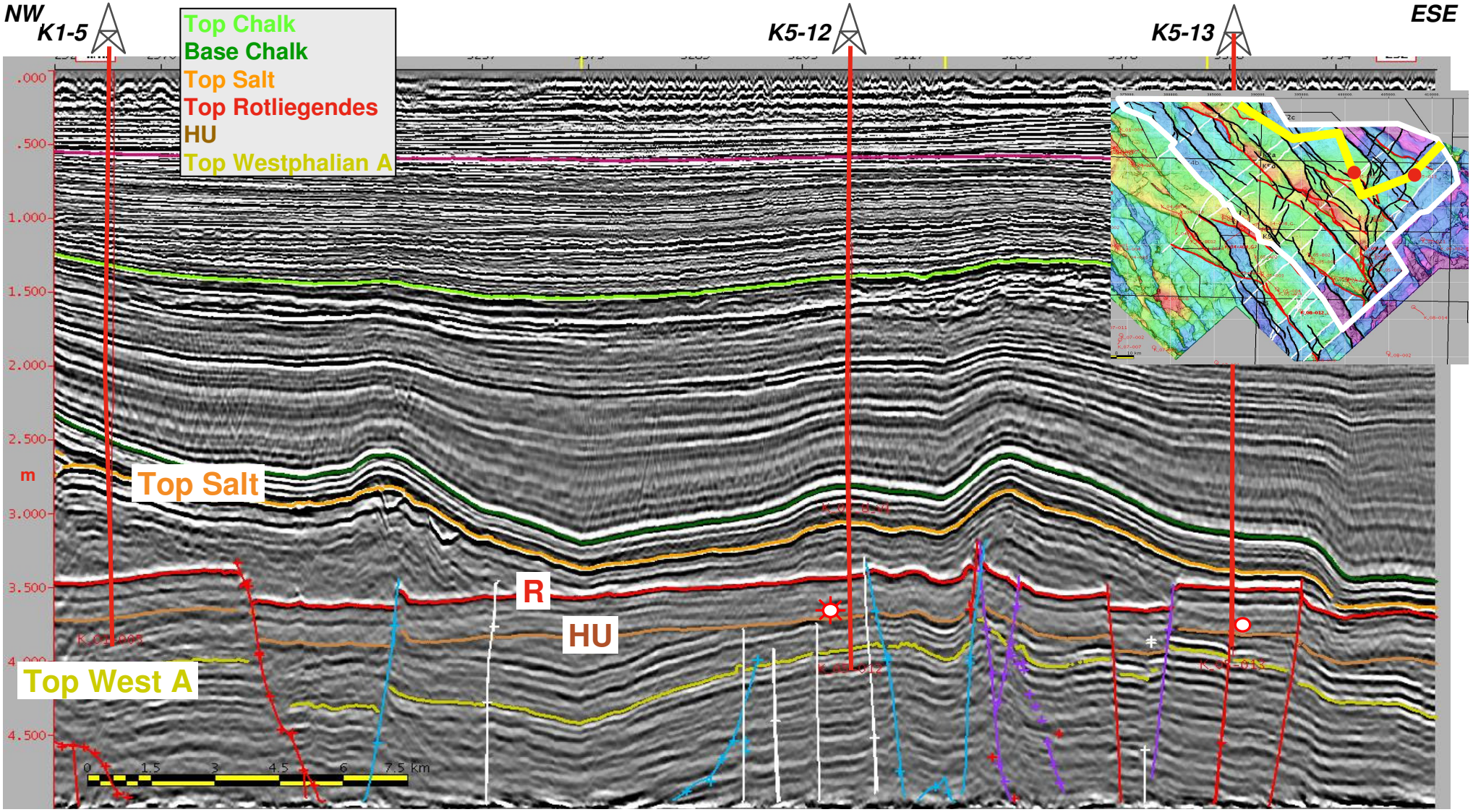
K2	2	2	100%
K3	2	1	50%
K5	12	12	100%
K6	11	11	100%



Regional seismic line



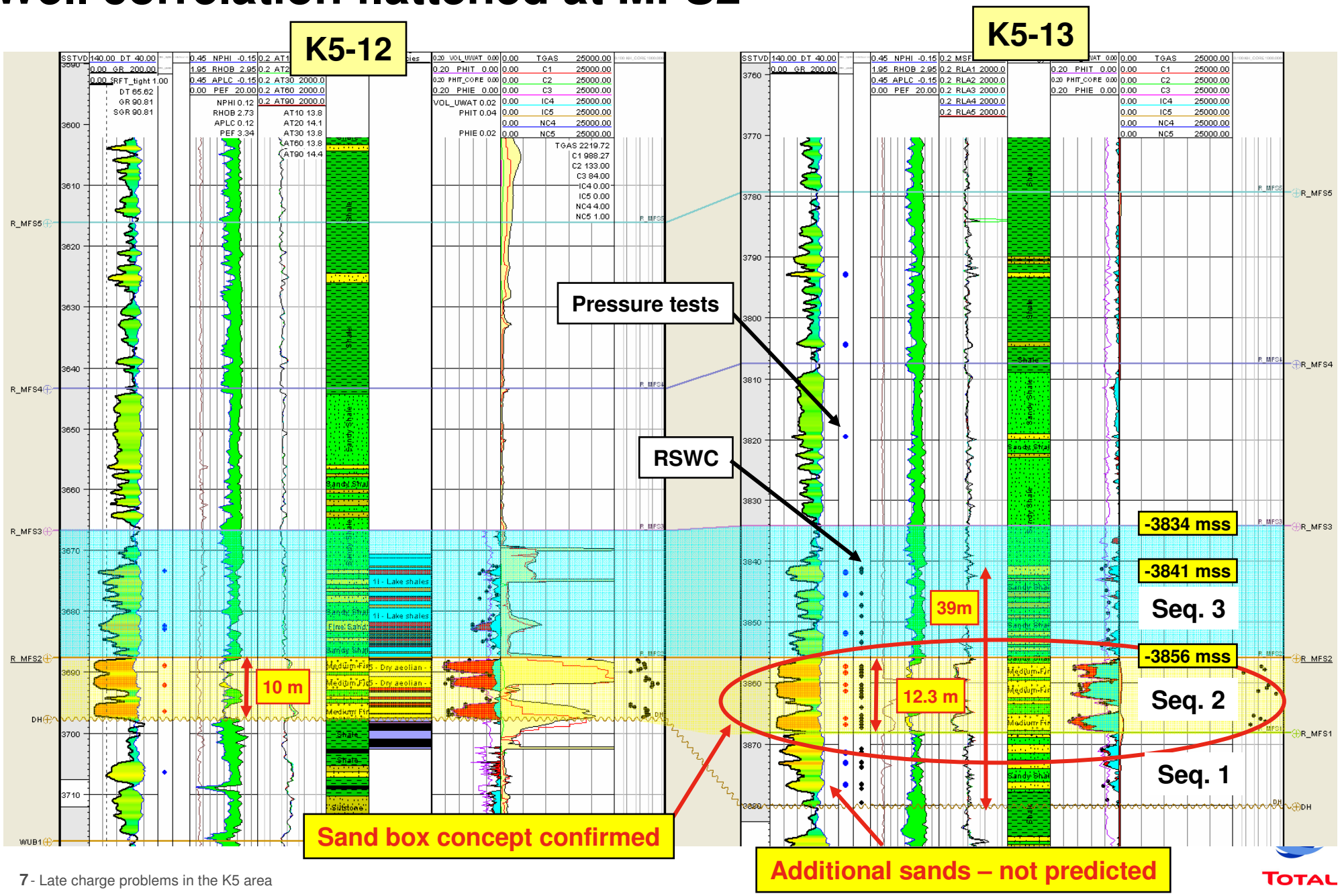
Random tie line K5b



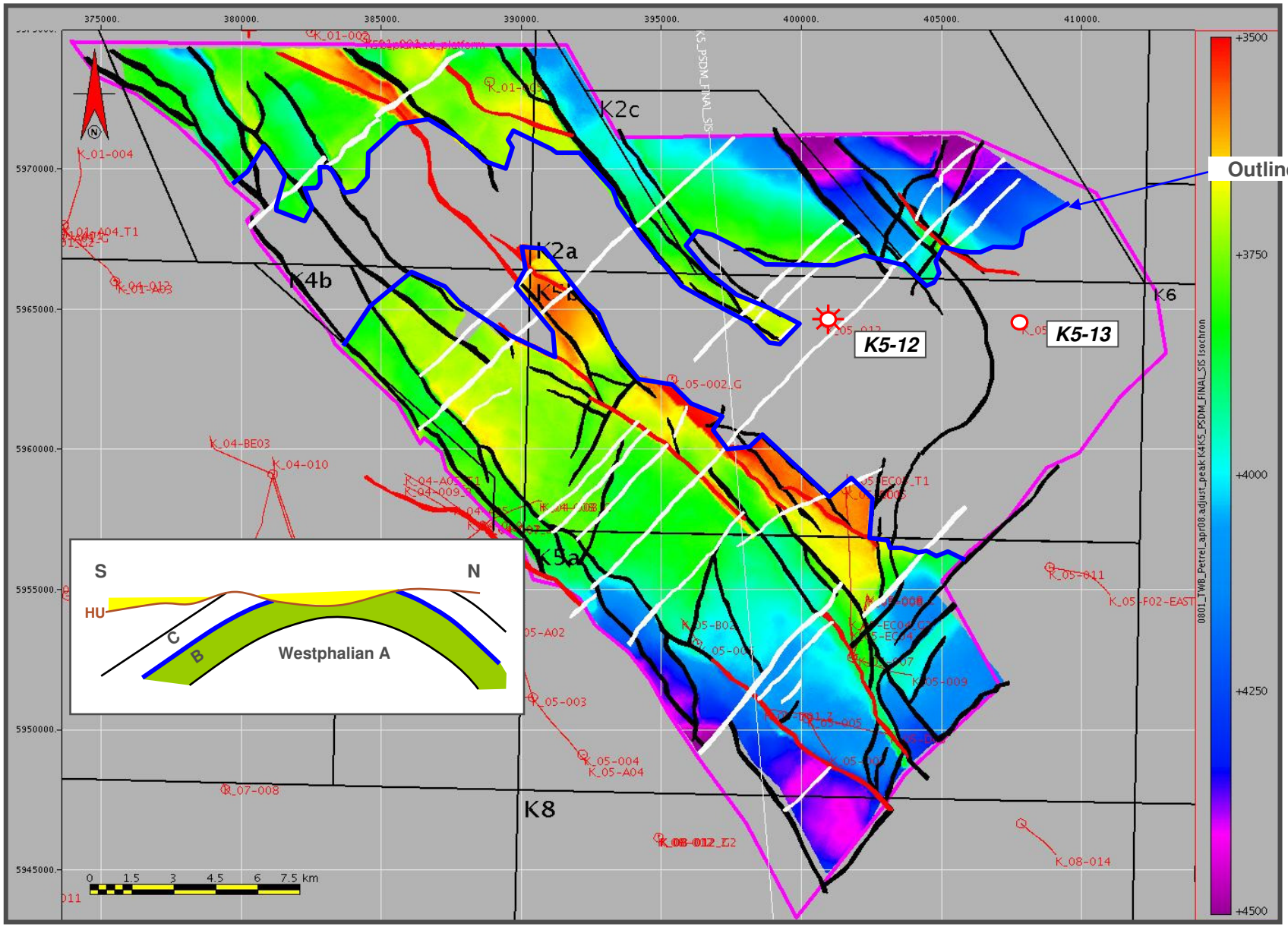
Fairly similar context with K5-12

TOTAL

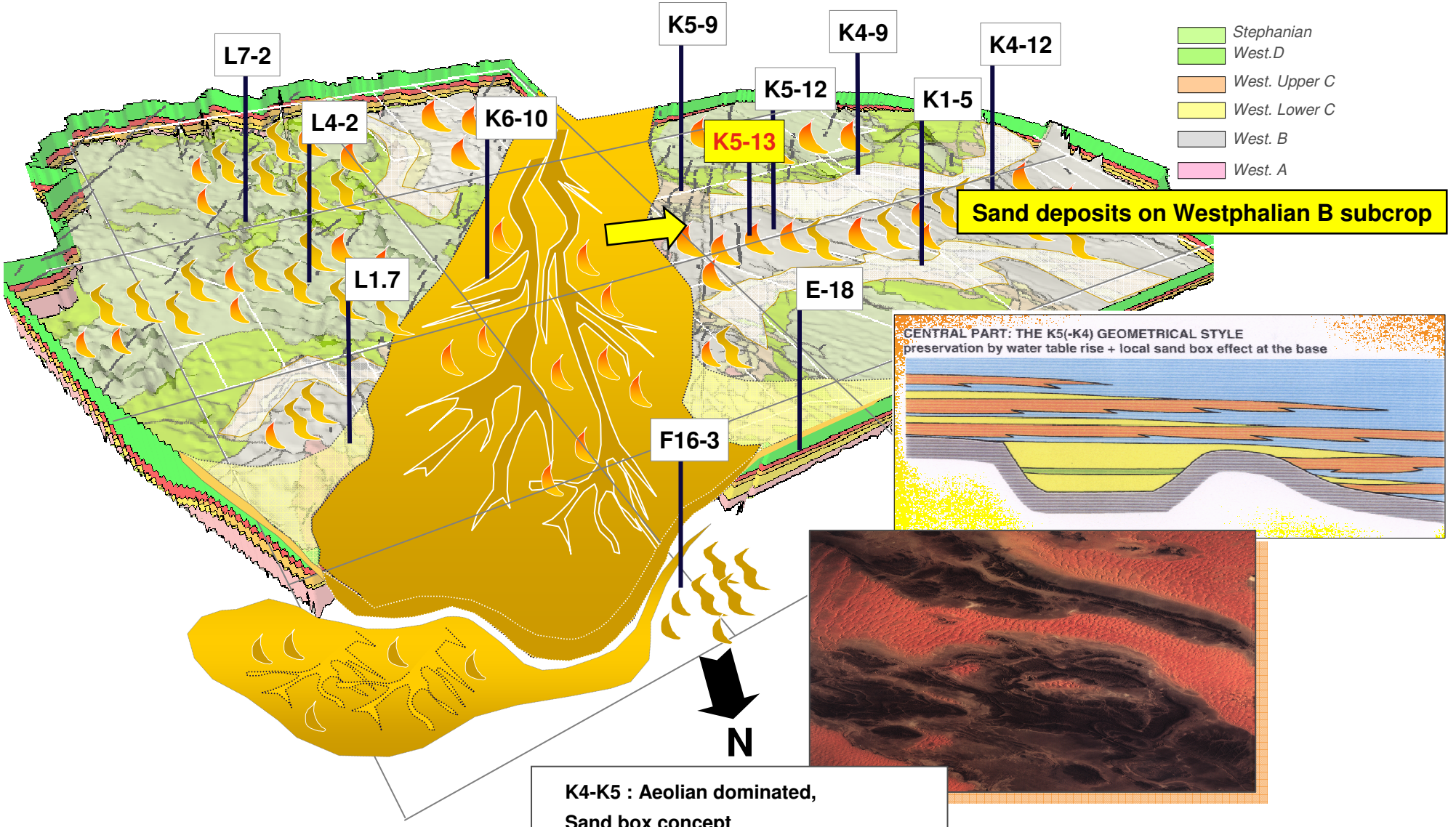
Well correlation flattened at MFS2



Seismic Interpretation: K5b Top Westphalian B Depth Structure



Regional Depositional environment sketch - confirmed



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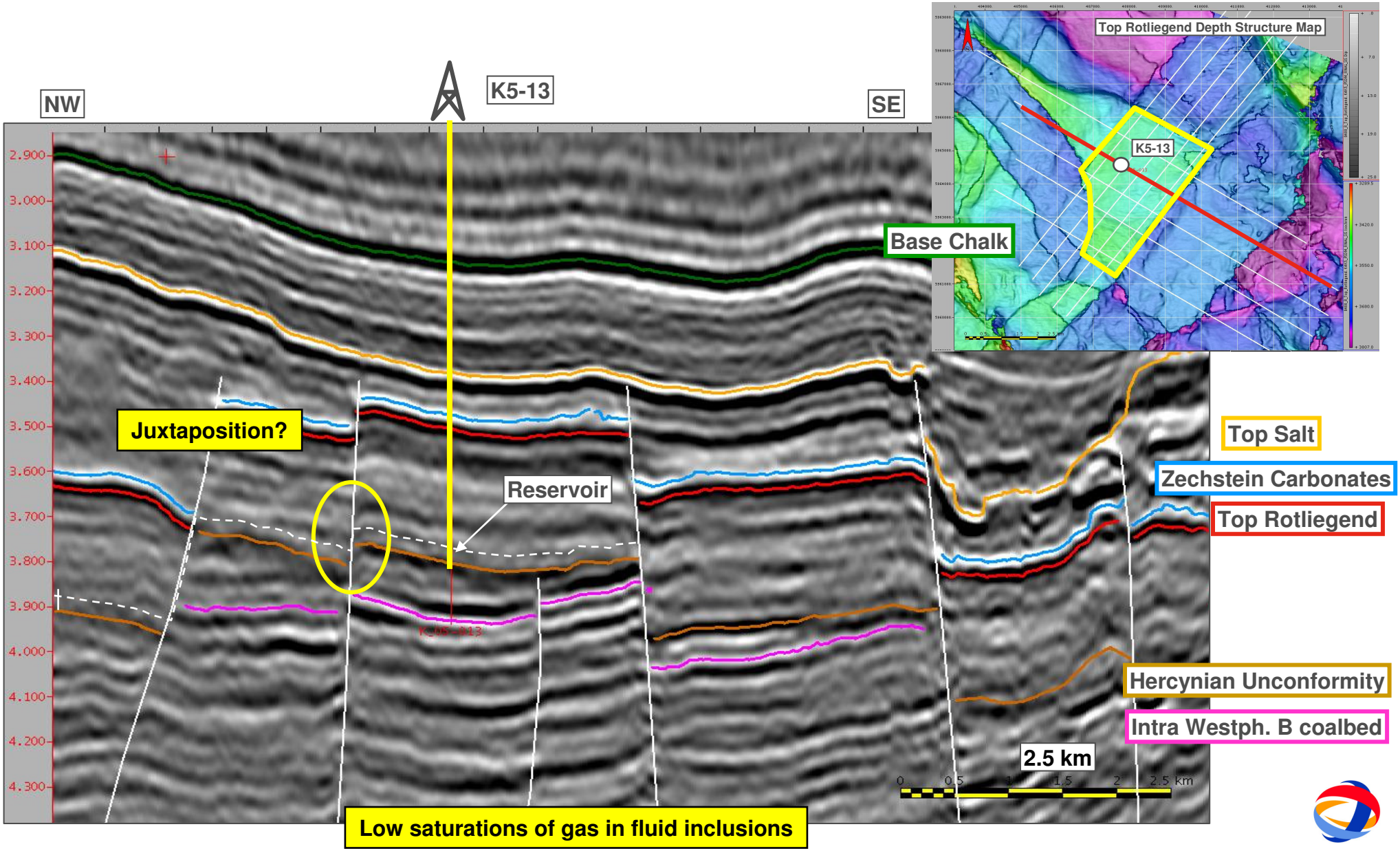
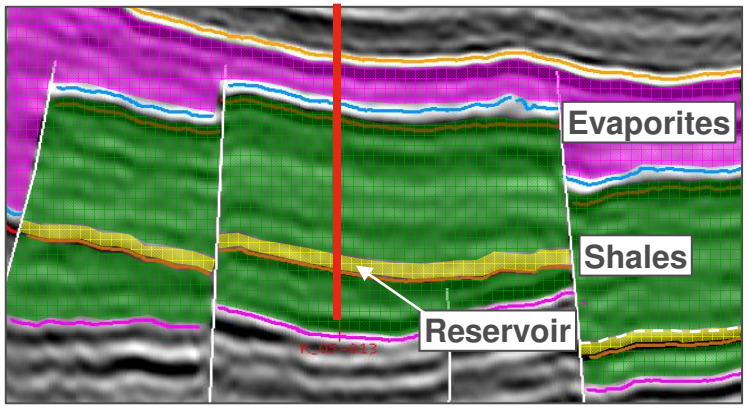
K5-13: What did go wrong?



The dilemma to explain the failure of K5-13

- Leakage ?
- Gas found in fluid inclusion but only low saturations
- More sands drilled. Sand juxtaposition across faults still unlikely but possible
- If such a juxtaposition is present then the spill point is below the well. However no attic gas found.
- Leakage through faults very unlikely as the surrounding formations are supposed to be highly sealing: Silverpit shales laterally and vertically, Zechstein evaporites as ultimate vertical seal.

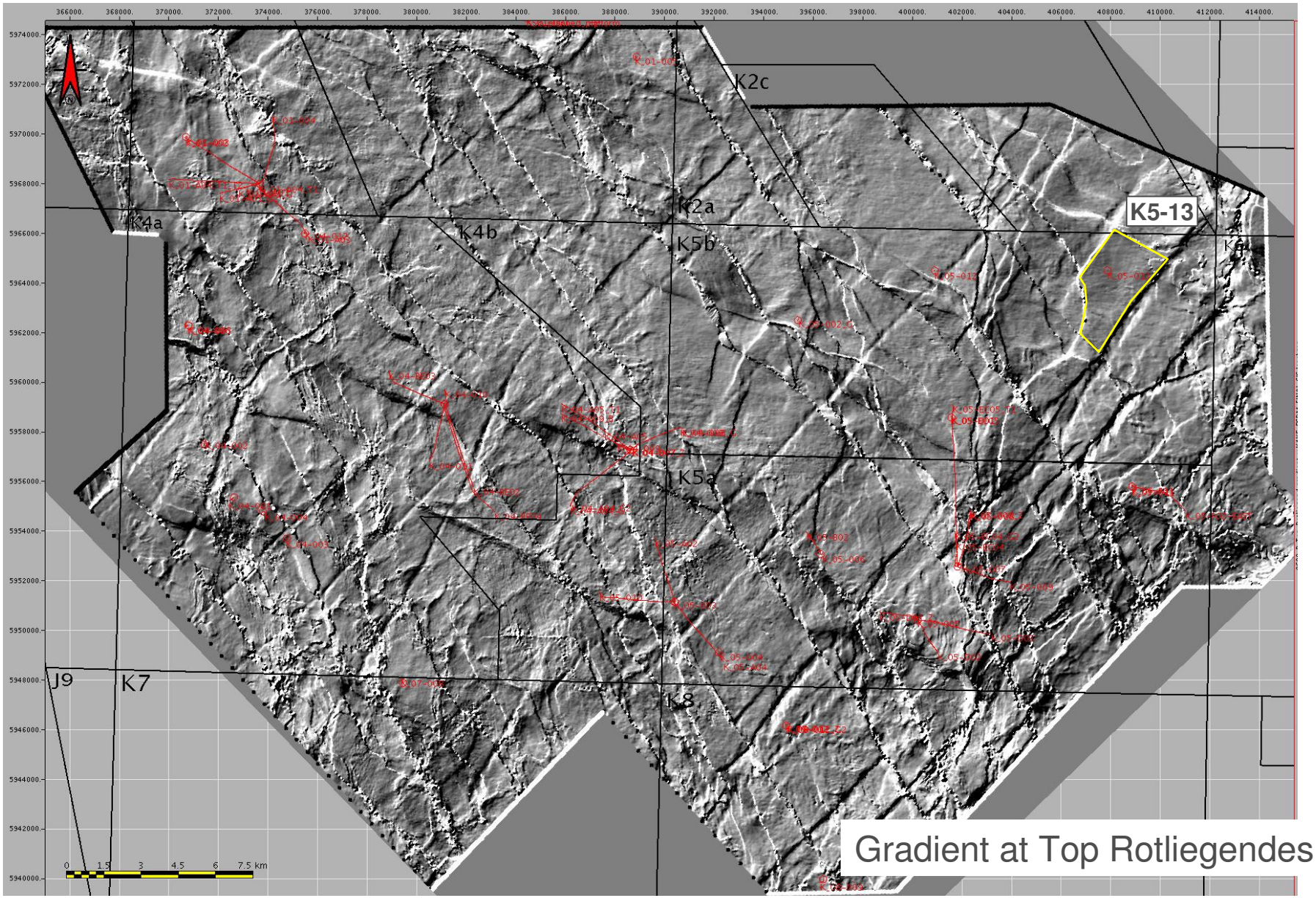


- Lack of HC Charge ?
- Gas in fluid inclusions – where has it gone?
- Never observed in K4-K5 area
- Westphalian SR within the K5-13 horst block not mature enough to expell sufficient amounts of gas
- Presence of N45 oriented faults, separating kitchen area from K5-13 panel

What is so peculiar about these N45 oriented faults?

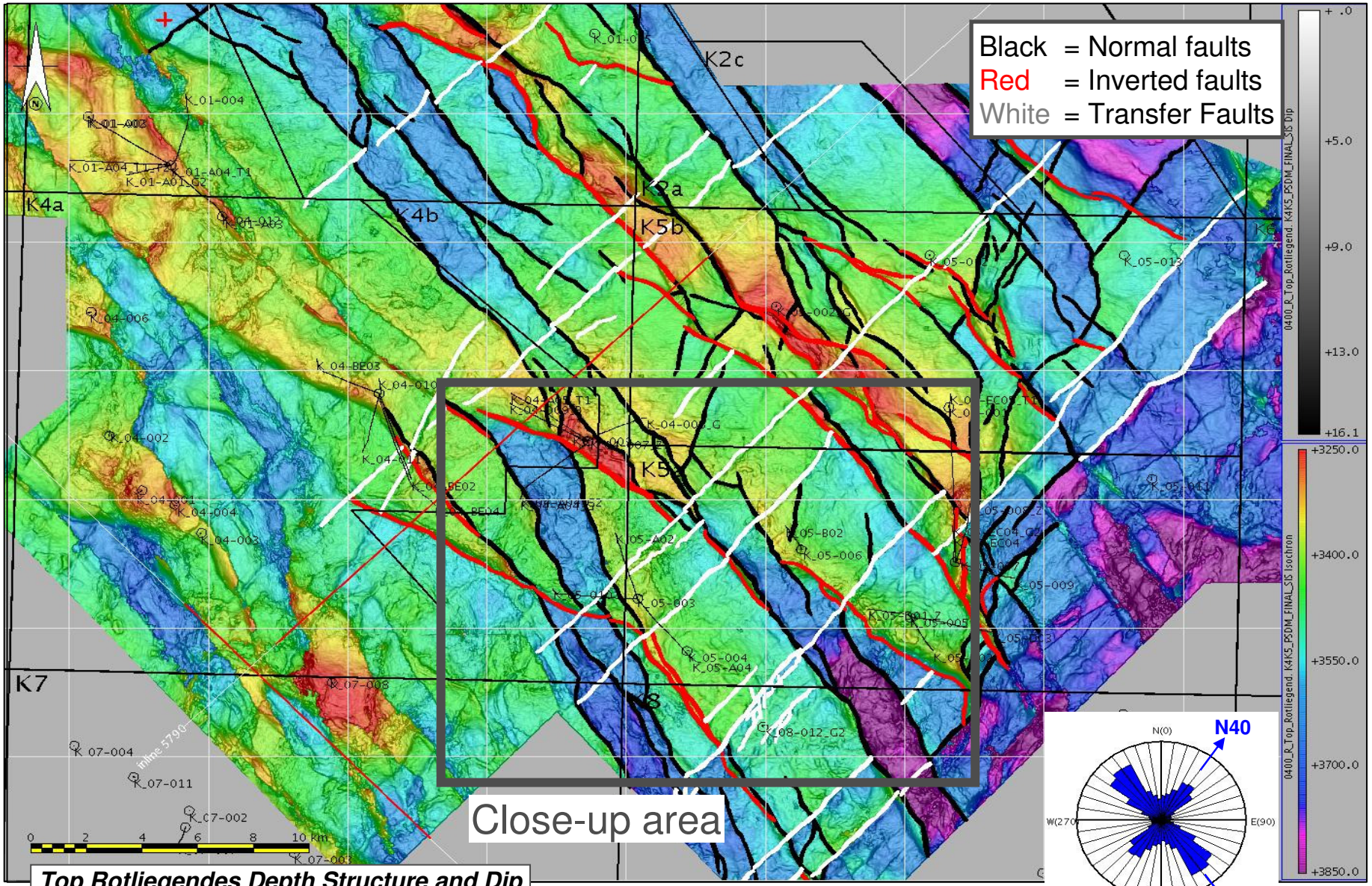
TOTAL

Fault pattern K4/K5 area on NW-SE gradient map



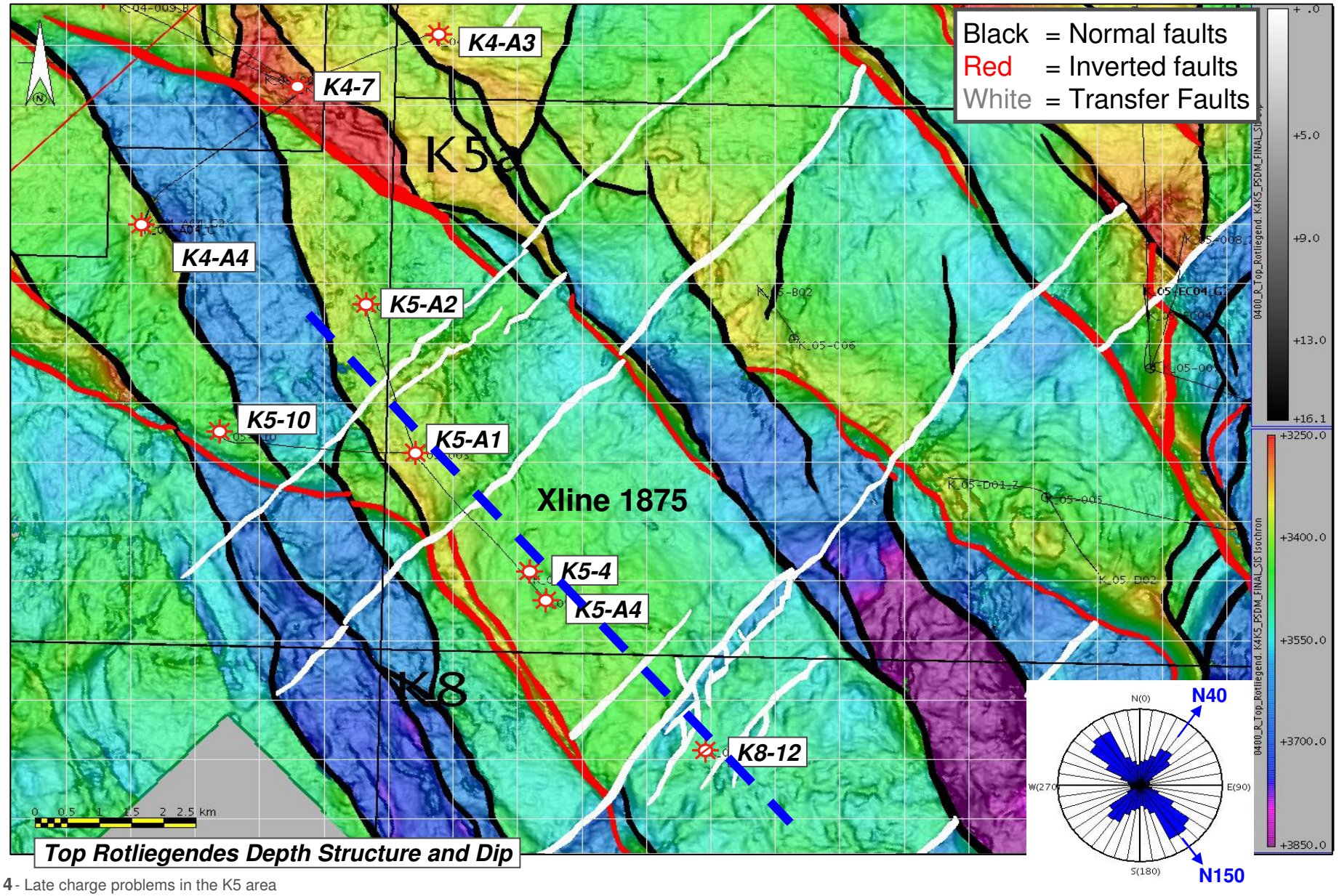
Gradient at Top Rotliegendes

K4-K5 Structural Pattern at Top Rotliegendes



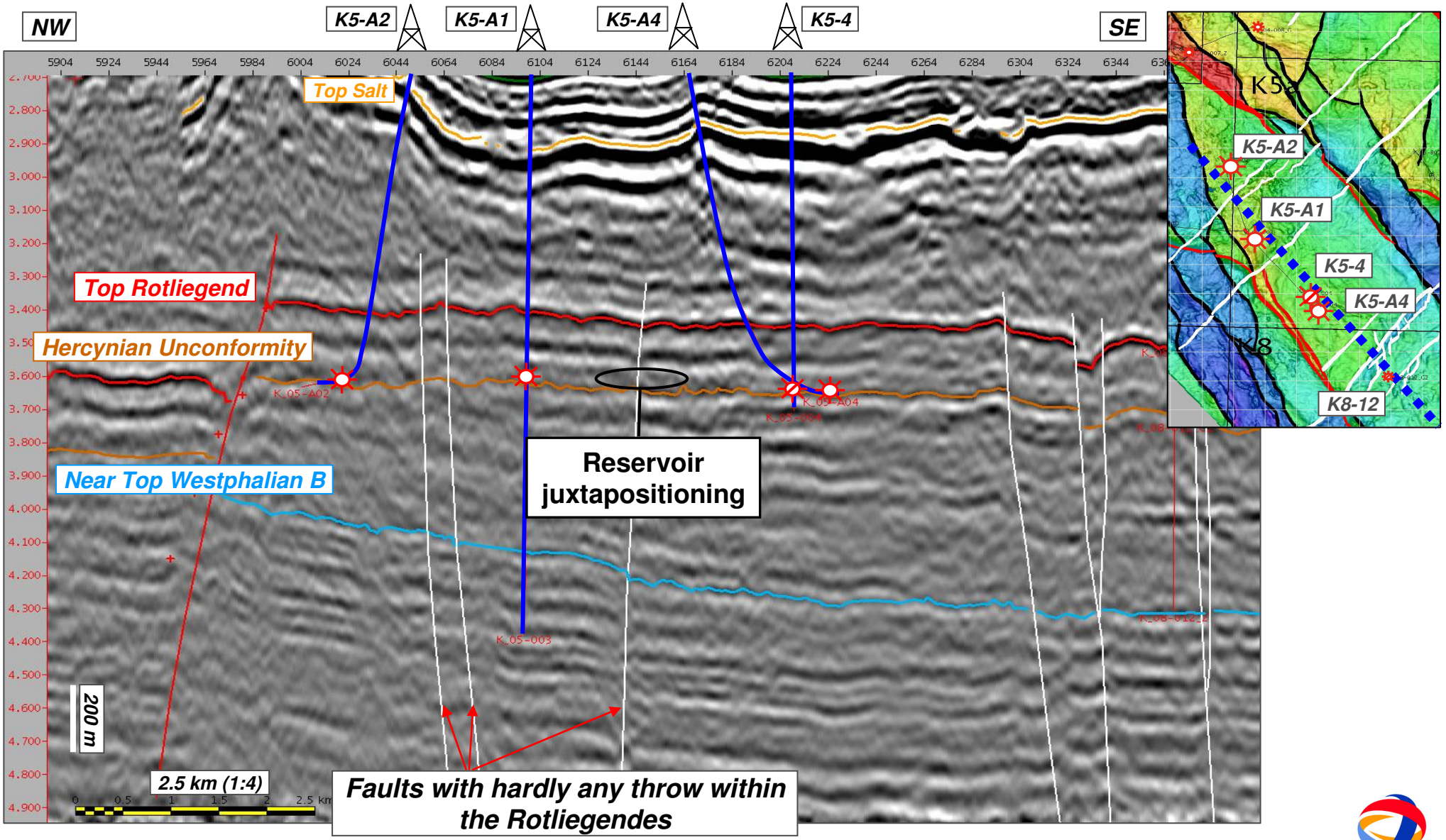
Top Rotliegendes Depth Structure and Dip

K4-K5 Close-Up Structural Pattern at Top Rotliegendes

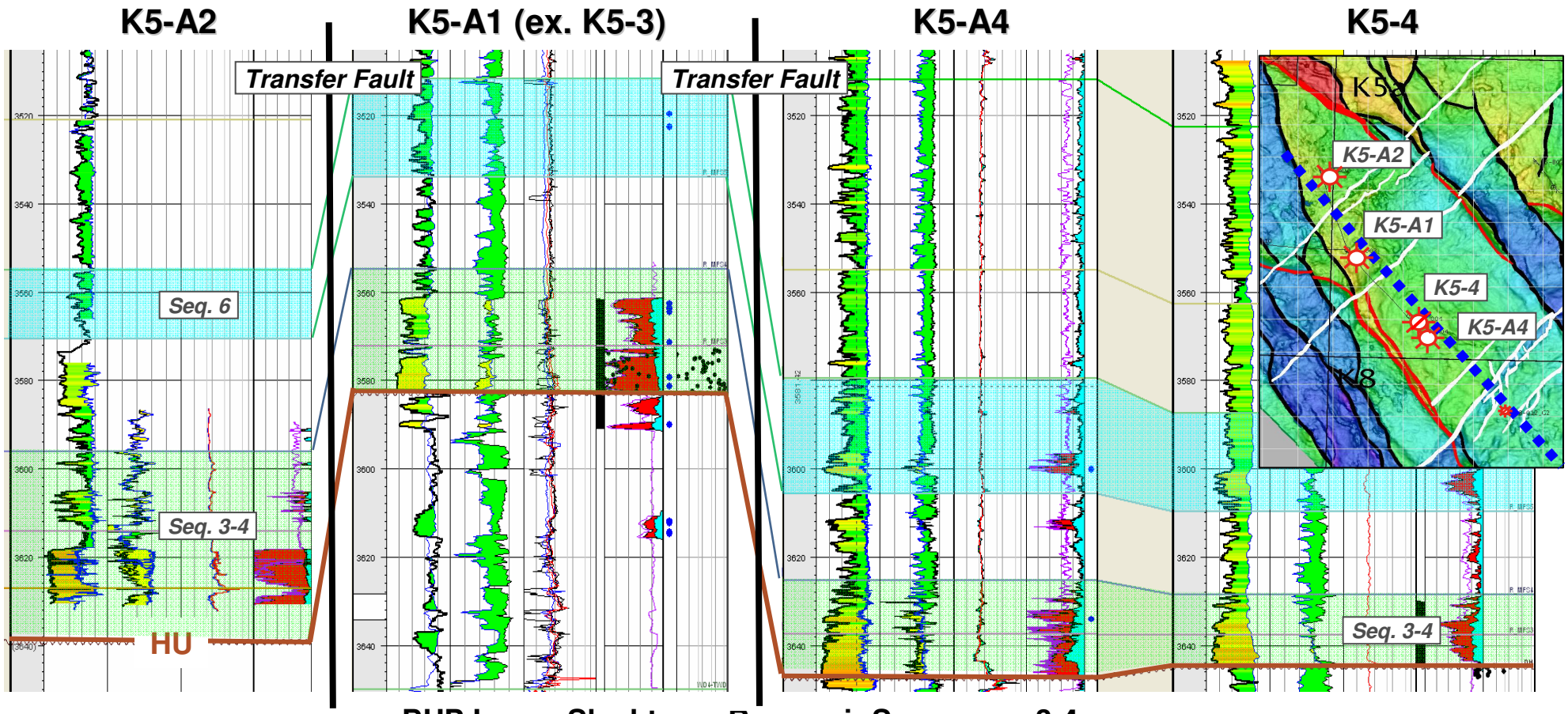


Top Rotliegendes Depth Structure and Dip

Subtle Transfer faults on Xline 1875



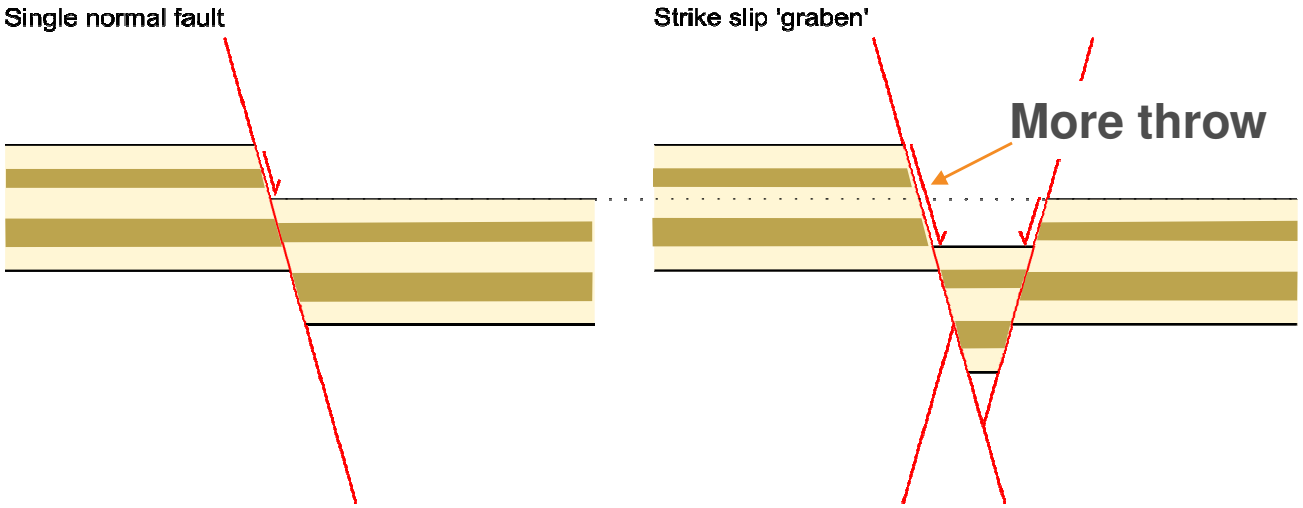
K5A Pressure History on Well correlation

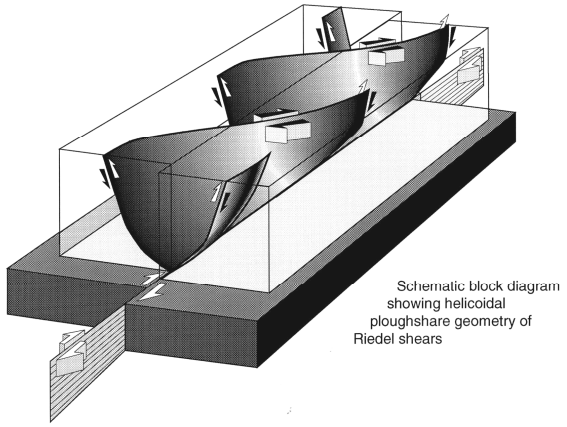


BHP Lower Slochteren Reservoir Sequences 3-4

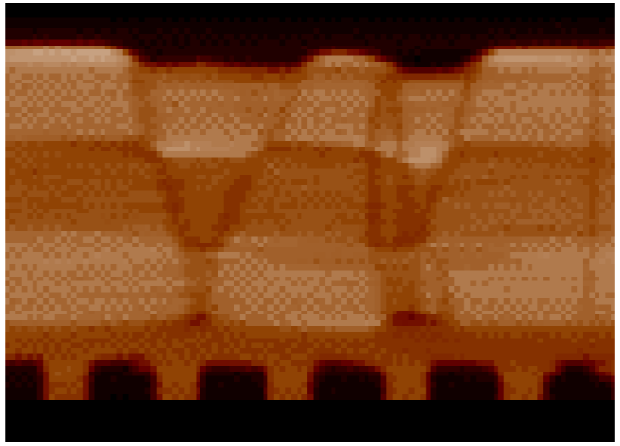
1988	409 bar	409 bar	Not yet drilled	409 bar
1994	Production start-up K5-A1 & A2		Not yet drilled	409 bar
1999	236 bar	198 bar	401 bar	
2006	126 bar	96 bar	221 bar	

Small scale: Graben alike structures along transfer faults

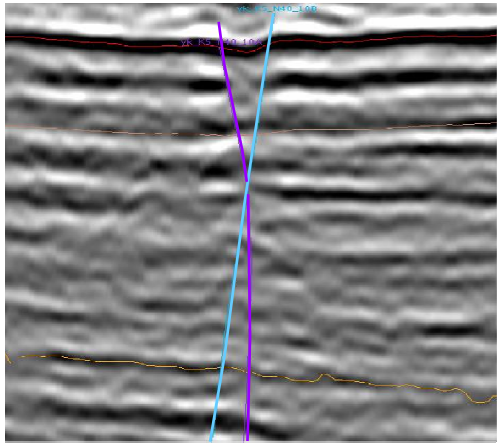




'Graben' in analogue model under transtension by IFP



Strike slip 'graben' on seismic section



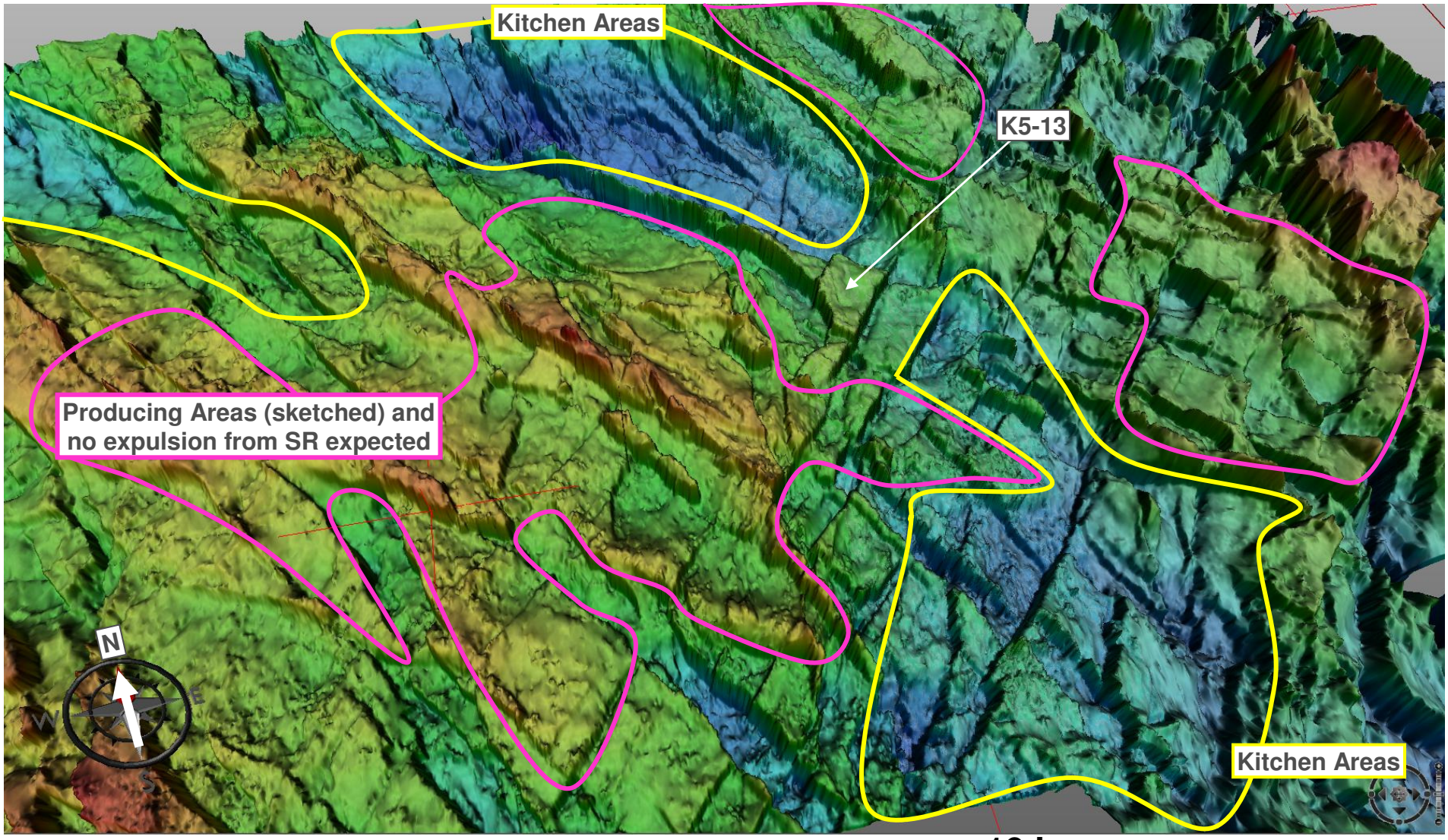
The observed vertical throws are little but may be underestimated as they are often resembling conjugate fault systems.

When evaluating juxtaposition and SGR, we are constantly hurdling against the lack of vertical resolution. Therefore deterministic evaluations are uncertain.

Further uncertainties are the horizontal throw and fault cementation

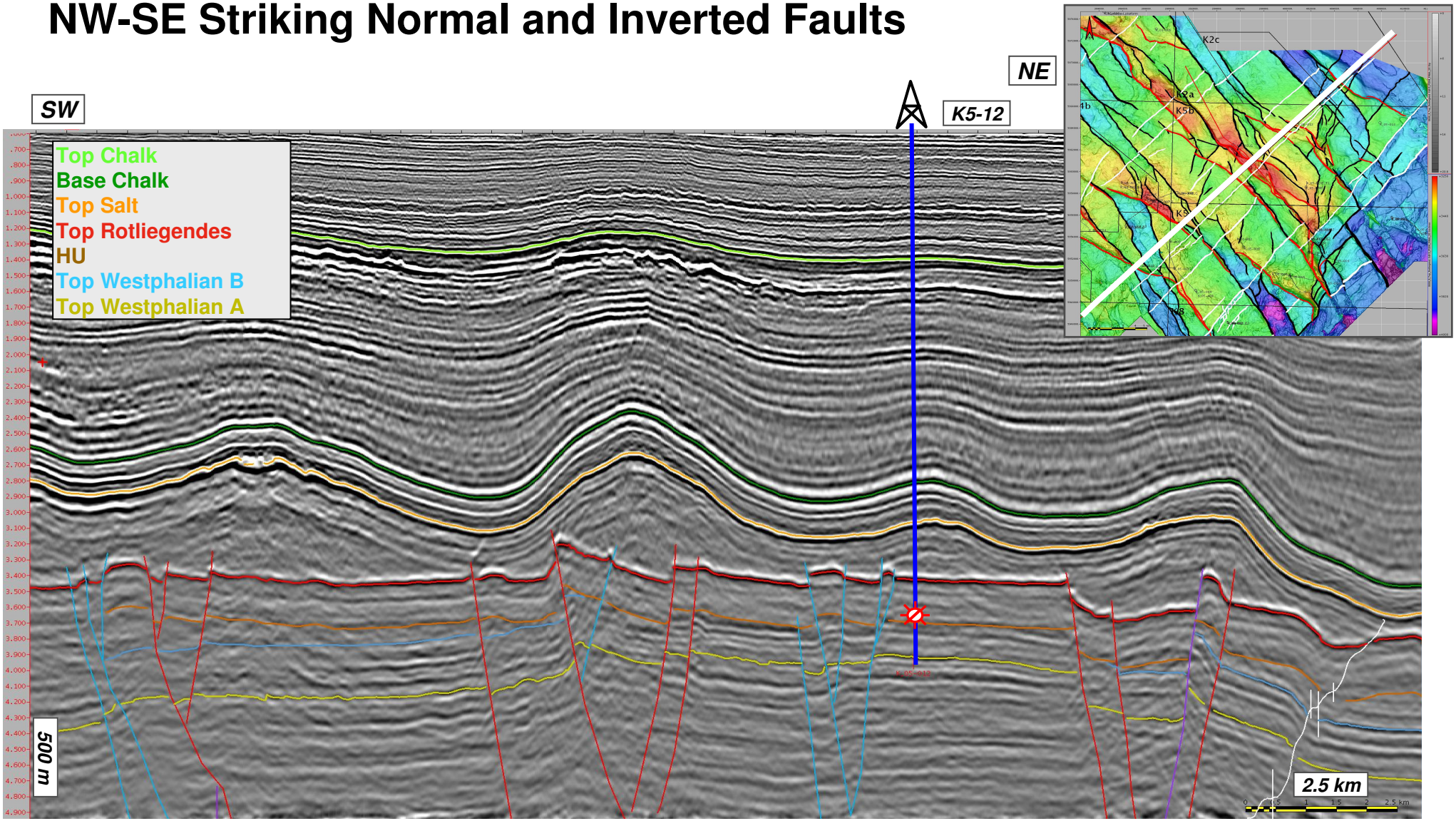
TOTAL

Large scale: Separation of K5-13 from kitchen by …



TOTAL

NW-SE Striking Normal and Inverted Faults

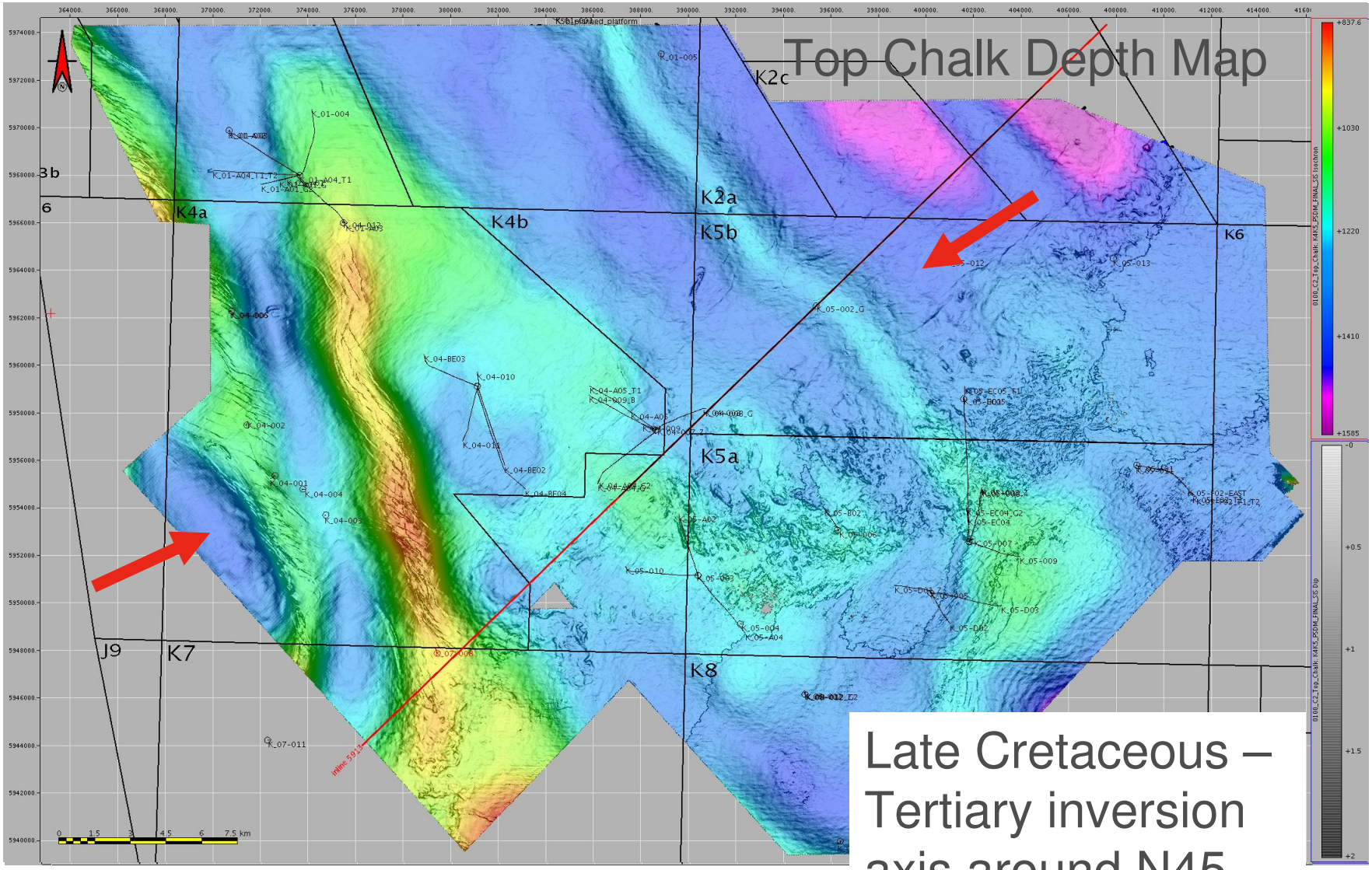


Strong throws on the NW-SE (N120-150) faults ➔ no reservoir juxtaposition

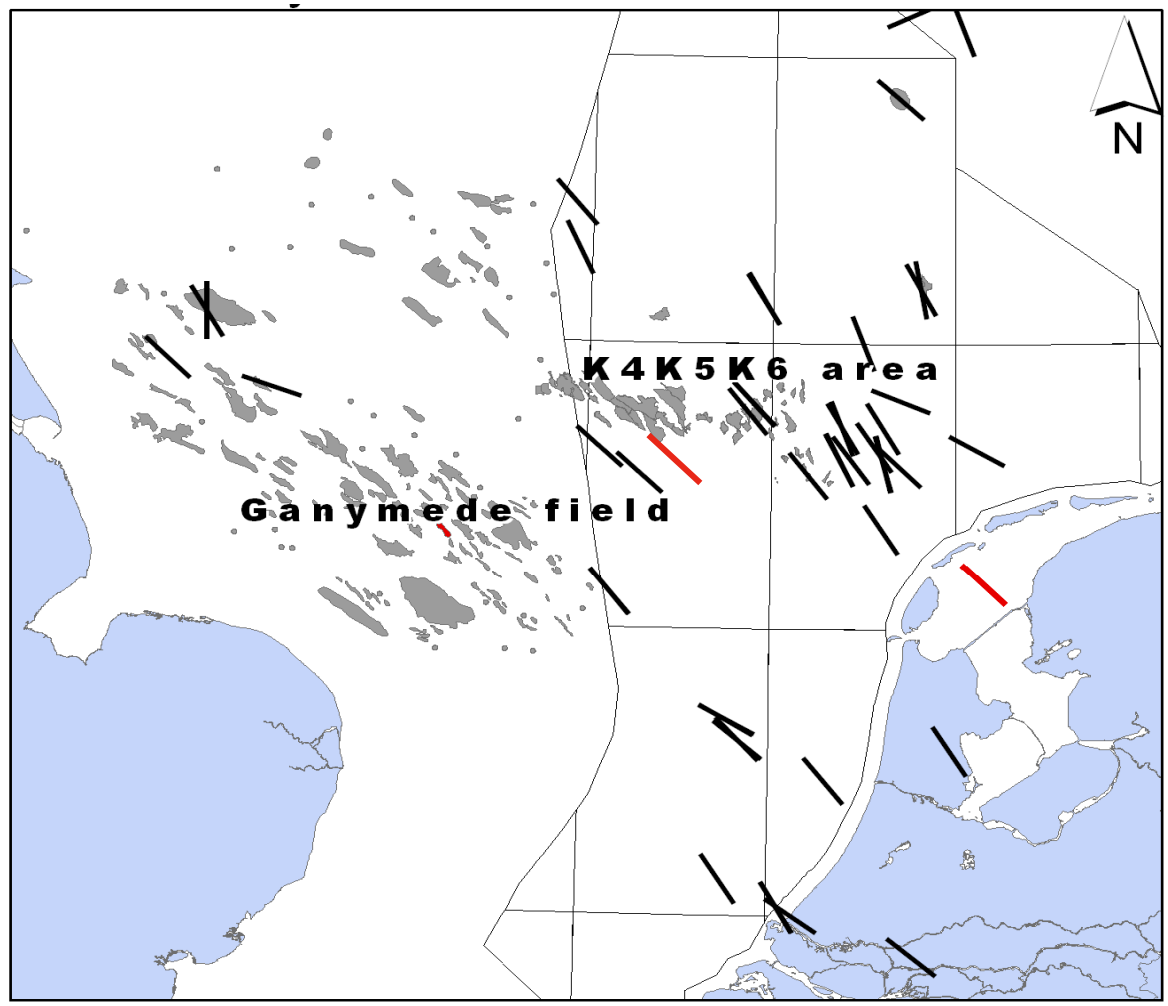
Decoupling between Pre- and Post salt. Salt cored buckle folds above Rotliegend Highs

TOTAL

Late Cretaceous to Tertiary Inversion



Present day maximum horizontal stress oriented N135



The N135 direction of the present day maximum stress is also confirmed by borehole induced fracturing.

The N45 transfer faults are therefore very likely to be closed

Leveille et al. 1997

- Sealing N40 trending faults
- SGR predicts clay smear is not sealing
- Leveille argues for cementation, on the basis of cemented fractures from cores

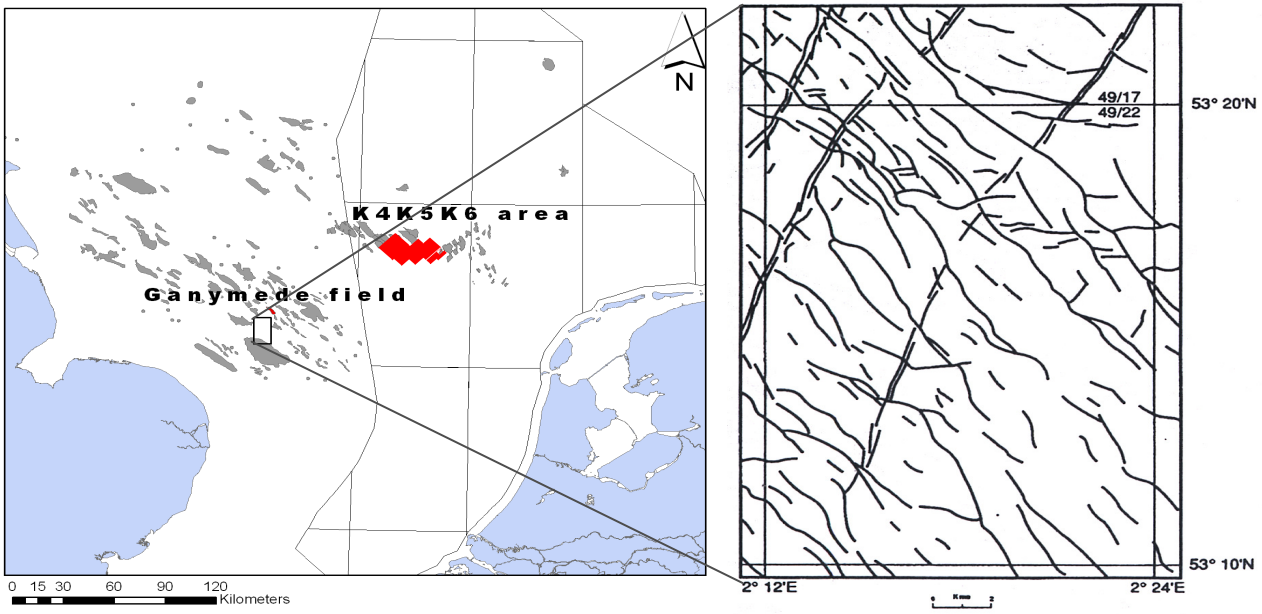
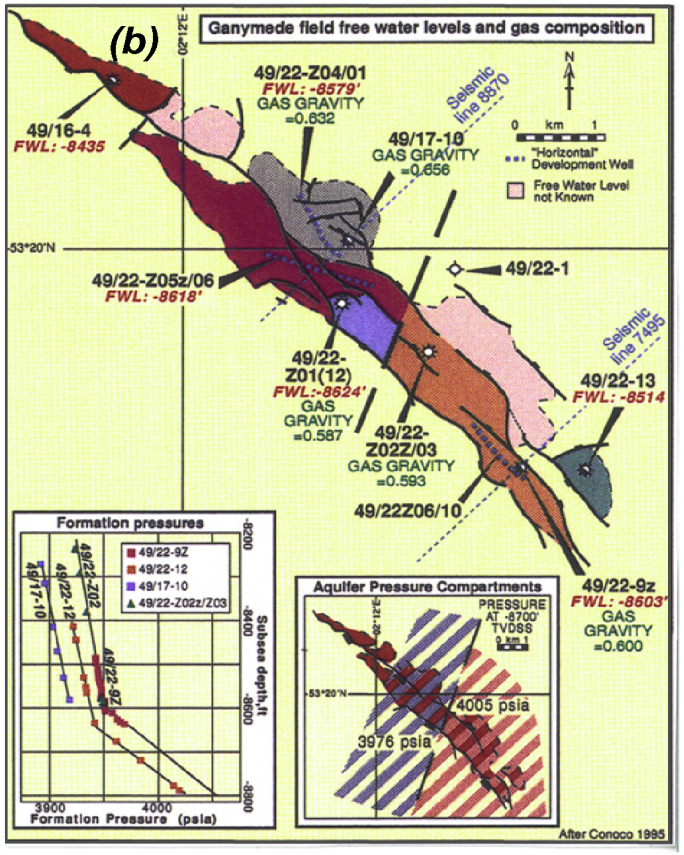


Fig. 8. Line drawing of fault pattern at top Rotliegendes level. Fault pattern is based on 3D seismic mapping and top Rotliegendes seismic time images.



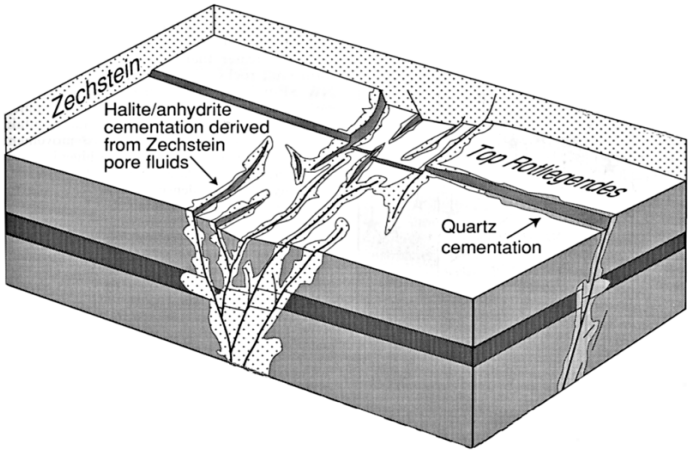


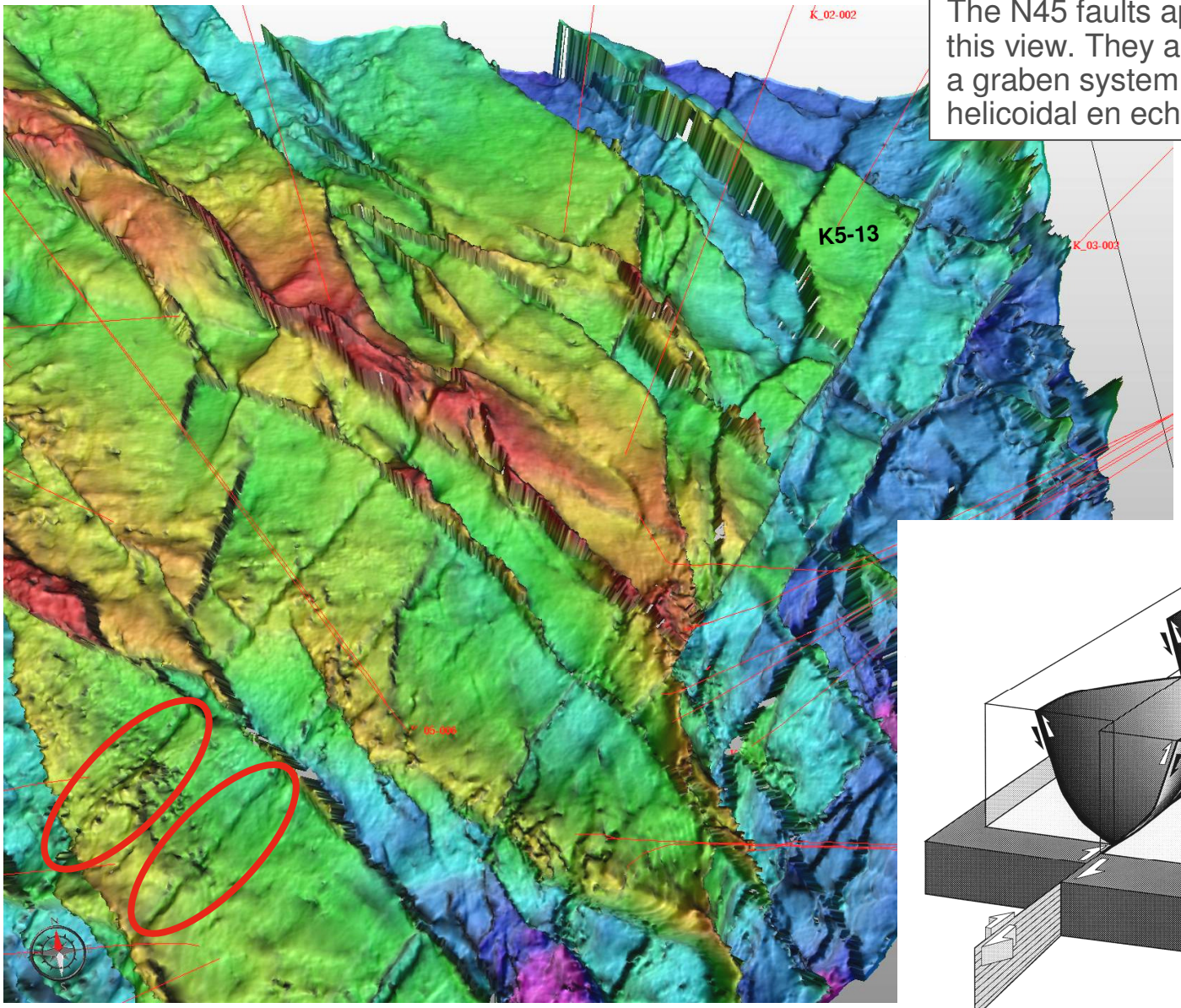
Fig. 16. Schematic block diagram depicting the formation of salt and anhydrite cements from saline, high-density pore fluids derived from the overlying Zechstein Supergroup.

Conclusions

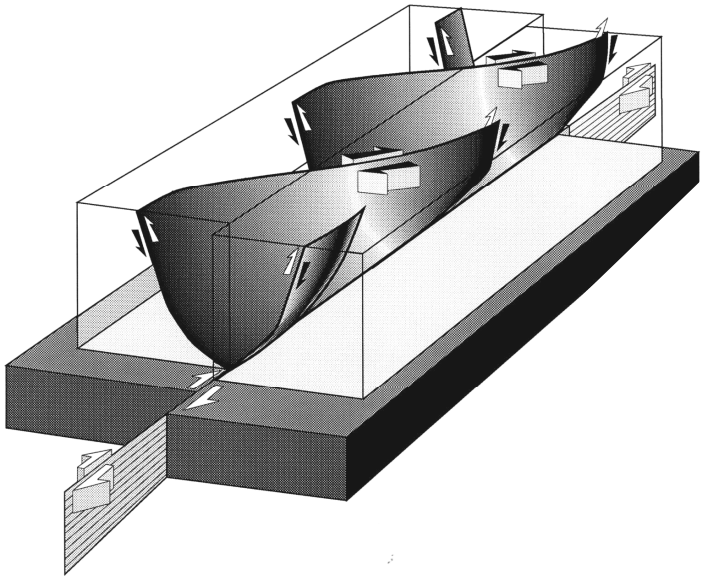
- Confirmation of the geological model for sand deposits above Westphalian B subcrop (Sand box concept)
- Fluid inclusions can not conclude on the reason of the failure
- Migration from northern kitchen may be deflected by closed N45 faults
- These transfer faults have hardly any vertical throw but may form significant barriers to fluid flow. This is not fully understood today
- Beware of certainties even in a mature area

TOTAL

3D View of K5b area

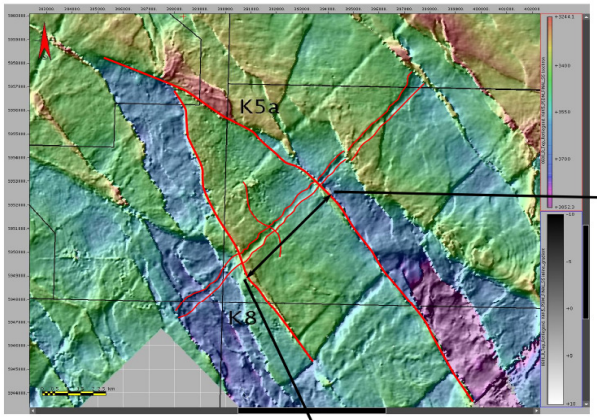


The N45 faults appear as distinct corridors on this view. They are not just a thin lineament but a graben system probably composed of helicoidal en echelon faults.

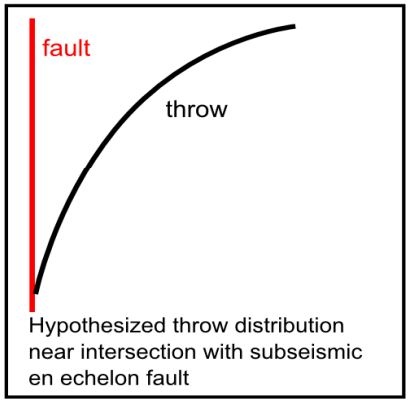


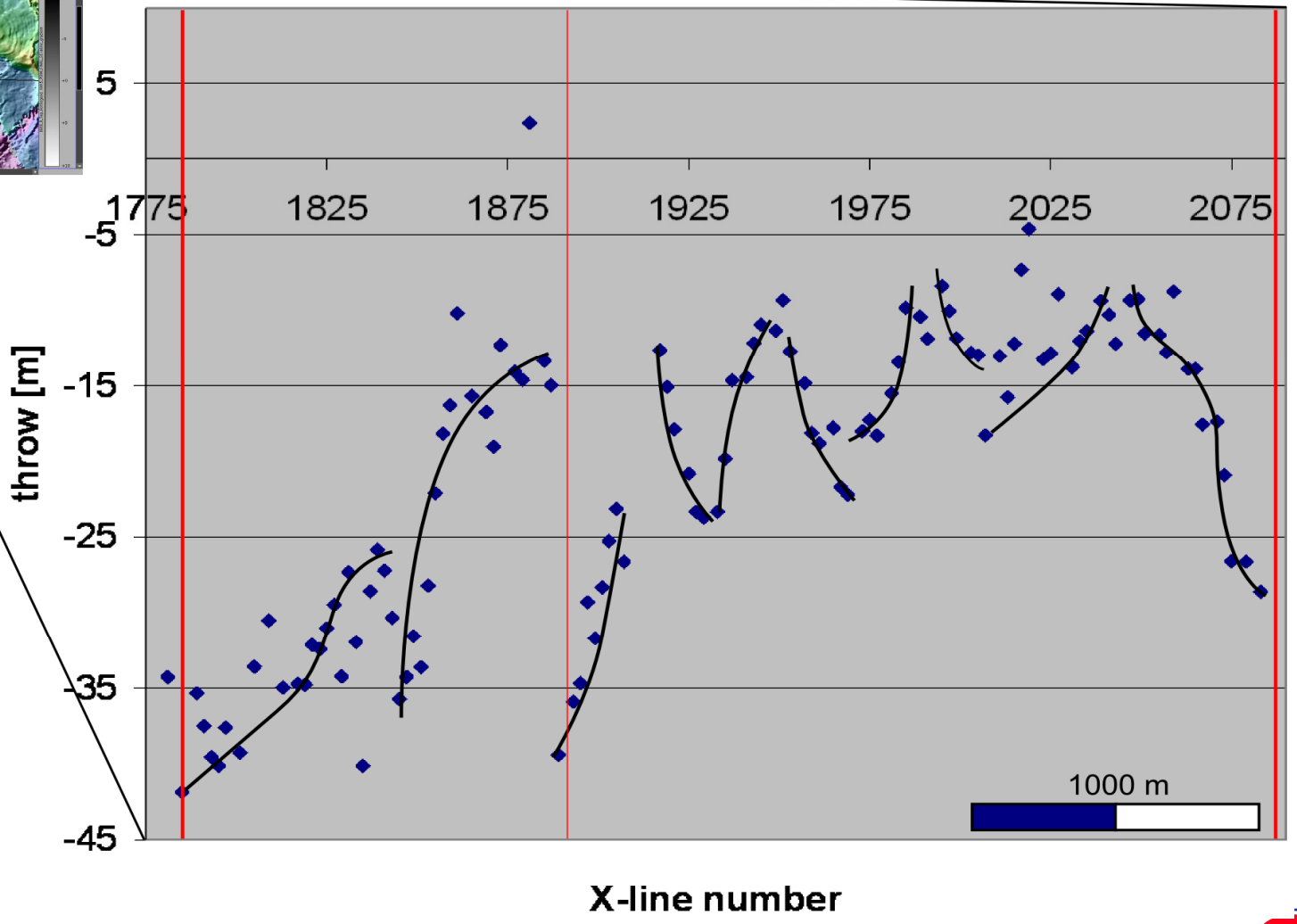
TOTAL

Throw variation along fault



- Observed graben throw
- Seismic scale intersecting fault
- Sketched interpretation of local throw distribution





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