

Floaters in the Zechstein: (un)predictable & (un)safe to drill?

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TNO Expert Meeting: “Stringers in Salt – a drilling hazard”

Pieter Gerritsen – ENGIE E&P Nederland B.V.

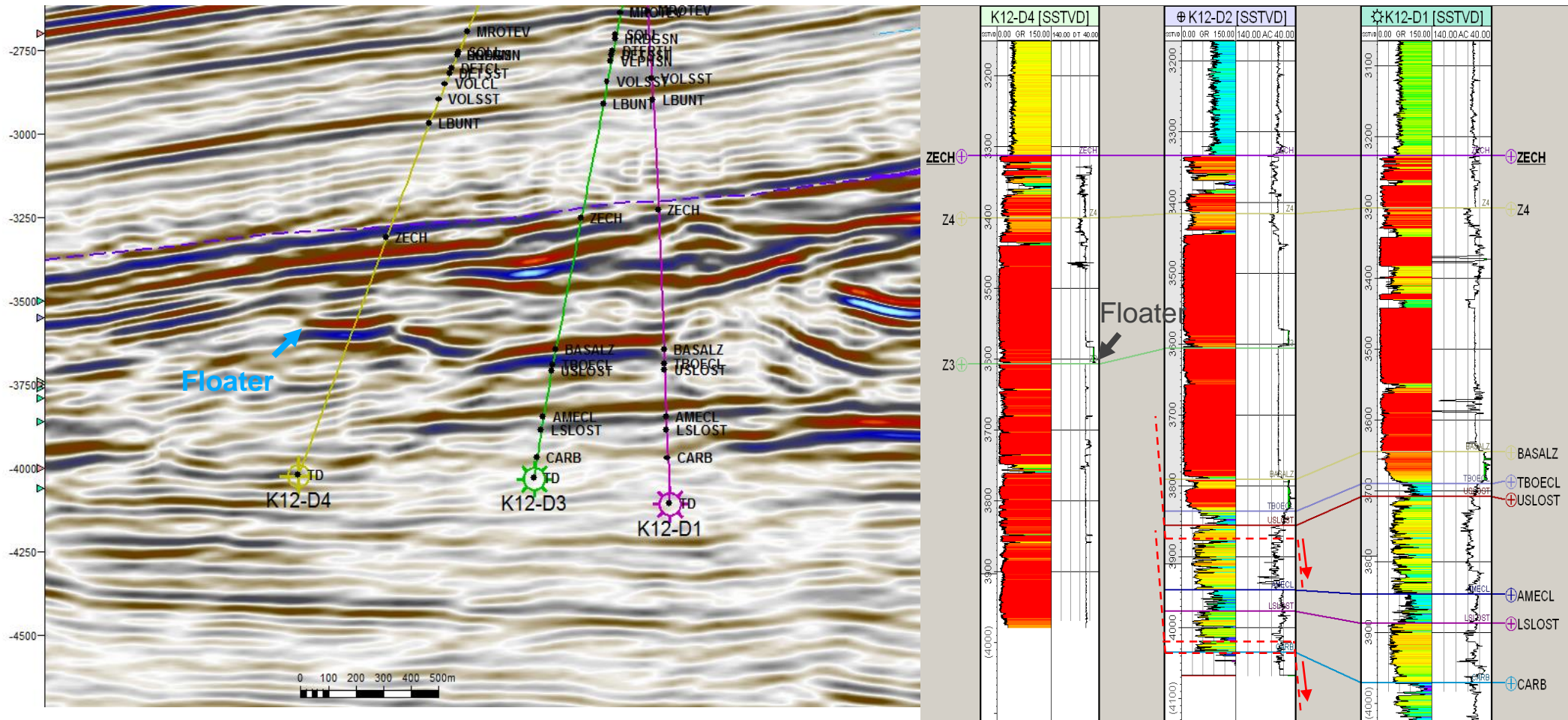


Introduction / Outline

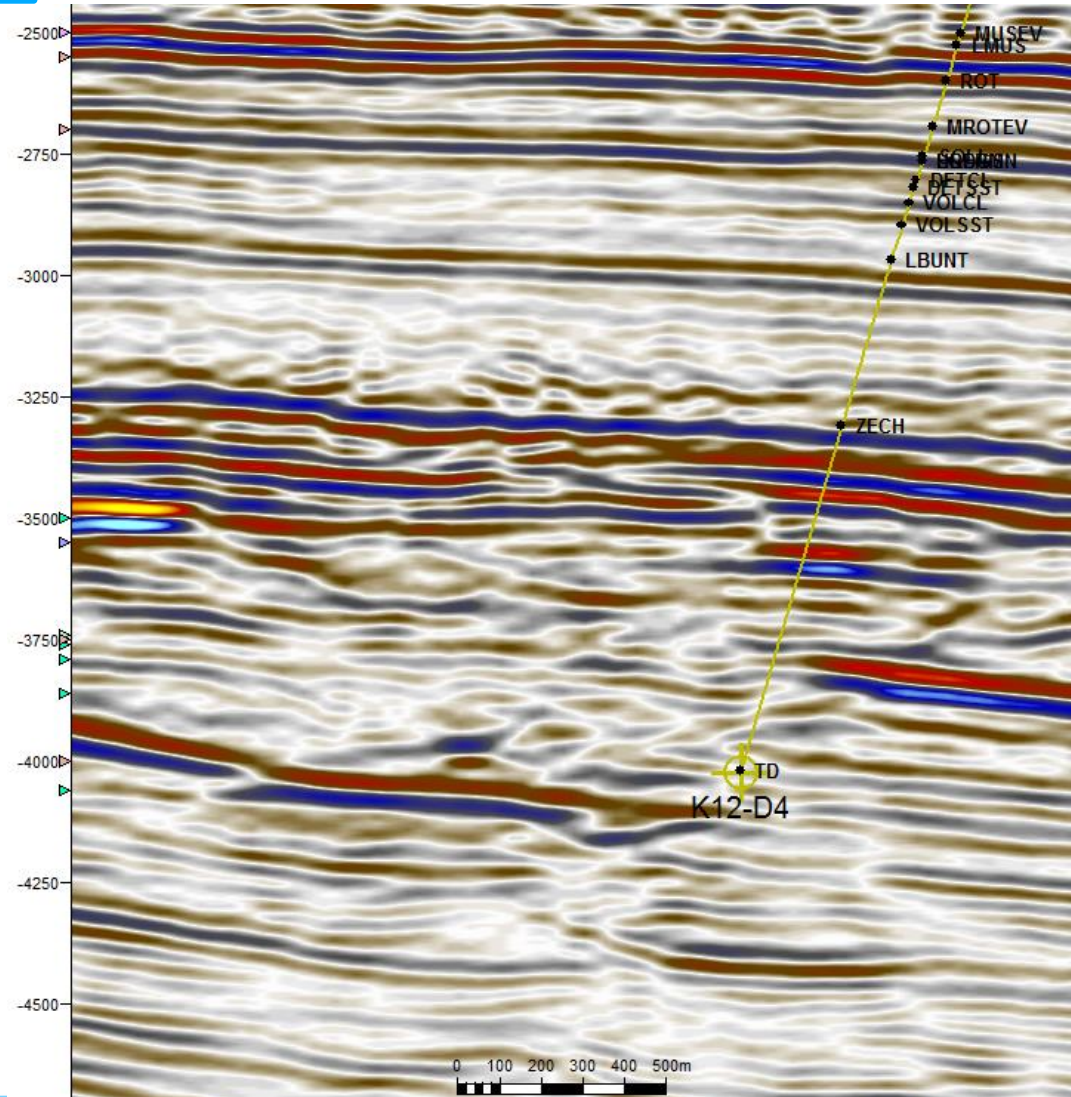
- ENGIE E&P NL has extensive Zechstein drilling experience across several decades
- Numerous incidents with stringers / floaters across the years
- Quite a few unexpected surprises (not always leading to problems)
- Can a trend be extracted from the available data?
- Conclusions / current ideas

K12-D4: prognosis vs. reality

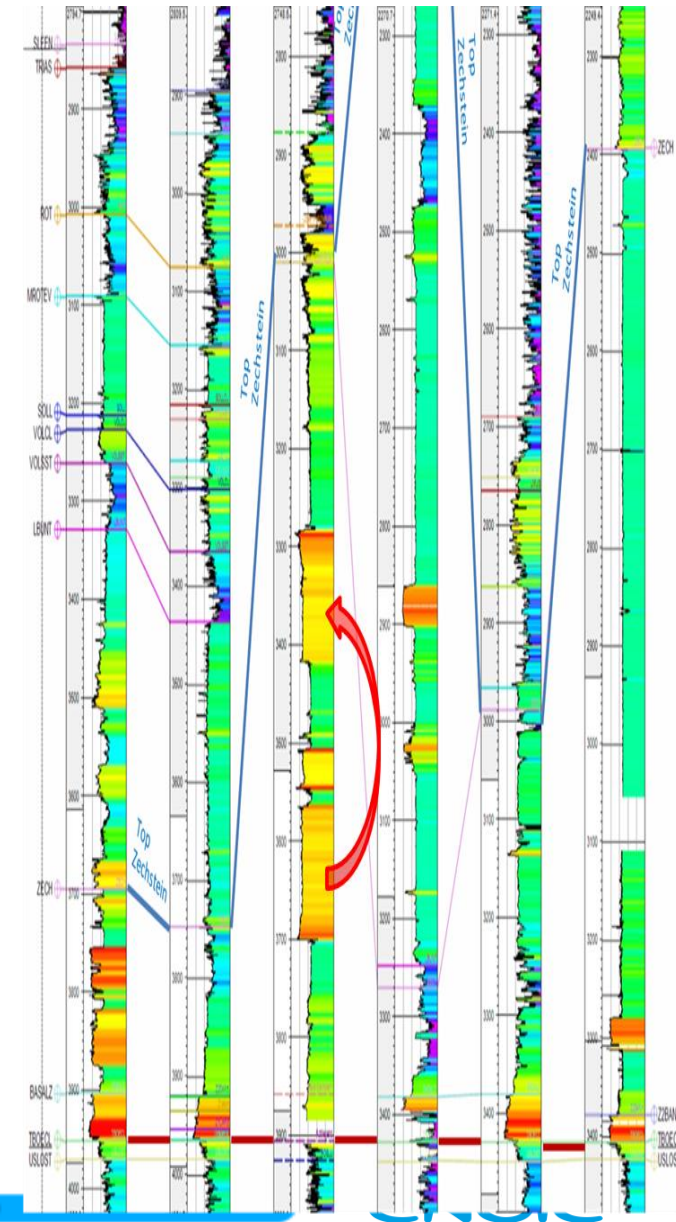
- Well never reached Rotliegend reservoir
- Top Rotliegend pick turned out to be a floater (Z3 anhydrite)
- No problems



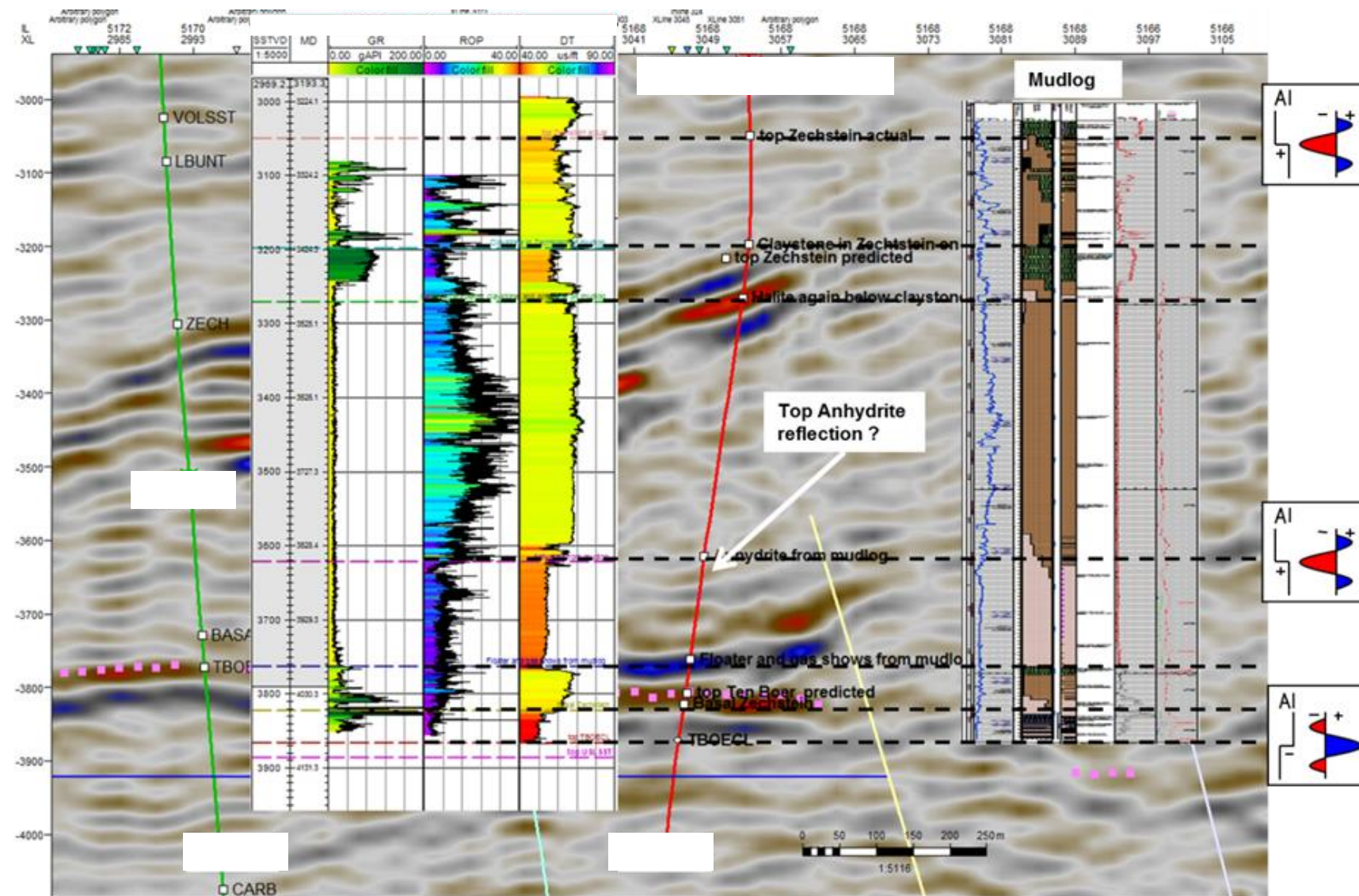
K12-D4: reprocessed seismic (post-drilling)



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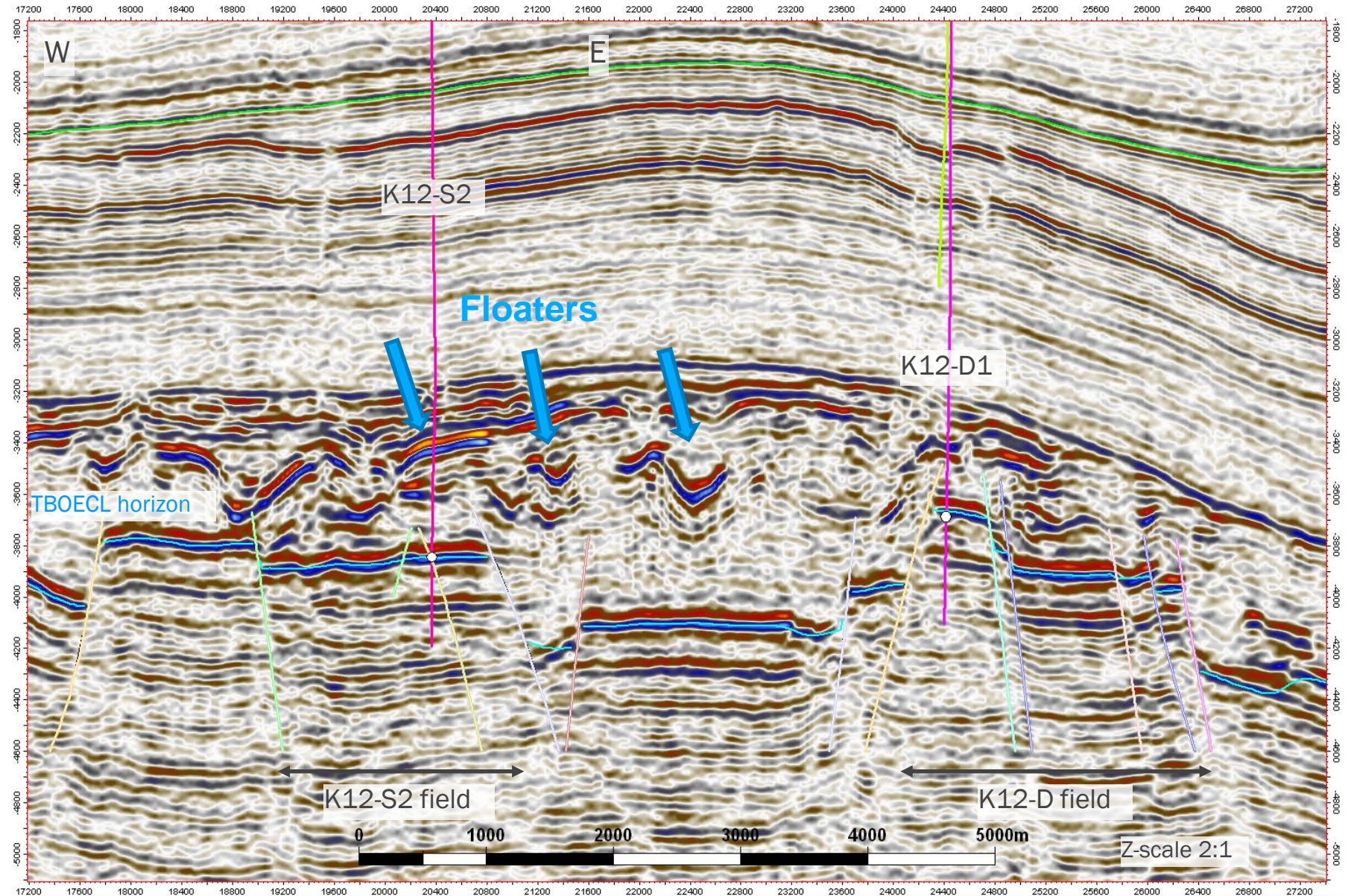


- Predicted floater was at 3680m TVDSS: no anhydrite found in cuttings, high GR, high velocity: most likely intrusive body
- Thick anhydrite found at 3850-3990m MD, not seen on seismic!
- Saltwater kick at 4000m MD, at bottom of anhydrite where shaly layer was found. Pressure was bled off in several stages. Gas influx up to 16% was seen
- Reservoir came in too deep as result of exceptional anhydrite thickness, well abandoned after test



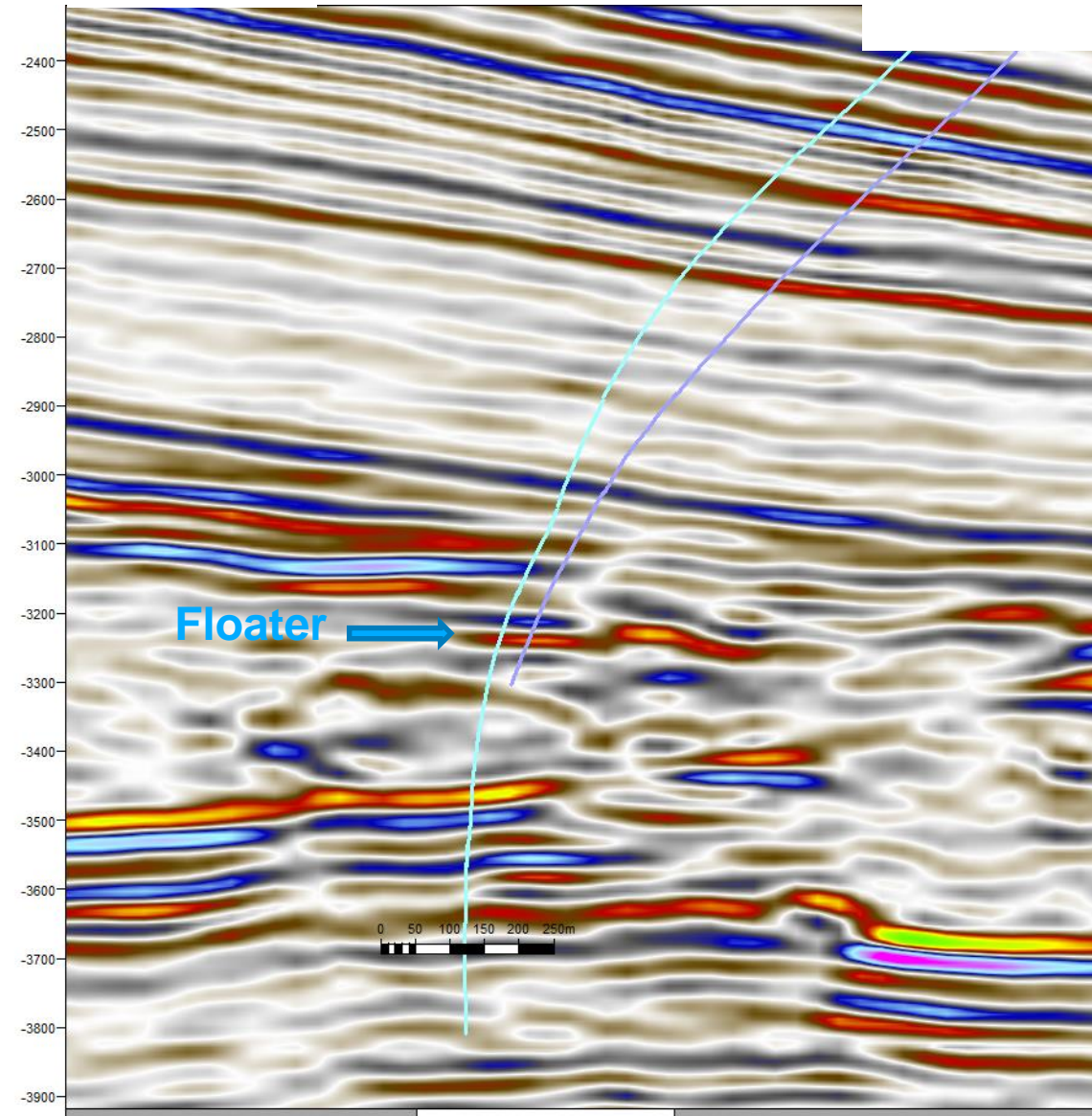
K12-S2 (K12-15)

- Floater found at 3435-3450m MD
- Initial kick of 2.11 SG, killed well, continued drilling, 2nd kick of 2.30 SG
- Had to deplete in stages, loss/gain situation (9 5/8" set in Triassic)
- Total lost time: 50 days
- No clear explanation for overpressure from seismic



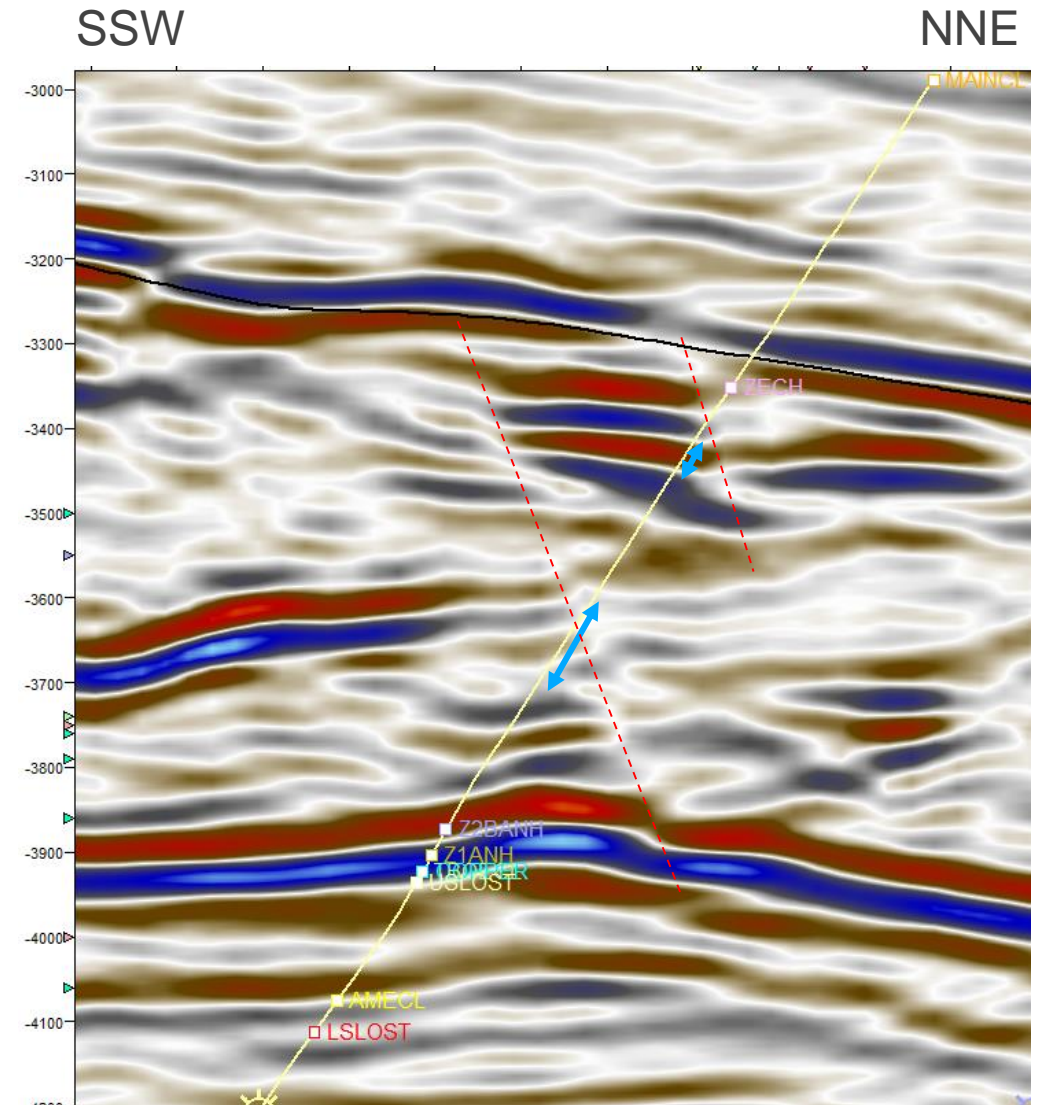
K9ab-B3(ST1/2/3/4)

- Initially set 9 5/8" in Triassic
- Drilled into floater, took kick
- Triassic too weak, continuous loss/gain situation (5 weeks)
- Sidetracked from Chalk, set 9 5/8" in Zechstein
- Same problem (10 days), suspended well due to rig commitment elsewhere
- Re-entry: drilled out cement plugs, well flowing, depleted for 5 days
- Continued drilling, had to ST again due to lost BHA
- Drilled to section TD /w minor gains, managed to spot pill & run liner

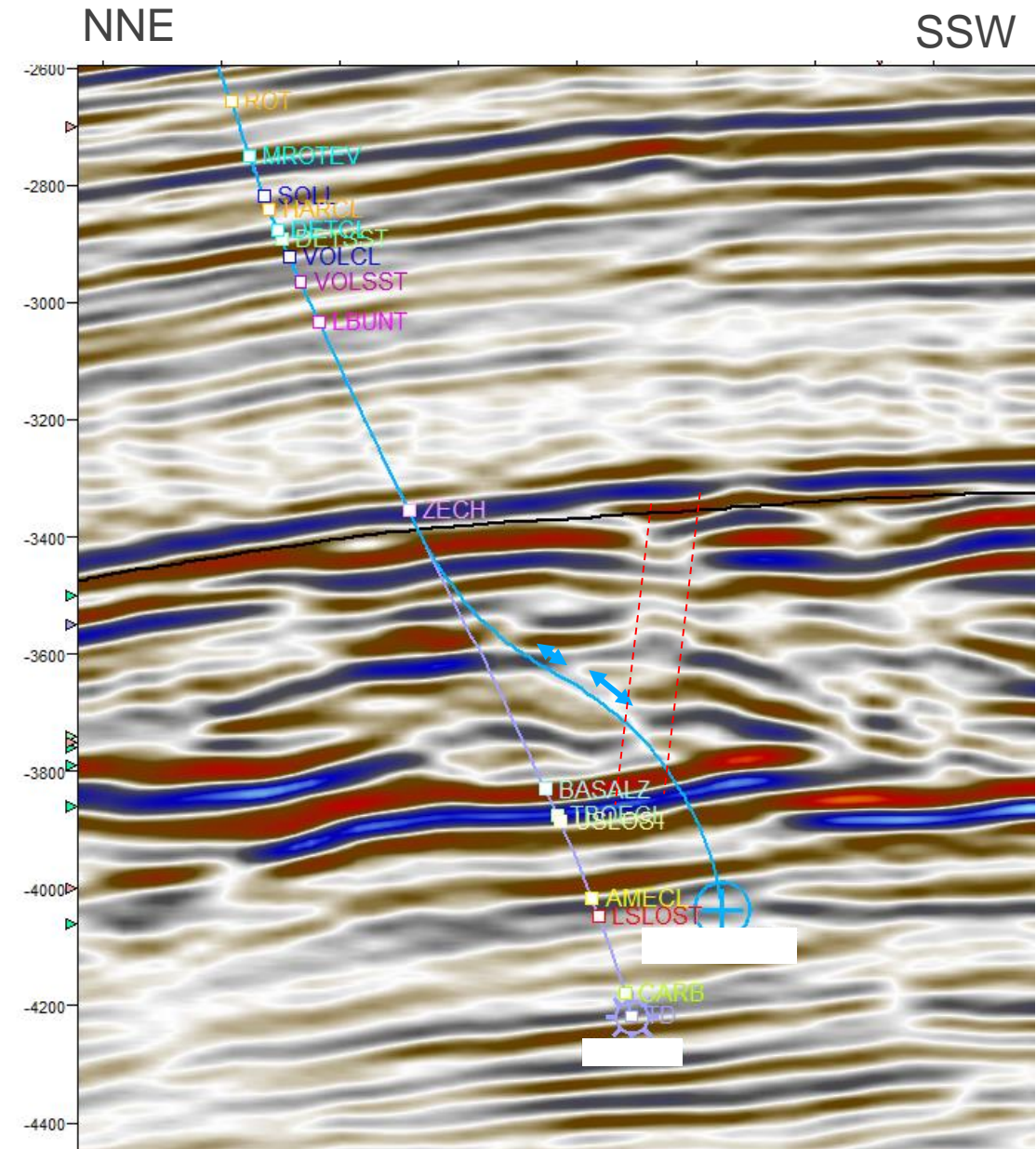
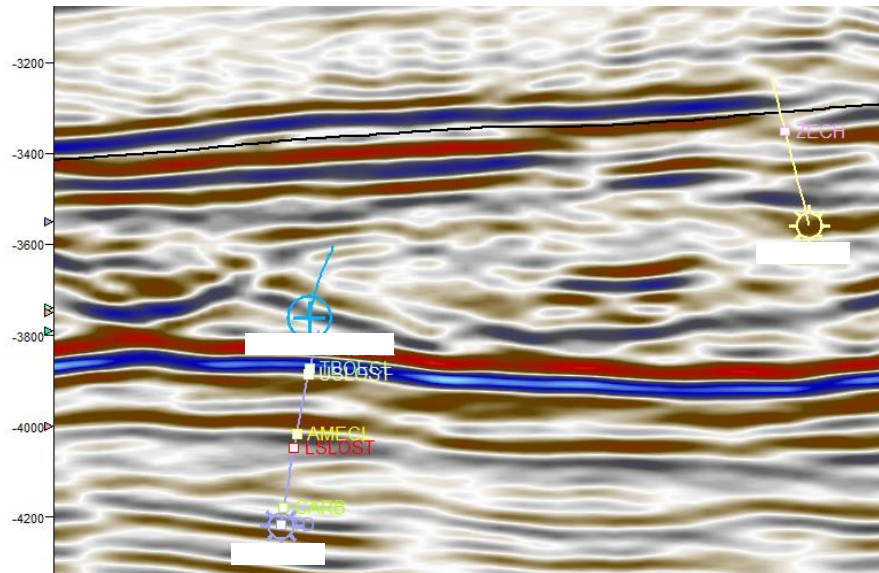


K12-G8

- Igneous rocks found in intervals 3880-3905m MD (3443-3465 mTVDss) and 4080-4250m MD (3613-3756 m TVDss)
- Slow drilling progress (4 days 1st interval, 12 days 2nd interval, worn out bits)
- Seismic signature is not clear: potential presence of faults through which igneous material came in?



- Igneous rocks found in intervals 3915-3970m MD (3591-3620 m TVDss) and 4010-4105m MD (3641-3694 m TVDss)
- Better drilling progress than nearby well – 1 bit worn out in each interval
- No apparent relationship visible on seismic



Discussion

- If stringer hasn't been drilled before: difficult to predict what you will find & what consequences are
- You would expect that anhydrite floater originating from large depth that has migrated up contains pressure → does not follow from data
- Likely permeability plays role, usually unstudied, cannot predict from seismic
- Recently, we have found intrusiva more often than anhydrite floaters
 - Extent of drilling delay varies hugely with range of rock texture (fresh/hard, weathered/soft, composition)

Conclusions

- If you see something on seismic, most likely something is there, BUT:
- Very difficult to predict from seismic what kind of stringer / floater will be encountered
 - Even if good well coverage in the area!
- You may find:
 - Thick or thin anhydrite blocks
 - Fresh or weathered intrusive bodies
- These may give a kick, induce total losses, or give no response at all
- From the available data, no consistent relationship can be seen between what is seen on seismic and what is actually drilled
- You may encounter very thick anhydrites that are not visible on seismic at all (esp. in salt domes) → can you exclude drilling risk?
- Policy: avoid as much as possible in well planning stage
- Standard mitigation measures: sufficient kick tolerance, salt-saturated mud