NAM

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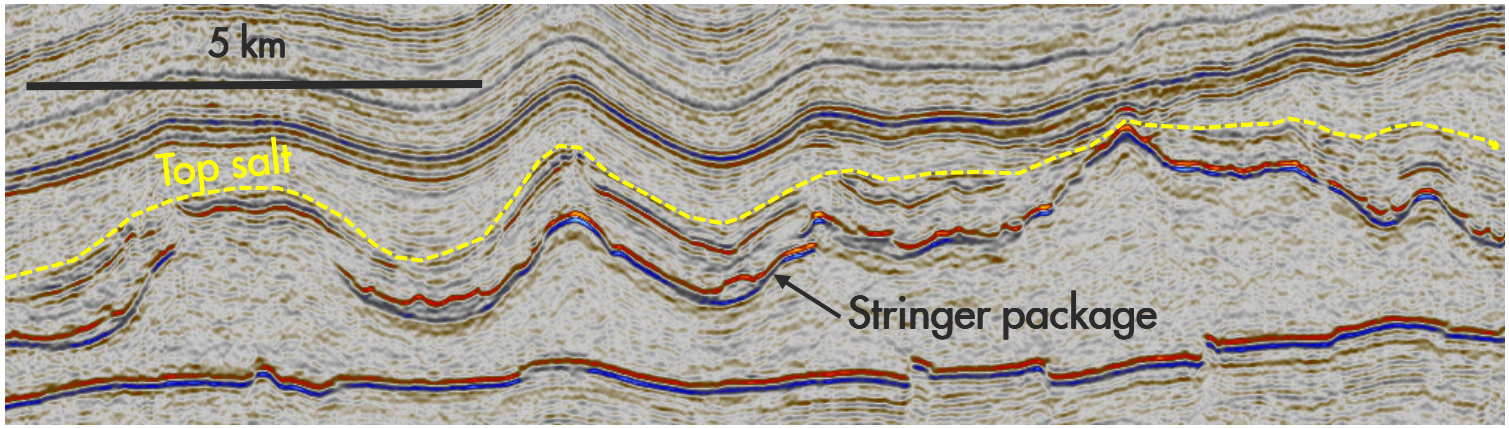
Planning a well through a Zechstein Stringer - Best practices used in NAM



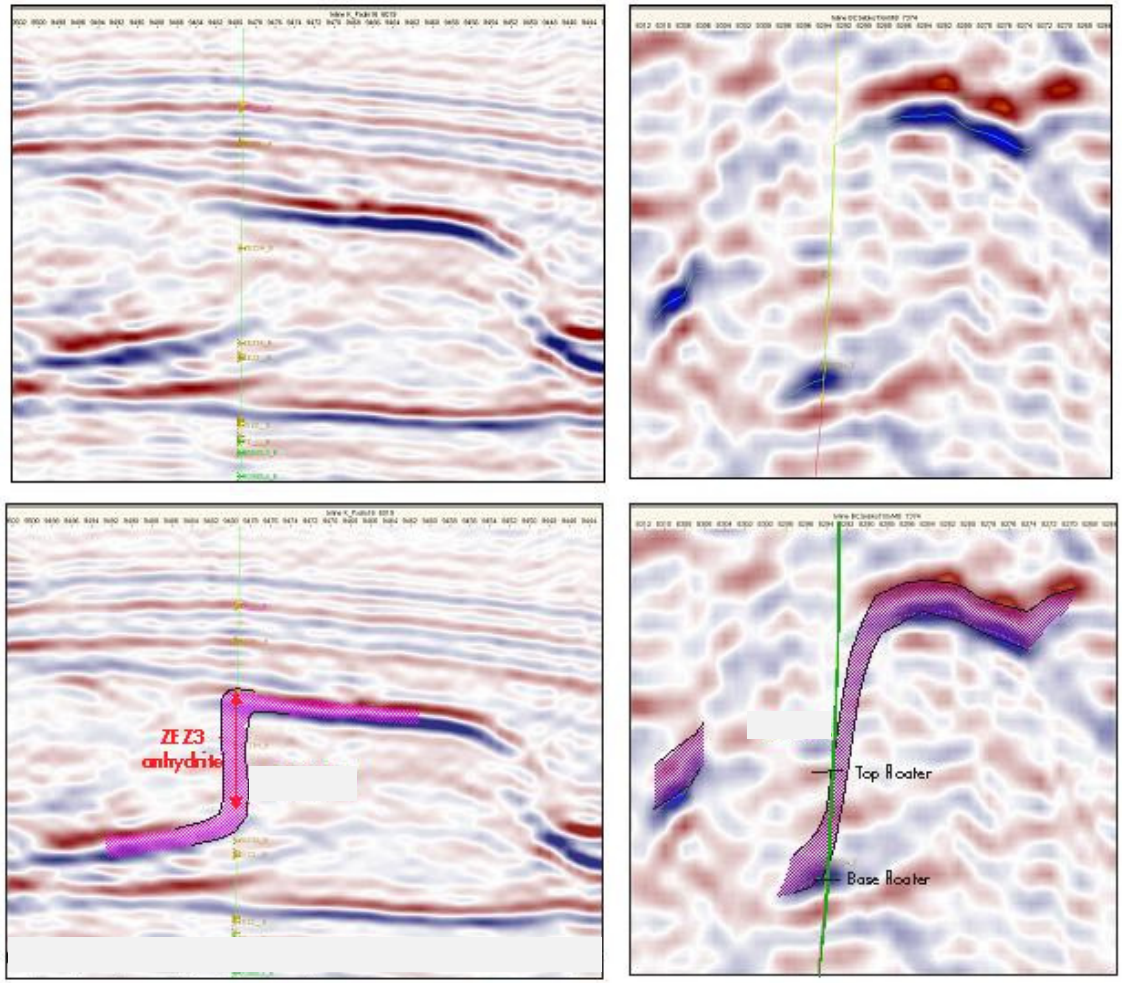
With acknowledgements to Martin de Keijzer, Piet van den Heuvel, and Ide van der Molen

OUR STEPS IN PLANNING A WELL

- Interpretation & Stringer Identification
- Well trajectory planning
- Pore pressure prediction
- Risk assessment

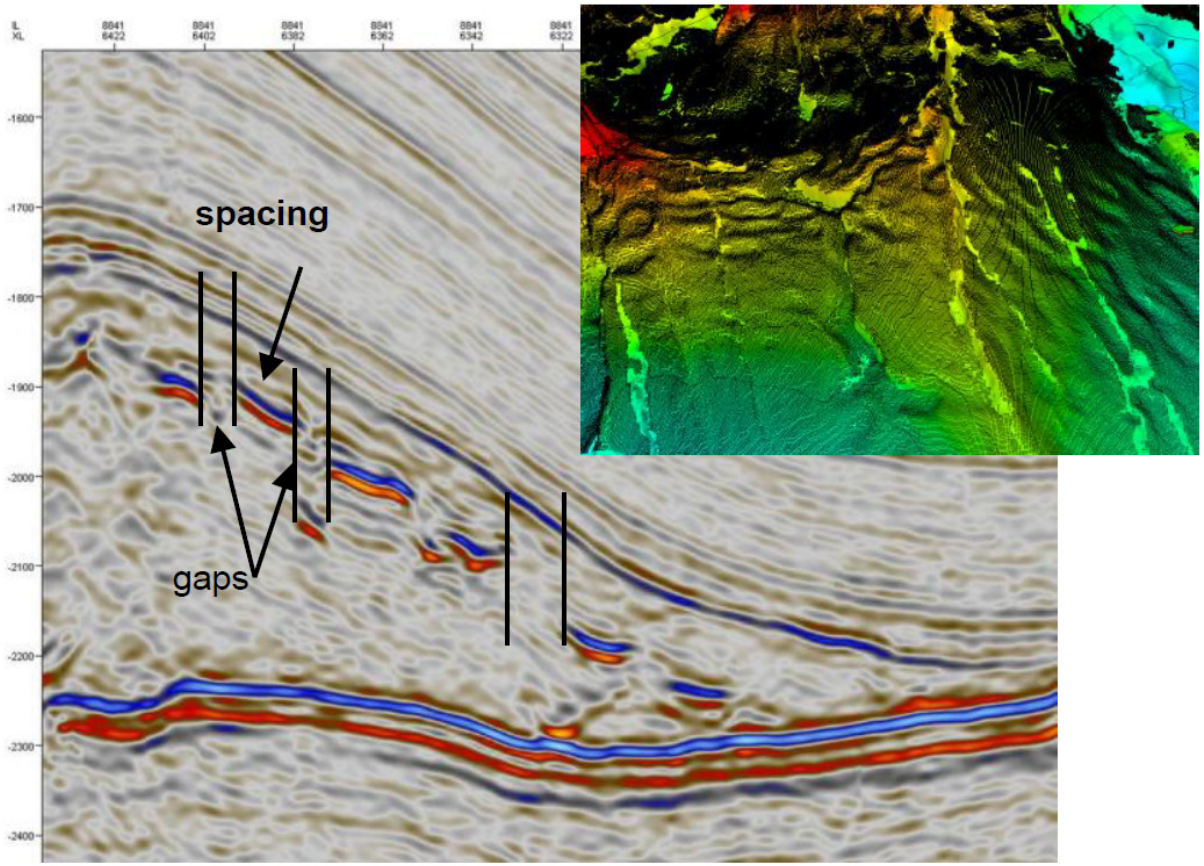
STRINGER IDENTIFICATION

- Scanning for high amplitude events with expected polarity.
- Beware of poor imaging :
  - Stringer edges
  - Stacked stringers
  - Vertical sections
  - Small stringers
- (subtle) pull-ups at ZEZ2A level can be indications for poorly or non-imaged stringers.
- Consider all available seismic datasets and seismic vintages.



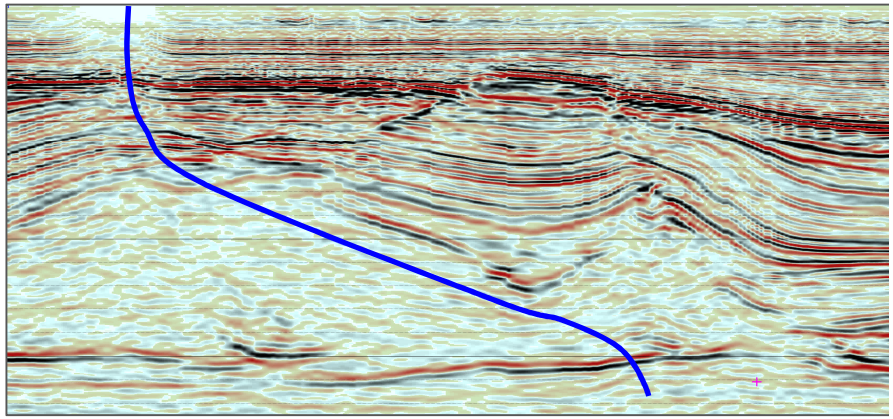
INTERPRETATION – REGIONAL MAPPING

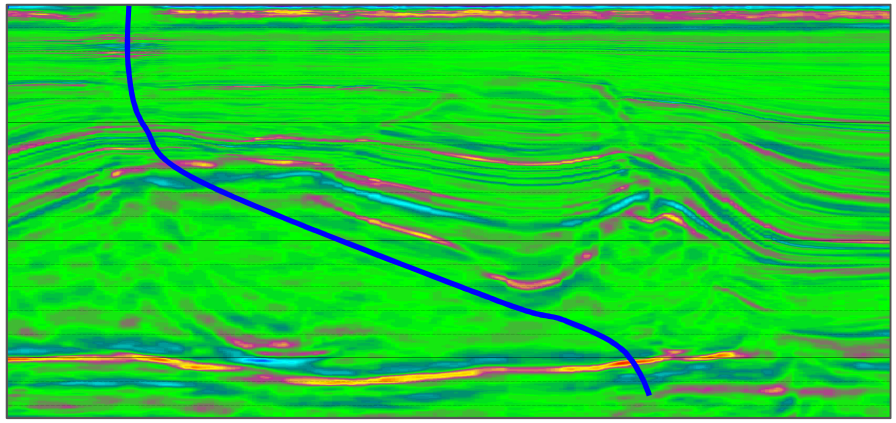
- ZEZ3AC geological model of deposition and deformation taken into account.
- Regional mapping can be used to identify gaps and chance for "invisible" sections

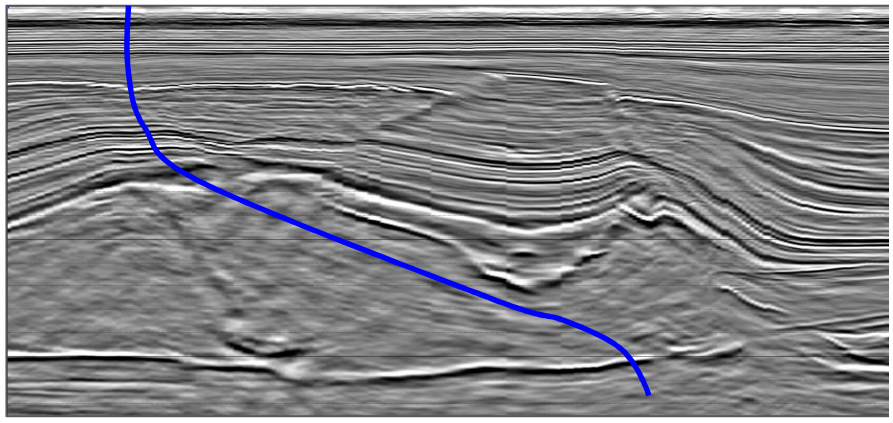


STRINGER INTERPRETATION

- If available we use different seismic datsets, e.g.,
- 2 Vintages of processing
- Inversion

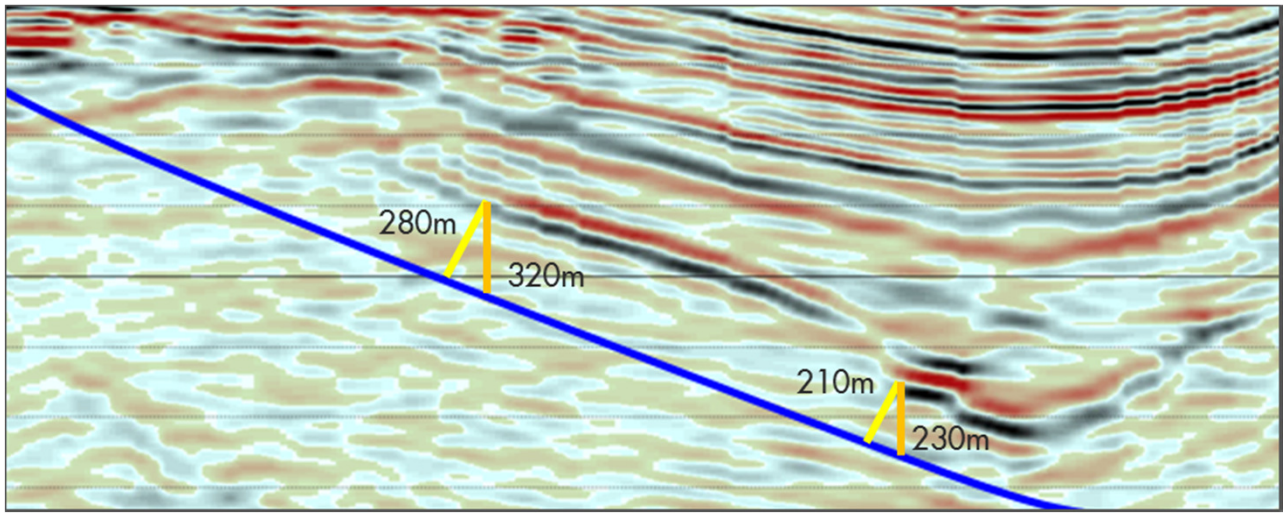






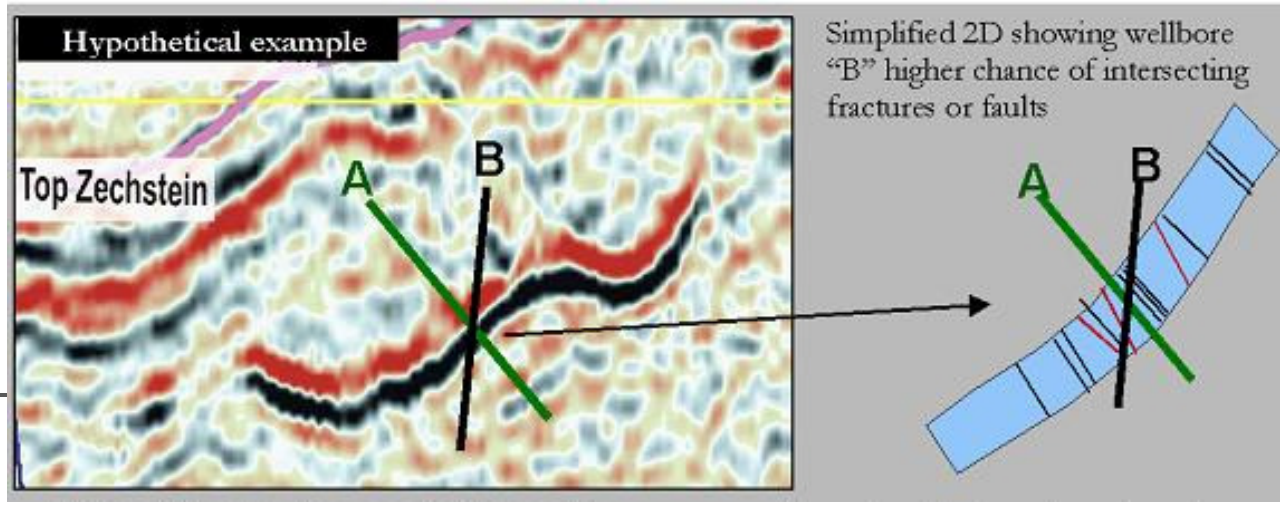
POSITIONING UNCERTAINTY

- We include both VERTICAL and LATERAL uncertainty
- Different seismic datasets may help to assess positioning uncertainty as well



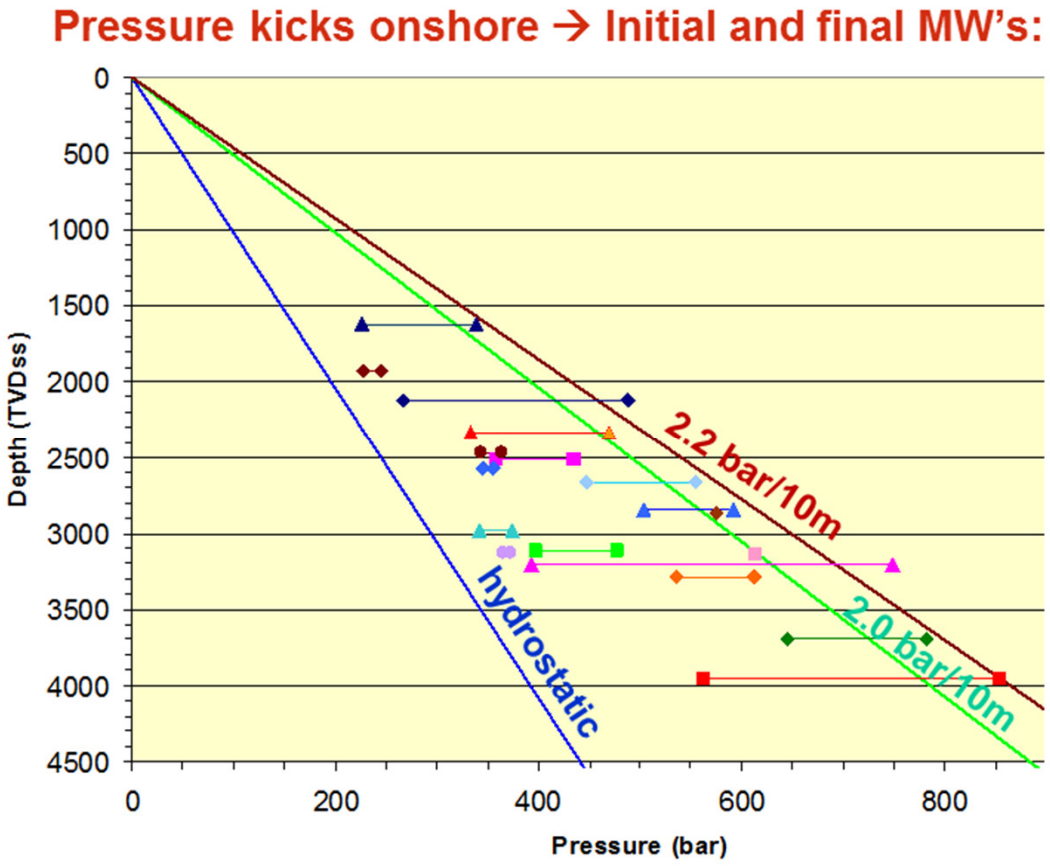
TRAJECTORY & WELL DESIGN

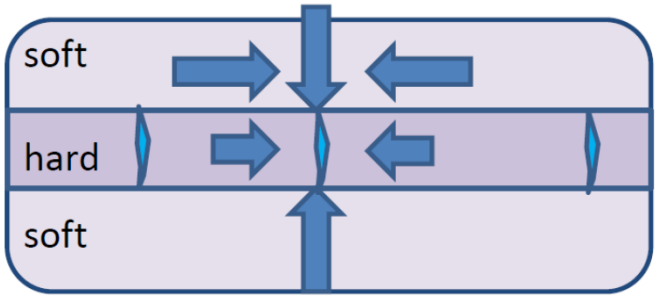
- We try to avoid stringers if possible
  - Use targets and anti-targets to guide trajectory
- Include distance uncertainty (lateral and vertical)
- Reduce risk for intersecting fractures:
  - Avoid high curvature areas
  - Stay away from edge
  - Perpendicular intersection
- Casing scheme
- mud weight



PORE PRESSURE PREDICTION

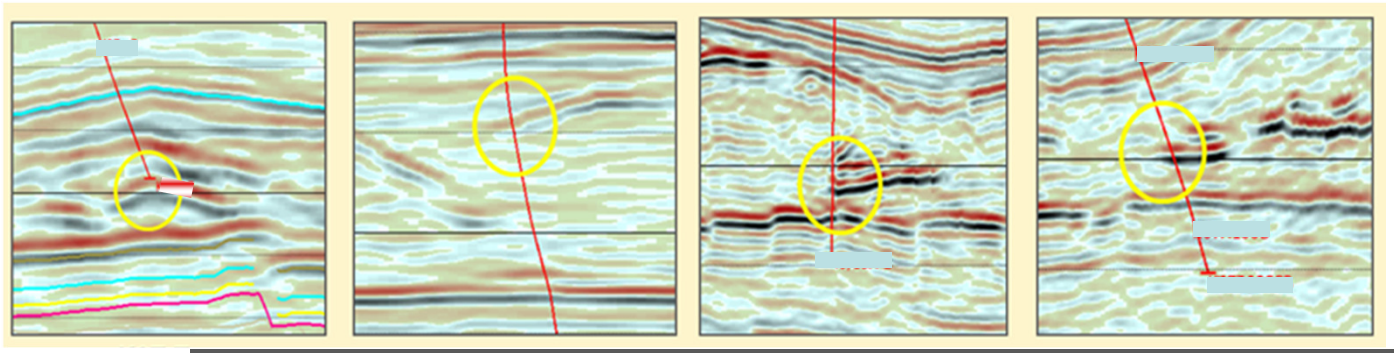
- Rafts are fully surrounded by salt
- Hence pressures are assumed close to lithostatic
- In line with observed kick data

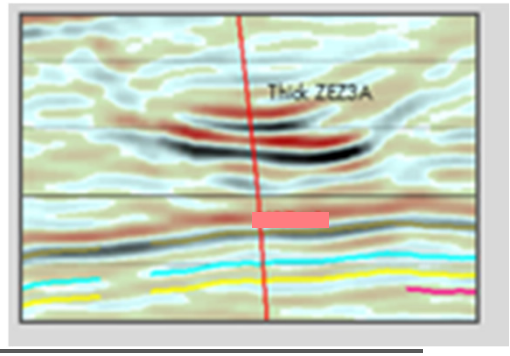




"CHANCE FOR FLOW"

- We use "Chance for flow" as the key indicator tor risk tor a kick
- In our understanding only flow from carbonates, not anhydrite
- Parameters used to assess "Chance for flow":
  - Intersection angle
  - Seismic amplitude (dimming indicates fractures)
  - Vicinity of edge
  - Curvature

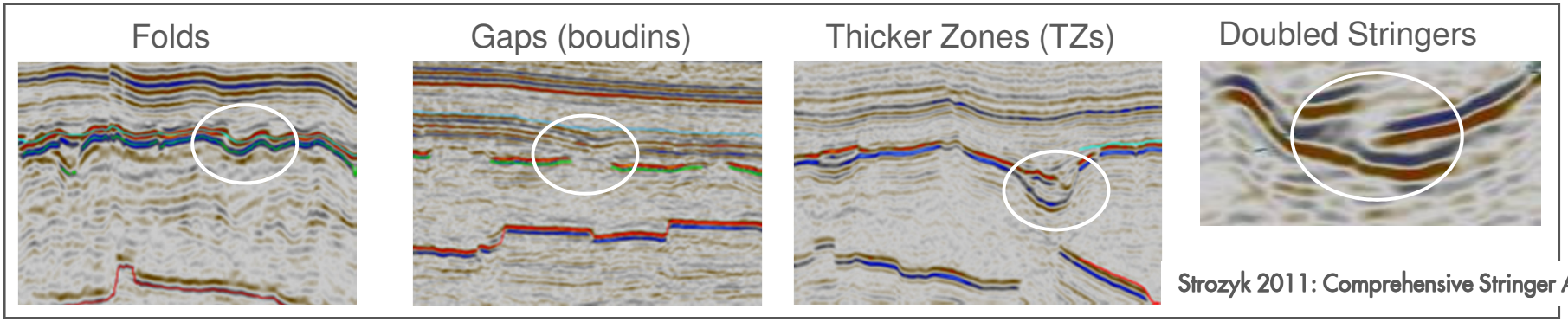




RISKING

- Bottom line: A kick can never be 100% excluded
- G&G rules-of-thumb that help (de-)risk ZEZ3C kicks:
  - Stringer positioning uncertainty and imaging resolution
    - Likelihood of hitting the stringer
  - Stringer geometry in combination with planned well trajectory,
    - risk of fractures or fault intersection
  - Stringer position in the salt,
    - risk of overpressure
  - Offset well data, both geographically close-by and structurally analogous
  - Regional knowledge (deposition & deformation understanding)

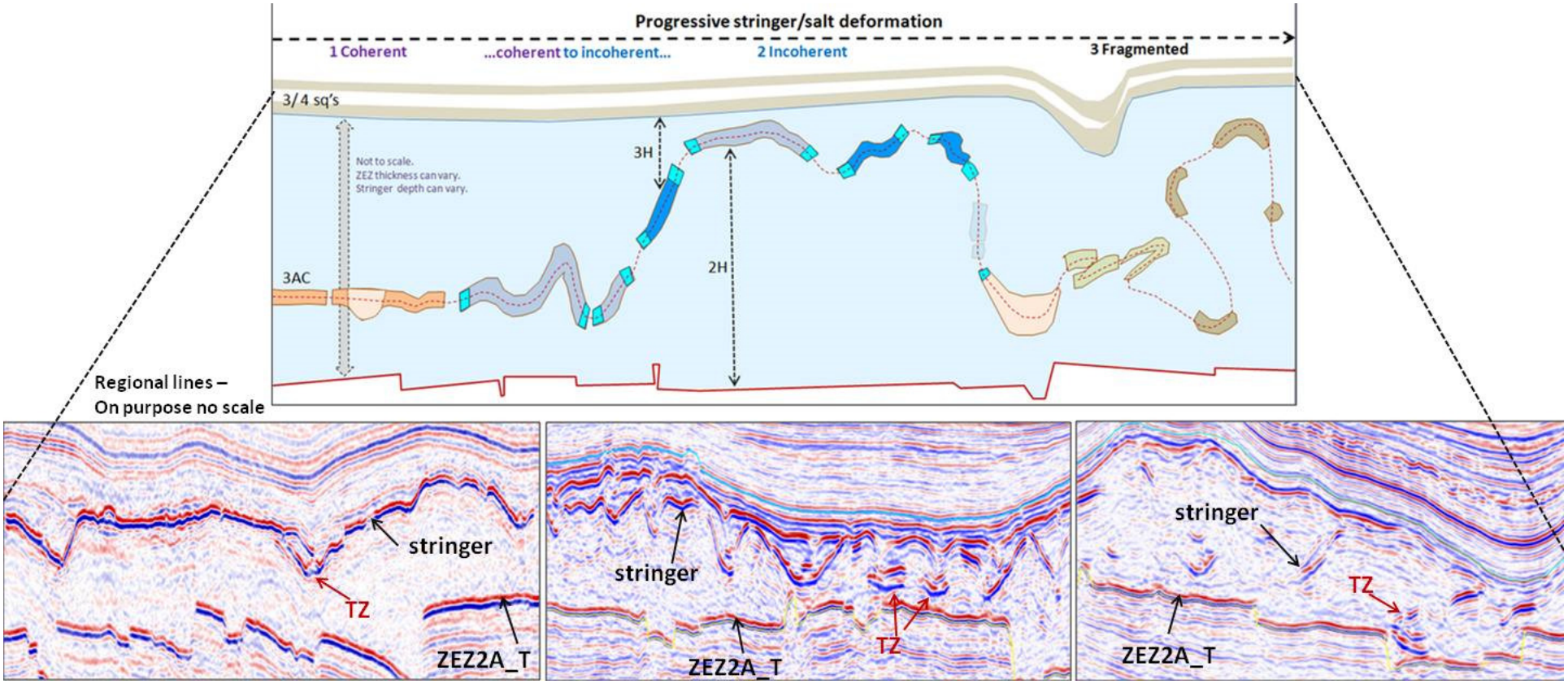
STRINGER GEOMETRIES



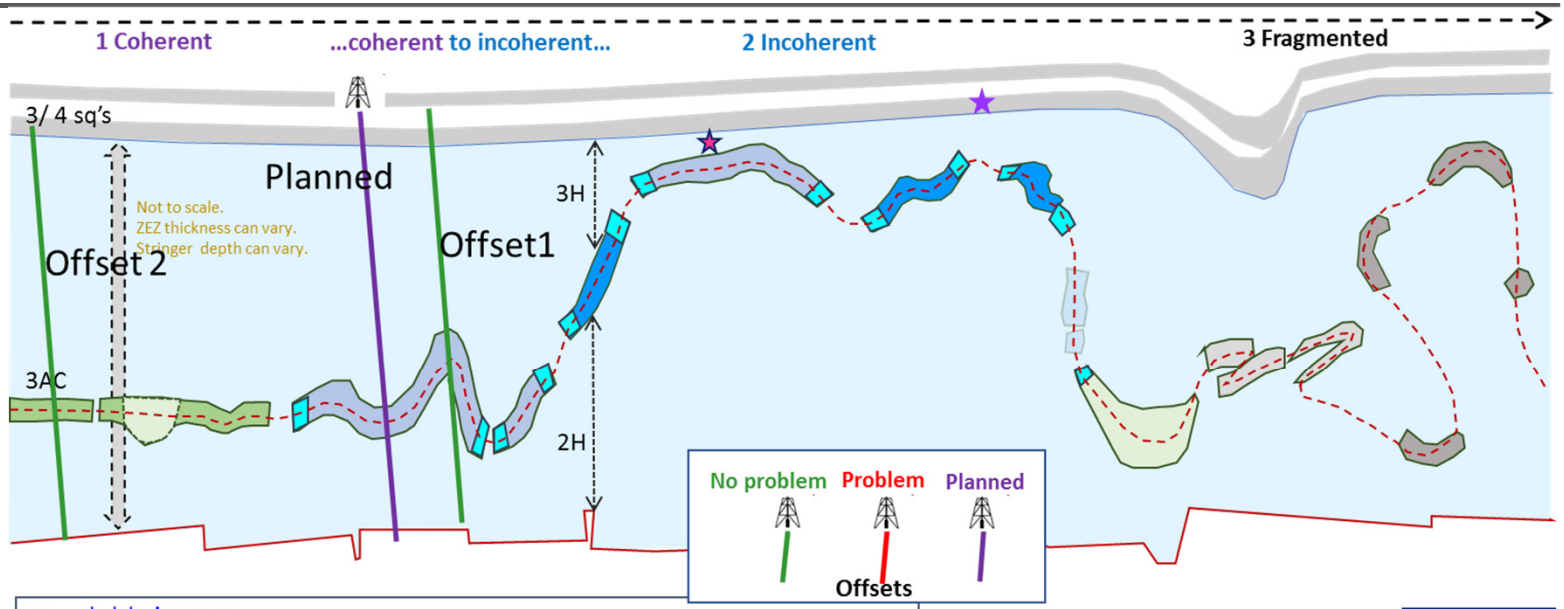
Strozyk 2011: Comprehensive Stringer Atlas

- Stringer geometry affects the risk assessment
  - Higher deformation (fragmented) increases change for encoutering fractures
  - Folded coherent sections also have higher risk for encountering fractures
  - Floater gaps provide an opportunity to avoid the floater, but also can be deceptive (poorly imaged edges or sections)
  - 'Simple' thick zones are not considered an increased risk (thicker anhydrite)

RISKING DEPENDENT ON GEOLOGICAL SETTING



ZECHSTEIN RISKING SUMMARY – Worked example



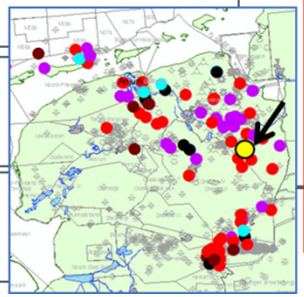
3C probability **hit**: 100%
- The well will drill through ZEZ3C in a syndinal position

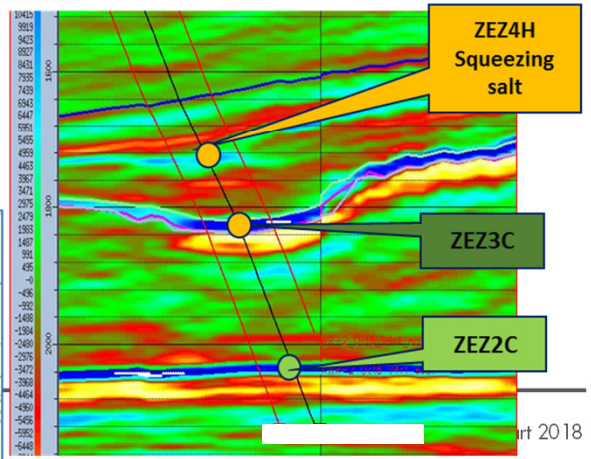
3C probability **kick** (5%)
- No kick experienced in nearby wells induding OW-1
- The well orientiation is orthogonal to the stringer
- Not many analogue wells shown, but the closest analogue well (OW1) did not have problem

2C probability **hit** (100%)
- All surrounding wells drilled through ZEC 2C

2C probability **kick** (0%)
- No Kick reported in surrounding wells, but high gas reading reported
- (Connection gas ~500,000ppm).
- Trajectory hits the 2C in a benign area avoiding identified lineaments.

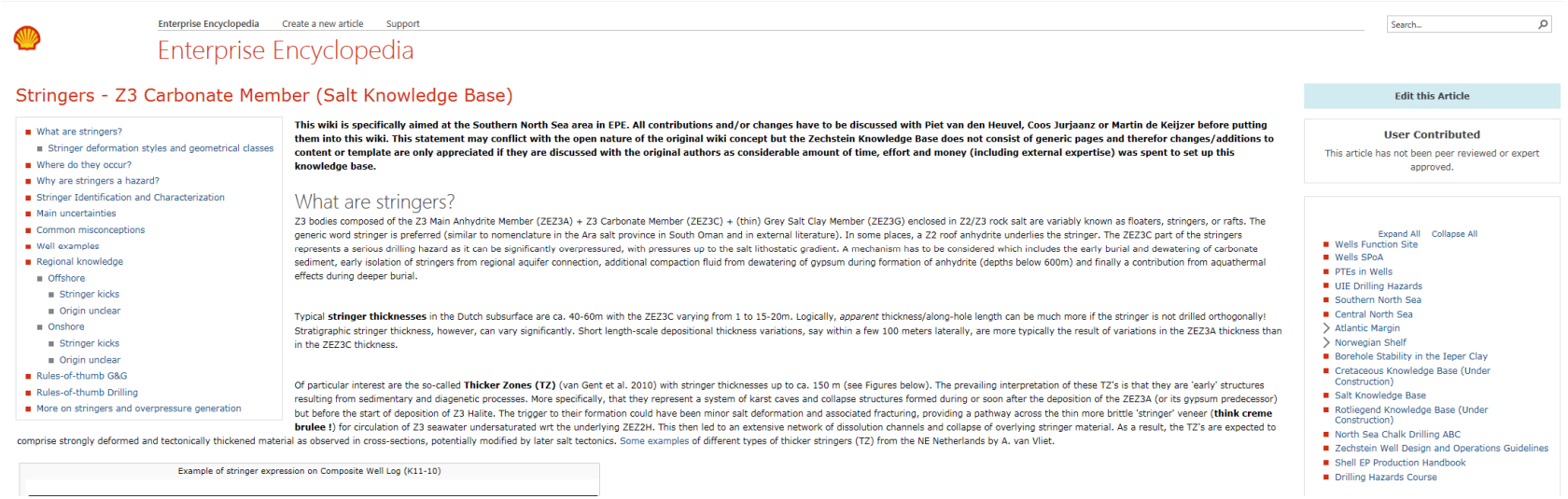
Other induding intra-salt BRINE INFLOW
- Squeezing Salts is expected at the top of ZEZ4H
- Brine kick risk is low in this area
-





NON TECHNICAL ASPECTS

- People competency
  - Drilling hazard workshop (mandatory 2year refresher)
  - Pore pressure prediction course
  - Salt knowledge database (“salt wiki”)



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Stringers - Z3 Carbonate Member (Salt Knowledge Base)

- What are stringers?
  - Stringer deformation styles and geometrical classes
- Where do they occur?
- Why are stringers a hazard?
- Stringer Identification and Characterization
- Main uncertainties
- Common misconceptions
- Well examples
- Regional knowledge
  - Offshore
    - Stringer kicks
    - Origin unclear
  - Onshore
    - Stringer kicks
    - Origin unclear
- Rules-of-thumb G&G
- Rules-of-thumb Drilling
- More on stringers and overpressure generation

This wiki is specifically aimed at the Southern North Sea area in EPE. All contributions and/or changes have to be discussed with Piet van den Heuvel, Coos Jurjaanz or Martin de Keijzer before putting them into this wiki. This statement may conflict with the open nature of the original wiki concept but the Zechstein Knowledge Base does not consist of generic pages and therefor changes/additions to content or template are only appreciated if they are discussed with the original authors as considerable amount of time, effort and money (including external expertise) was spent to set up this knowledge base.

What are stringers?

Z3 bodies composed of the Z3 Main Anhydrite Member (ZEZ3A) + Z3 Carbonate Member (ZEZ3C) + (thin) Grey Salt Clay Member (ZEZ3G) enclosed in Z2/Z3 rock salt are variably known as floaters, stringers, or rafts. The generic word stringer is preferred (similar to nomenclature in the Ara salt province in South Oman and in external literature). In some places, a Z2 roof anhydrite underlies the stringer. The ZEZ3C part of the stringers represents a serious drilling hazard as it can be significantly overpressured, with pressures up to the salt lithostatic gradient. A mechanism has to be considered which includes the early burial and dewatering of carbonate sediment, early isolation of stringers from regional aquifer connection, additional compaction fluid from dewatering of gypsum during formation of anhydrite (depths below 600m) and finally a contribution from aquathermal effects during deeper burial.

Typical **stringer thicknesses** in the Dutch subsurface are ca. 40-60m with the ZEZ3C varying from 1 to 15-20m. Logically, *apparent* thickness/along-hole length can be much more if the stringer is not drilled orthogonally! Stratigraphic stringer thickness, however, can vary significantly. Short length-scale depositional thickness variations, say within a few 100 meters laterally, are more typically the result of variations in the ZEZ3A thickness than in the ZEZ3C thickness.

Of particular interest are the so-called **Thicker Zones (TZ)** (van Gent et al. 2010) with stringer thicknesses up to ca. 150 m (see Figures below). The prevailing interpretation of these TZ's is that they are 'early' structures resulting from sedimentary and diagenetic processes. More specifically, that they represent a system of karst caves and collapse structures formed during or soon after the deposition of the ZEZ3A (or its gypsum predecessor) but before the start of deposition of Z3 Halite. The trigger to their formation could have been minor salt deformation and associated fracturing, providing a pathway across the thin more brittle 'stringer' veneer (**think creme brulee !**) for circulation of Z3 seawater undersaturated wrt the underlying ZEZ2H. This then led to an extensive network of dissolution channels and collapse of overlying stringer material. As a result, the TZ's are expected to comprise strongly deformed and tectonically thickened material as observed in cross-sections, potentially modified by later salt tectonics. Some examples of different types of thicker stringers (TZ) from the NE Netherlands by A. van Vliet.

Example of stringer expression on Composite Well Log (K11-10)

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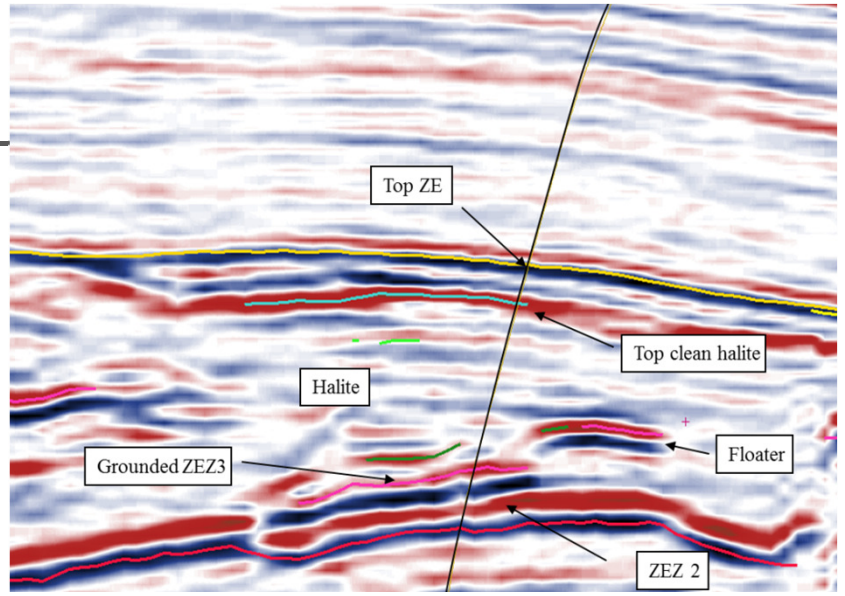
- Central North Sea
- Atlantic Margin
- Norwegian Shelf
- Borehole Stability in the Ieper Clay
- Cretaceous Knowledge Base (Under Construction)
- Salt Knowledge Base
- Rotliegend Knowledge Base (Under Construction)
- North Sea Chalk Drilling ABC
- Zechstein Well Design and Operations Guidelines
- Shell EP Production Handbook
- Drilling Hazards Course

GOLDEN RULE



- Zechstein is always unpredictable

Hence

- Hope for uneventfull drilling
- But be prepared and plan for anything

- *Studies and understanding of the drilling hazards helps in preparation and planning, and communication of the risks*

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Q&A

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