Gannet F

4D Still Driving Decisions After 20 Years

Seismic 2019
14th May

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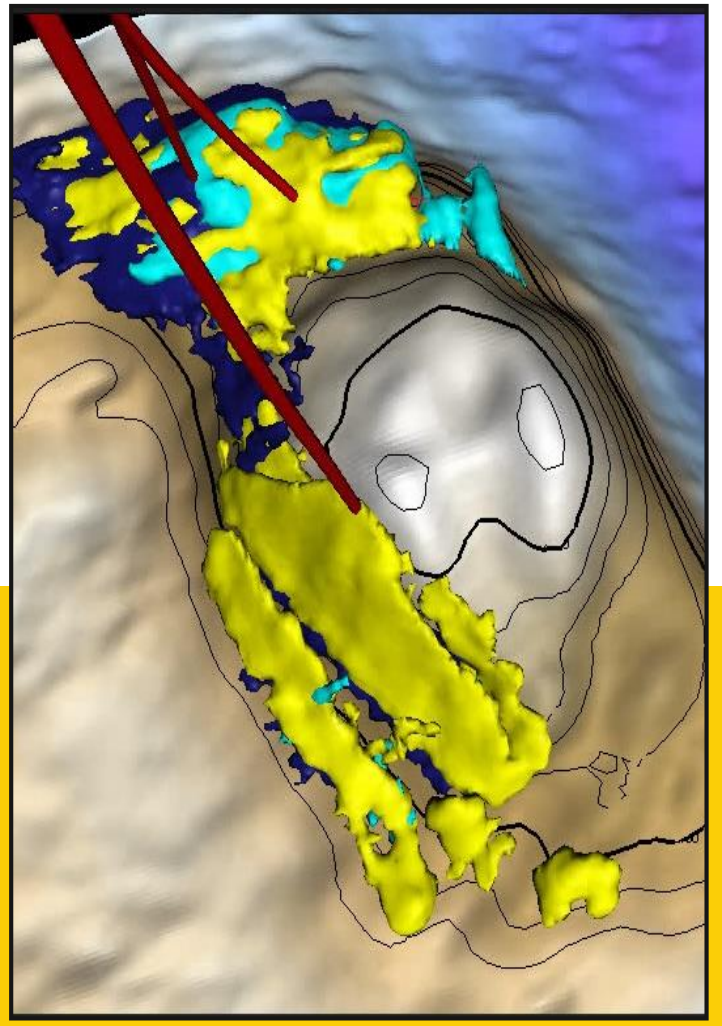

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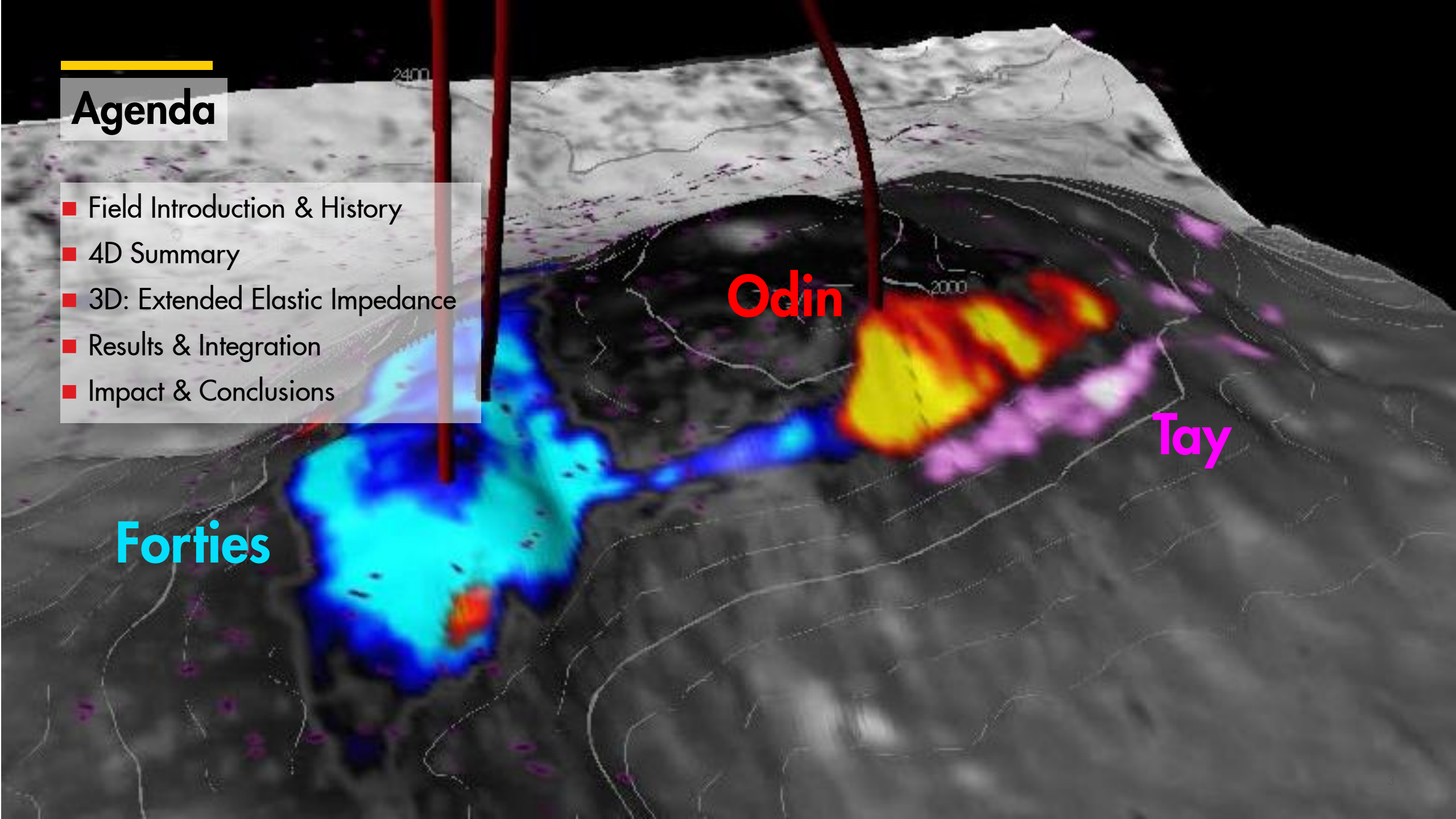
Agenda

- Field Introduction & History
- 4D Summary
- 3D: Extended Elastic Impedance
- Results & Integration
- Impact & Conclusions

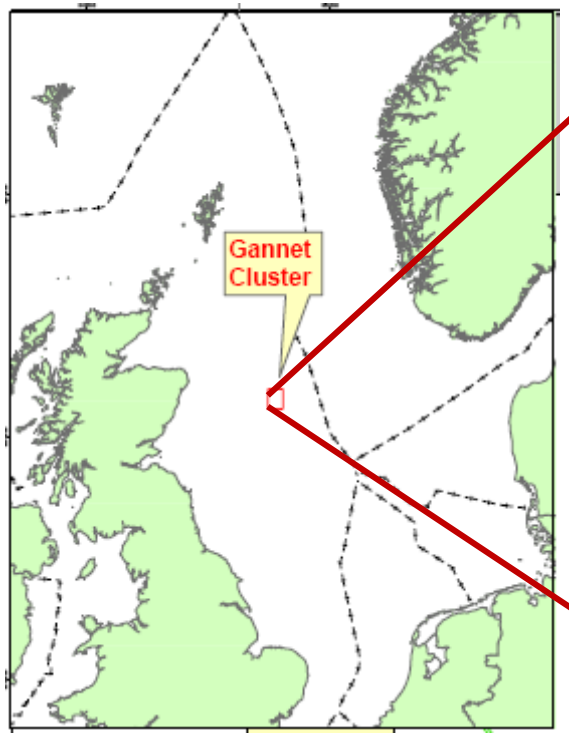


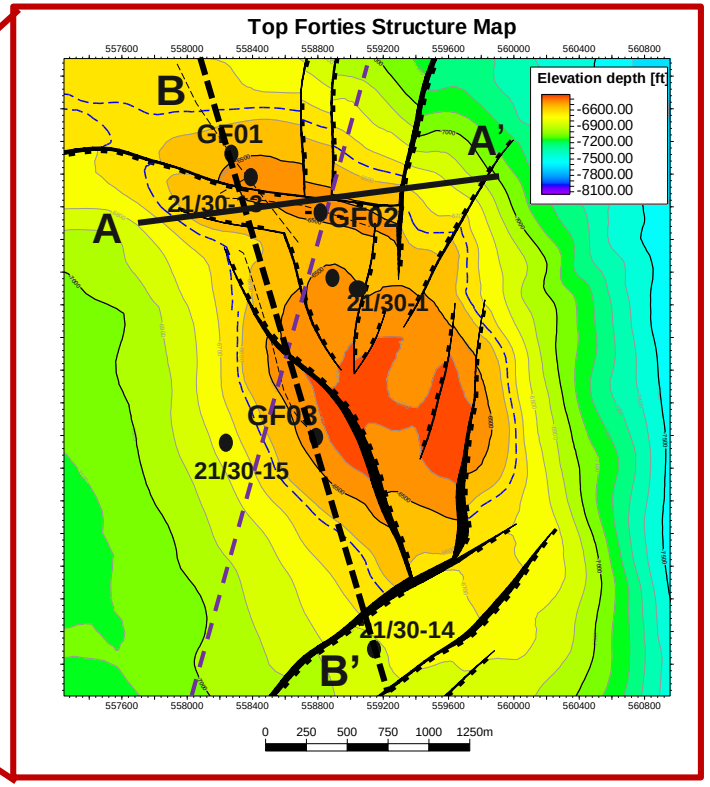
Gannet F

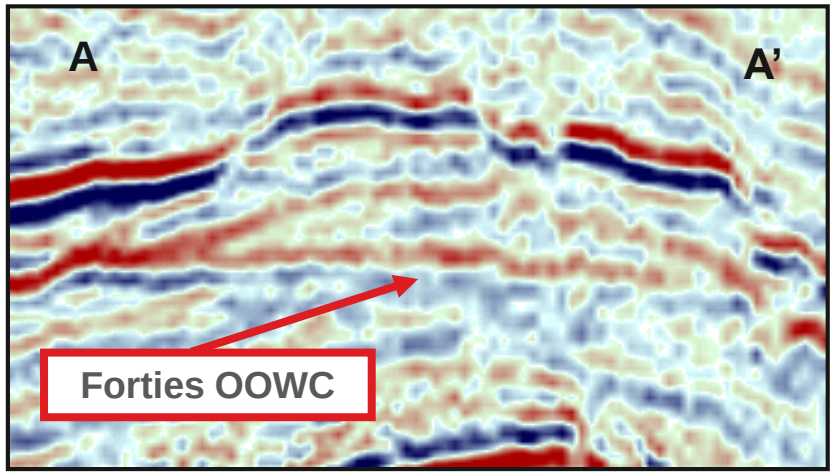
- Shell (operator) 50%, ExxonMobil 50%
- 1960s-’80s E&A wells, 1st oil 1997
- Subsea tie back to Gannet A platform

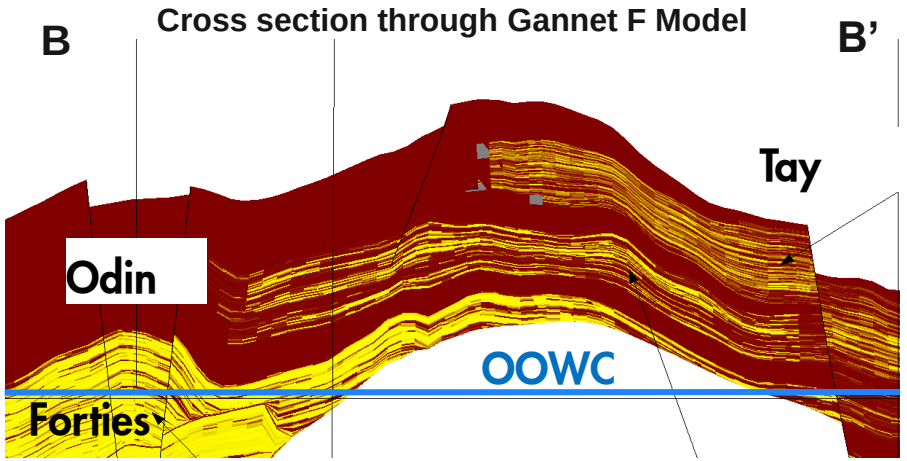
- 3 primary Paleocene/Eocene reservoirs
  - Tay, Odin, Forties (other minor sands)

- 3 production wells
  - GFA01, GFA02 (Forties)
  - GFA03 (Odin & Forties)

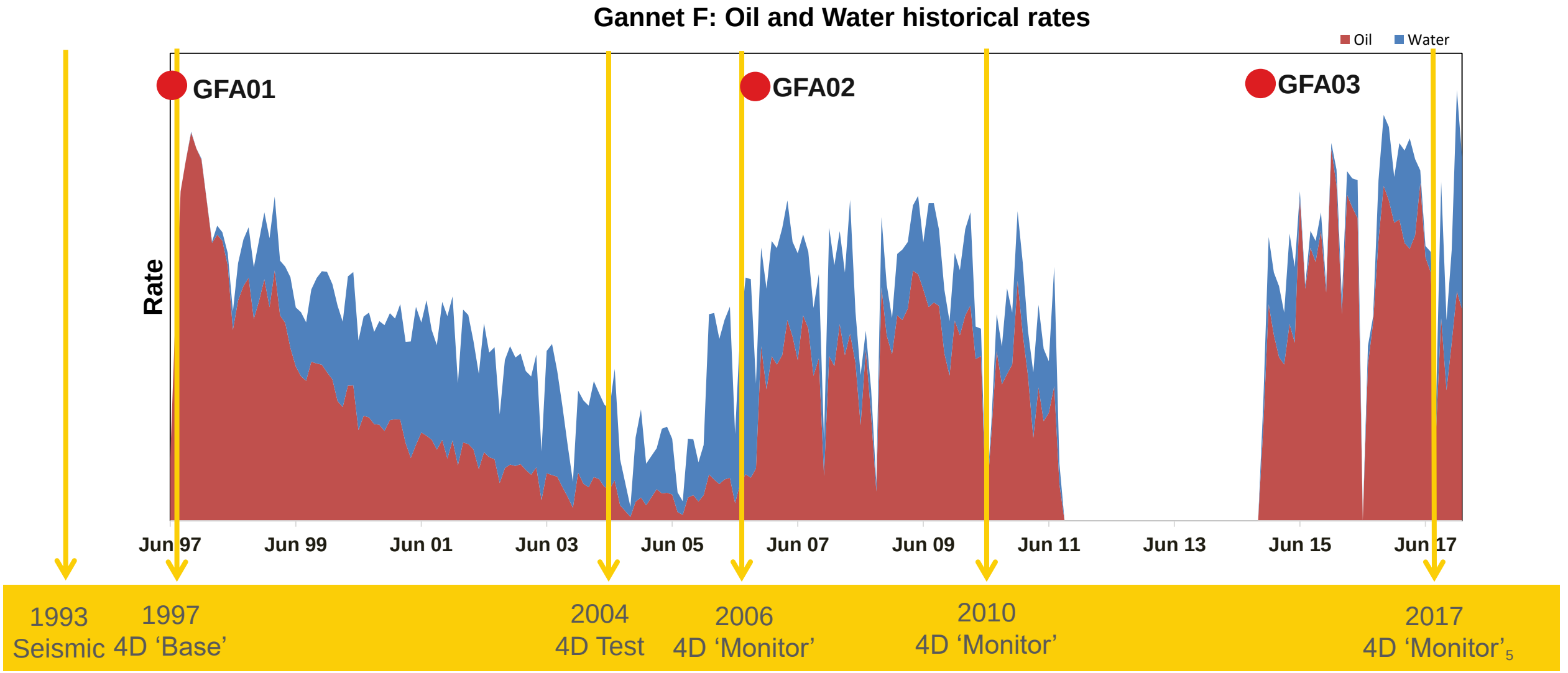








Production, Seismic & Infill Wells

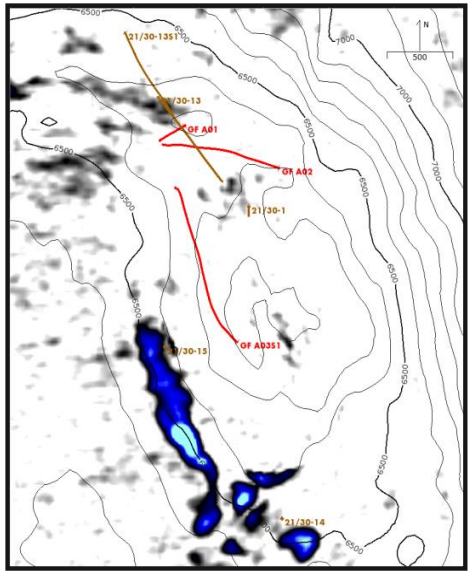


2017: 3rd 4D Monitor Water Sweep

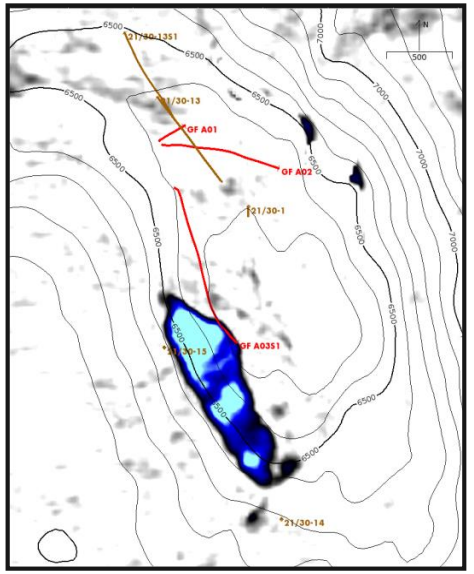
- 2015 GFA03: Forties & Odin, Not Tay
  ~12Mmboe incremental
- 2006 ‘barrier’ between GFA01 & GFA02 removed

Background: NtG
4D: 10-97
4D: 17-10

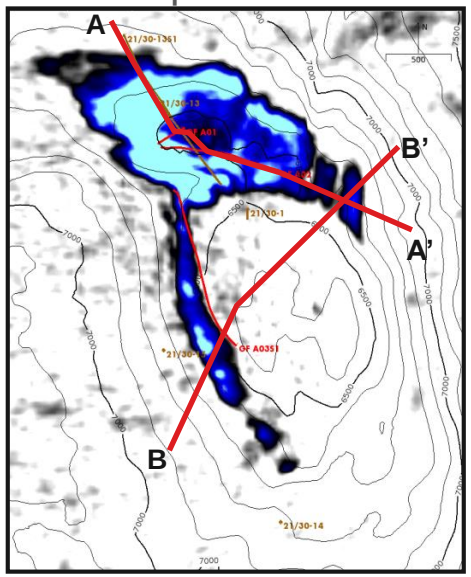
Top Tay

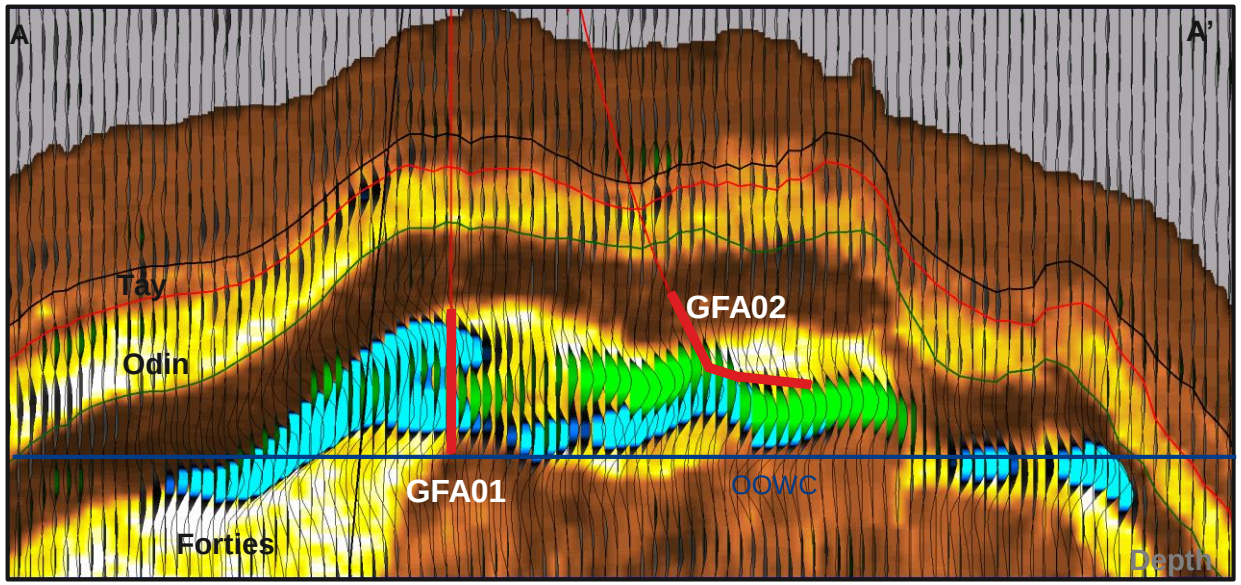


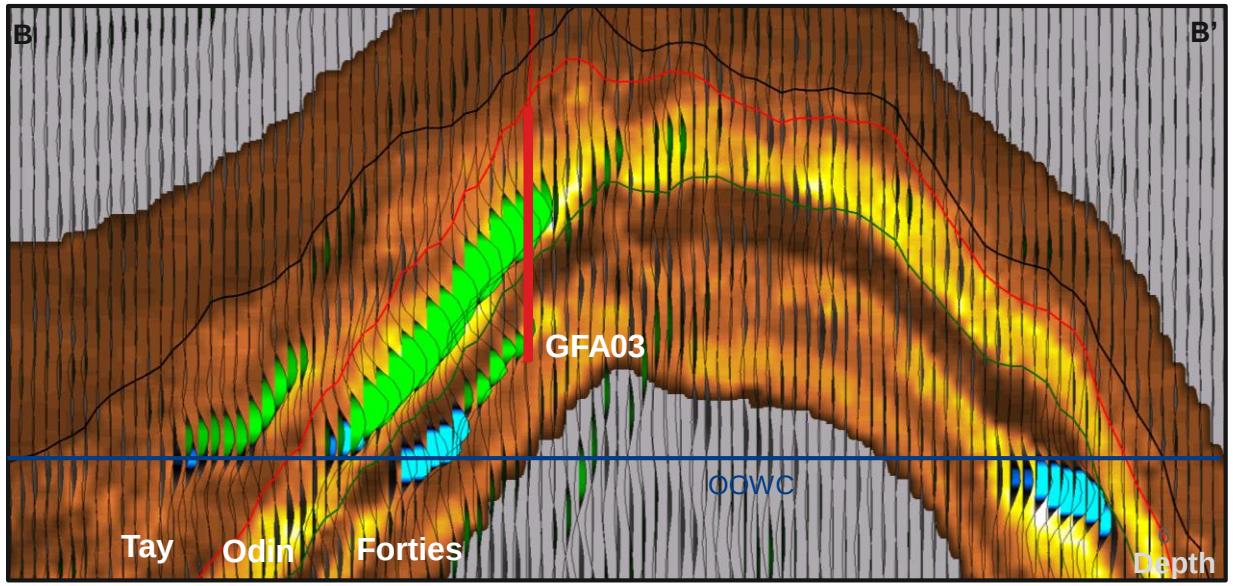
Top Odin



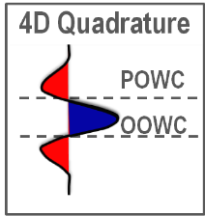
Top Forties



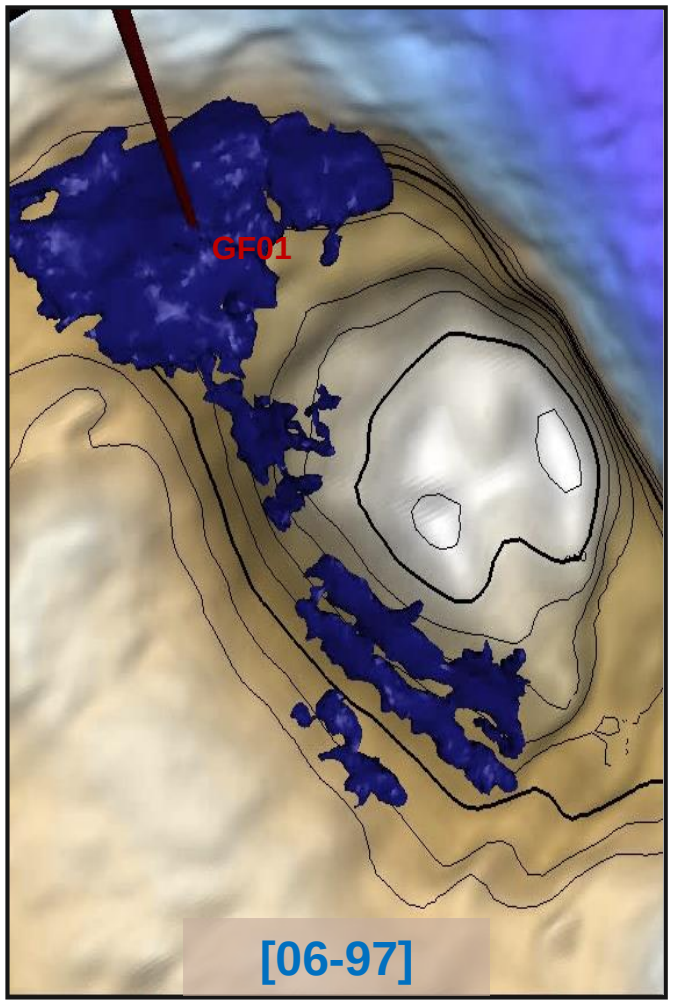


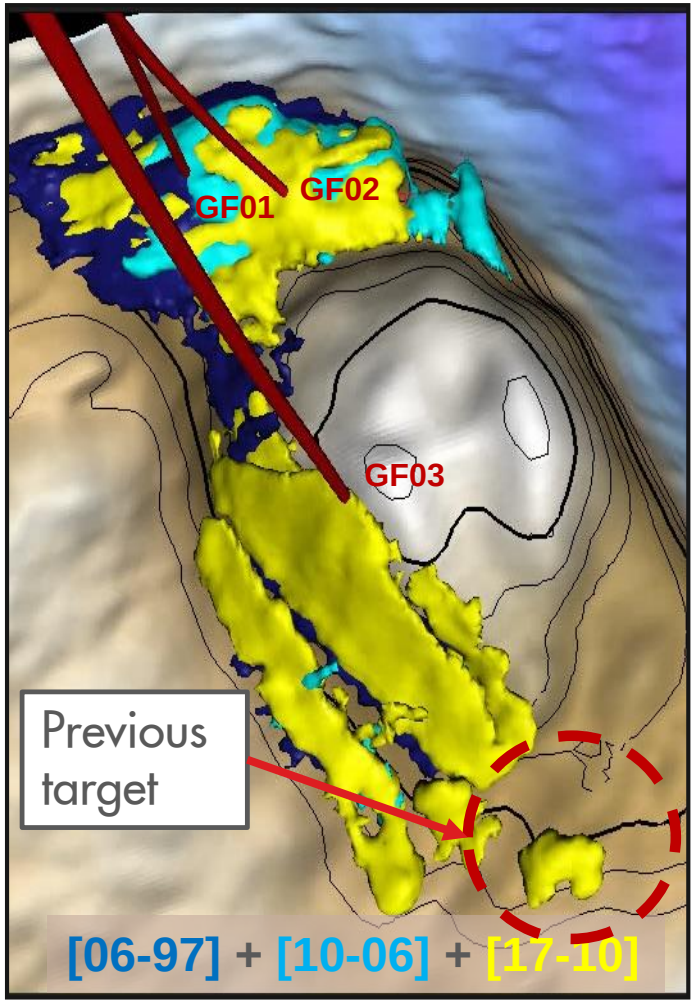


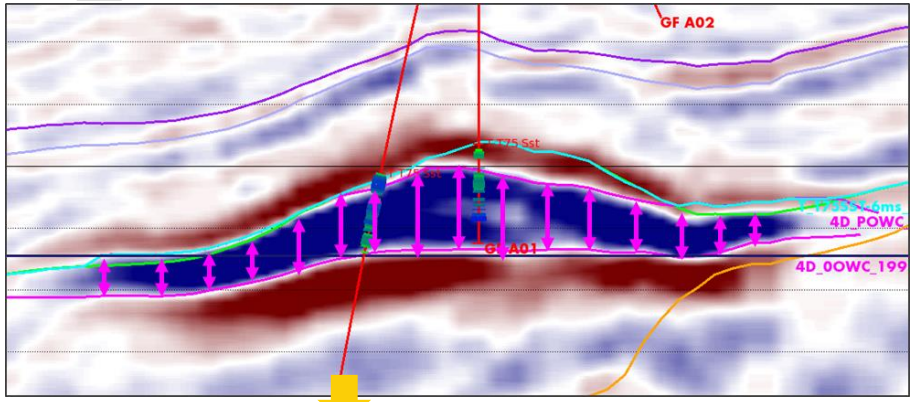
So where does that leave us? Where next?

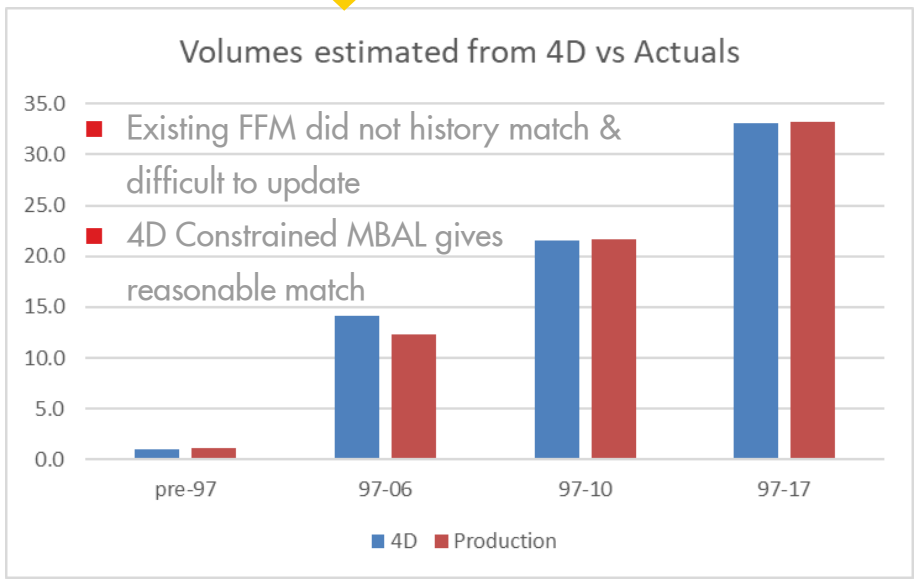


$$Prod\ Vol = \sum \Delta Sw\ height\ * 25^2\ * NTG * \emptyset\ * (1 - Swi\ - Sor)/Bo$$



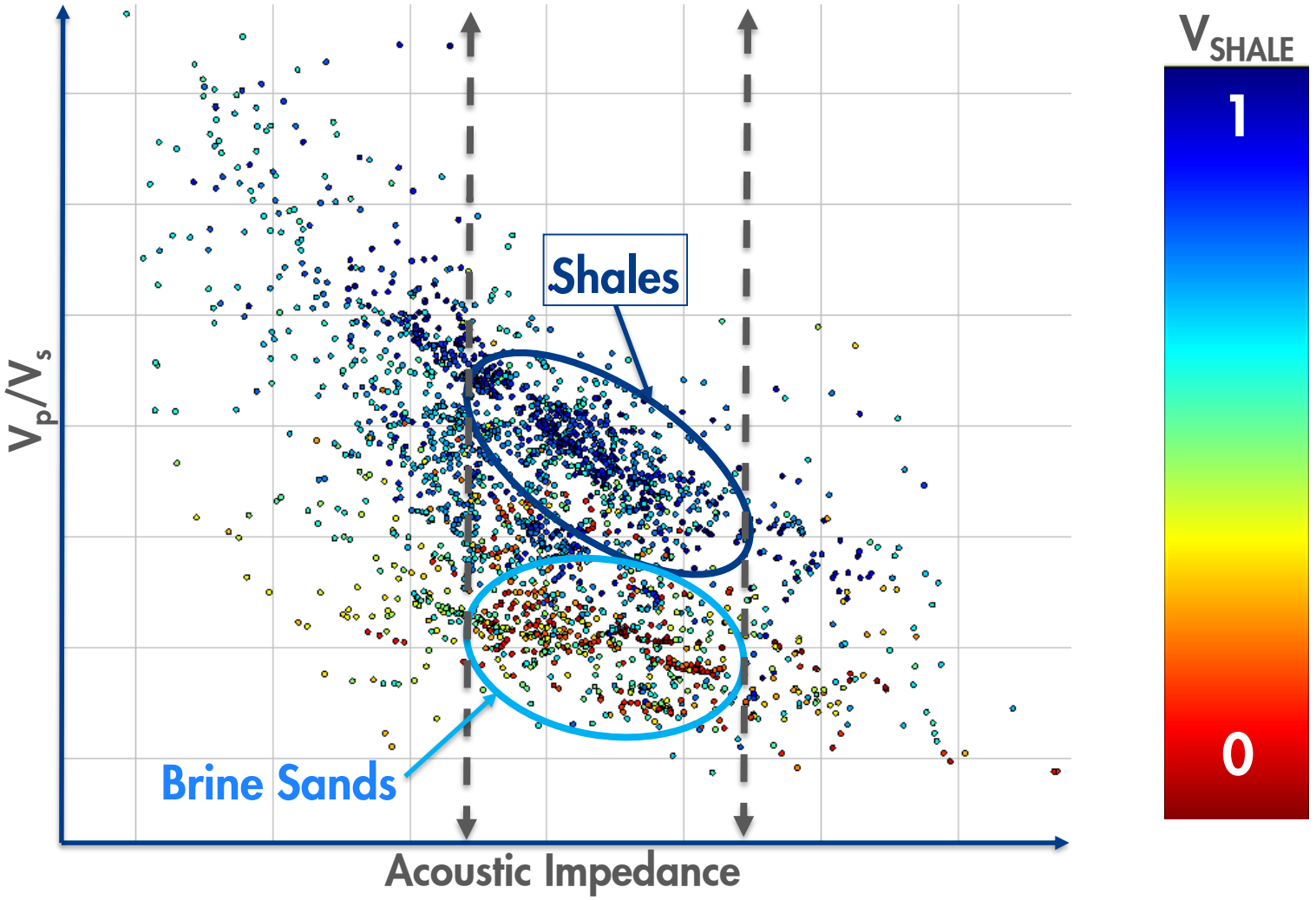






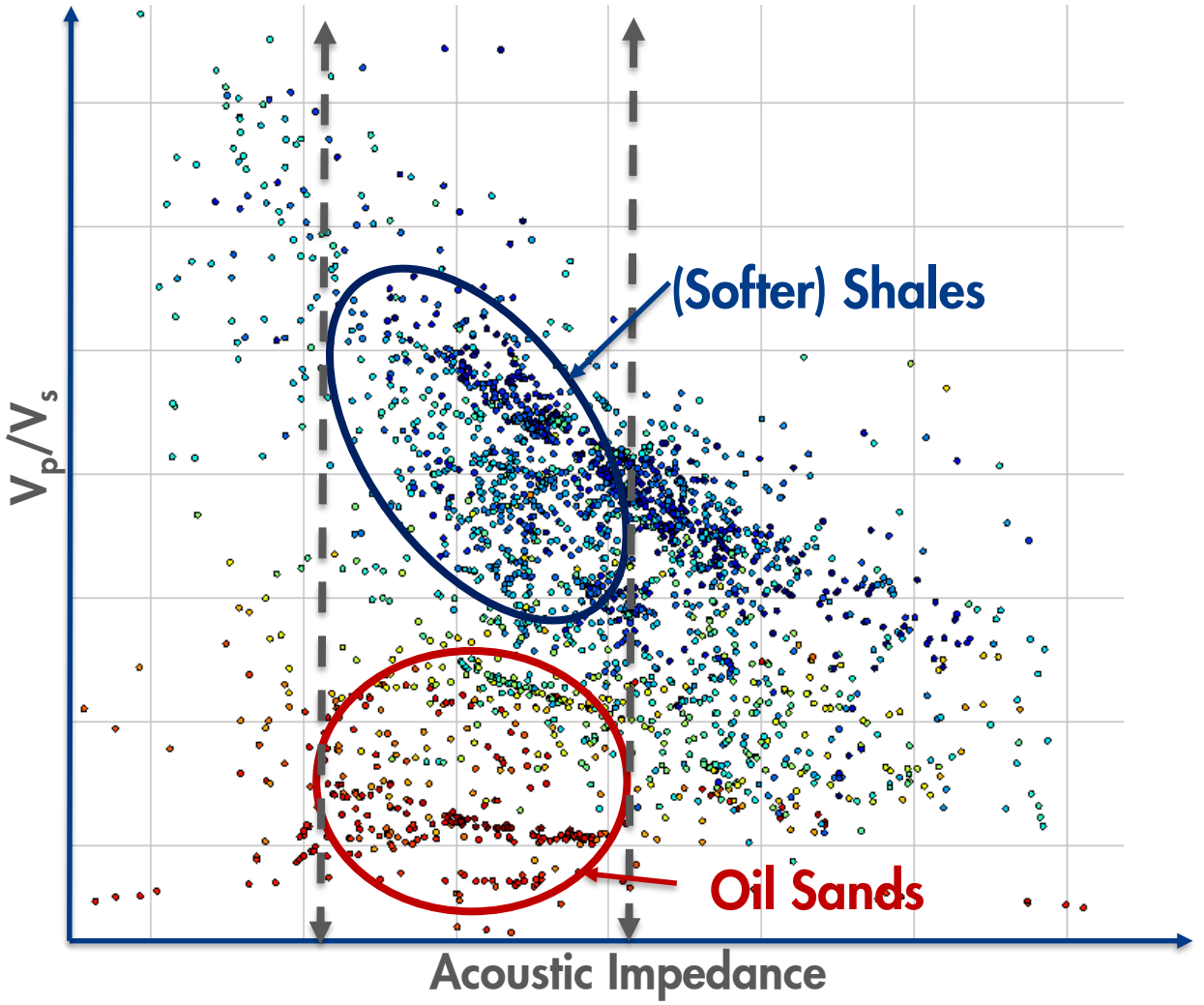
Acoustic Impedance vs V_p/V_s

- Elastic properties of Tay, Odin and Forties are practically identical.
- Wet (Brine) sands have the same AI as much of the (harder) shales and are therefore not visible in AI space



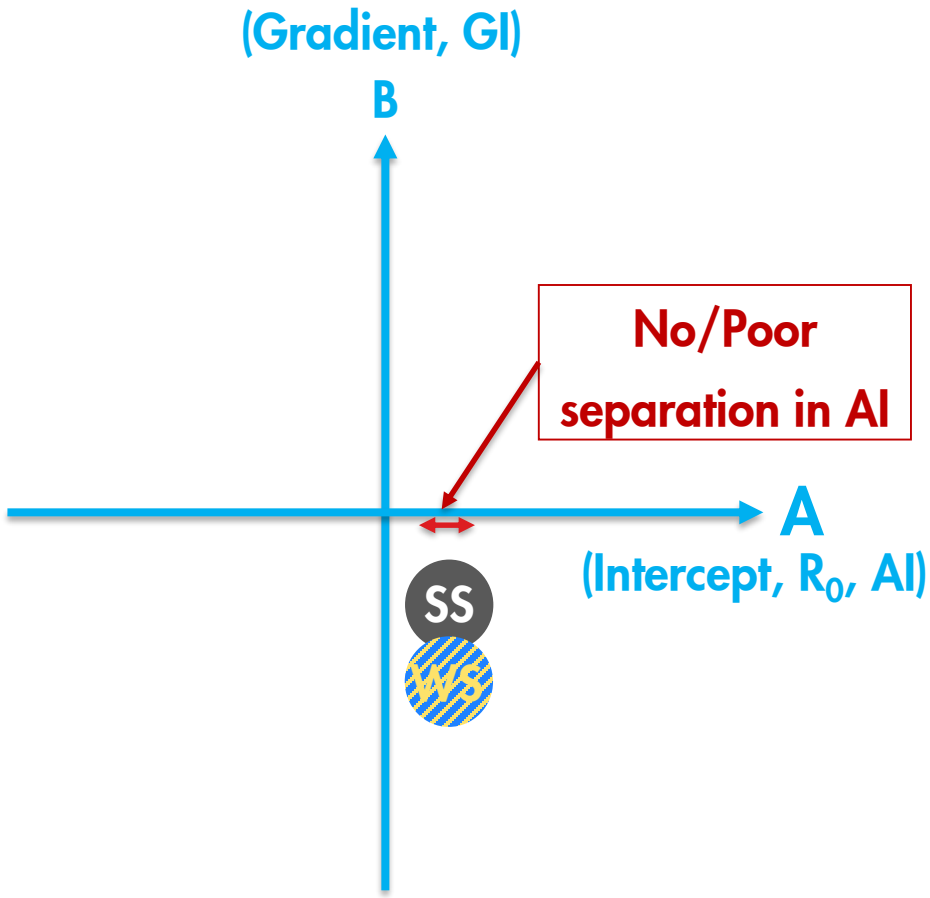
Acoustic Impedance vs V_p/V_s

- Oil Sands have a different AI to the harder shales but have the same AI as softer shales, mostly in the Tay interval.
- Therefore, Pre-Stack Attributes will help to distinguish Oil Sands.



A concept for Extended Elastic Impedance (EEI) and Chi

- The Shuey* approximation gives reflectivity, R, for a given incidence angle θ; $R_{(\theta)} = A + B \sin^2\theta$
  - With **intercept**, A (**AI**, zero offset reflectivity) and **gradient**, B (**GI**) respectively.



*Shuey 1985, Aki and Richards 1980

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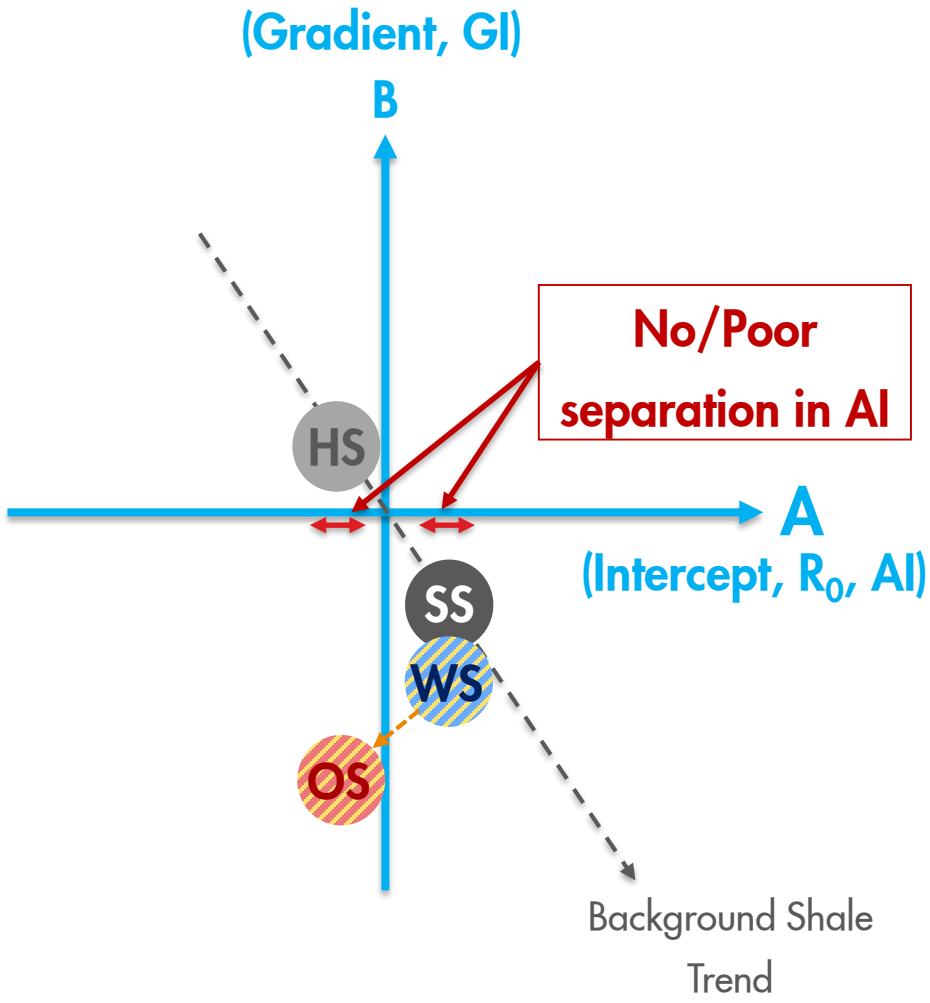

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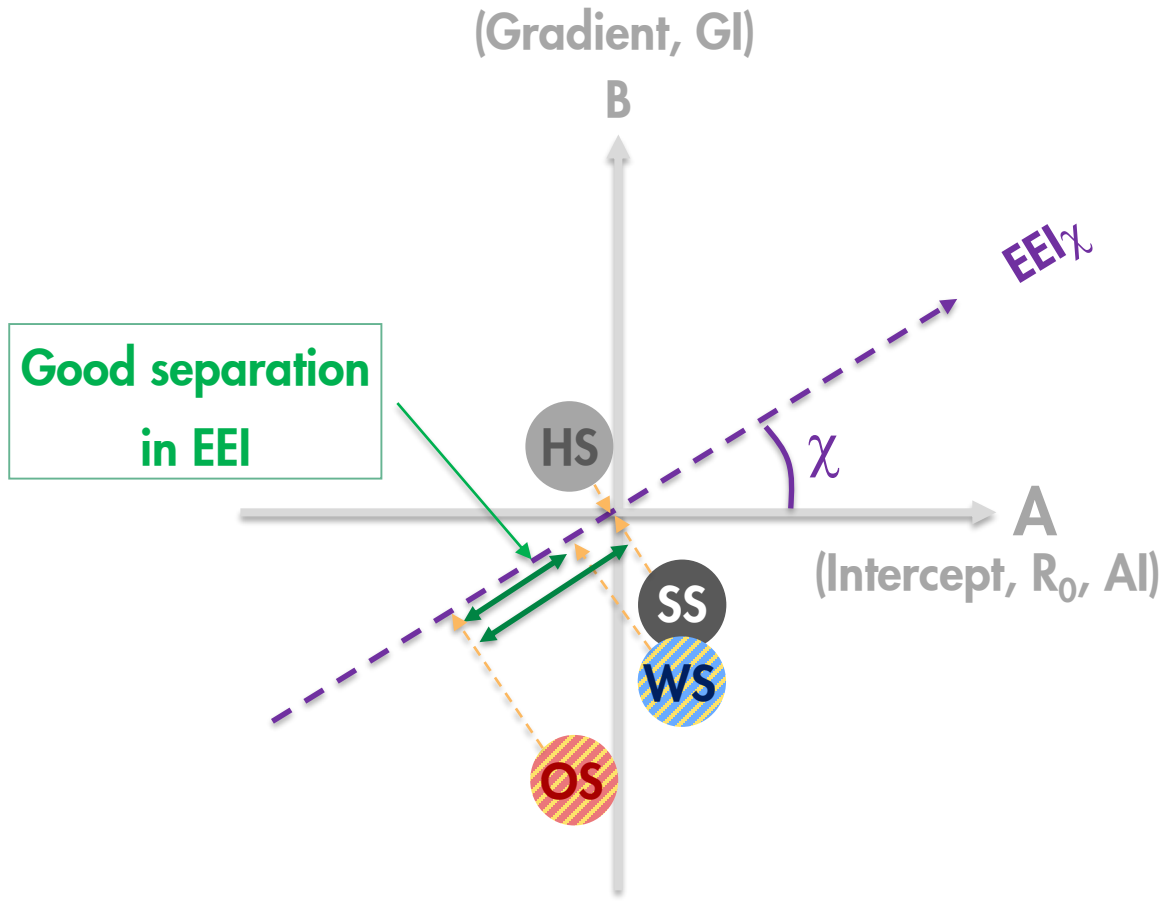
- Whitcombe et al. (2002) define EEI as:

$$\mathrm{EEI}(\chi) = \mathrm{AI}_o \left[\left(\frac{\mathrm{AI}}{\mathrm{AI}_o} \right)^{\cos(\chi)} \left(\frac{\mathrm{GI}}{\mathrm{AI}_o} \right)^{\sin(\chi)} \right]$$

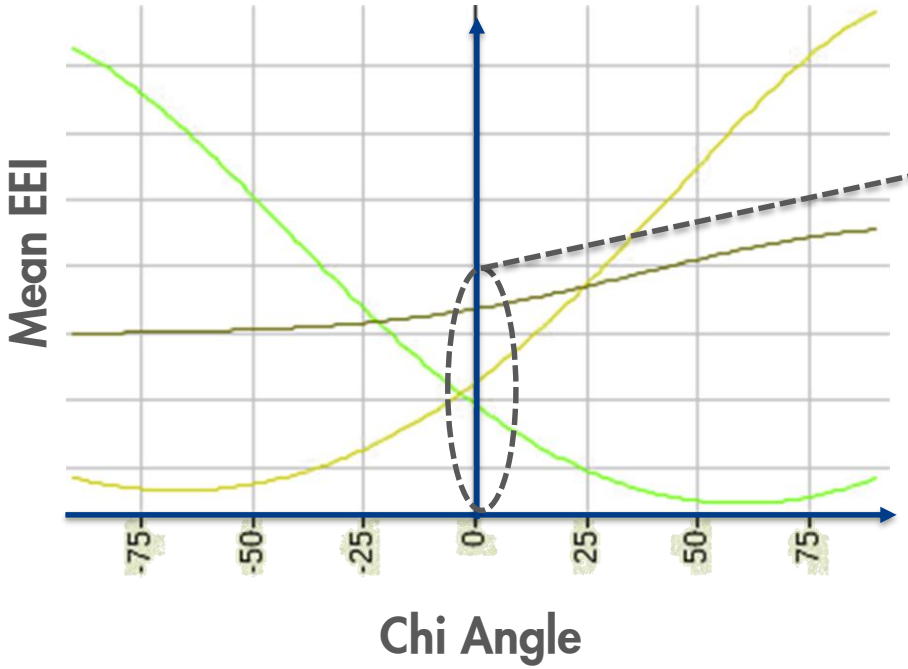
- Conceptually, this rotates the axis in an intercept-gradient plot by the angle χ and can improve separation of events indistinguishable in Acoustic Impedance, AI.



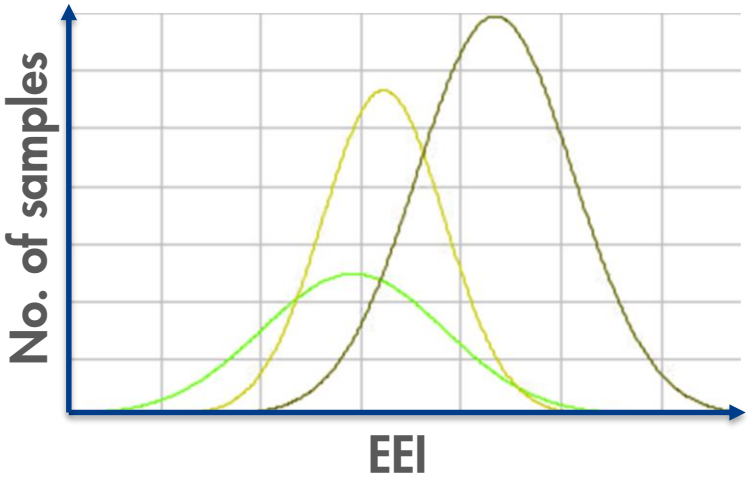
*Shuey 1985, Aki and Richards 1980

EEI Analysis – Oil Sands vs Shales

Oil Sands, Hard Shales, Soft Shales



Chi=0



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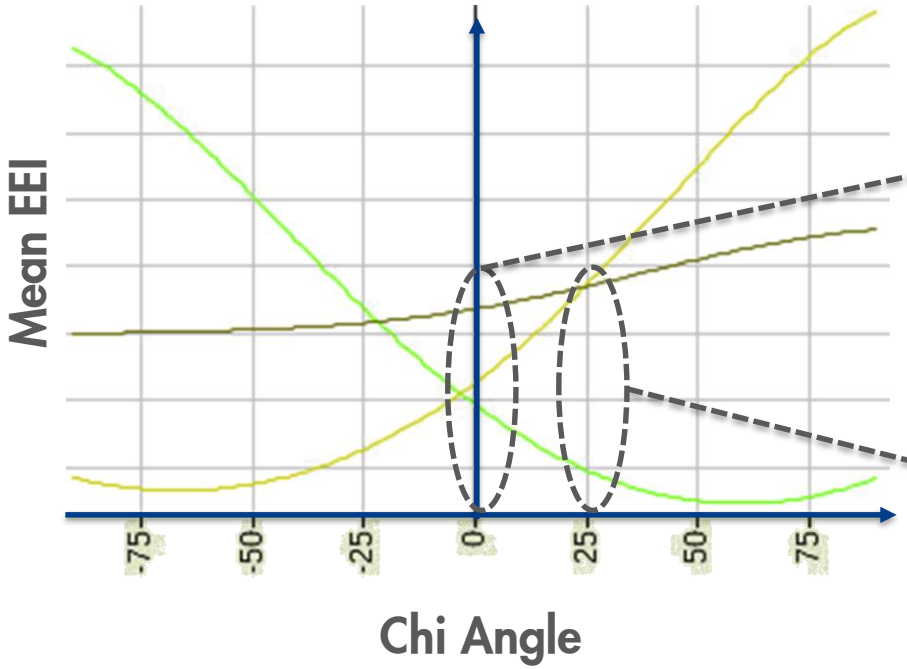
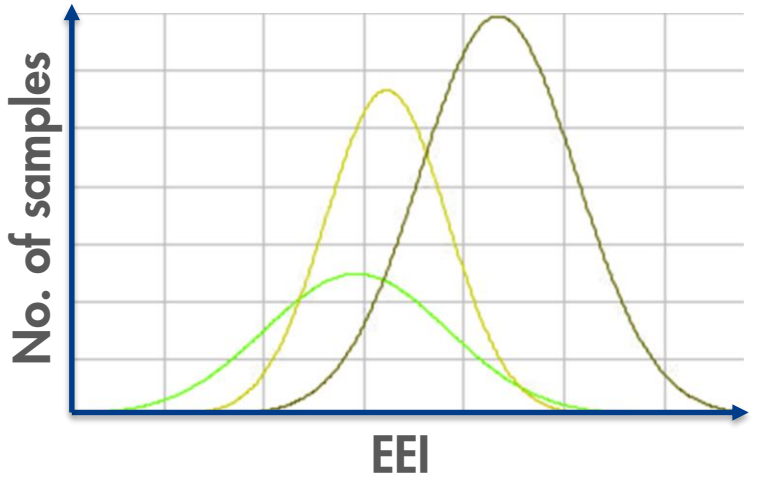
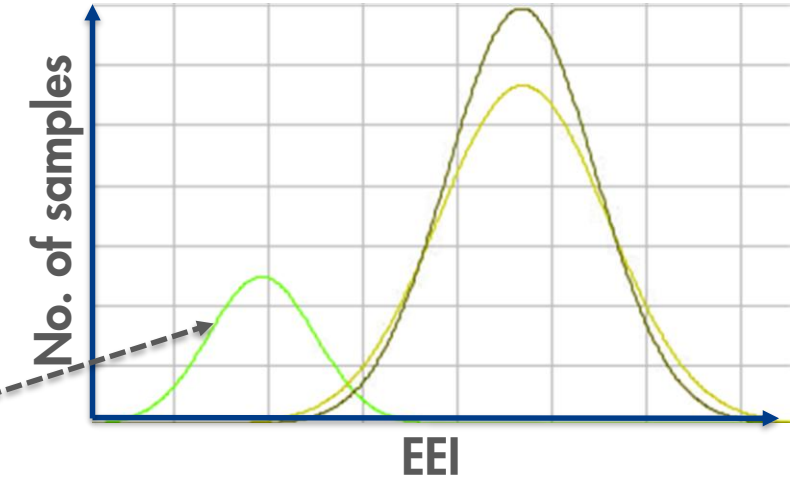


Chi=0

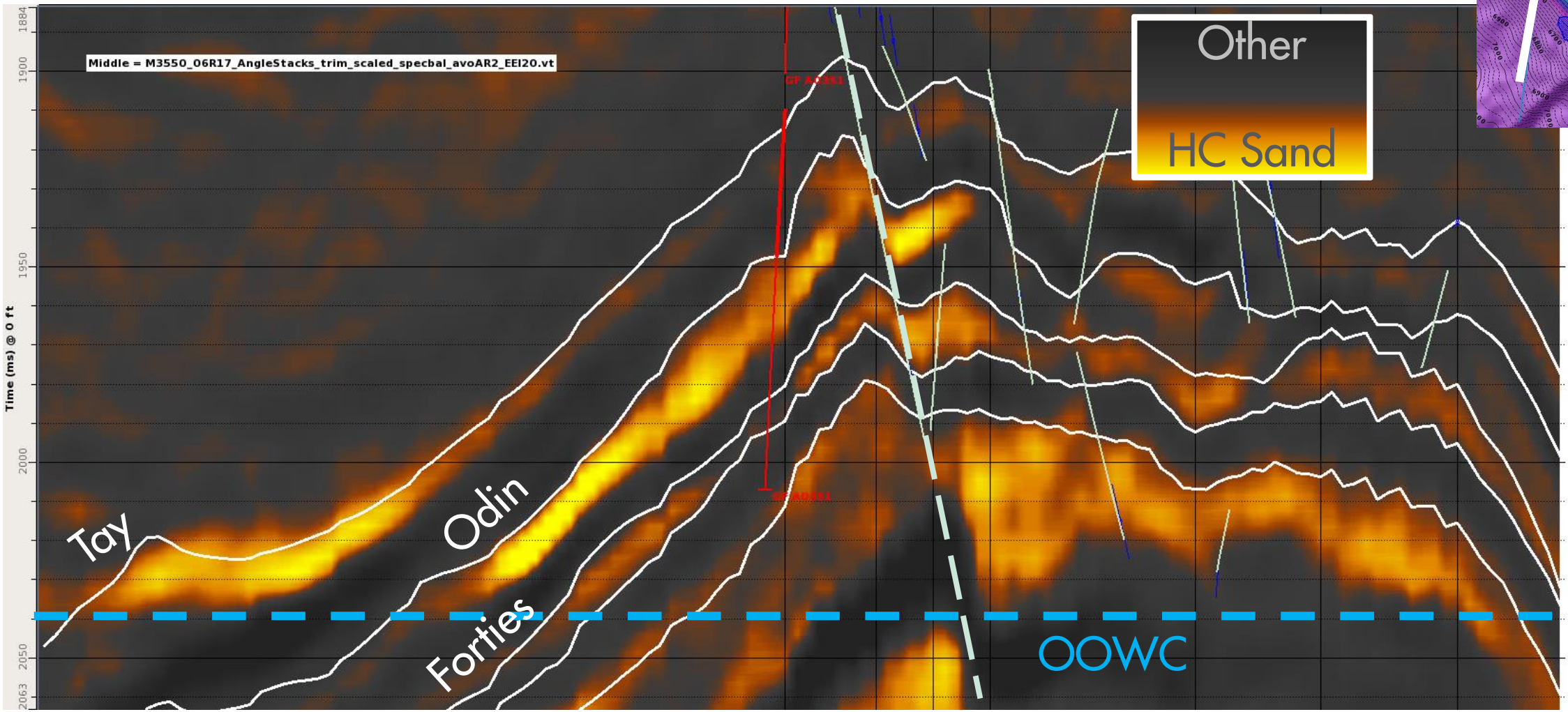


Chi=25

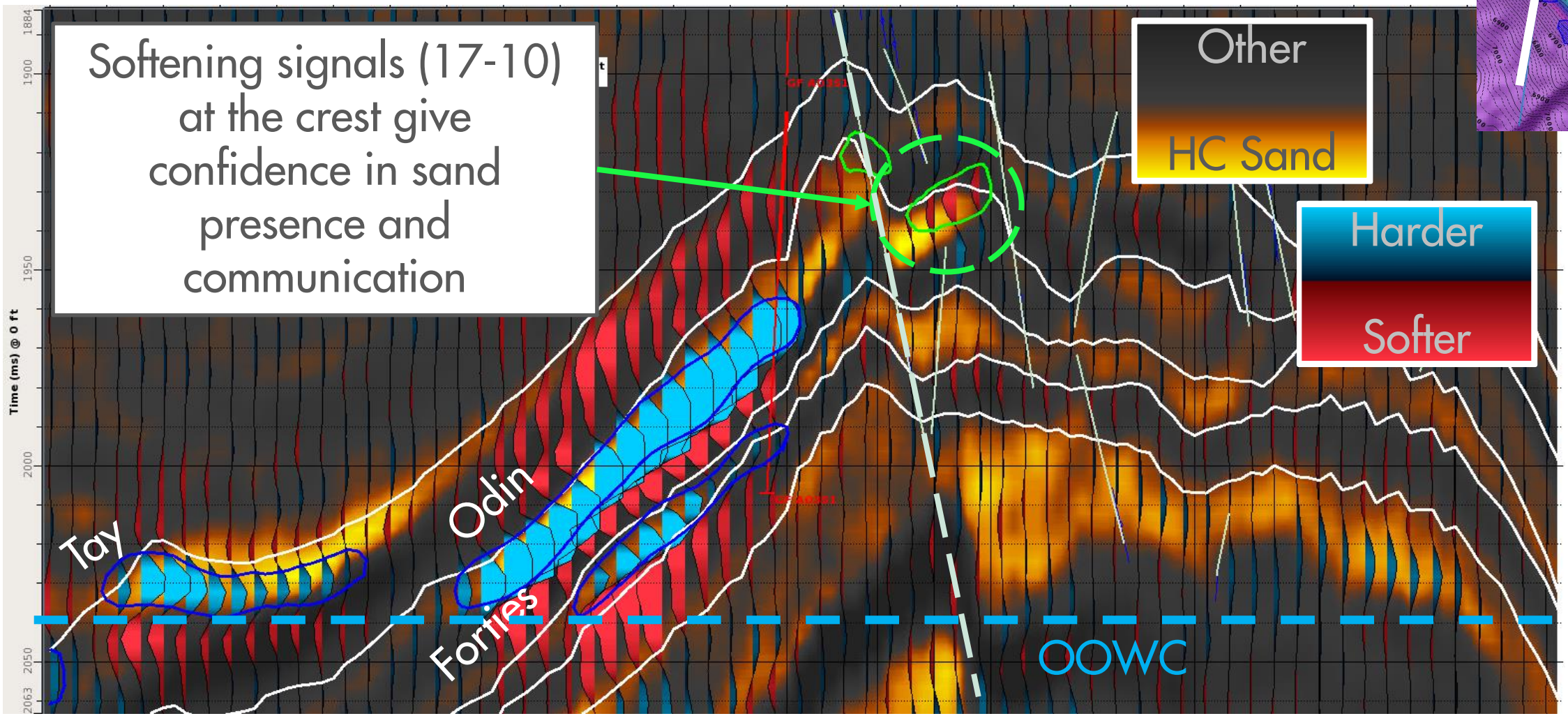


- Chi 25 aligns hard shales and soft shales but also greatly reduces overlap with oil sands in EEI space.

Updated 3D; Relative Extended Elastic Impedance Provides Evidence for crestal targets



4D Provides supporting evidence for crestal targets

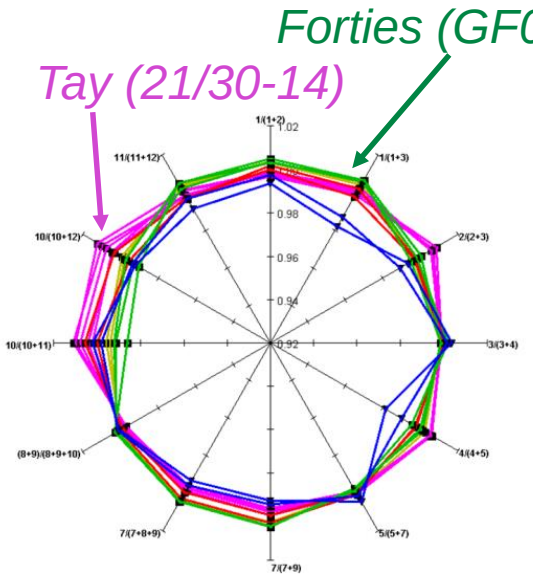


Integrating data; Can we believe the softening signals at the crest?

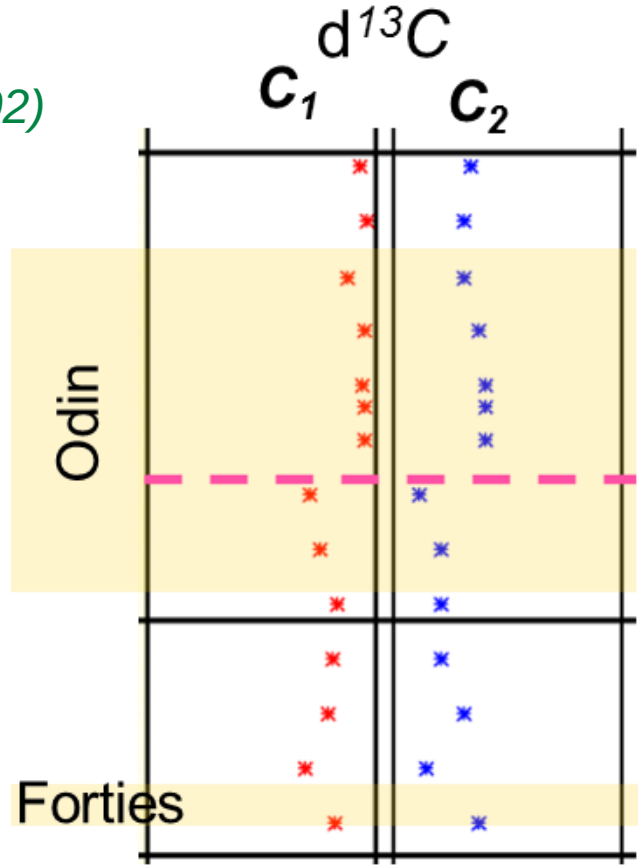
- Good connectivity and strong aquifer shown by a wealth of different data.
- Based on RFT data, we're ~200psi above bubble point at the crest.
- Given GFA03, we wouldn't expect Tay sands at the crest but we see softening in Odin and Tay.

- **Geochemistry,** provides compelling supporting evidence that fluids in the upper reservoirs are lighter so could be below bubble point

Fluid Fingerprints



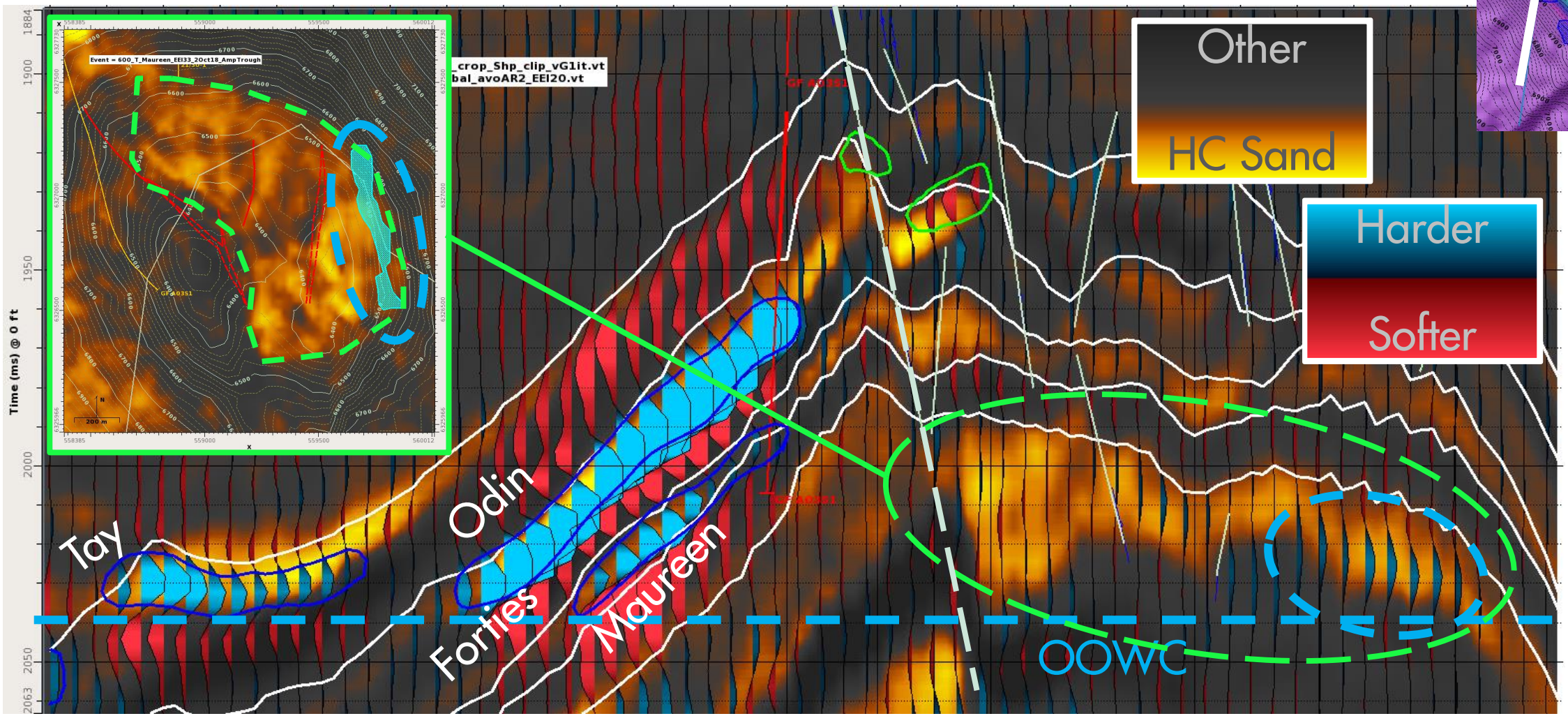
GF03 isotube isotope data



Meet Maureen; Is she a beauty or a witch?

Credit: Anon, 19th Century Germany

4D Shows tantalising hints of potential deeper Maureen



Meet Maureen; Is she a beauty or a witch?

GP

Looks great! It doesn't match a chalk response but we **can't rule out siltstone.**

PG

It's **outside regional GDE maps**. What concepts support it? **Risks of higher pressures.**

RE

It could be my **missing volumes** but water **could back out primary target production**

PP

Only **thin sands** encountered by nearby wells (fluorescing sidewall core). Analogues (for properties) are often far away.

WE

Getting there might be difficult. **Increased risk of sidetrack**

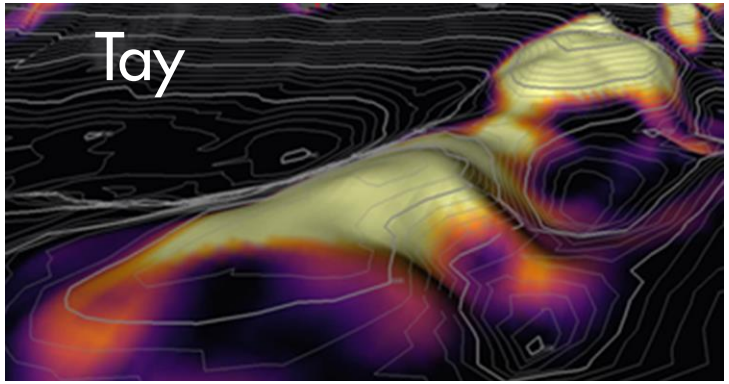
PT

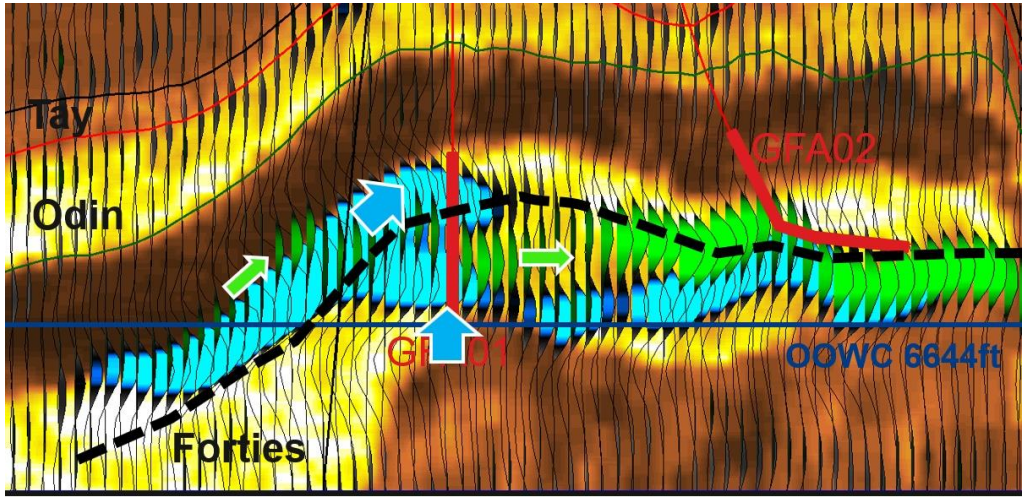
Increases the risk of water breakthrough. No constraint on the grain size for the completion.

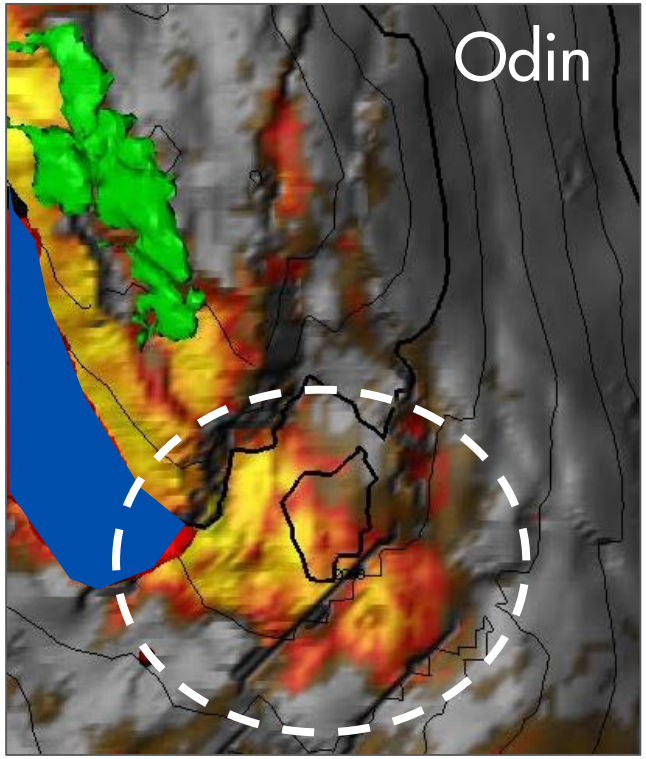
- And much more!

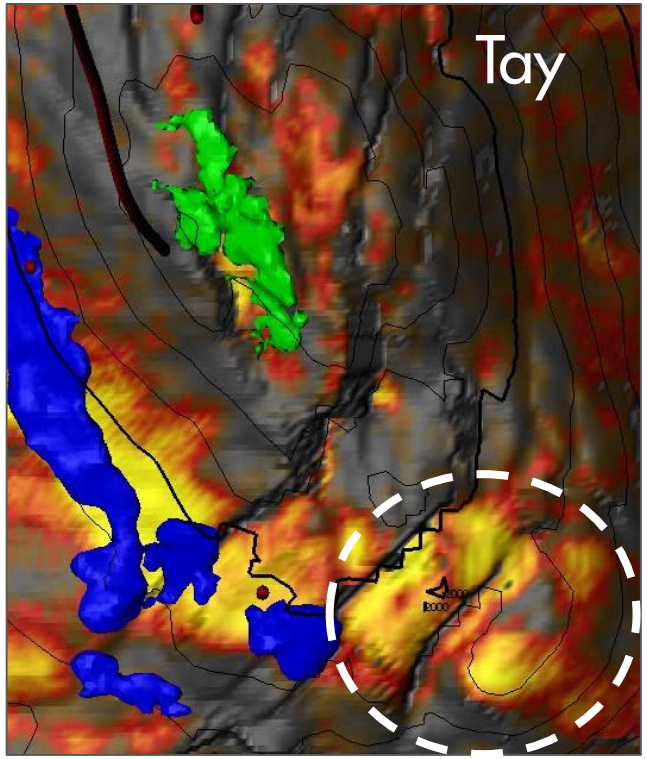
Considerations for the next 20 years...

- What are the volumes in the Tay, Odin and Forties to the South?
- What explains the tilted contact in the Forties at the North?
- Northern fault bounding Odin sweep or cusping?
- And more!









Conclusions and Impact

- Previously, 4D was used to drill & monitor 2 infill wells (GFA02 and GFA03s1)
  - **Delivering over 20 MMboe and among the top performing Shell CNS wells**
- The 4D and updated 3D is now being used to
  - **Prevent drilling swept reservoir** (previously identified next target)
  - **Justify an additional infill well**
  - **Highlight possible previously unknown/undocumented reservoir** (can be targeted by the same infill well)
  - **Bolster and add to opportunities in the South (some not previously documented)**
  - **Support WRFM**: highlighting the importance of ensuring GFA02 is kept on production

Acknowledgements

Shell Gannet F Subsurface Team

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Charles Ileagu (RE & Opportunity Manager)
Susannah Stott (Well Engineer)

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Stacey Emmerton (Geophysicist)
James Harrison (Geophysicist)

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Thomas Piesold (Acquisition)
Richard Shipp (Processing)
Dan Bright (Processing)
Steve Gouldesbrough (Processing)
Pim van Bergen (Geochemistry)

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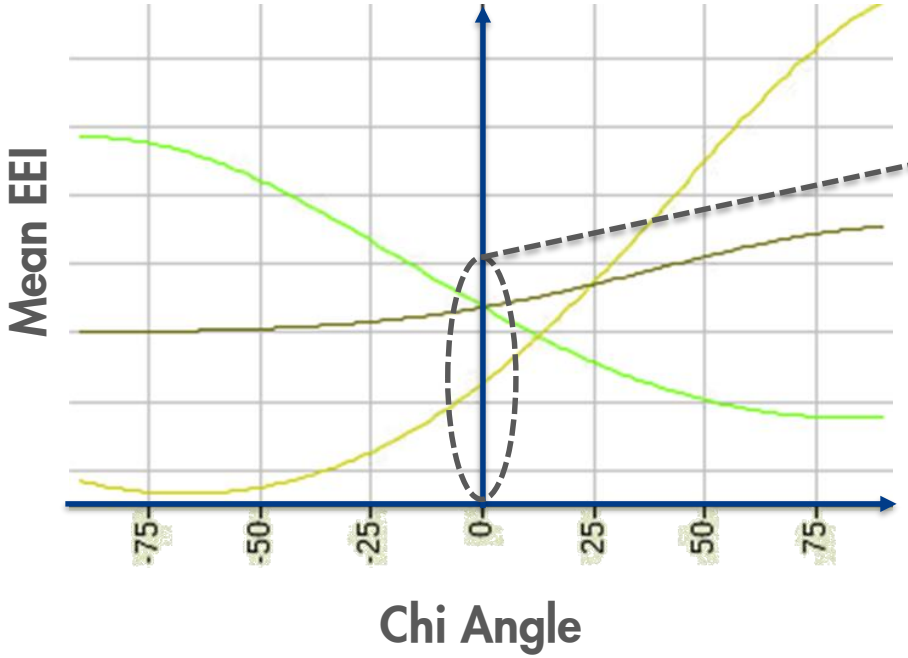
Dag Isaksen (Operations Technical Manager, Geoscience)
Jon Saundry (Joint Interest Reservoir Advisor)

Questions and Answers

EEI Analysis – Wet Sands vs Shales

Wet Sands, Hard Shales, Soft Shales



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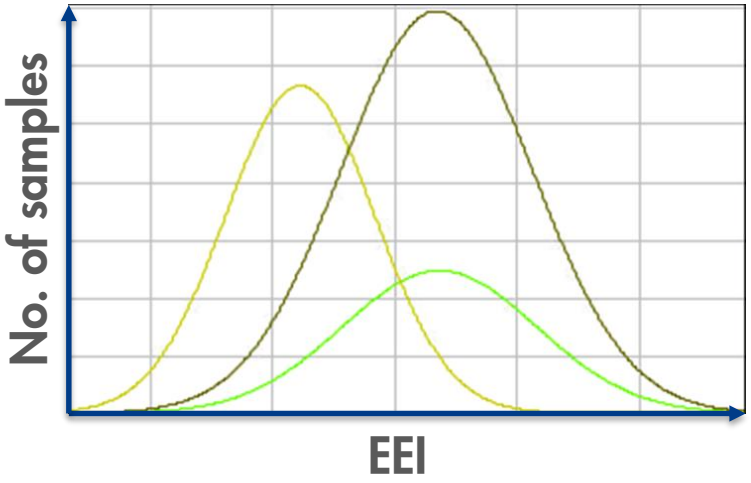

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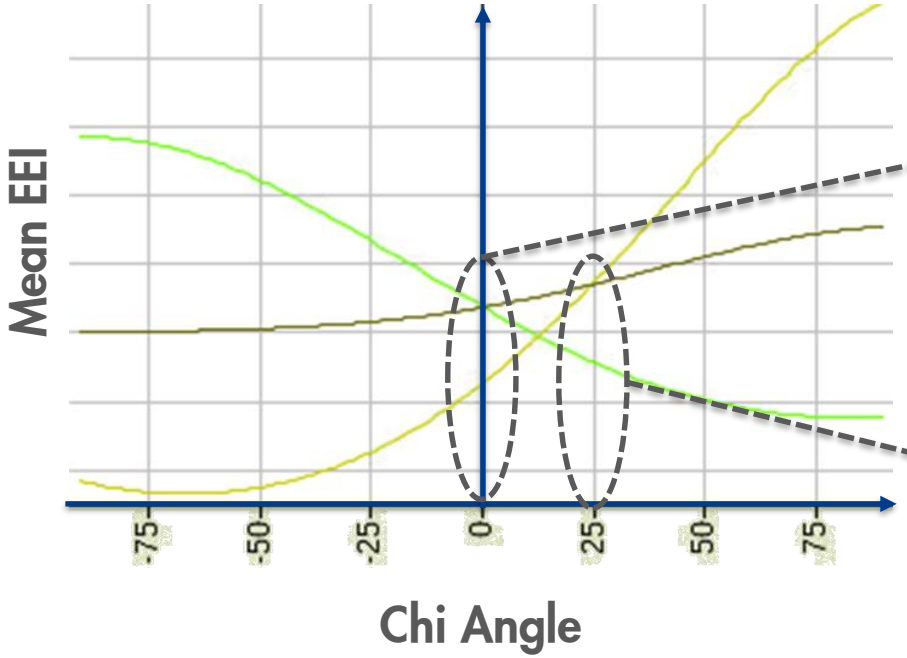

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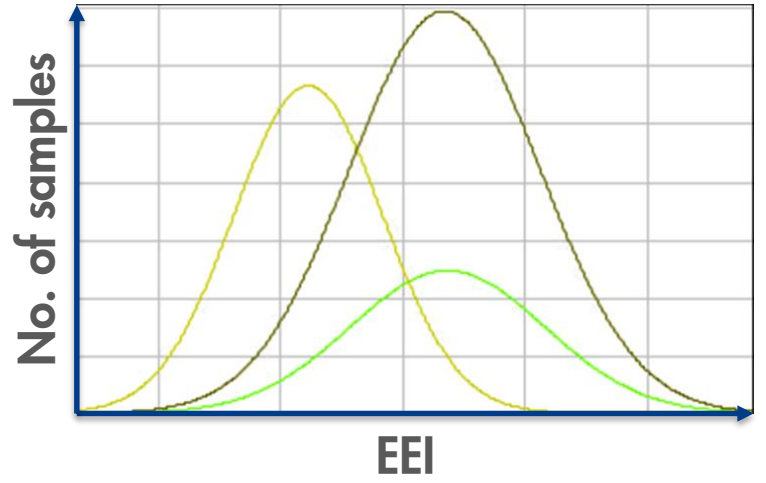
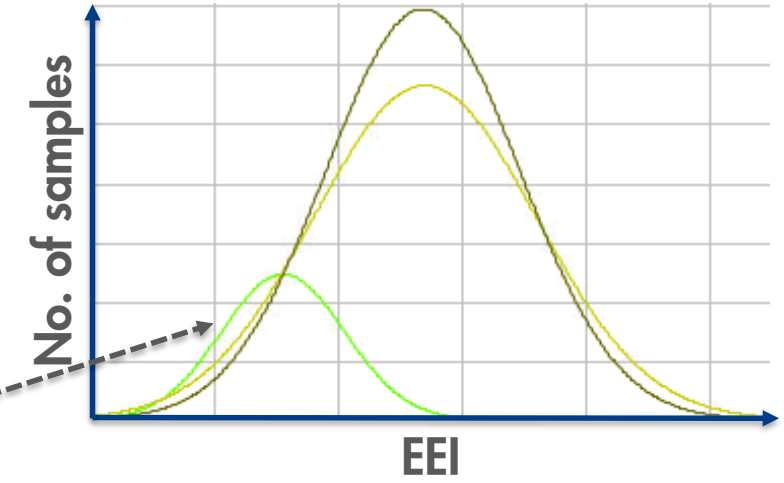


Chi=25



- Chi 25 aligns hard shales and soft shales but also greatly reduces overlap with wet sands in EEI space.