Well planning in fractured and faulted sandstones,Clair Field (Phase 2)

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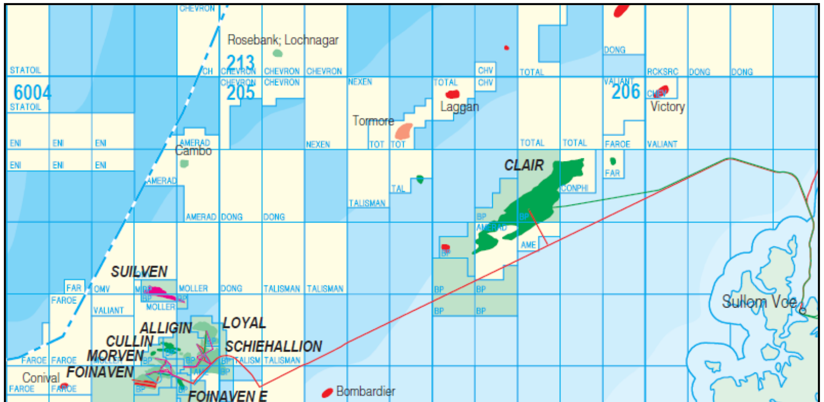
Objectives

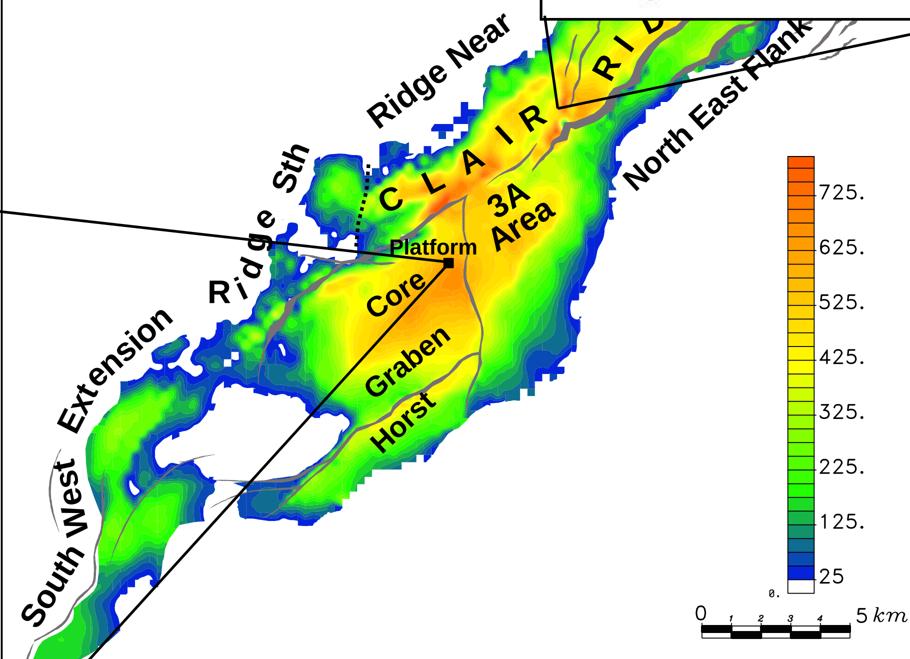
- Presentation of the various aspects of structural geology relevant to detailed planning of Clair Phase 2 wells
- Outline data and techniques used to place wells for intersection of potentially productive fractures and avoid sealing faults
- 3 scales of faults/fractures considered along the wellpath
  - Joints (sub-seismic)
  - Small faults (seismic, throw 10s m)/fracture swarms
  - Segment bounding faults (seismic, throw 100s m)

Clair Field Location



Partners
BP (Operator) 28.60%
Shell/Hess 27.97%
ConocoPhillips 24.00%
Chevron Texaco 19.42%

CLAIR FIELD AREAS
Phase 1 Development Area =
Core Graben and Horst
Phase 2 proposed development area =
Ridge Near and Ridge Far
(or Phase 2 South and North)

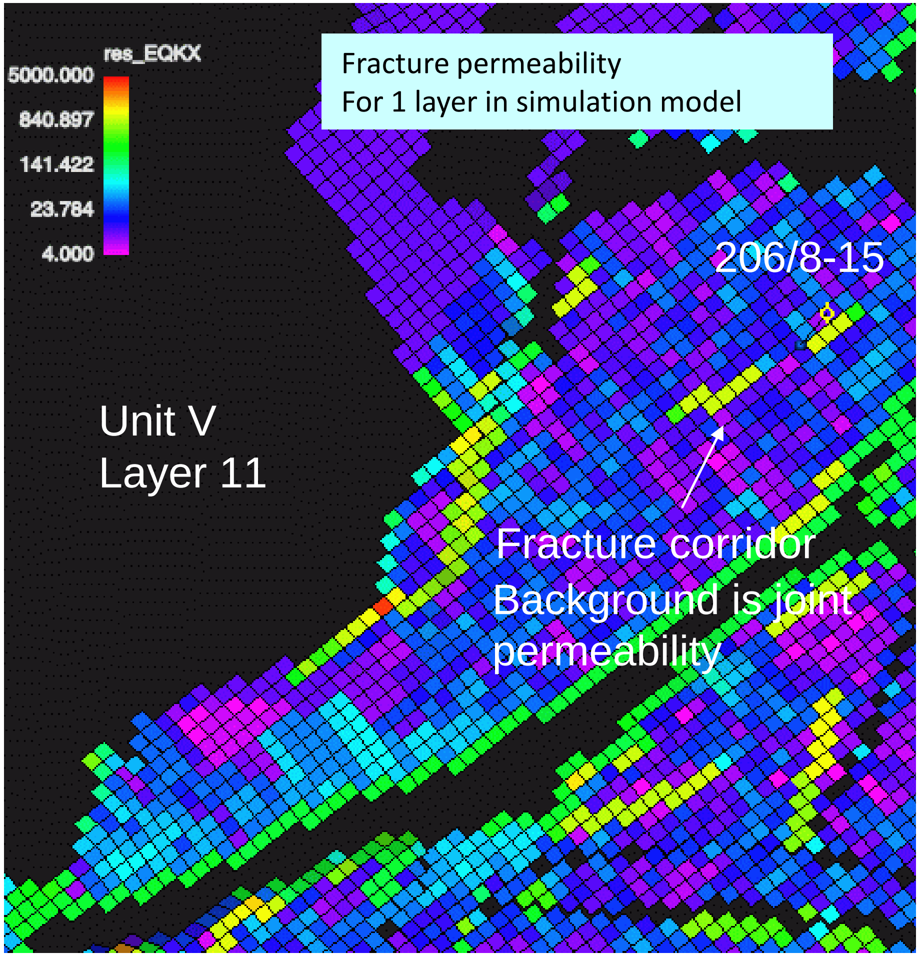


Discovered in 1974
1977 – 1980: vertical appraisal wells failed to confirm economically recoverable reserves
1990s: improved understanding of influence of natural fractures upon productivity and horizontal well technology
2005: First oil
17 wells drilled to date recovering *c.* 62 million barrels of oil

1. **Joints** in reservoir for no. of wells and well layout

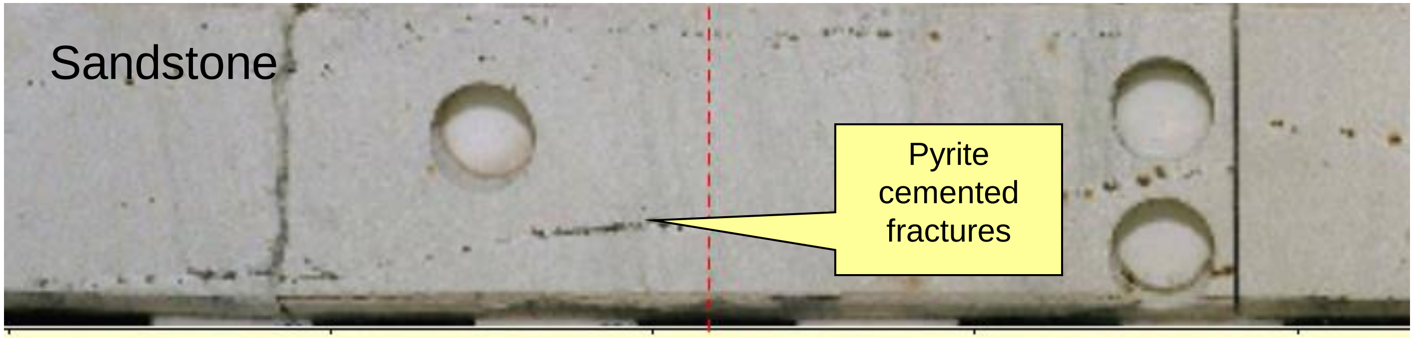
- **Why is this important ?** As joints (and good quality matrix) determine degree of connectivity between wells

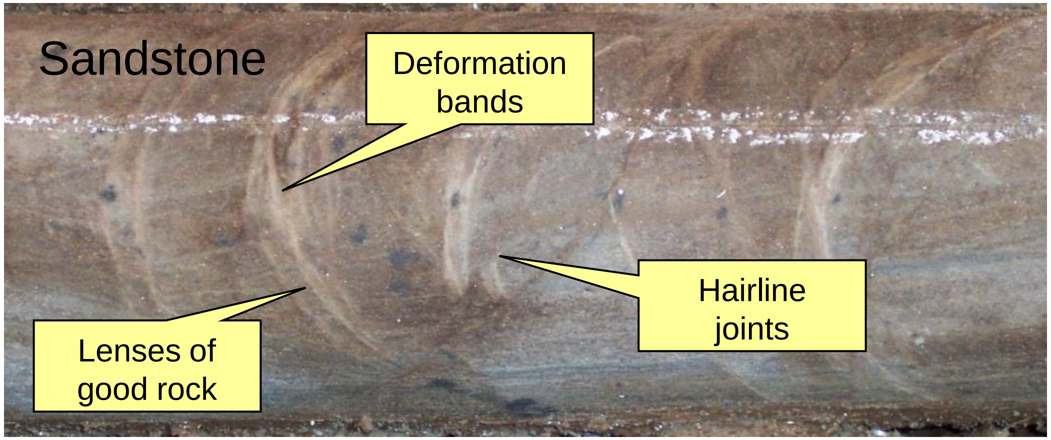
- **How ?** Joint density (from well data and outcrop study) captured as a case during depletion well planning in simulation model

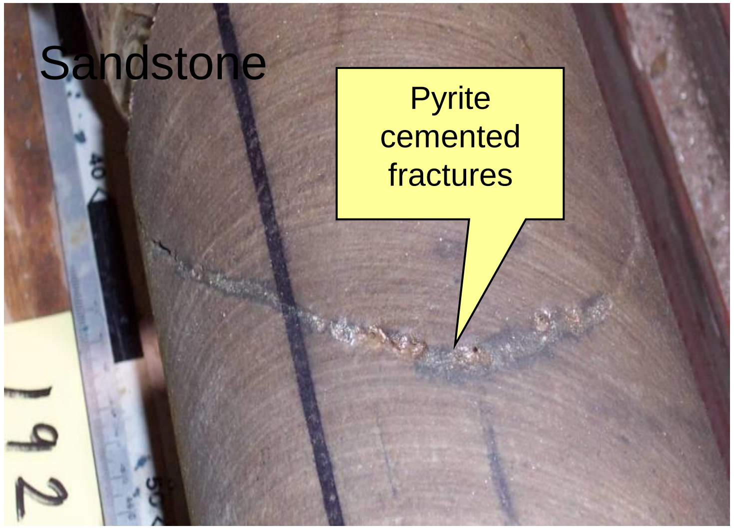


1. **Joints** in reservoir for no. of wells and well layout

- Note that some joints are cemented and the core also contains numerous deformation bands
- These may negative impact upon oil sweep but are cross-cut by later open (conductive fractures)

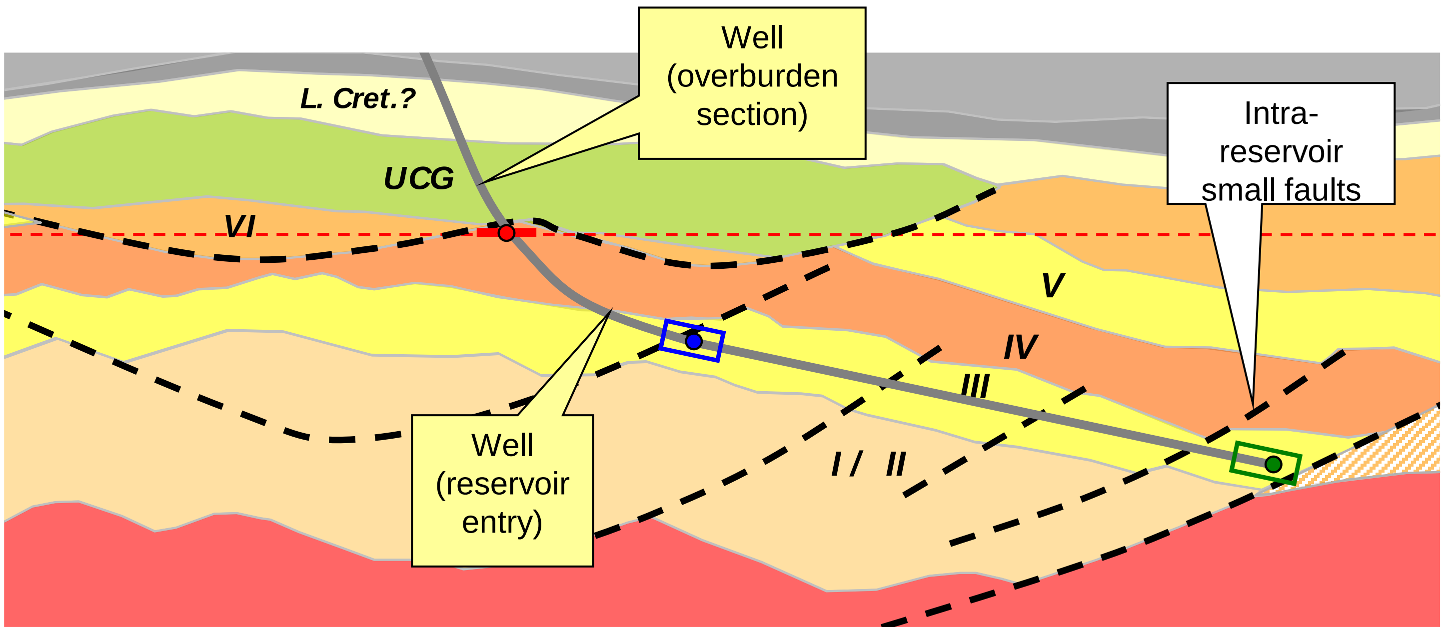




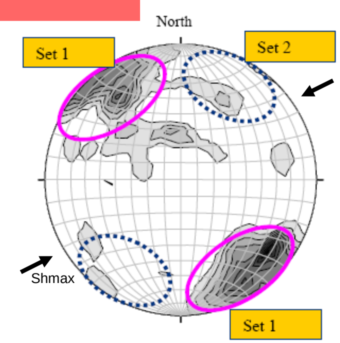


2. Open **small faults** in reservoir section

- **Why is this important ?** As in some cases they are required for productivity (e.g., in 1 appraisal well, 85% of flow through a single feature), in others they help it



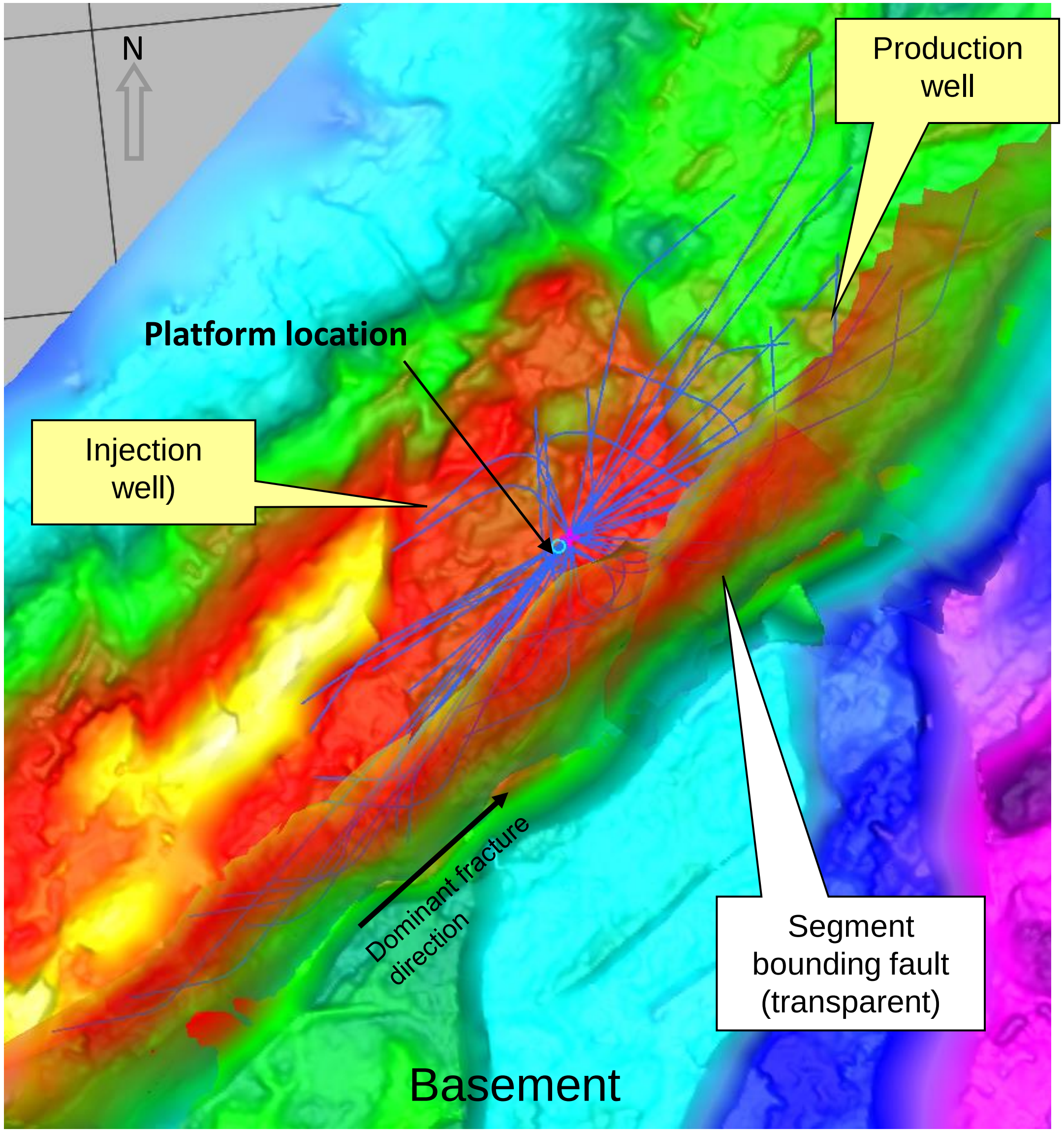
- **How ?**
  - Open fracture orientation studied from well (and core) data



2. Open **small faults** in reservoir section

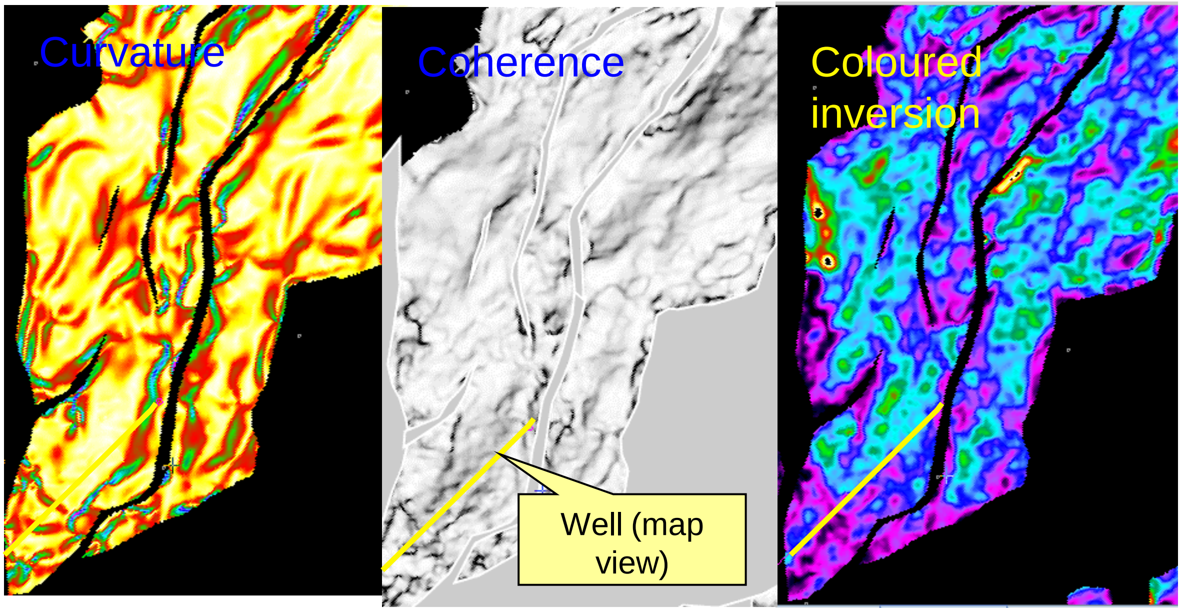
- Production wells intersect dominant fracture direction at ~ 45 degrees

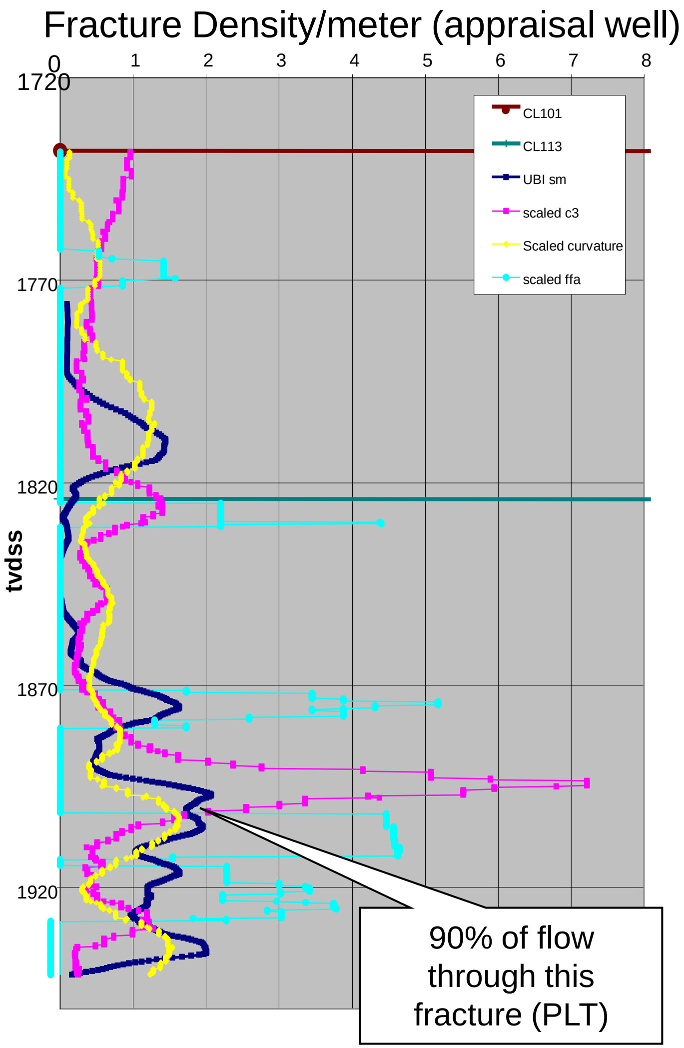
- Injection wells can parallel dominant fracture direction



2. Open **small faults** in reservoir section

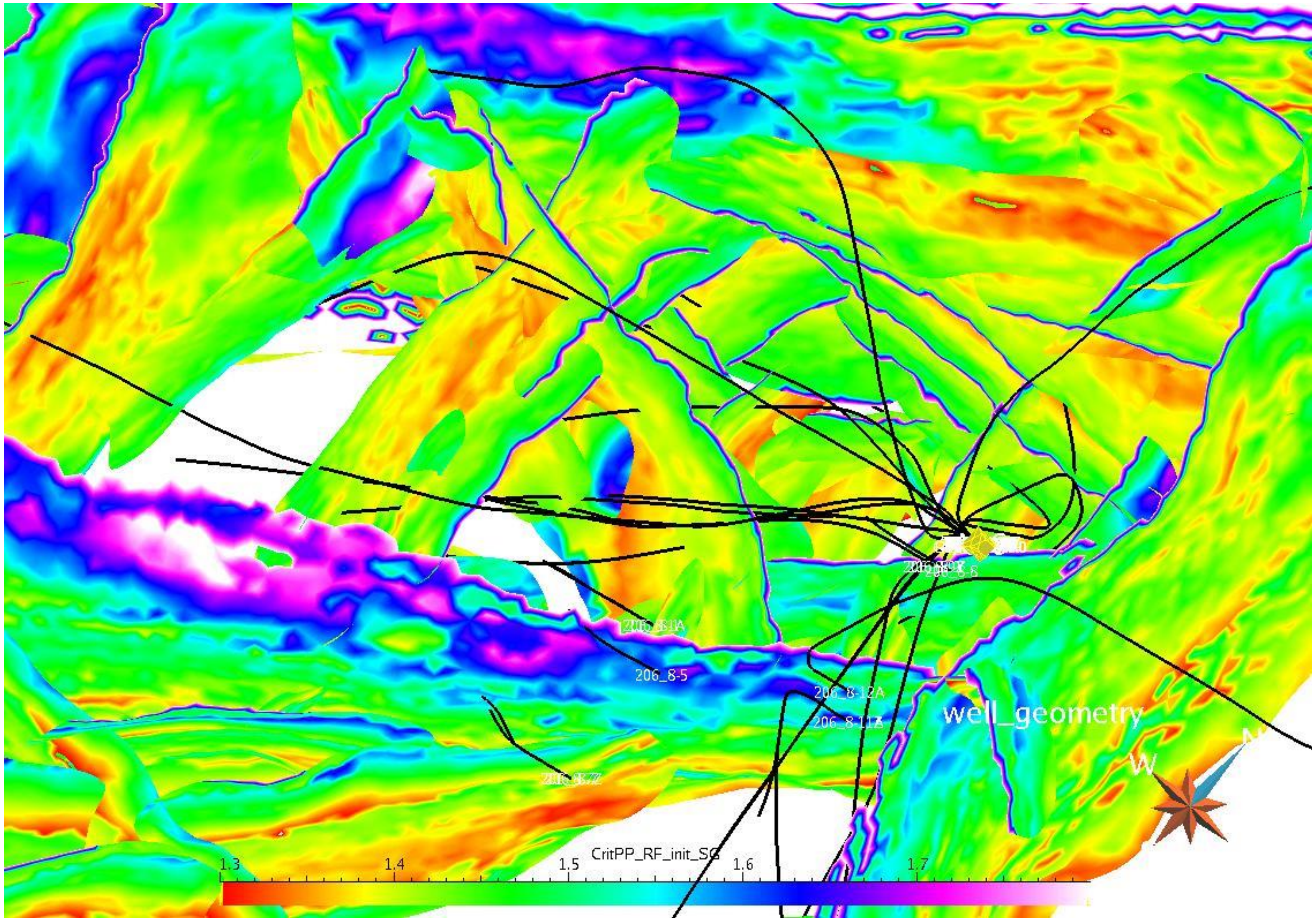
- There is no single attribute that can explain fracture density at wells
- Use all available seismic attributes to intersect fracture swarms





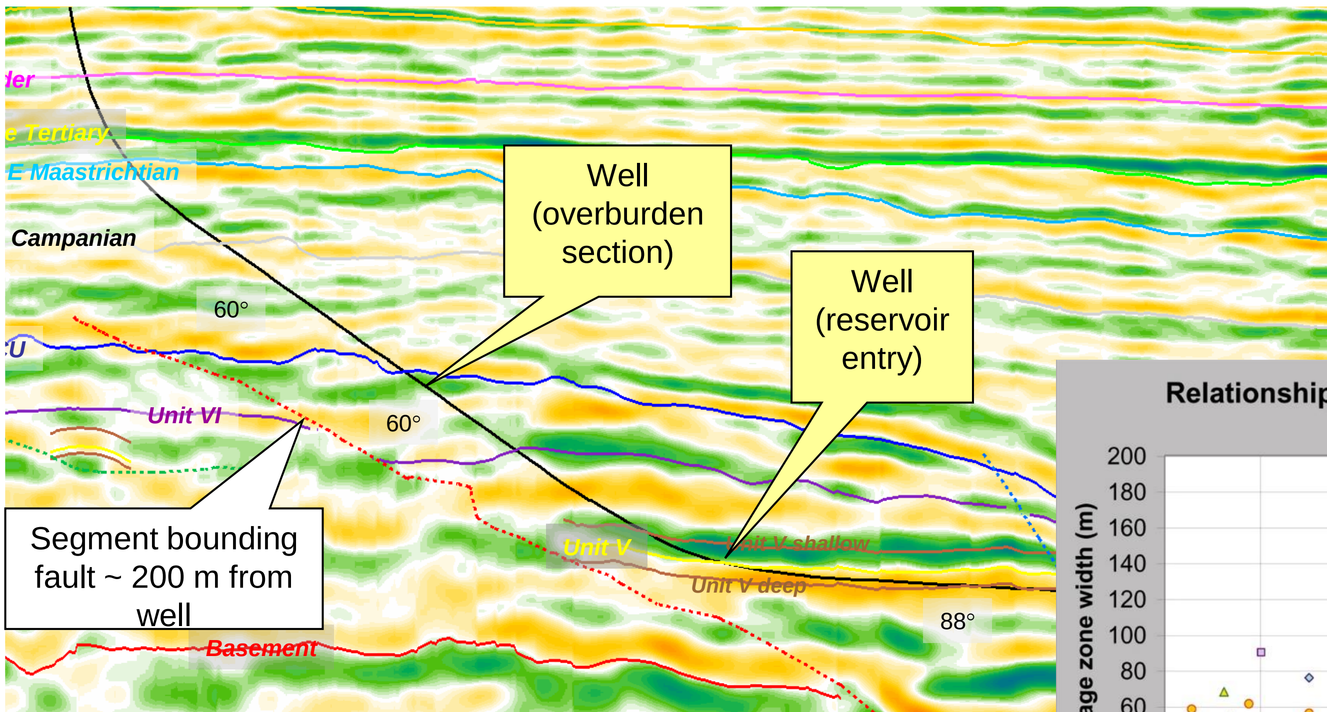
2. Open **small faults** in reservoir section

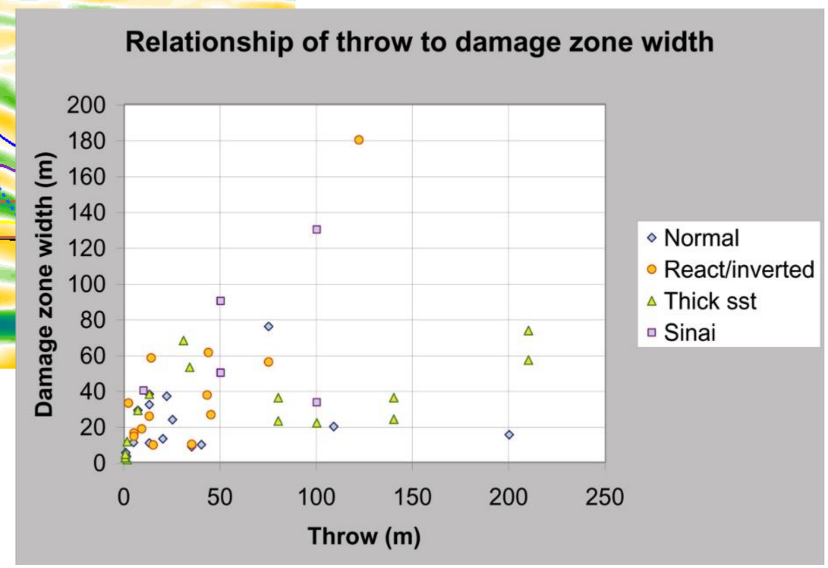
- **Some work in progress:** Pore pressure change required for fault reactivation (red = closest to critical)
- Assume that the most critically stressed faults (those which would require the least overpressure to reactivate) will have associated open fractures and be the most conductive
- Extended well tests can tell if the well sees a boundary i.e., sealing fault



3. Stand-off from **segment bounding faults**

Why is this important? To allow the stratigraphy to be tagged as a "countdown to entering the reservoir and to avoid difficult drilling in fault damage zones



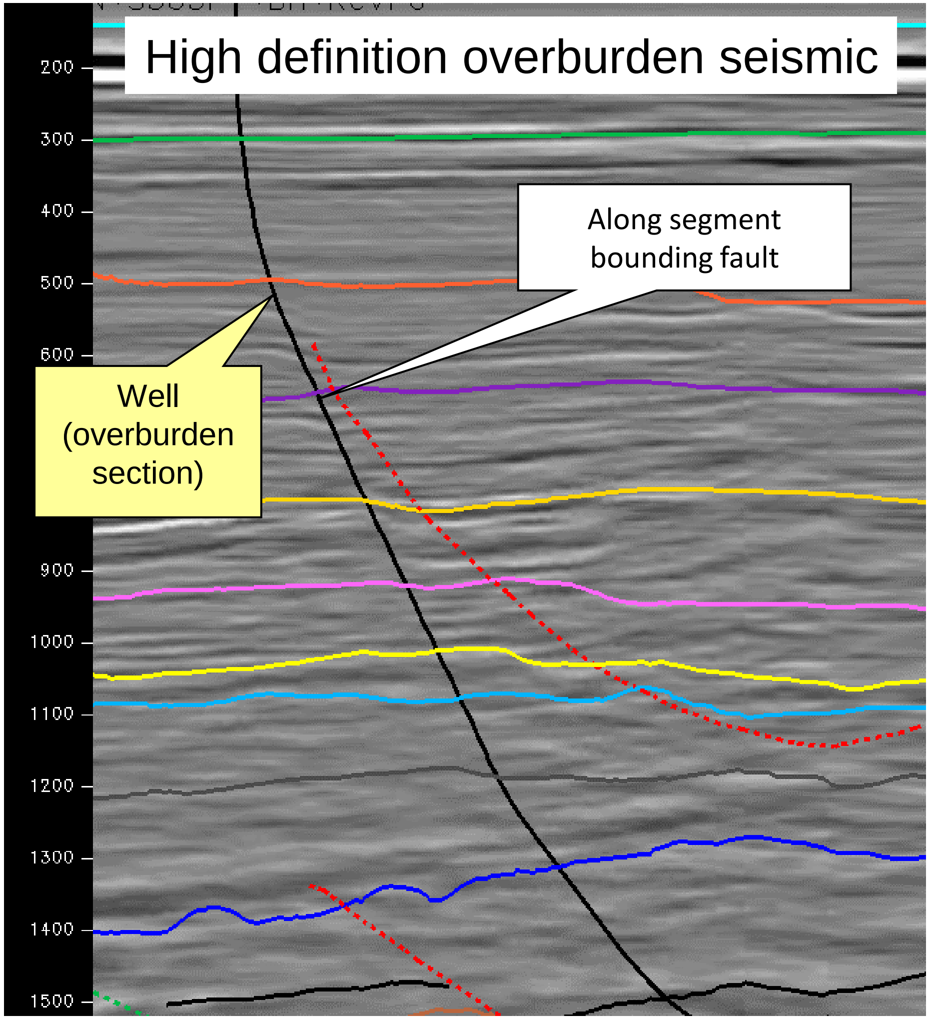


Guideline only, not simple relationship

How? Use ~ 100 m stand-off; which accounts for ~ 50 m damage zone thickness and ~ 50 m seismic uncertainty

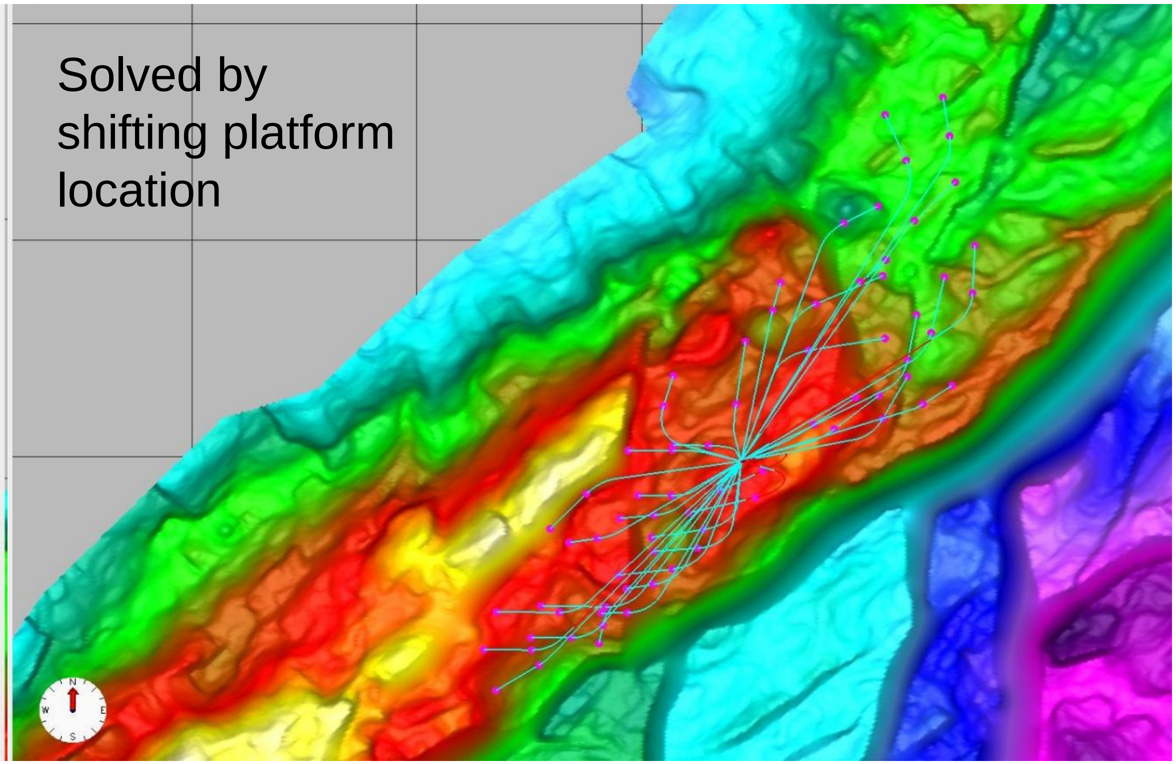
3. Stand-off from **segment bounding faults**

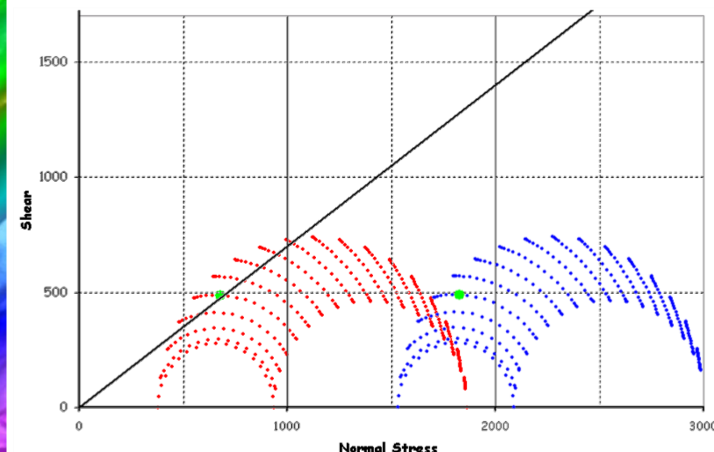
- This example shows that the well runs along a fault in overburden section and should be shifted



4. Avoiding drilling through or down **segment bounding faults**

- **Why is this important ?** As production/injection fluids can lubricate the fault, causing well mechanical failure and there is risk of wellbore collapse due to compaction induced subsidence and fault reactivation

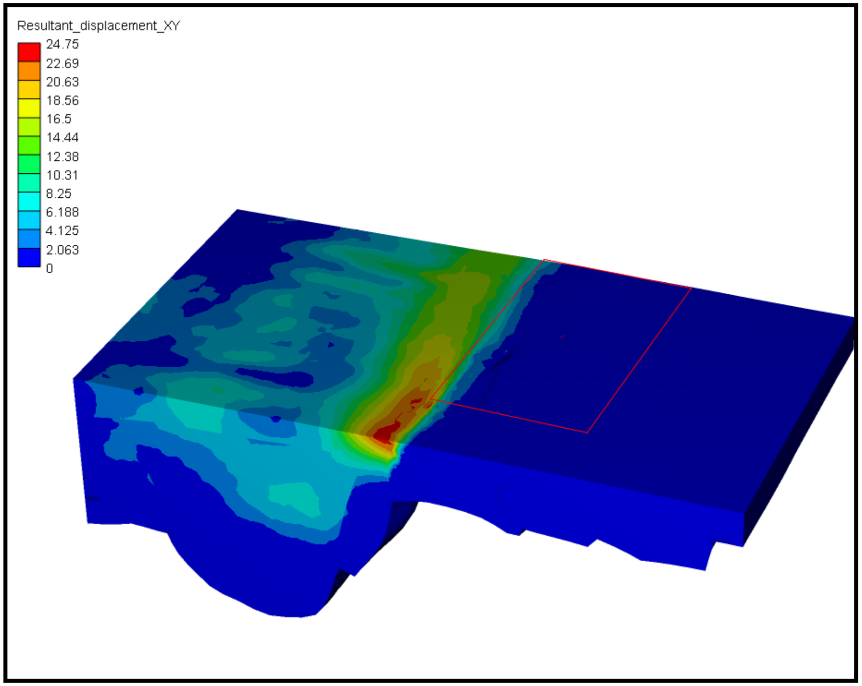


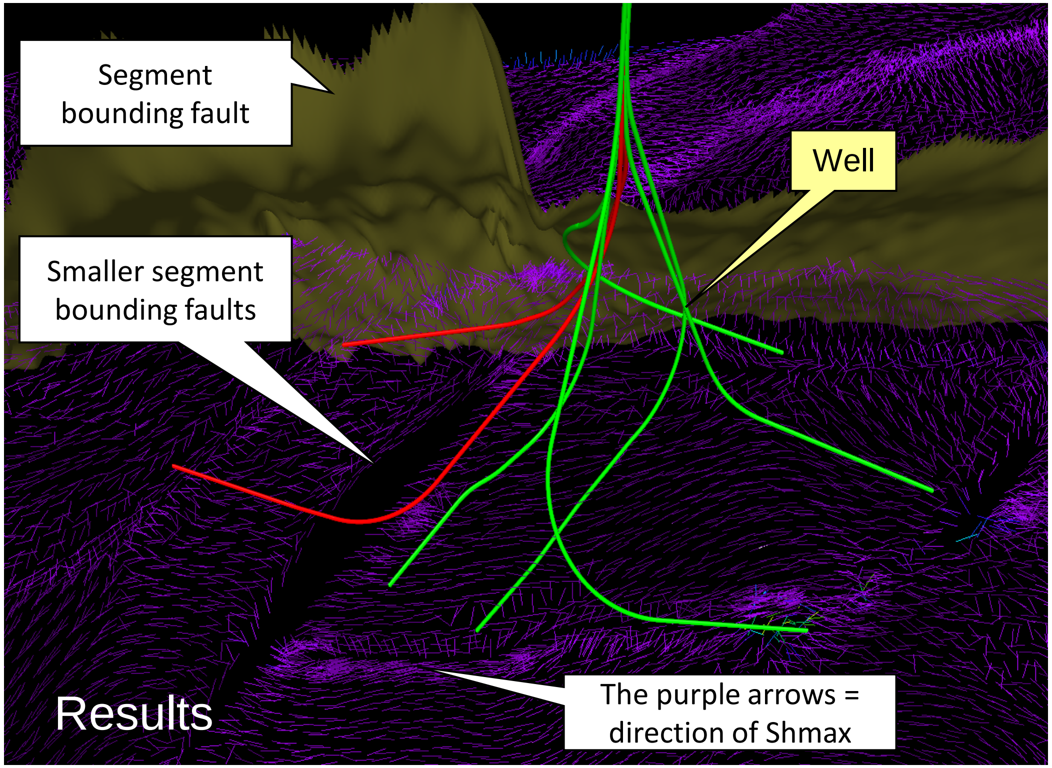


Novel approaches – FEM for fracture prediction in reservoir

- In-situ stress predicted by Finite Element Model (FEM) – used for wellbore stability in overburden and for open fracture prediction in reservoir

Regional model (and detailed, red box)





Conclusions

- Aspects of structural geology relevant for detailed well planning outlined
- Intersect open (conductive) features in reservoir section to enhance productivity
- Avoid sealing features if possible as adverse effect on reservoir performance
- Avoid planning well down seismic scale bounding fault planes and allow > 100 m stand-off from fault

We would like to acknowledge the support and input of the Clair partnership and Stephan Bergbauer and Aubrey Hewson (BP)