Naturally Fractured Reservoirs in the UKCS

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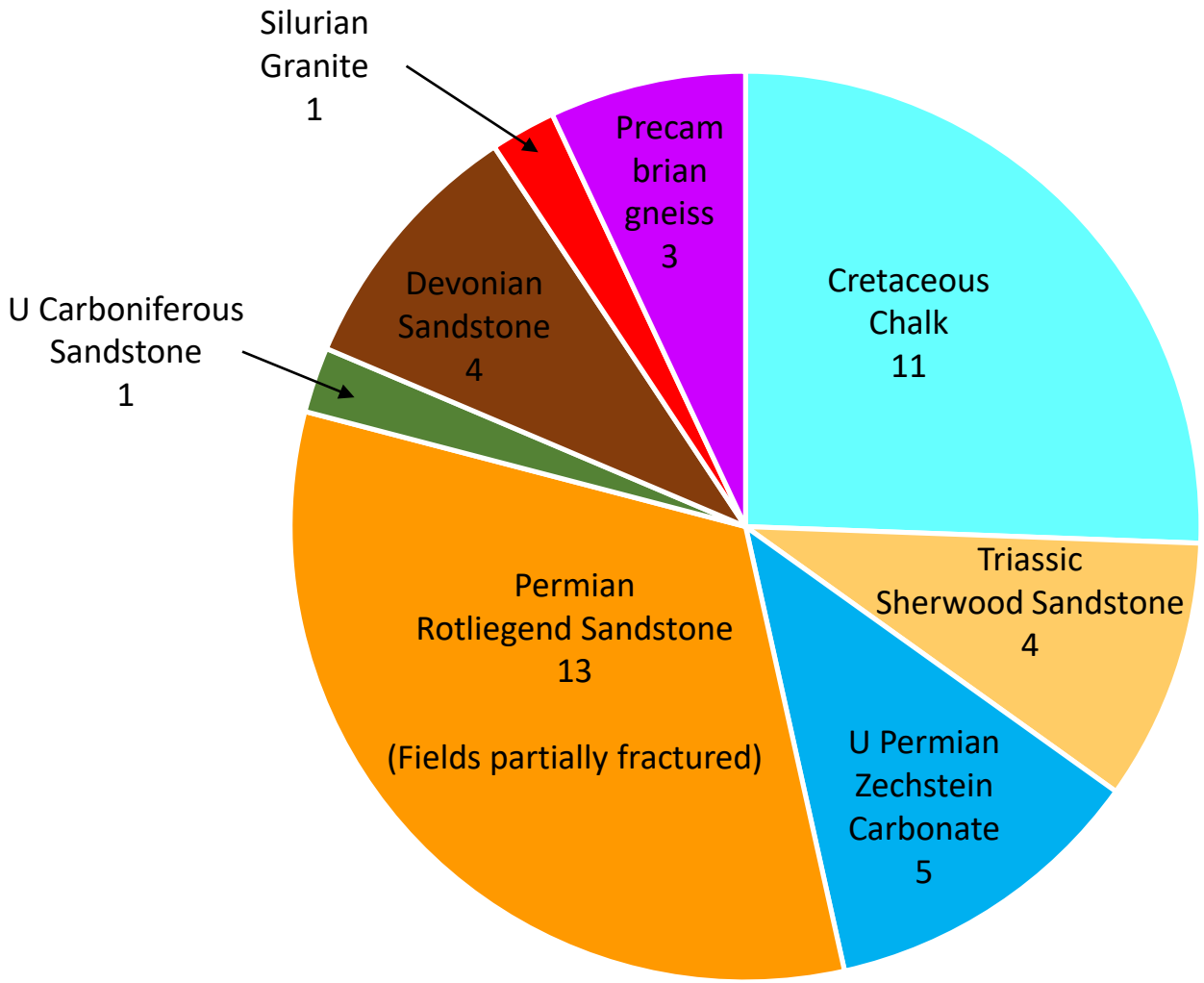
AGR TRACS

GLOBAL TECHNICAL EXPERTISE & SOFTWARE SOLUTIONS

UKCS Fractured Reservoirs – Units & Lithologies



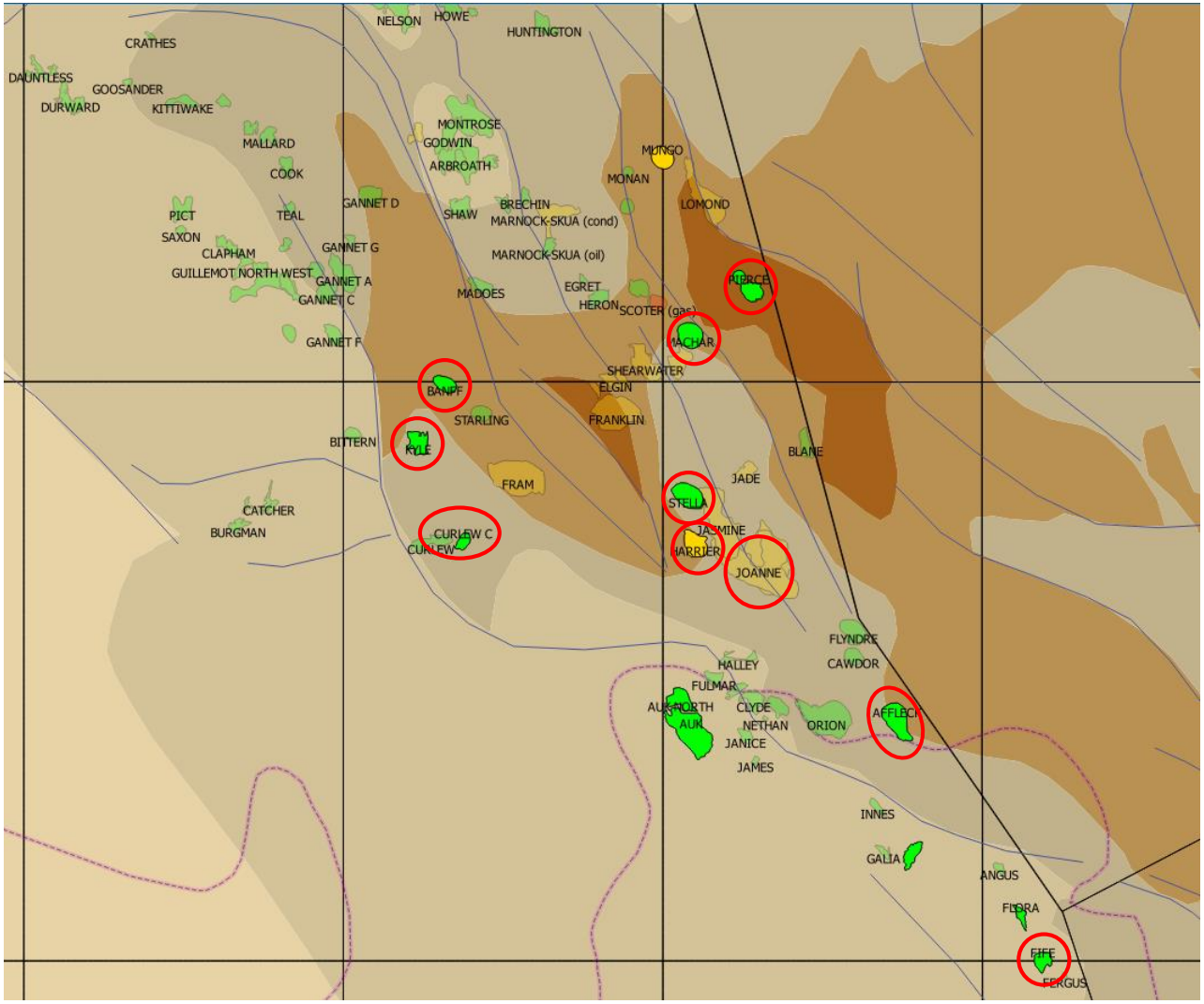
Definition:
Fields where natural fractures (joints, veins or faults) enhance flow compared with the matrix

470 UKCS fields analysed

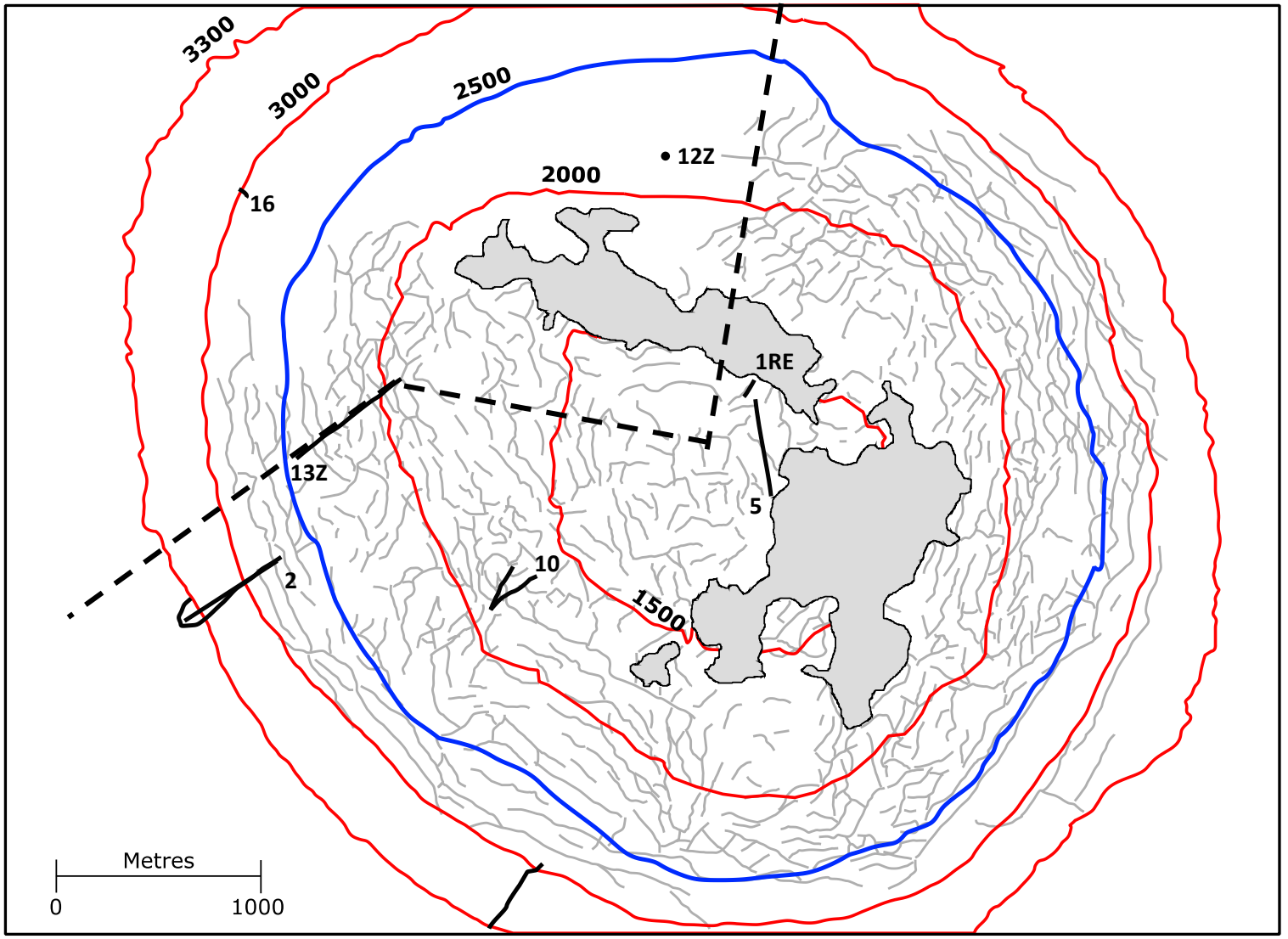
38 NFR fields (8% of total). Number of fields up for debate!

Talk focusses on long term field performances related to natural fractures

Chalk Reservoirs

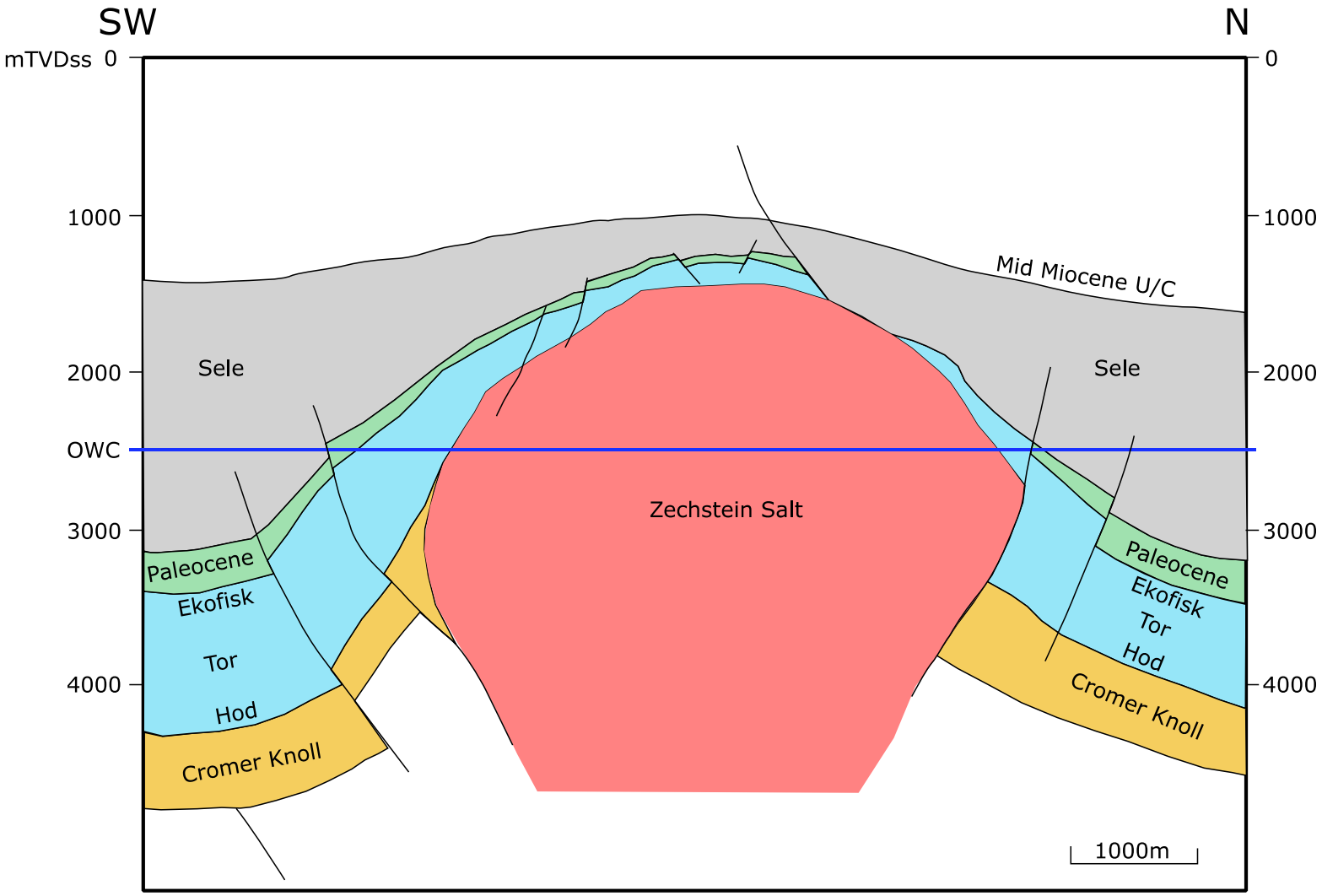


Machar – The Classic N Sea Chalk Diapir?



After Ward et al 2014

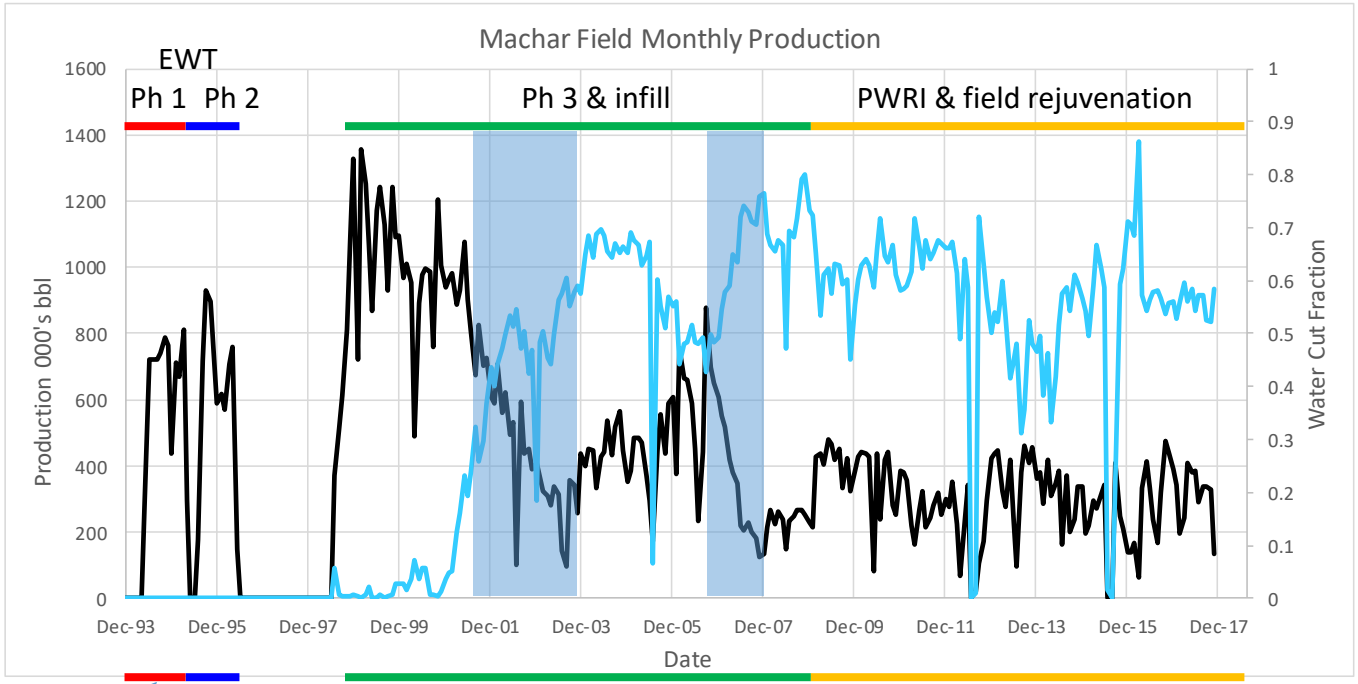
Machar



After Foster & Rattey 1993

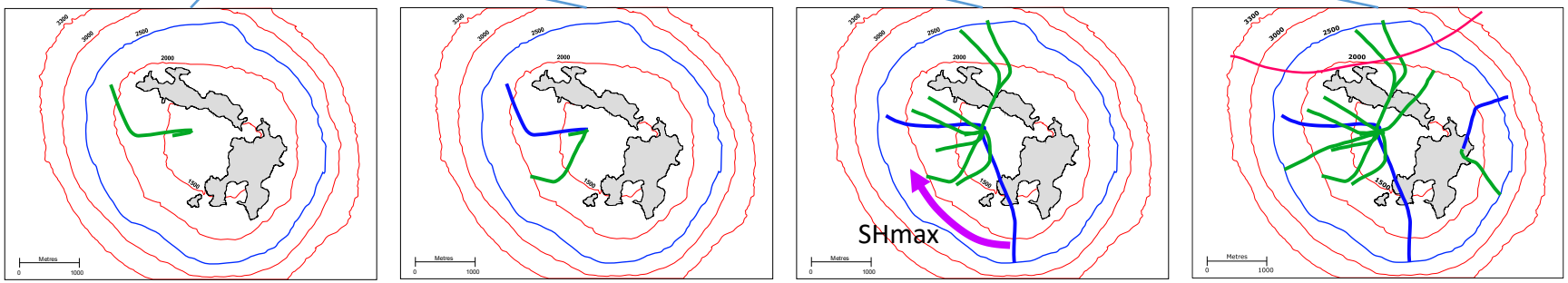
Machar – Production History

STOIIP 400-500 mmbbls



97.8 mmbbls

119.7 mmbbls



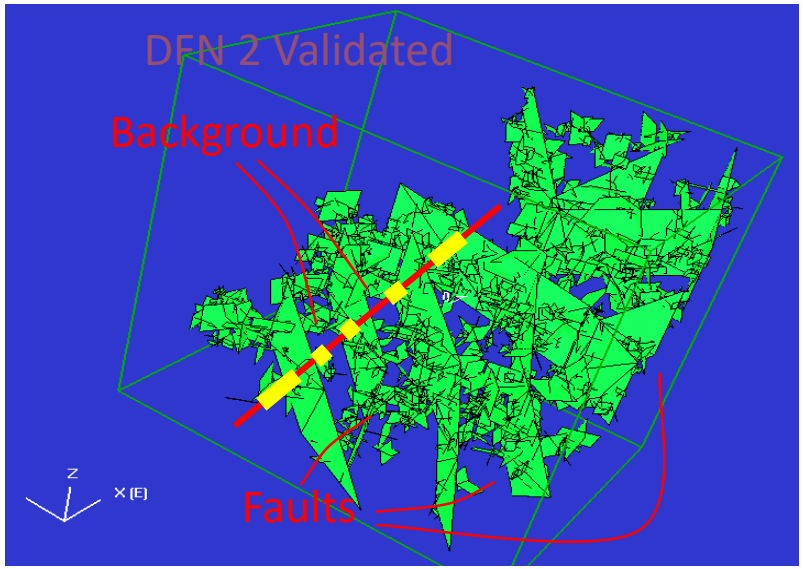
After Ward et al 2014

Machar - Viscous Displacement vs Imbibition

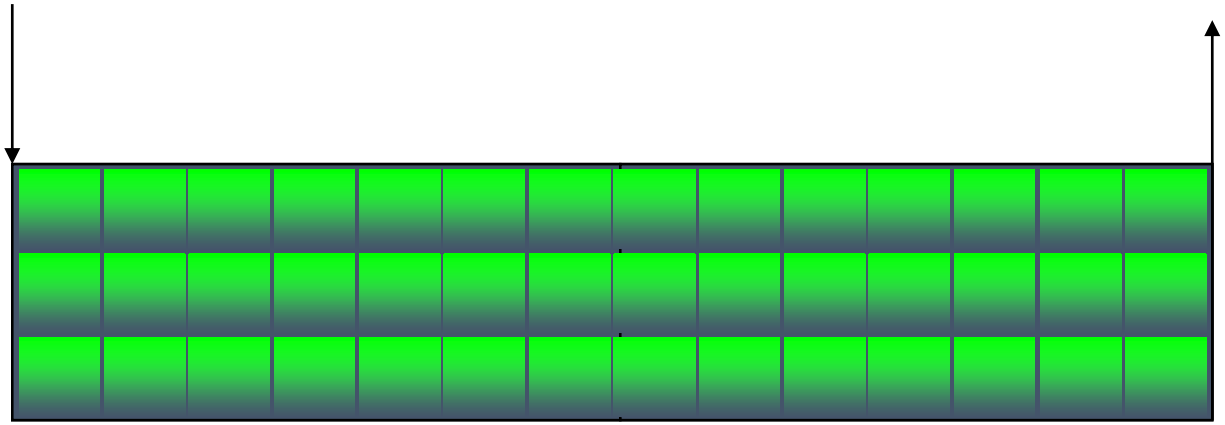
In fractured reservoirs viscous displacement often fails:

The high permeabilities of the fractures effectively "short circuits" the matrix blocks, making it difficult to establish sufficiently high pressure gradients to allow effective viscous displacement of the oil in the matrix

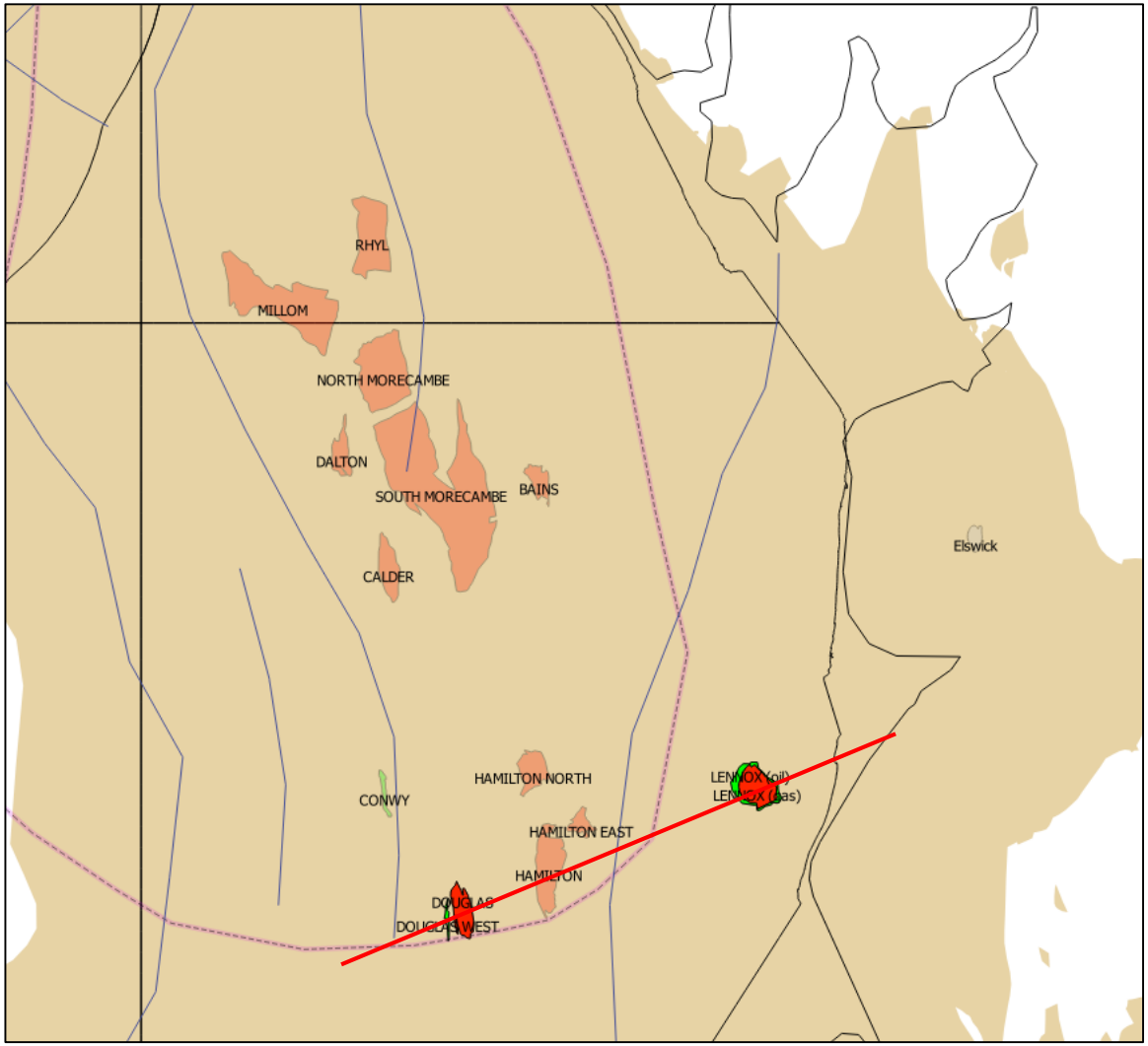
A new important effect comes into play - imbibition:



From McDonald 2005

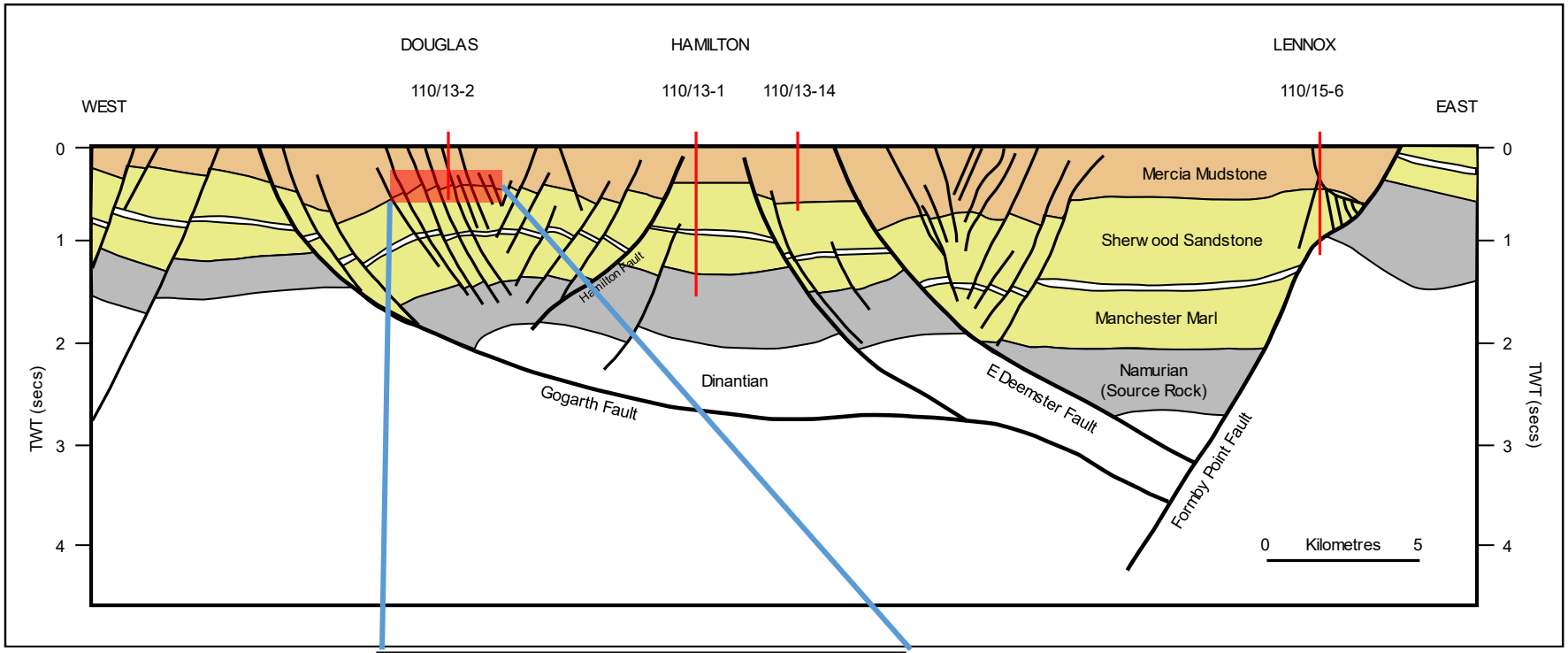


Triassic Reservoirs

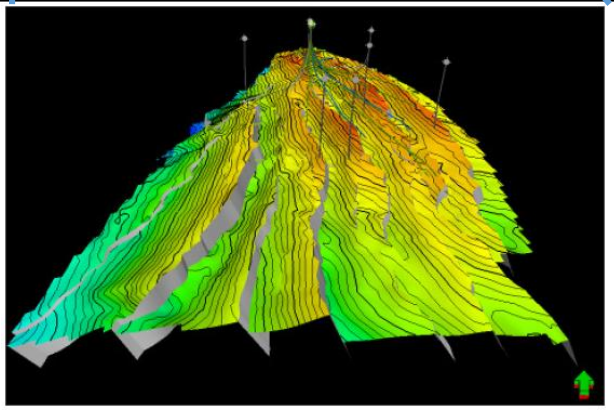


- Fluvial and lacustrine Sherwood Sandstone
- EISB but possibly also Wytch Farm

EISB – Normal Faulting of Sandstones



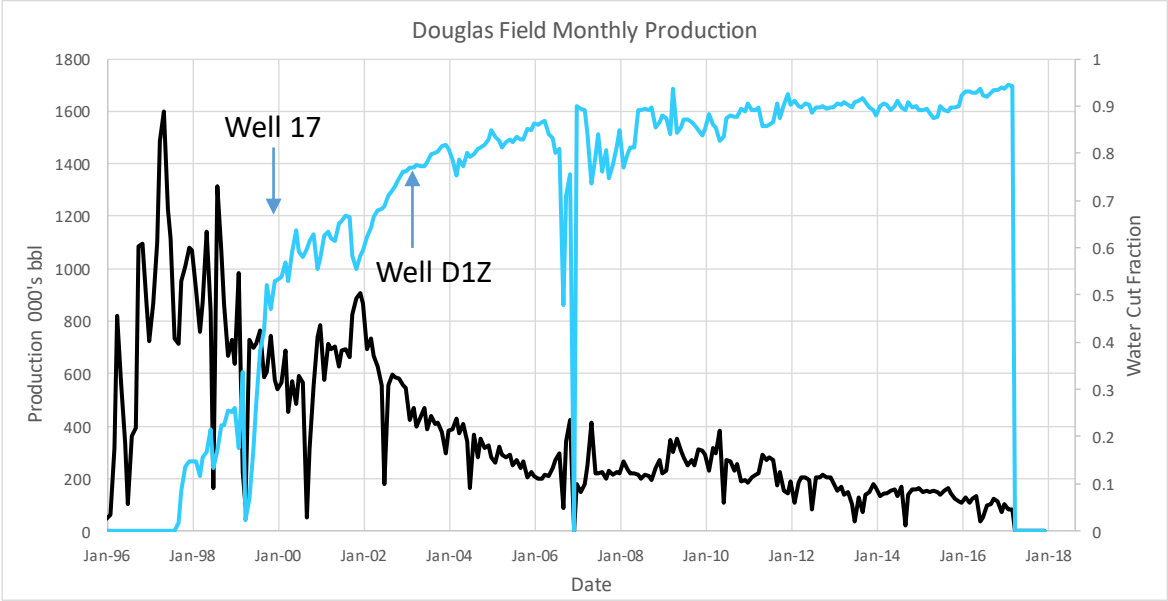
After Yaliz & McKim 2003



From Bentley & Elliot 2008

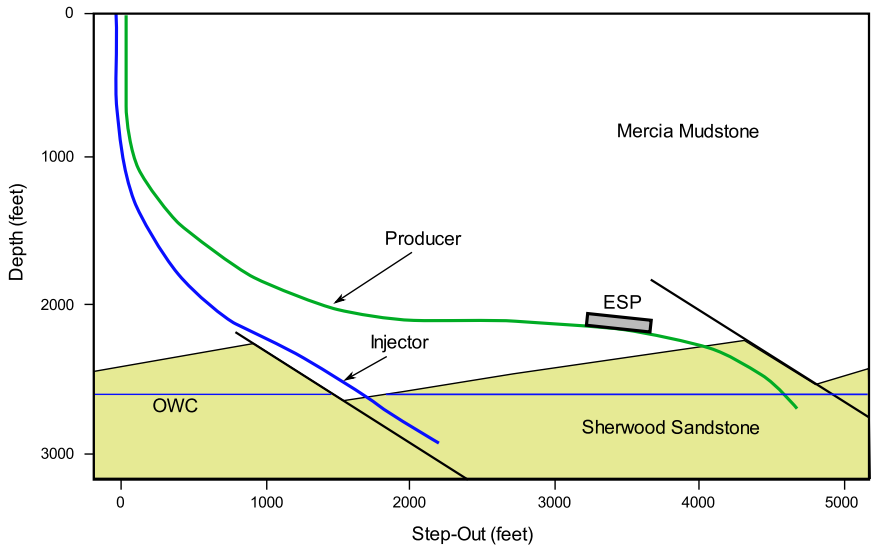
Douglas – Sandstone with Fault Influence

STOIIP 200 mmbbls



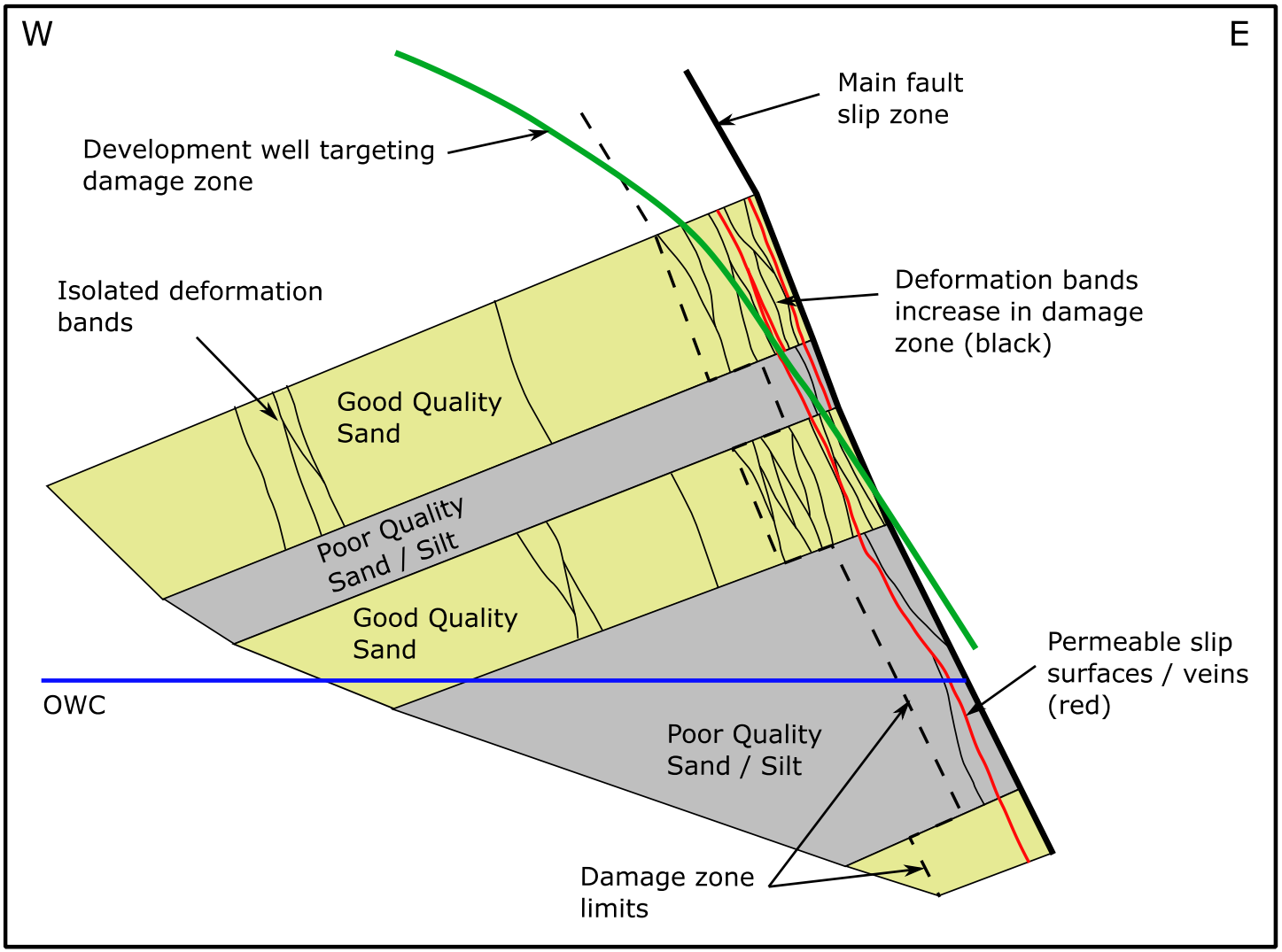
285.7 mmbbls

96.8 mmbbls



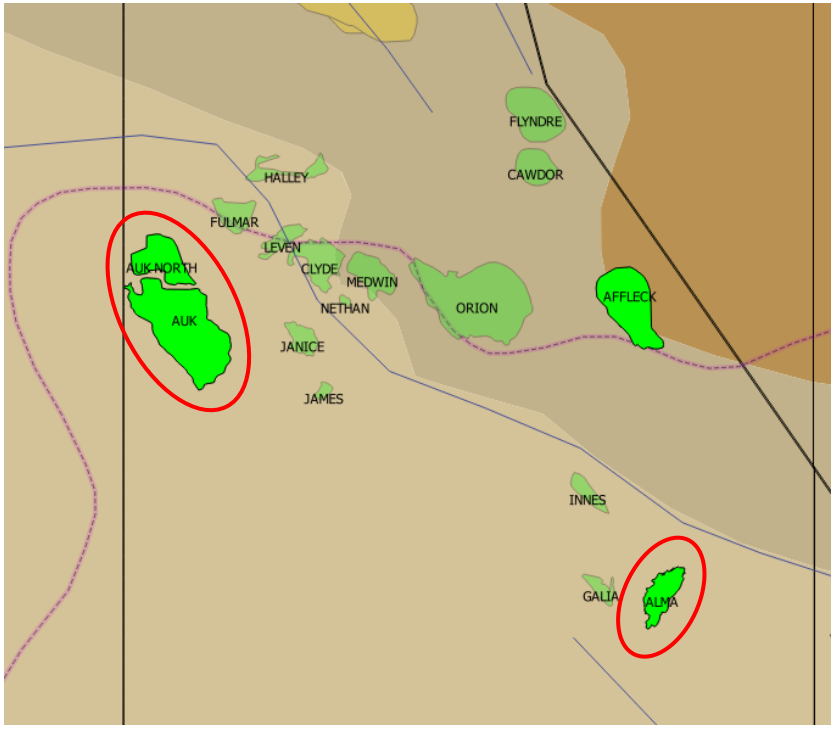
After Yaliz & McKim 2003

Douglas – Anisotropic Fault Permeability



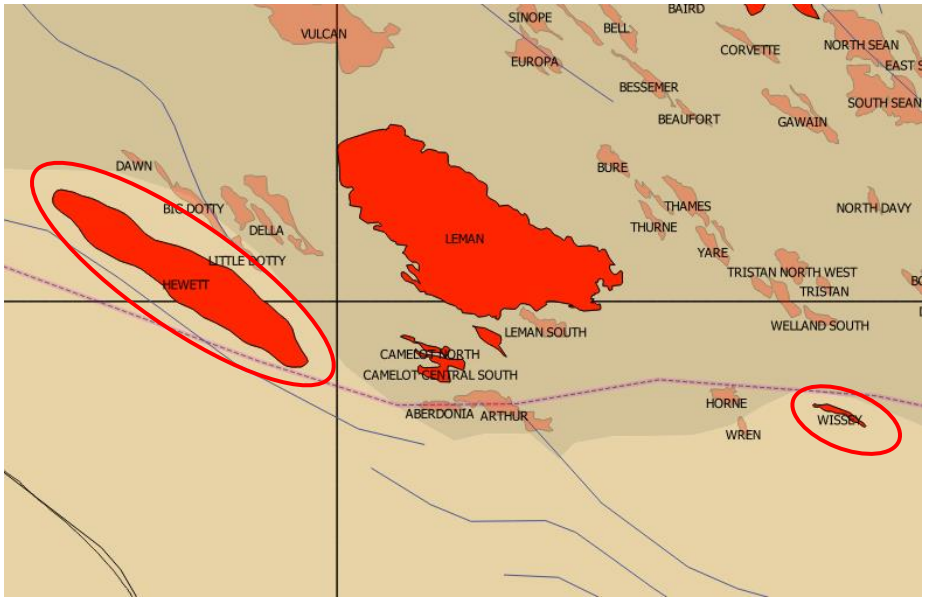
After Gutmanis et al 1998, Bentley & Elliot 2008

U Permian Zechstein Carbonate Reservoirs



CNS
Auk – Zechstein, Rotliegend reservoirs

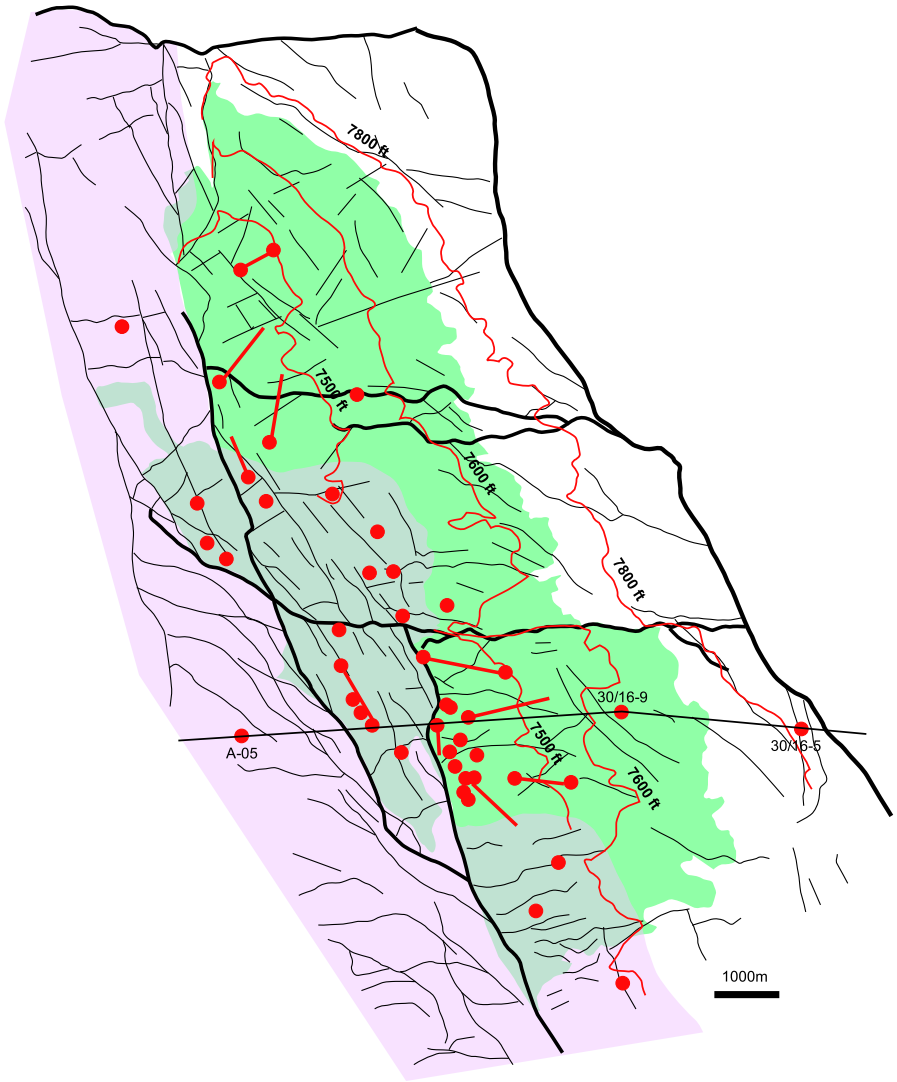
Alma – Zechstein, Rotliegend, Devonian reservoirs

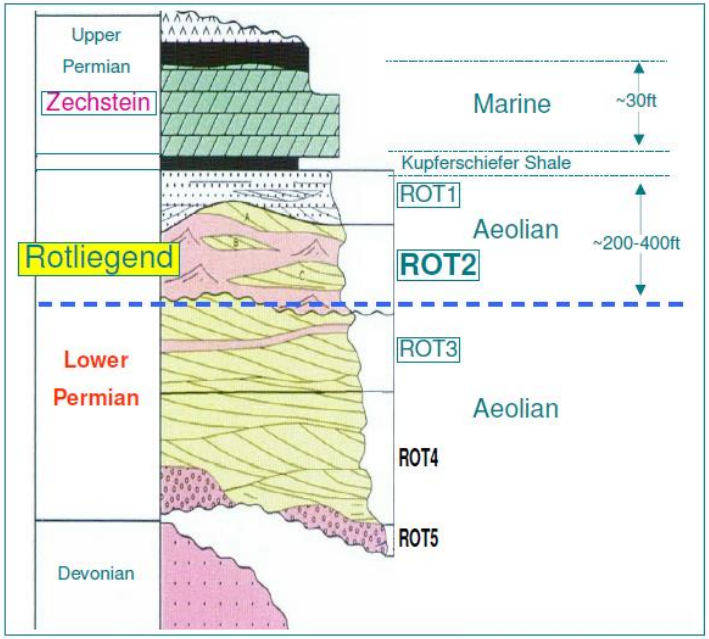


SNS
Hewett – Bunter, Zechstein, Rotliegend reservoirs. Zechstein heavily fractured, some anhydrite cementing.

Wissey – Zechstein. Fractured near main bounding fault to S. Gas production from well near fault but water ingress up intra field fault

Auk – Zechstein and Rotliegend



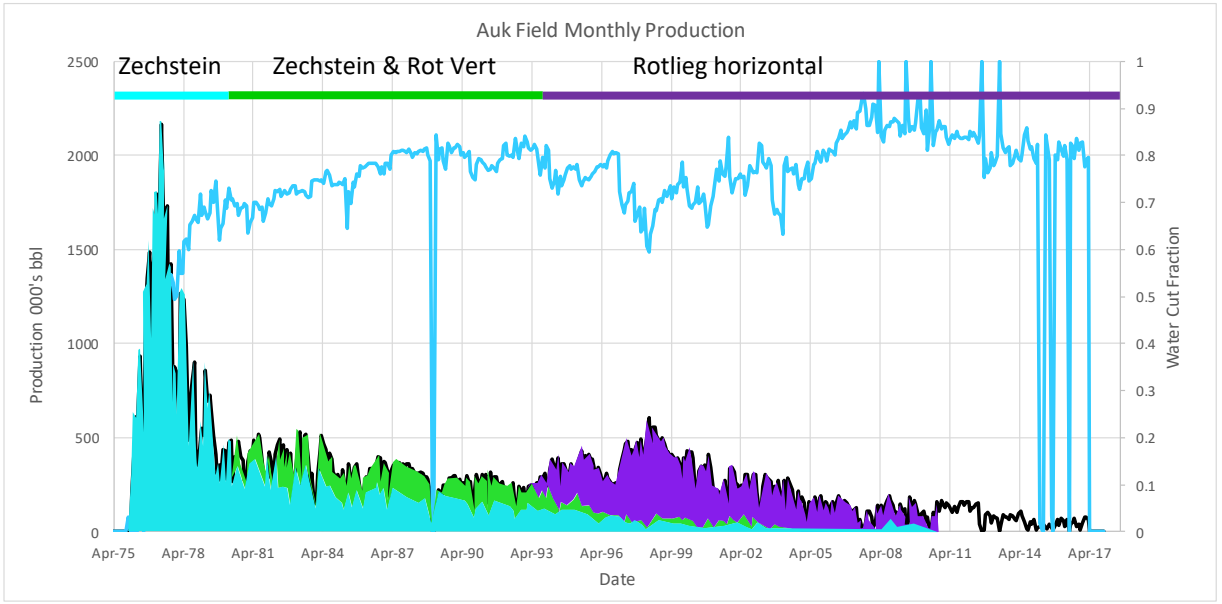


From Talisman 2011 (DEVEX)

After Trewin et al 2003 & Talisman 2011 (DEVEX)

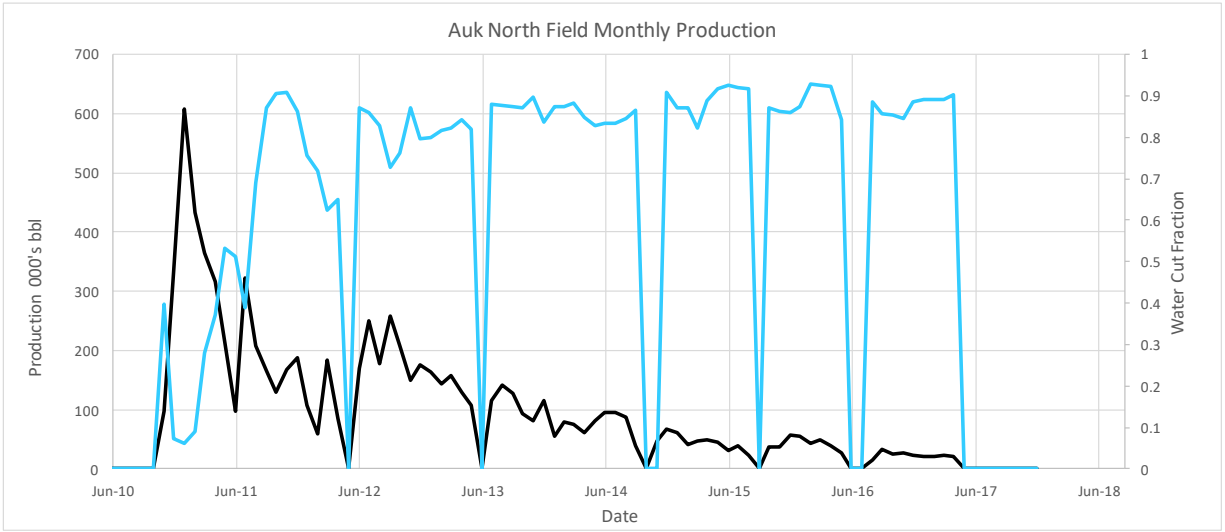
Auk – Production History

STOIIP 800 mmbbls



447.9 mmbbls

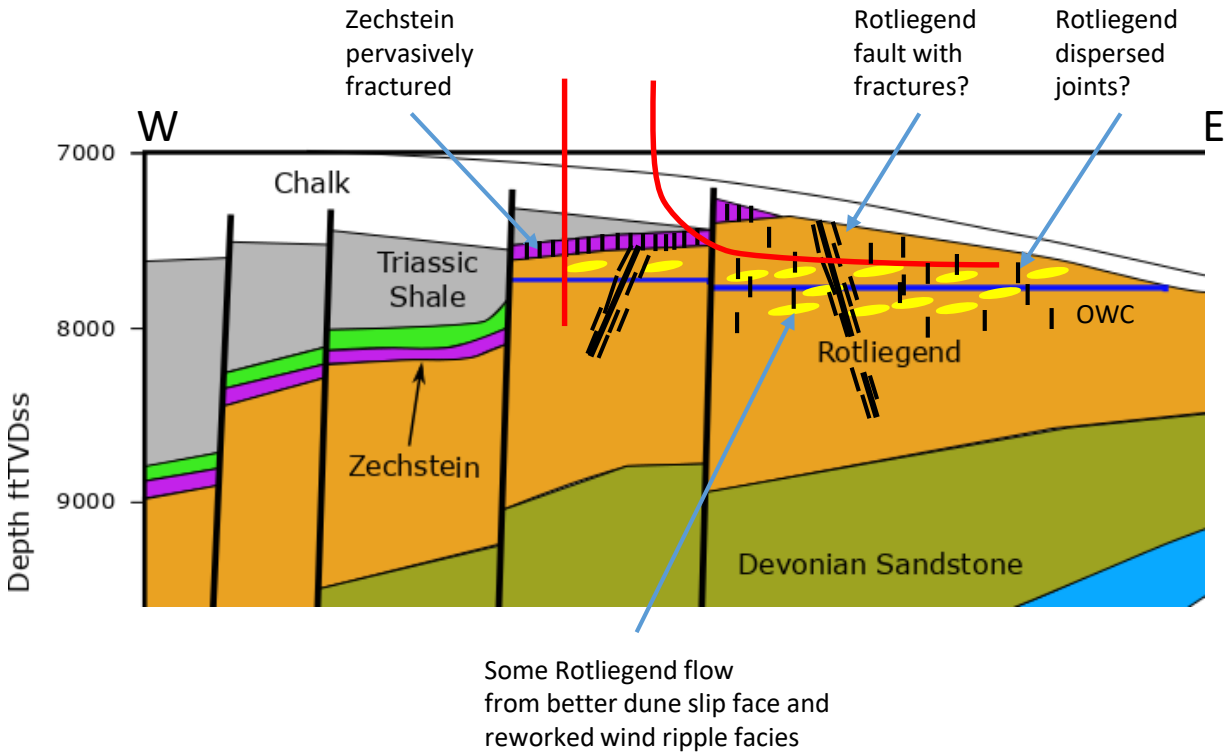
150.5 mmbbls



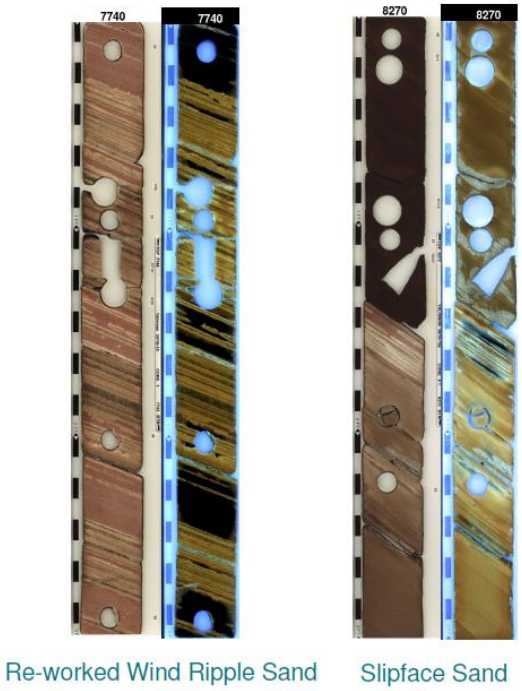
34.2 mmbbls

8.5 mmbbls

Auk – Production Mechanism?

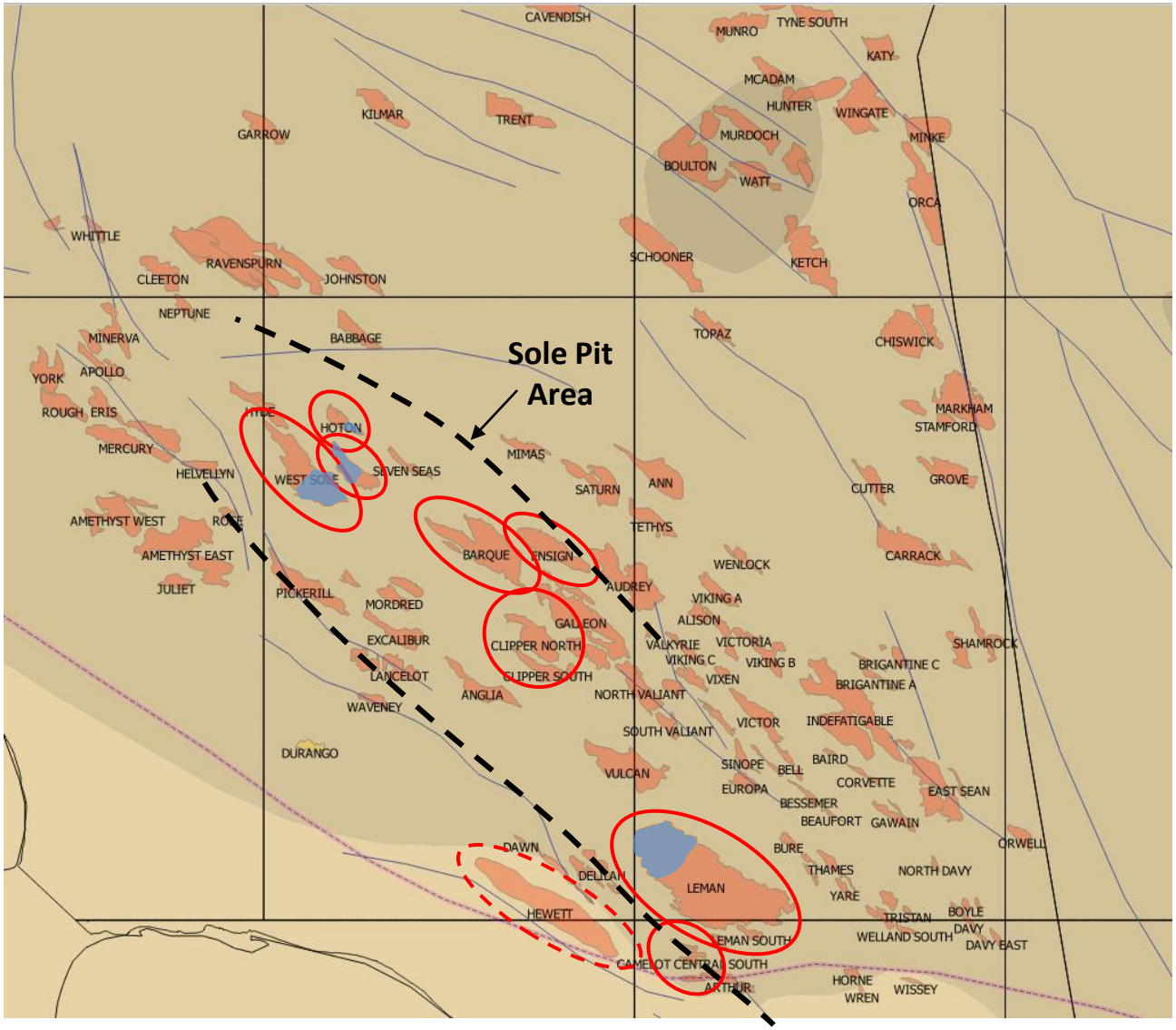


Modified after Trewin et al 2003

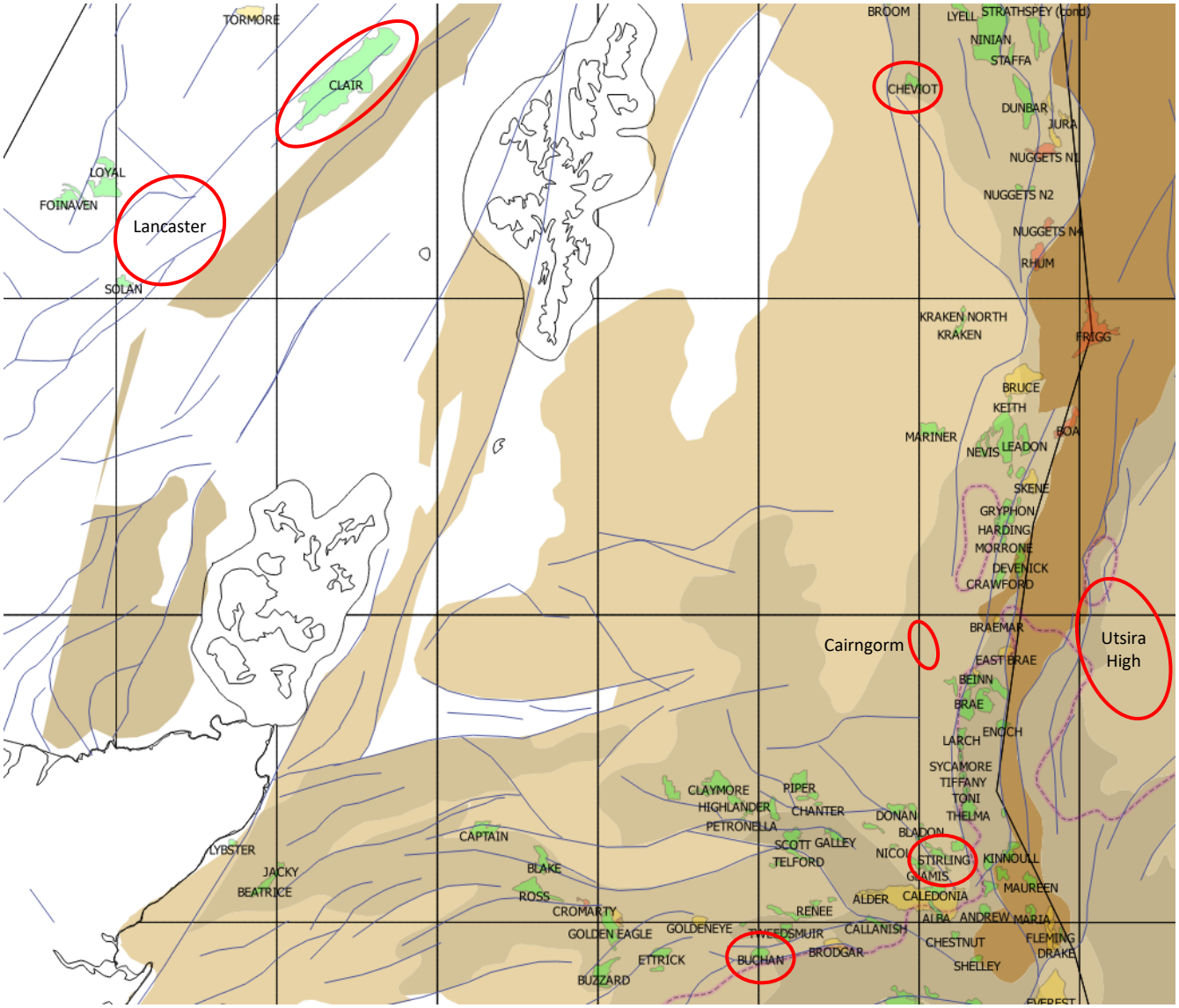


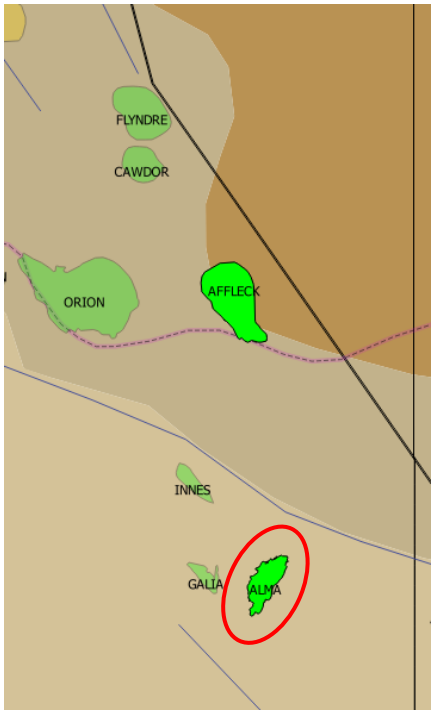
From Talisman 2011 (Devex)

SNS Gas Rotliegend Sandstone Reservoirs



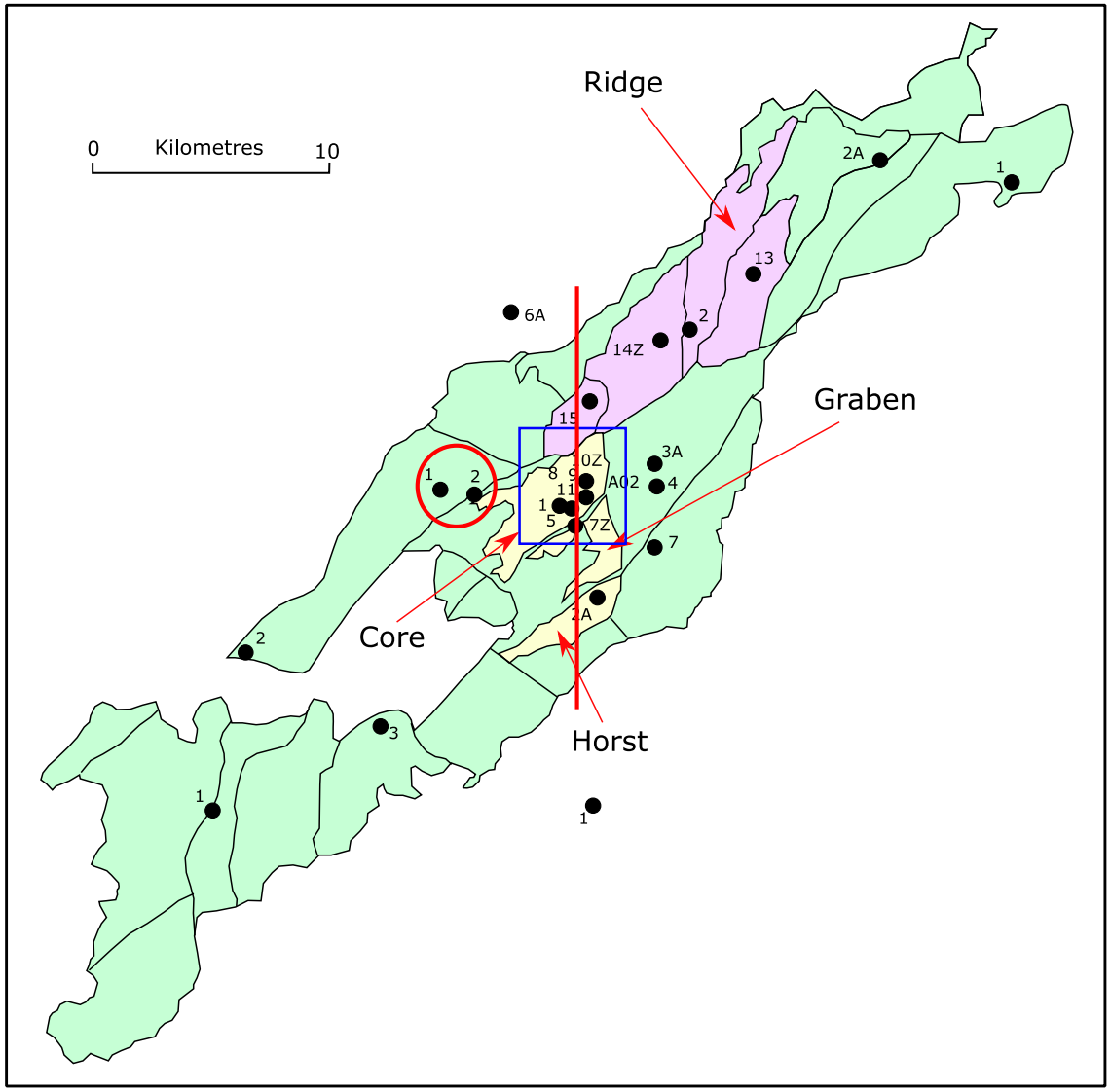
Devonian Sandstone and Basement Reservoirs





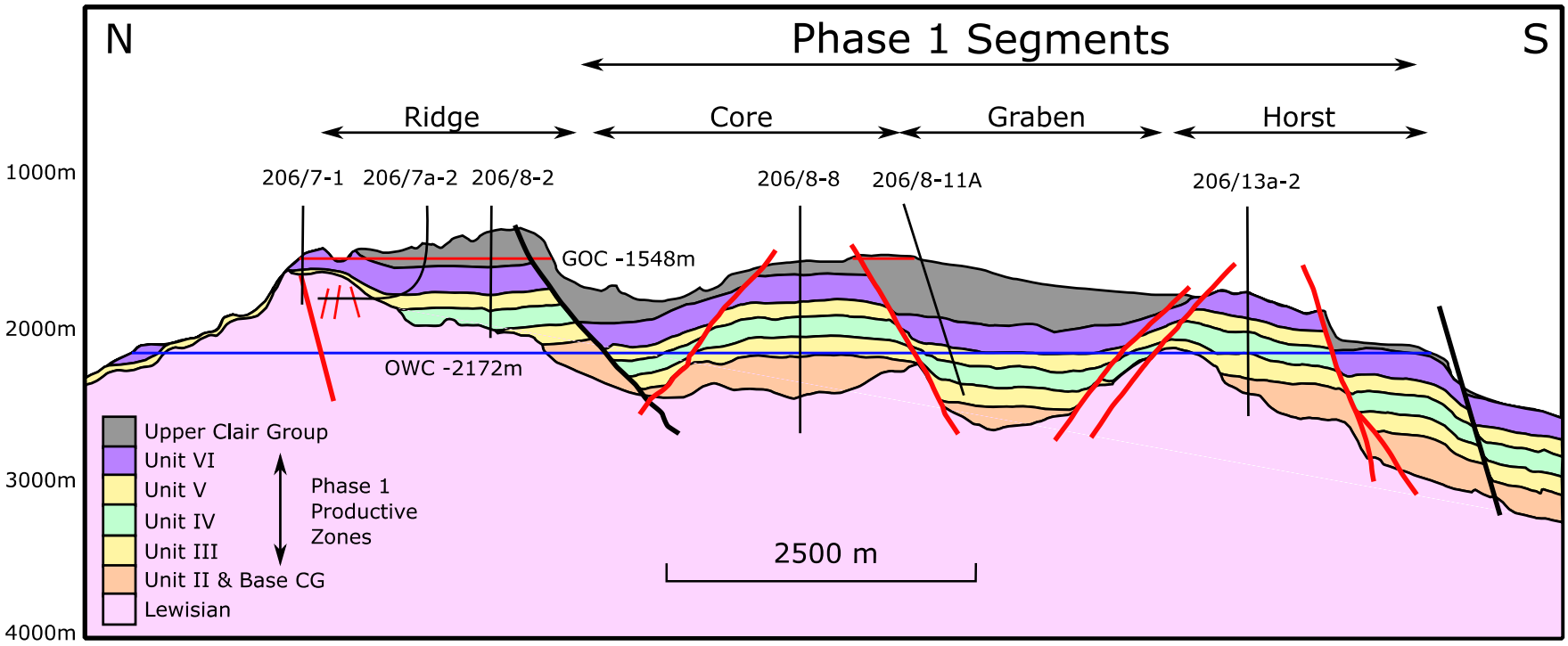
Alma
Devonian has some fractures but do they contribute?

Clair – Devonian & Lewisian Heavy Oil



After Ogilvie et al 2015

Clair – Devonian & Lewisian Heavy Oil

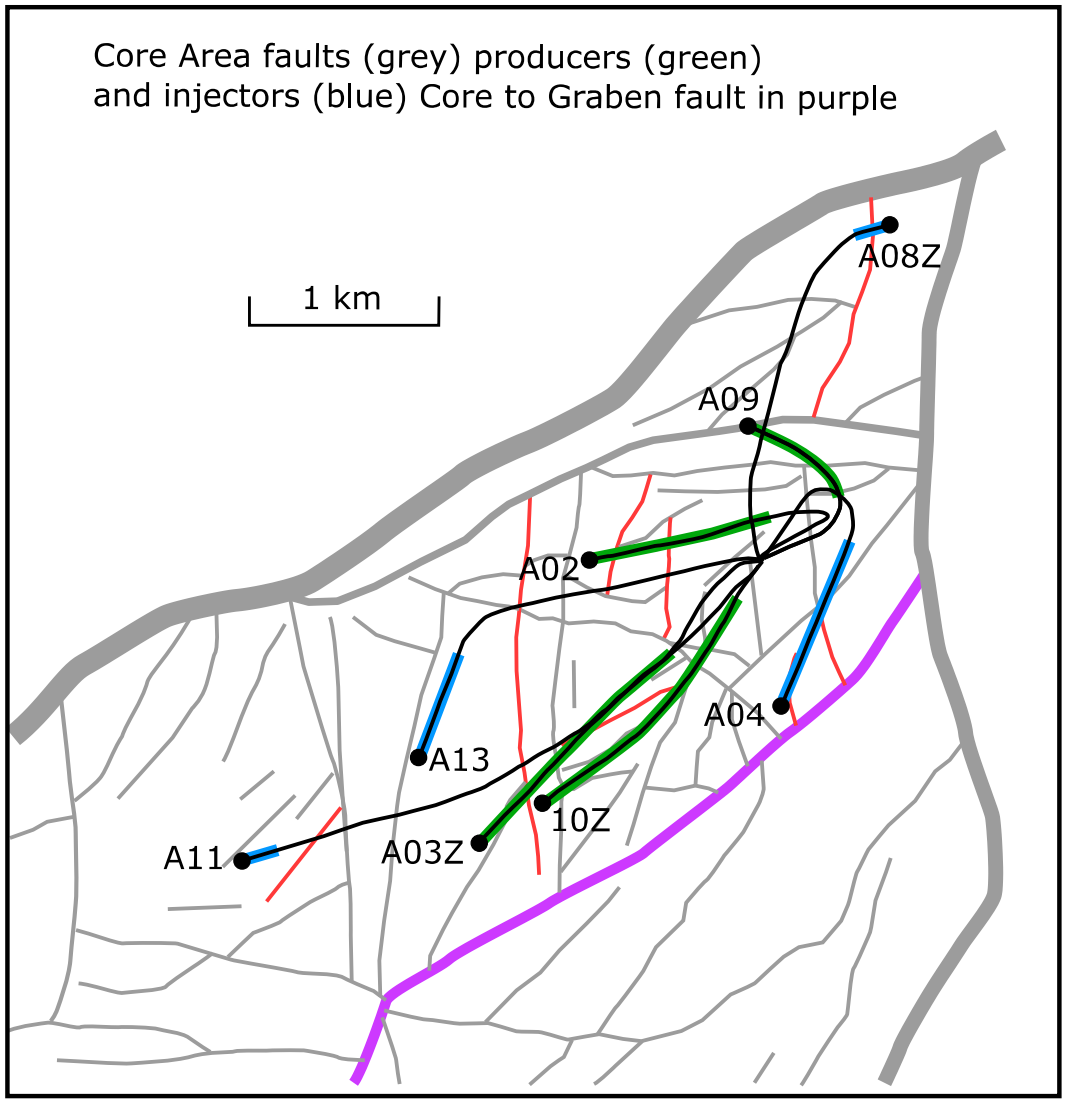


LCG Devonian – Mainly fluvial sands and channel sands. Some aeolian reworking in III, more heterolithics in VI. Fractures important in VI, some fracture influence in V and III which have best matrix

UCG Carboniferous – Fluvial channels and heterolithics. Damp conditions, more clay.

After Barr et al 2007

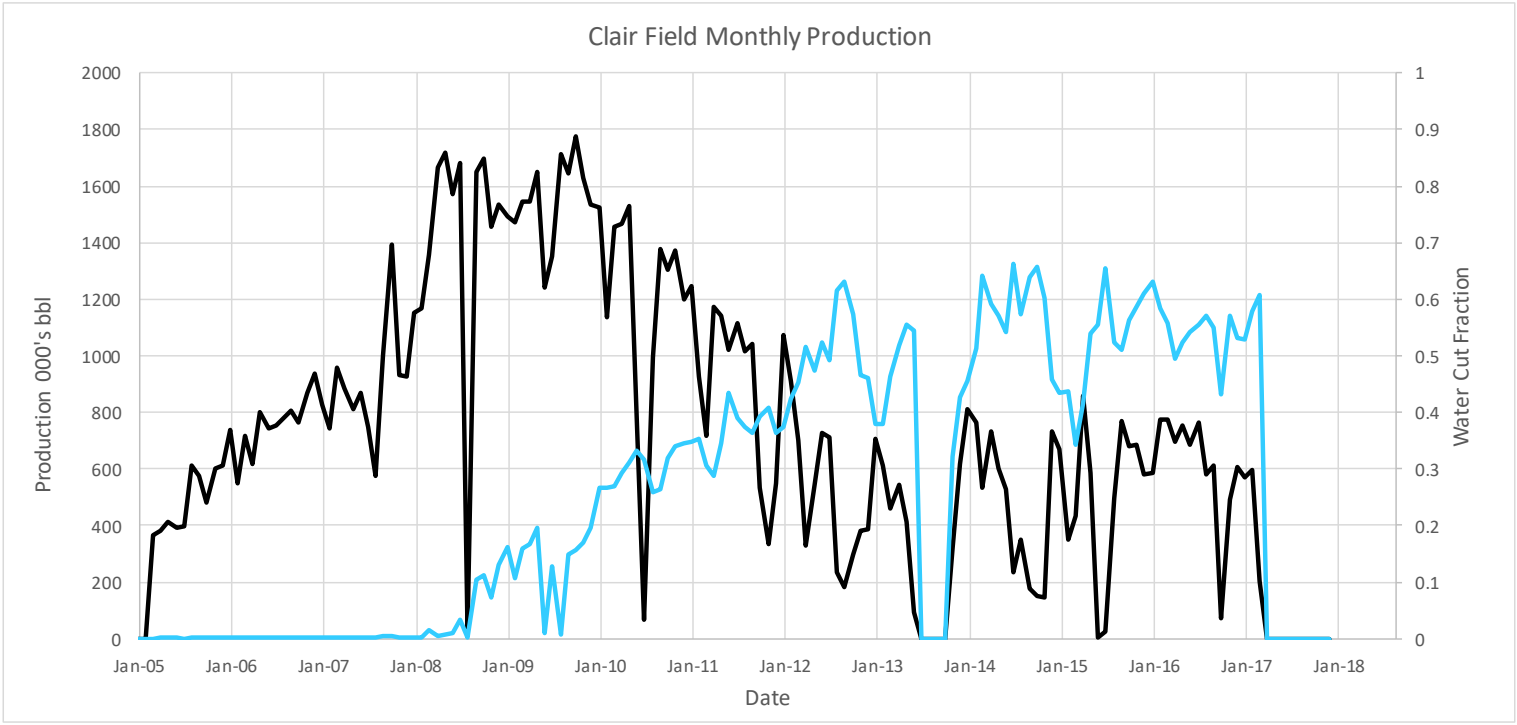
Clair – Devonian & Lewisian Heavy Oil



After Witt et al 2010

Clair Phase 1 – Devonian Heavy Oil Waterflood

Phase 1 STOIIP 1500 mmbbls



49.9 mmbbls

115.7 mmbbls

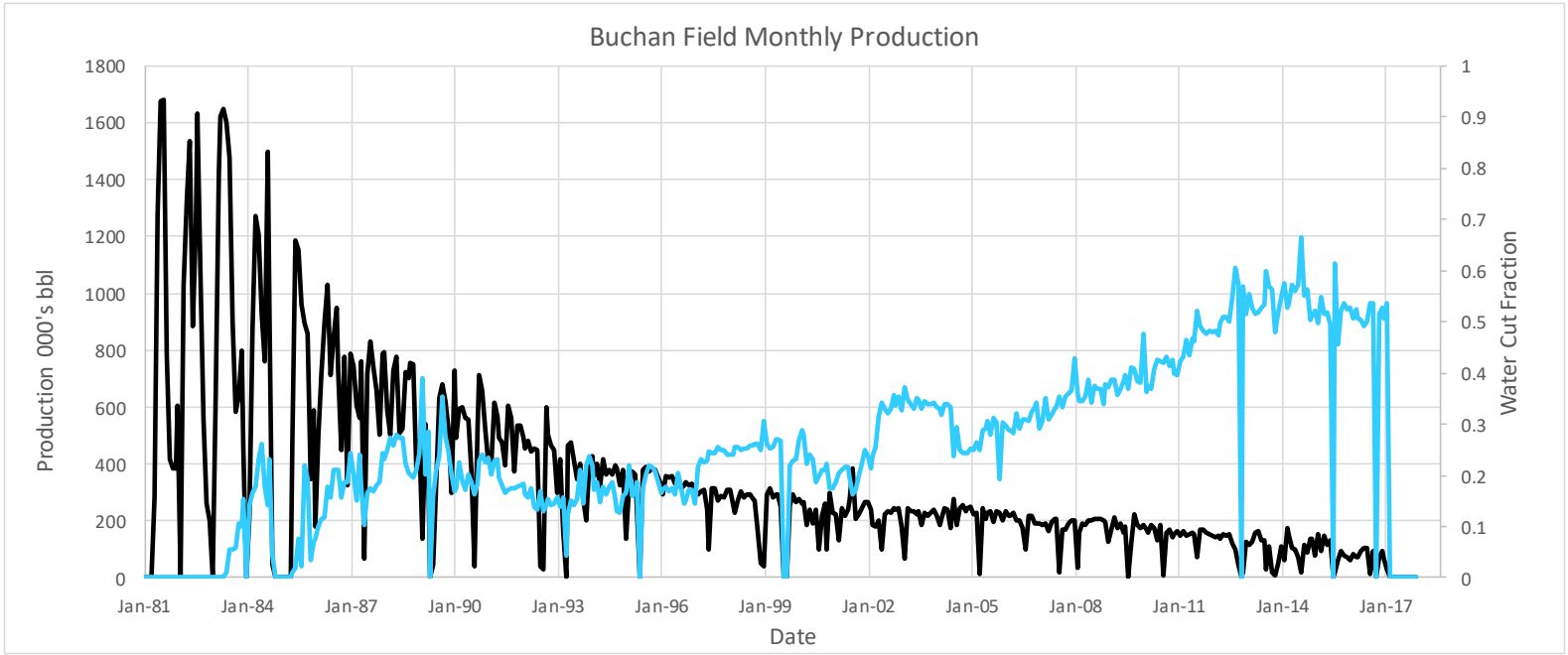
Initial depletion to determine connectivity. Injectors placed to optimise pressure support and sweep

Some injectors connected to producers via faults / fracture corridors

Others injectors appear to have distributed joints that get water into matrix where imbibition occurs. Good recovery

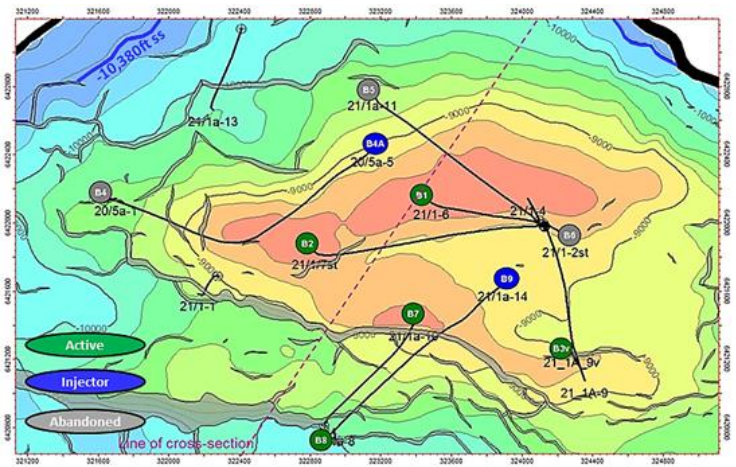
Buchan – Long Column, Light Oil, Depletion

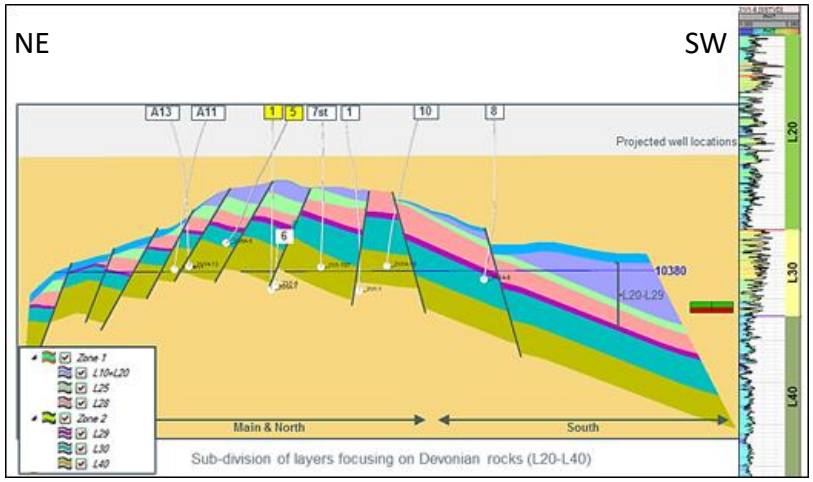
STOIIP 350-600 mmbbls



47.6 mmbbls

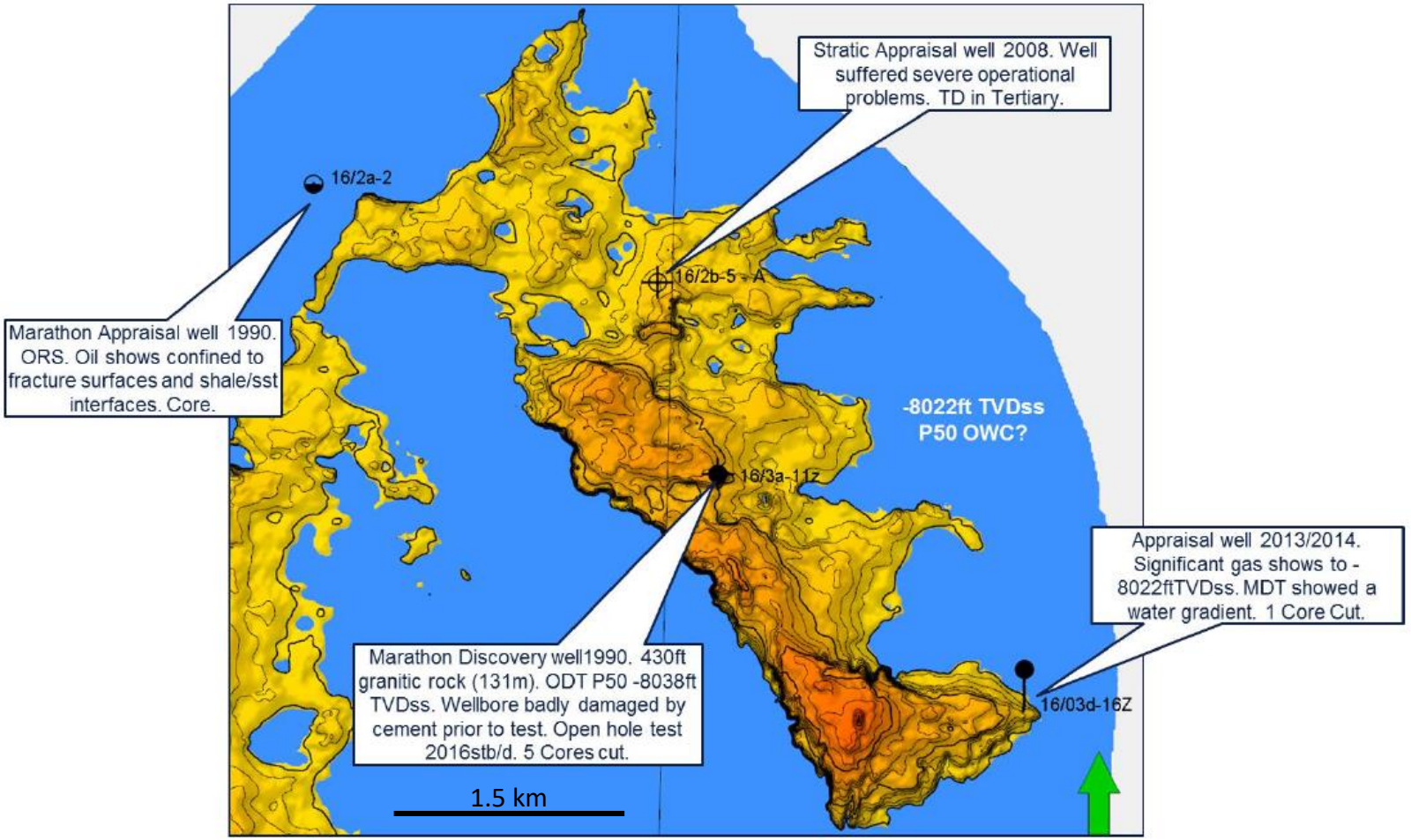
147.5 mmbbls





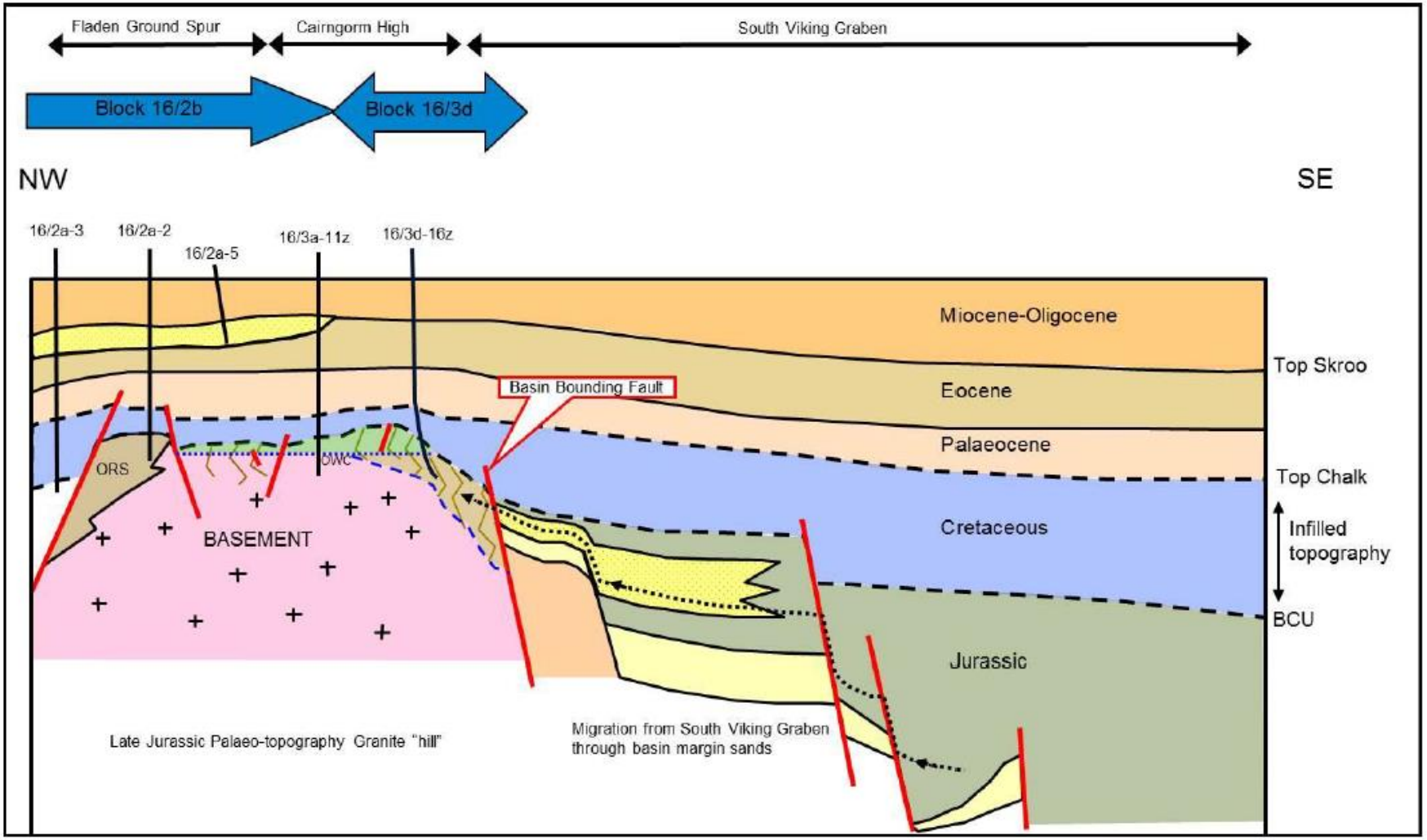
From Wynn & Saundry (In Review)

Basement Reservoirs - Cairngorm



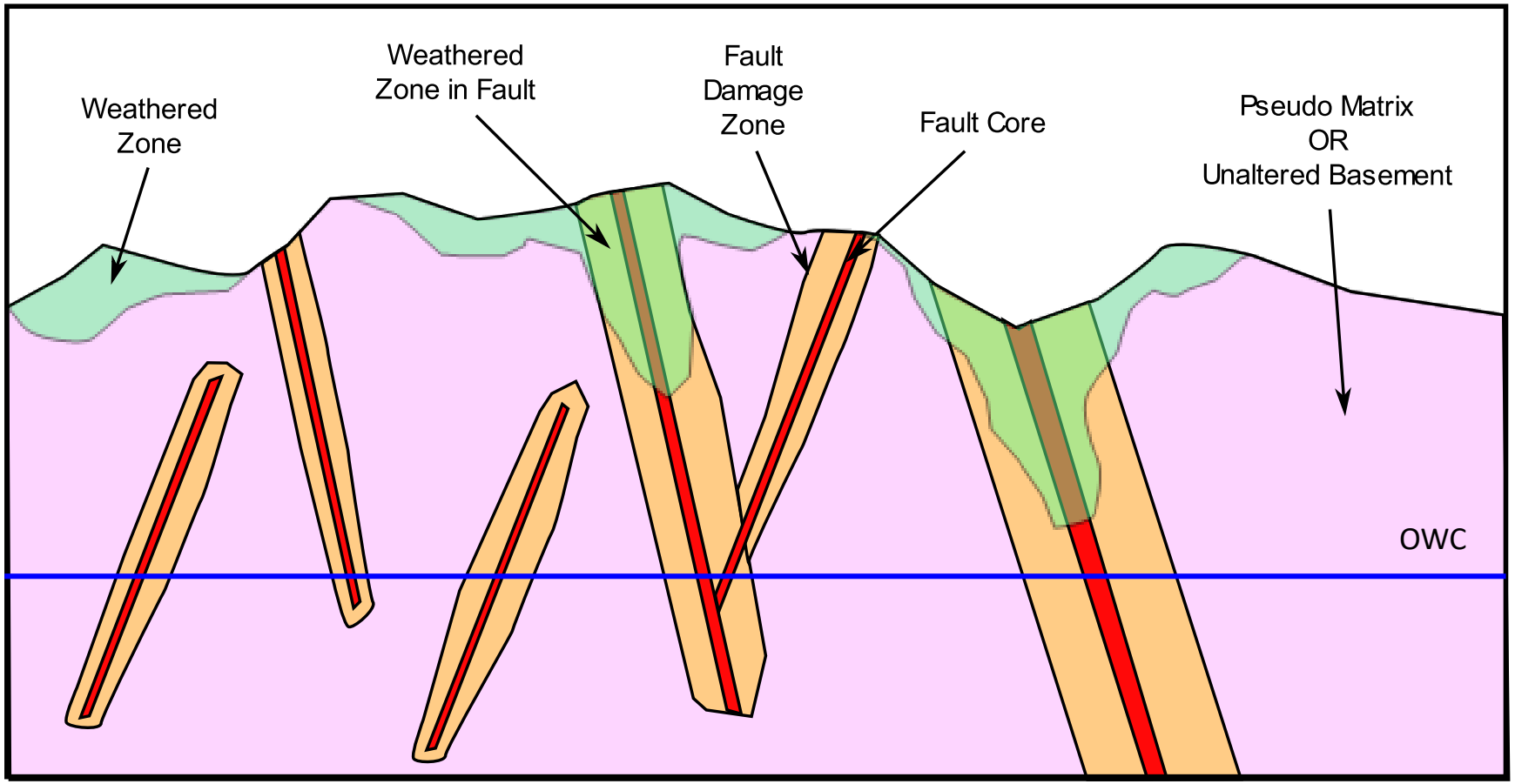
From Enquest 2016

Cairngorm – Migration Route



From Enquest 2016

Basement Poroperm System Concept



- Identifying the elements – Seismic, logs, core
- Calibration of effective fracture porosity – Very difficult
- Viscous sweep only or imbibition / gas oil gravity drainage possible?

Observations & Conclusions

- Non fractured units
  - Hod Chalk – High clay content and isotropic stresses, no open fractures
  - Jurassic. Lithologies too clay rich? Not enough burial / cementation prior to reactivation?
  - Triassic Bunter & Skagerrak. Lithologies too clean? Mainly granulation seams?

- Pervasive fracture influence – imbibition / good matrix sweep or rapid water cut
  - Chalk (Machar, Banff, Curlew C, Affleck, Kyle?, Harrier?) – Imbibition / good matrix sweep?
  - Devonian Sandstone (Clair, Buchan, Stirling) – Imbibition / good matrix sweep?
  - Zechstein (Auk, Alma, Hewett?, Wissey) – Viscous sweep of pervasive fractures – early water

- Locally important fracture influence – fault conduits / baffles
  - Triassic Sherwood (Douglas, Lennox, Wytch Farm?). Viscous sweep in localised damage zones? Early water or gas
  - Rotliegend (Auk, West Sole, Newsham, Hoton, Ensign, Clipper, Barque, Leman, Camelot) – Locally increased well rates but early water (e.g. Auk)

- Crystalline basement (Clair, Lancaster, Cairngorm)
  - Permeability and storage in faults, fault damage zones, weathered intervals and microfractures? What proportions of these elements occur in each reservoir / discovery?
  - How much measured porosity is effective for storage & flow?
  - What is the long term (1-2 yr plus) potential for production?

Managing the Risks

- Identifying the poroperm system elements. Integrate seismic, drilling, logs, core, tests, production data
  - Non-intuitive open fracture directions
  - Connectivity of facies to fractures
  - Multiple scenarios and iterate models

- Permeability architecture
  - Early understanding of dynamic performance important but well tests / Early Production Systems don't always see everything
  - Phased development optimal?

- Connectivity of well / injectors to fracture system
  - Skin and drainage. Stimulations required?
  - Injector placement WRT wells and fracture system
  - Patchy fractures > more wells?

- Well performance – manage offtake & injection
  - High rates > More oil but high water cut?
  - Low rates > Less water but less oil?

Acknowledgements

- AGR TRACS for permission to give this talk
- All colleagues and clients for projects and discussions on fractured reservoirs

Proterozoic reactivated shear zone in Archaean gneiss, Achmelvich, Sutherland