Naturally Fractured Reservoirs in the UKCS

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AGR TRACS
UKCS Fractured Reservoir Status

- Cretaceous
- Triassic
- U Permian
- Permian
- U Carboniferous
- Devonian
- Silurian
- Precambrian

**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
After Ward et al. 2014
After Foster & Rattey 1993
Machar – Production History

Machar Field Monthly Production

EWT
Ph 1  Ph 2

Ph 3 & infill

PWRI & field rejuvenation

Production 000's bbl
Date
Machar Field Monthly Production

STOIIP
400-500 mmbbls

97.8 mmbbls

119.7 mmbbls

After Ward et al 2014

After Ward et al 2014

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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

Well 17
Well D1Z

285.7 mmbbls

96.8 mmbbls

After Yaliz & McKim 2003
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
After Trewin et al. 2003 & Talisman 2011 (DEVEX)

From Talisman 2011 (DEVEX)
Auk – Production History

Auk Field Monthly Production

Zechstein Zechstein & Rot Vert Rotlieg horizontal

STOIIP
800 mmbbls

447.9 mmbbls

150.5 mmbbls

34.2 mmbbls

8.5 mmbbls

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Auk – Production Mechanism?

Modified after Trewin et al 2003

Some Rotliegend flow from better dune slip face and reworked wind ripple facies

From Talisman 2011 (Devex)
SNS Gas Rotliegend Sandstone Reservoirs

Sole Pit Area
Devonian has some fractures but do they contribute?
Clair – Devonian & Lewisian Heavy Oil

After Ogilvie et al 2015
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
Core Area faults (grey) producers (green) and injectors (blue) Core to Graben fault in purple

After Witt et al 2010
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

Buchan Field Monthly Production

STOIIP
350-600 mmbbls

From Wynn & Saundry (In Review)

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47.6 mmbbls

147.5 mmbbls
Marathon Discovery well 1990. 430ft/131m granite rock. ODT P50 -8038ft TVDss. Wellbore badly damaged by cement prior to test. Open hole test 2016stb/d. 5 Cores cut.

Marathon Appraisal well 1990. ORS. Oil shows confined to fracture surfaces and shale/sst interfaces. Core.


Appraisal well 2013/2014. Significant gas shows to -8022ftTVDss. MDT showed a water gradient. 1 Core Cut.

From Enquest 2016
Cairngorm – Migration Route

From Enquest 2016
• 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. Sti"mulations 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?
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Proterozoic reactivated shear zone in Archaean gneiss, Achmelvich, Sutherland