The Lancaster Field
Progress in opening the UK’s Fractured Basement Play

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After 50 years of evaluation the UKCS still has surprises and new opportunities to offer. One such example is the Fractured Basement Play. My presentation is focused on Lancaster, the UK’s first fractured basement field.

The presentation is split into four parts;

• Geology setting and reservoir characteristics

• Technical progress so far achieved in de-risking Lancaster

• UK basement potential

• Could basement represent an infrastructure led opportunity?

Could basement represent an infrastructure led opportunity?
Lancaster is located on the Rona Ridge one of the four areas defined by Pilot as having a proven Fractured Basement Play.
The Petroleum system is much like that at Clair. Hydrocarbon source is provided by the Kimmeridge Clay which on-laps the basement. Seal is provided by a thick Cretaceous mudstone succession.

The Lancaster reservoir is the oldest UK reservoir at circa 2.4 billion years old. The Reservoir is Lewisian Gneiss which comprises fractured tonalite with subordinate fractured dolerite.
Our reservoir knowledge of Lancaster comes from four wells:

- **205/21a-1A** Drilled in 1974 discovering oil in open fractures identified from a TD basement core.
- **205/21a-4** Thirty five years later 205/21a-4 confirmed the presence of a permeable fracture system, and an extensive column of 38° Api oil.
- **205/21a-4Z** A side-track appraisal of the 4 well demonstrated oil productivity from fault zones and the surrounding fractured basement. The well had a maximum flow of @2,500 bopd but rates were compromised by skin.
- **205/21a-6** Building on the experience of the 4 and 4Z well, a 1 km production well was drilled in 2014 confirming Hurricane’s fracture model and producing at high flow rates with an exceptional PI.

Both the 4Z and 6 well are suspended in expectation of them being tied into a Lancaster field development.

As of September this year Lancaster was granted field status by OGA.
The Lancaster reservoir
Fractured reservoirs are commonly subdivided into four “Types” based on the relative contributions of matrix and fracture poroperm.

Lancaster is classified as a Type 1 fractured reservoir, which means that fractures provide the effective poroperm system with no contribution from matrix.

The effective poroperm system is a hydrodynamic fracture network, which consists of interconnected fractures capable of storing and transmitting fluid under reservoir conditions.

For the purpose of this presentation I will refer to this effective poroperm system as the fracture network.
The fracture network has been identified from a variety of static and dynamic data. The underlying philosophy being, that any interpretation of static data must be corroborated by dynamic data when describing the fracture network.

The reservoir model consists of three end members; micro fractures, joints and seismically identified faults.
Micro fractures can be identified from SWC, core and image logs. Micro fracture properties are assessed from thin section and core analysis.

Micro fractures have a trace length less than the borehole diameter and cannot be readily quantified from image logs to generate fracture frequency curves.
Joints are fractures that can be defined as a discrete plane from borehole image logs.
Joints are classified into joint sets with specific geometric properties.

Regional joints are high angle features having a ne-sw orientation,

Cross joints have variable distribution.

All joint types have been recorded in the 205/21a-4, 205/21a-4Z and 205/21a-6 wells.

Joints and cross joints having apparent apertures in excess of 1.5cm and are classified as large aperture fractures.
Minimum fracture aperture from thin section analysis is 20 microns which when compared to published work by Aguillera (1999) indicates high permeability and no irreducible water saturation.

Effective apertures estimated from image logs indicate maximum effective apertures are likely to be in the order of 2m. Such apertures are indicative of aperture enhancement by epithermal and hydrothermal processes both of these processes can be inferred from diagenetic fabrics described from sidewall core data.
Analysis of micro fracture and joint distribution indicates that a 10m cube is considered to be a sensible Representative Elementary Volume (REV) to describe the fracture network.

The REV is used to constrain cell size in field simulation.
The conceptual model is of a well connected fracture network. Micro fractures connect to joints which connect to faults.

The reservoir is formed of two facies; Fault Zones and Fractured Basement:

- Fault Zones are preferentially permeable and are associated with faults identified from 3D seismic.
- Fractured Basement is also permeable and forms the remainder of the GRV.

Both facies contain micro fractures, joints, cross joints and large aperture fractures.
Faulting of the Lancaster reservoir is pervasive as demonstrated by this Ant Tracked Interpretation of the 3D seismic volume at top basement surface.

Light blue lines are Ant Tracked faults.

Further details on fault identification at Lancaster can be seen at http://sp.lyellcollection.org/content/early/2012/09/11/SP374.6.abstract

By reference to the drilled crestal area, on the next slide, more detail of fault distribution can be appreciated.
A number of high priority drilling target faults, identified from seismic, have been corroborated by well penetrations.

Well penetrations not only provide information about Fault Zone properties, but also confirm that the majority of reservoir faults are vertical or sub vertical.
Borehole data is used to distinguish Fault Zones (yellow) from Fractured Basement (green).

Looking at an example Fault Zone there is little difference in joint frequency (red box highlighting dip track), however porosity, (blue box highlighted red curve), drilling breaks, (yellow highlighted box and blue curve representing C1/ROP) and permeability indicators from gas chromatography (orange arrows) are all elevated relative to the Fractured Basement.
Fault Zone boundaries are interpreted to be associated with joints separating distinct image log fabrics. Joint strike at these boundaries is typically parallel to seismic fault strike.
A conceptual model is all well and good, but it is necessary to demonstrate the fractures in the model are associated with an effective poroperm system.
Confirmation of effective joint poroperm comes from integrating the available drilling, wireline and LWD data. Of particular significance to confirming permeability is MDT pressure analysis. An example MDT point is highlighted.
In detail the MDT point is seen to be high quality and clearly indicating permeability. Comparing the available log suite gives confidence in assigning poroperm characteristics to joints not associated with an MDT measurement.
Further support for a highly effective fracture network is provided by the flow scanner a multi probe/spinner PLT which demonstrates that permeable and productive fractures are present throughout the drilled section (red highlighted box over twin green curves).
In the absence of wireline data, poroperm indicators are identified from resistivity, C1/ROP, aromatic/alkane ratio and dynamic losses.
Calculating basement porosity is achieved through bulk porosity measurements calibrated to core porosity and core grain density. Bulk fracture porosity for the reservoir is of the order of 4%.
Wireline and LWD based analysis gives confidence that an effective poroperm system is present, however a fractured reservoir relies on the connectivity of the fracture network away from well based sample points and DST data is required to gain an understanding of this larger reservoir volume.
Drill stem testing of last year’s horizontal well confirmed a highly productive reservoir with high flow rates constrained by surface equipment, a high PI and no evidence of permeability barriers.

The test supported observations derived from static data that a well connected fracture network is present within the Lancaster reservoir.
In addition to demonstrating high permeability downhole pressure, sea bed gauges have demonstrated the fracture network is compressible.

Compressibility can be clearly demonstrated during this highlighted 28 hour shut in period.
The down hole pressure exhibits a 1.- 1.5 psi cyclicity, which is interpreted as the reservoir responding to tidal induced compression.

This cyclicity is also noted on the sea bed gauges designed to monitor tidal effects.

Correcting the downhole pressure for tidal effects produces a clean pressure response which is used in pressure transient analysis.
Pressure transient analysis indicates that the early reservoir response is dominated by well connected, steeply dipping, high permeability joints which are not considered to be compressible (box surrounding image picked joint).

The later time (box surrounding blue circle and microfractured image log) is dominated by micro fractures which are interpreted as compressible.

Such dual porosity behaviour is common in Type 1 fractured reservoirs and indicates a highly connected fracture network.
### Fault Zones
- High priority reservoir targets
- 50% of the GRV
- 60% of the reservoir pore volume

### Fractured Basement
- Intervening rock between Fault Zones
- 50% of the GRV
- 40% of the pore volume

### Dynamic data based on MDT, PLt, pressure transient analysis and well history matching

- **High conductivity fractures (present in Fault Zones and Fractured Basement)**
  - Provide primary production
  - Incompressible
  - 33% of the reservoir pore volume

- **Dynamically compressible fractures (present in Fault Zones and Fractured Basement)**
  - Provide secondary production – similar to a conventional “matrix” response
  - Compressible
  - 67% of the reservoir pore volume
By combining the static and dynamic observations, a history matched, full field simulation has been constructed. The model has over 80 million active cells and 750 faults explicitly modelled.
When Hurricane started its exploration of the Lewisian basement there were many technical challenges. Of these the three most significant were:

a) the ability to drill the basement safely and in a cost effective manner  
b) whether the basement was permeable  
c) the ability to demonstrate commercial flow rates

Since our first well in 2009 we have been able to address these issues through a sequential process of technical de-risking. This de-risking has only been possible through working closely with the authorities, drilling contractors, well management companies, well testers and numerous geoscience specialists.
From the perspective of drilling, the Lewisian is a relatively benign basement rock. This is attributed to the high fracture frequency and the nature of the matrix.

ROP’s of 8m/h are typical and we have drilled over 430m in a single bit run.

Effective loss management and hole cleaning can be achieved with viscosified brine leading to minimum formation damage (horizontal well skin of @15) and excellent LWD/wireline data acquisition.
A wide range of formation evaluation measurement has been acquired in the reservoir.

This data has contributed to the development of a robust formation evaluation work flow which has been verified by third party specialists. This work flow gives Hurricane confidence in its resource estimates and in its ability to plan future development wells.
Using Intersect simulation (refer to [https://www.hurricaneenergy.com/Communications/Presentations/](https://www.hurricaneenergy.com/Communications/Presentations/))

Enabling Geological Scale Dynamic Modelling of a Fractured Basement Reservoir using a high-Resolution Simulator - A UKCS Case Study, Hurricane has been able to accurately represent the reservoir facies using 10m *10m* 30m cells in the oil column.

Uncertainty in ODT, aquifer strength and length of well bore contributing to the DST has been evaluated.

Further dynamic data acquisition, coupled with a more refined geological input, is planned to help improve the model.
I trust that this Lancaster overview has demonstrated the material potential of Lancaster, but what of the wider UK basement play?
Basement prospectivity so far identified includes over 400 million barrels 2C (contingent resource) and over 300 million barrels P50 (prospective resource).

This resource is just on Hurricane's acreage, however other West of Shetland basement opportunities exist.

The techniques Hurricane have employed in the evaluation of Lancaster are equally applicable to other UK basement prospectivity, however, currently this UK potential remains unquantified.
Not only West of Shetland but the whole Atlantic margin has the correct elements for the basement play to be attractive. Hopefully this year's government funded seismic acquisition will add further clarification of the basement potential in the Rockall area and help de-risk the wider Atlantic Margin Basement Play potential.
Identified prospectivity in the North sea include the Ultsira High and Halibut horst. The basement is relatively young when compared to the Rona Ridge, however resource prospectivity benefits from proximity to a prolific source rock, long geological history and good structural configuration.
Similar arguments can be applied to the North and South Viking Graben, with demonstrable basement permeability and hydrocarbon charge.
The geological elements of a functional basement play are all present in the Central and Northern North Sea.

The other obvious benefit is that this area is covered by a robust geoscience data base. including numerous well ties and enviable 3D coverage. In fact many basement structures will have already been mapped in detail as part of clastic exploration and field development work programmes.

Perhaps the biggest driver for evaluating North Sea basement is its proximity to existing infrastructure, with at least one basement prospect lying directly below a North Sea producing field.

In fact the North Sea presents one of the most attractive basins worldwide for basement exploitation.
Since drilling our first basement well, Hurricane has acquired sufficient data to demonstrate the potential of a working basement play in the West of Shetland. Two discoveries and undrilled basement prospects indicate a significant resource base in shallow water and in an area much in need of infrastructure.

Whilst drilling and testing results are encouraging, it is clear that before the industry accepts that fractured basement is a proven play, a period of long term production must be demonstrated. Hurricane is working on achieving this goal with the support of OGA and the implementation of an Early Production System as part of a phased field development.

Currently there is significant UK basement prospectivity, much of it close to infrastructure, but to date this prospectivity remains poorly documented and unquantified.

Basement is a global phenomena and the UK has yet to bring a fractured basement field to production. We are close to achieving that goal and after we have achieved a period of sustained productivity I believe that Lancaster will pave the way to fractured basement becoming a game changer for the UK oil industry.