

## MULTIPLE HYDROCARBON SOURCES IN THE SHEARWATER HPHT FIELD – EXPECT THE UNEXPECTED

P. F. van Bergen, M. Gordon, B.J. Taylor, C. Prin, J.S. Watson, M. Hodzic, K. Ryzhikov and D. W. Jones

Shell UK Limited, Aberdeen, UK

The high-pressure and high temperature (HPHT) Shearwater Field is located in UKCS Block 22/30b. The field comprises gas-condensate at current conditions >10,000 psia reservoir pressure and temperature >300 F in three Jurassic reservoirs, Pentland, Fulmar and Heather. The initial reservoir pressures were in excess of 15,000 psia and reservoir temperatures exceeded 375 F (Jones et al. 2018 and refs therein). The field is located in the East Central Graben close to the Elgin–Franklin fields to the SW and the Erskine Field to the NE. The Field was discovered in 1988 and started first production in 2000.

The main stratigraphic zones are the shallow Tertiary, a major lower Tertiary and Cretaceous chalk section (e.g. Ekofisk, Tor, Hod), the organic rich Jurassic Kimmeridge and Heather Shales, and the Fulmar and Pentland sandstones. The latter also contains organic rich coals. The Kimmeridge and Heather shale are currently wet-gas mature.

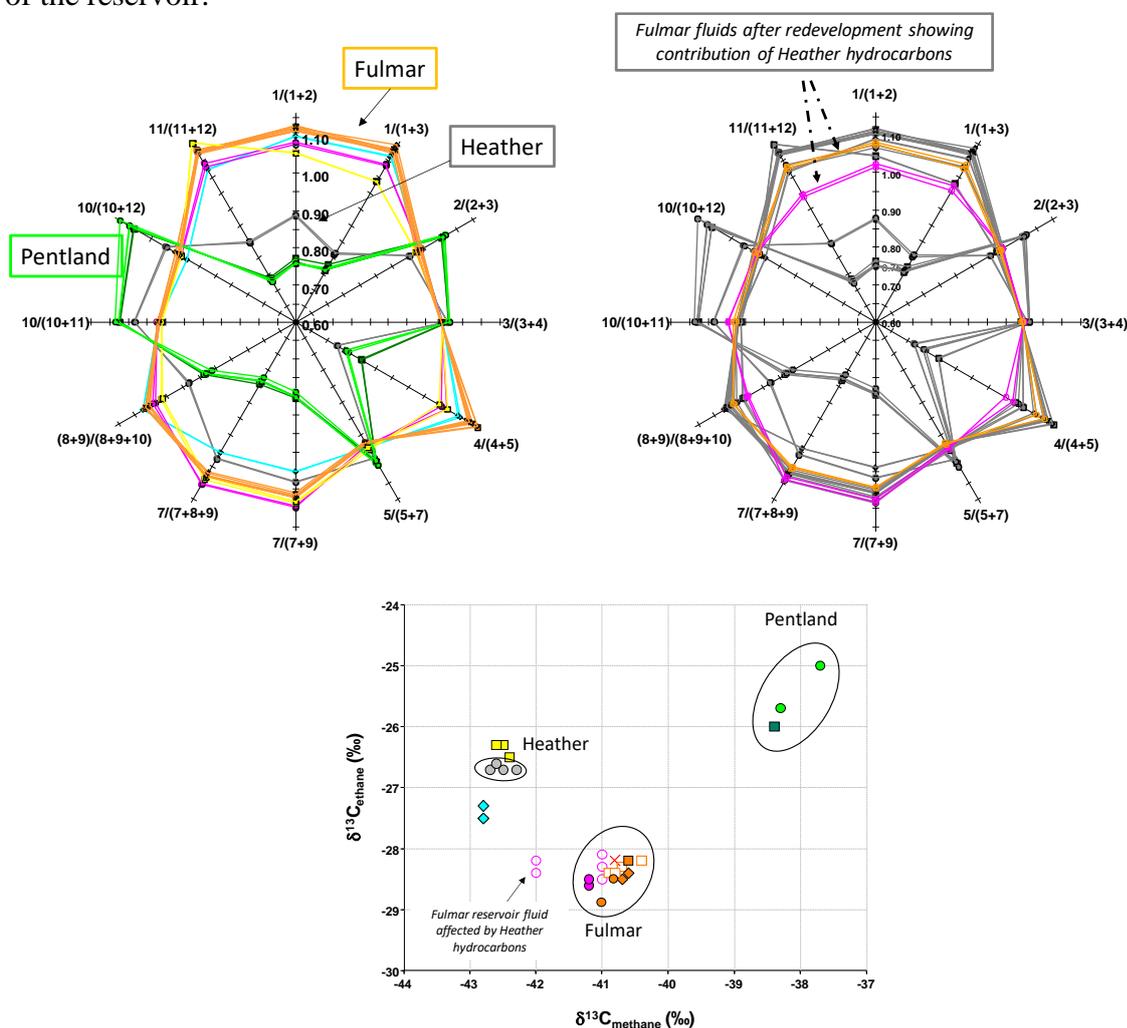
Hydrocarbons occur in the main three Jurassic reservoirs as well as in the overburden section starting from the Tertiary. Gas and liquid geochemical data collected during the early years of the field clearly indicated differences between the main Fulmar and Pentland reservoirs which could be explained by simple differences in the source contribution; Kimmeridge Clay derived hydrocarbons in the Fulmar with additional terrigenous derived hydrocarbons from the Pentland coals contributing to the Pentland reservoir.

During the fields redevelopment phase, multiple new wells were drilled between 2014 and 2017. Between start up and the redevelopment phase the main Fulmar reservoir underwent a significant reservoir pressure reduction with a maximum of 11,000 psi depletion. The new wells allowed further evaluation of the fluid changes observed in the two main reservoirs, due to this pressure depletion, as well as the detailed fluid characterisation of the Heather reservoir and the ubiquitous occurrence of the hydrocarbons in the overburden. Critical in this respect were the high resolution IsoTube sampling programmes that were implemented in all development wells. In addition, detailed gas (molecular and isotope composition) and liquid (fingerprinting, condensate isotopes, diamondoids) sampling were used to evaluate hydrocarbon presence, source and changes over time.

The IsoTube molecular and isotope data revealed clear vertical hydrocarbon breaks linked to lithologies indicating true vertical seals, i.e. just above the Kimmeridge shale, in the top of the Hod and in the top of the Tor. The diamondoid results further revealed that the hydrocarbons in the overburden were distinct from those in the deeper source rock and reservoir sections indicating lower mature fluids, the latter in accordance with the mud gas isotope results. During the latest drilling campaign, the within-source rock Heather Sandstone reservoir was also targeted. The combined gas and liquid geochemistry revealed that the hydrocarbons in this reservoir are *in-situ* generated and yield distinct signals from the hydrocarbons in the main Fulmar reservoir. In combination with the mud gas isotope data, it could be shown that the Heather hydrocarbons are more mature than those from the underlying Fulmar and in accordance with the actual maturity of the organic rich Heather shales.

The gas isotope and liquid fingerprint from the two new wells, which were drilled into the depleted deeper main Fulmar reservoir, yielded unexpected molecular and fingerprinting differences (Fig. 1). In particular a well in the western part of the field, which had been depleted for almost 10 years up to 11,000 psi showed clear changes. Further detailed geochemical comparisons with the hydrocarbon characteristics of the overlying organic rich Heather shales and the Heather reservoir indicated that the main Fulmar reservoir was receiving direct inflow from *in-situ* generated hydrocarbons from the overlying source organic rich Heather shale.

This is for the first time that it has been shown unequivocally that hydrocarbons generated in mature organic rich layers actively contribute hydrocarbon to reservoir hydrocarbons on a production time scale. This has major implications as this indicates reservoirs which are in direct communication with mature source rock or organic rich layers, in general, will be able to receive producible source rock-derived hydrocarbons. In addition, the energy generated from the source rock should be taken into account in the total energy balance during natural depletion of the reservoir.



**Figure 1** Star plots showing initial liquid fingerprints on the left and the Fulmar fingerprints from the redevelopment wells (Top). Gas fingerprints showing a Heather contribution to the Fulmar reservoir hydrocarbons (Bottom).

Jones, D.W., Taylor, B.J., Gill, C.E., Bevaart, M., van Bergen P.F., Watson J.S., De Gennaro S. & Hodzic, M. 2017. Proceedings of the 8th Petroleum Geology Conference, 429–443. <https://doi.org/10.1144/PGC8.36>