Cracked and full of sand: microstructural insights into how oil gets into the fractured Precambrian basement of the Rona Ridge, West of Shetland.

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The fractured Neoarchaean orthogneisses forming the 200km long, NE-SW trending Rona Ridge (or High) lie along the southeast margin of the Faroe-Shetland Basin. The ridge is thought to have been uplifted primarily during Cretaceous-age normal faulting and is flanked and immediately overlain by cover sequences ranging in age from Devonian-Carboniferous (Clair Group) to Cretaceous. Basement-hosted oil is known to occur in significant volumes in at least two fields (Clair, Lancaster) and is also thought to be present in a number of other locations along the basement ridge, most notably in the Victory and Whirlwind discoveries. Re-Os dating of bitumen samples from the Clair Field suggests that the oil present was generated in the period 64-72Ma.

A new microstructural study of legacy cores of basement rocks and overlying cover sequences from the Rona Ridge (held by the BGS and BP) was carried out in order to assess the mechanisms and timing of oil charge and other fracture-hosted mineralization. Early upper amphibolite-granulite facies deformation fabrics are overprinted by widespread epidote-quartz veining and local developments of cataclasite, pseudotachylyte and phyllonite. The age of these structures is uncertain, but is likely to be pre-Devonian as none are found cutting the overlying Clair Group, the oldest of the overlying cover sequences. Oil charge is everywhere directly associated with quartz-adularia-hematite-calcite-pyrite mineralization and is hosted in a complex mesh of interconnected shear and tensile fractures that formed during a single protracted, episode of brittle deformation. This association is recognized in all basement cores containing oil and also in locally overlying well-cemented Devonian Lower Clair Group and Upper Jurassic Rona Sandstone sequences (Fig. 1a-f).

For the first time, it is shown that mineralization is associated with clastic sedimentary infillings which occur either as vein-hosted injected slurries or as little deformed laminated infills in mm to dm-scale open fractures. The latter locally preserve delicate way-up criteria and geopetal structures. The largest accumulations of oil are found either in these poorly-cemented sedimentary infills or in fracture-hosted vuggy cavities up to several cm across. All these features, together with the widespread development of zoned mineral cements and cockade textures suggest a low-temperature hydrothermal system that likely formed in a near surface (<1-2km depth) environment where highly dilated, open fractures developed in relatively strong crystalline rocks (or overlying well cemented sedimentary rocks) and were able to act as long-lived fluid channel-ways. There is no textural evidence for reactivation and it seems likely that oil saturation ultimately shut down fracture cementation. Thus, the oil filled vugs are ‘left-over’ primary cavities.

The widespread preservation of dilational pull-apart features, together with the development of injected sediment-mineral slurries, and at least one possible silica gel along a fault, suggests that seismogenic faulting drove fluid flow through the basement fracture systems. Such a ‘dilatancy-pumping’ process may have also helped to drive oil migration from the Jurassic source rocks located to the west in the FSB, through the basement ridge and up into the overlying Clair Group and other cover sequences. This model is consistent with the age of rifting based on geological evidence and also with the ca 64-72Ma Re-Os ages of the Clair Field oils; it is also consistent with the observation that the mineralised fracture systems also occur in Devonian to Upper Jurassic cover sequences.

Our findings have major implications for the development of fractured basement reservoirs in the UKCS and worldwide. They also suggest that near-surface sesimogenic faulting and dilatancy in strong crystalline rocks such as basement, igneous intrusives/extrusives and some carbonates may help drive fluid flow and trigger hydrocarbon migration during rifting.

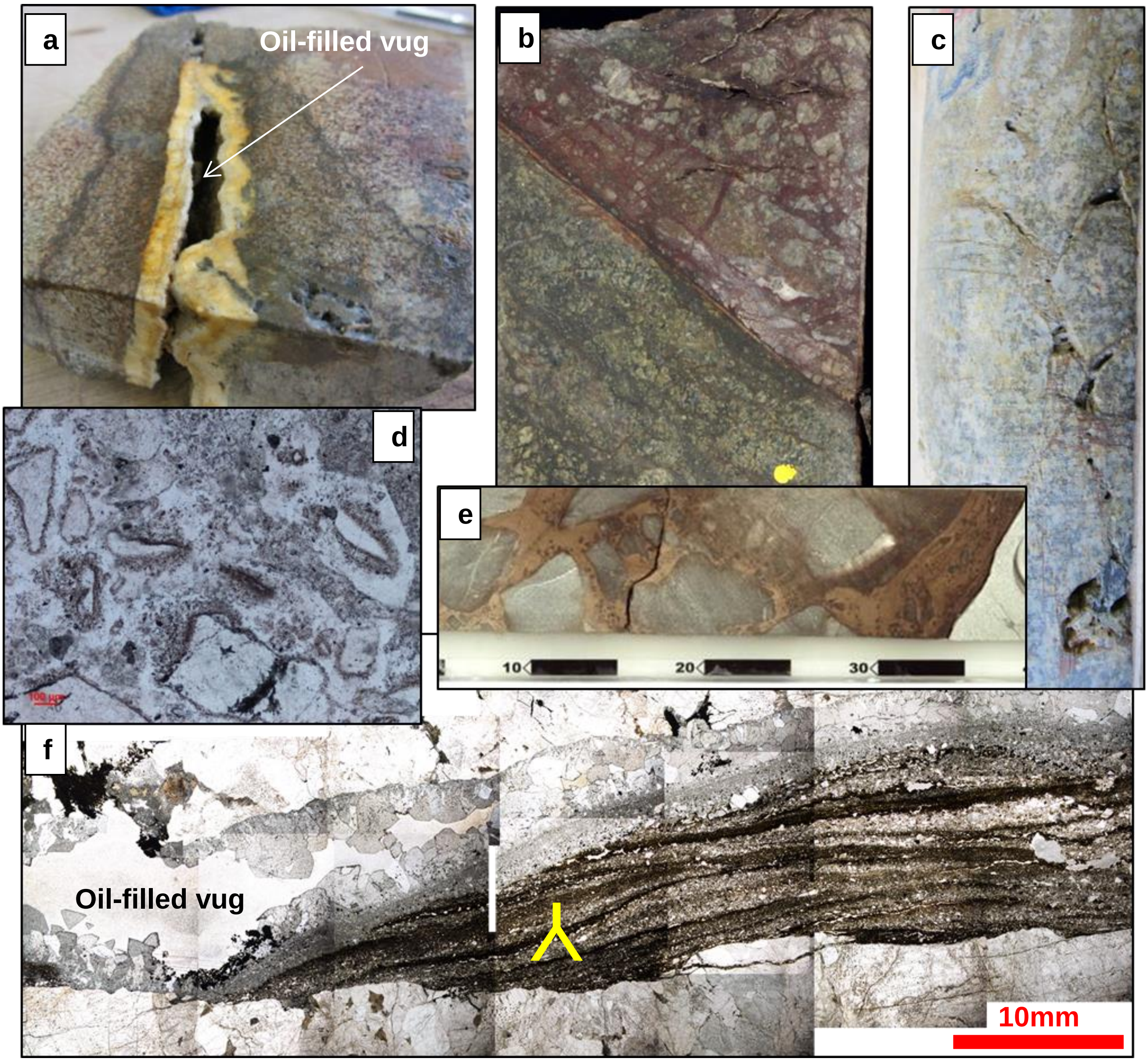

Figure 1) *Fracture systems and mineralization styles associated with oil charge in fractured basement and well-cemented cover sequences along the Rona ridge. a) Carbonate-quartz vein with central oil-filled vug; b) shear fracture and fault breccias, with fine sediment slurry injections (purple-red above) and possible silica gel along shear (orange layer); c) typical shear-tensile fracture mesh with oil-filled vugs; d) quartz-cemented cockade textures in fracture fill microbreccia; e) oil-stained, sediment-filled fractures in Lower Clair Group; f) graded laminated sediment, geopetal fill (quartz-cabonate-pyrite) and oil-filled vug in fractured basement – note that the younging from the grading and the geopetal structure are consistent.*