Cracked and Full of Sand: Insights Into How Fractures Enable Ingress of Oil Into Crystalline Basement Reservoirs

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ABSTRACT

The fractured Precambrian gneisses of the 200km long Rona Ridge form the SE margin of the Faroe-Shetland Basin (FSB). Uplifted during Cretaceous-age normal faulting, it is flanked and immediately overlain by Devonian to Cretaceous cover sequences. Basement-hosted oil is known to occur in substantial volumes in at least two fields (Clair, Lancaster). Re-Os dating of bitumen and new U-Pb dating of calcite fills suggests that mineralization and oil charge occurred over a period of 20-30 Ma during the Upper Cretaceous. A new study of basement cores was carried out to assess the mechanisms and timing of oil charge and other fracture-hosted mineralization. Oil charge is everywhere associated with quartz-adularia-calcite-pyrite mineralization and is hosted in meshes of interconnected shear/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 and Upper Jurassic clastic sequences. Mineralization and oil charge is everywhere associated with clastic sedimentary material which occurs either as vein-hosted injected slurries or as laminated infills in mm to dm-scale open fractures. The latter preserve delicate way-up criteria and geopetal structures. The largest accumulations of oil are found either in the poorly-cemented sedimentary infills or in fracture-hosted vuggy cavities up to (at least) several cm across. All these features, together with the widespread development of zoned mineral cements and cockade textures suggest a near surface (<1-2km depth) low-temperature hydrothermal system. Highly dilated, open fractures developed in strong basement and overlying well cemented sedimentary rocks, and were able to act as long-lived fluid channel-ways. There is no evidence for reactivation. Oil saturation likely periodically shut down fracture cementation. The widespread preservation of dilational pull-apart features, together with the development of injected sediment-mineral slurries, and possible silica gels along faults, suggests that Upper Cretaceous seismogenic faulting drove fluid flow through the basement fracture systems. This 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 cover sequences. The significance of these findings for fractured basement reservoirs worldwide will be discussed.