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Age dating of mineralization and brittle deformation using rhenium-osmium (Re-Os) geochronology in pyrite-bitumen bearing fracture systems

Robert Holdsworth (1), Eddie Dempsey (1), David Selby (1), Anna Dichiarante (1), Alex Finlay (1,2), and Steven Ogilvie (3)

(1) University of Durham, Dept of Earth Sciences, Durham, United Kingdom (R.E.Holdsworth@durham.ac.uk), (2) 2Chemostrat Ltd., Unit 1, Ravenscroft Court, Buttington Cross Enterprise Park, Welshpool, Powys, SY21 8SL. United Kingdom , (3) BP Exploration, Aberdeen, AB21 7PB, United Kingdom

The relative ages of different fault rocks are generally established using cross-cutting relationships seen in the field and thin section. However, the absolute dating of fault rock formation events remains a problematic issue. In many Phanerozoic basins, hydrocarbon (mainly bitumen)-bearing fault and fracture systems also carry sulphide minerals such as pyrite. The bitumen and pyrite are commonly enriched with rhenium (Re) so that the 187Re-187Os geochronometer can be used to date mineralization and better constrain the timing of brittle deformation. Furthermore, the determined 187Os/188Os composition of the sulphide minerals at the time of formation can yield insights into the origins of the fracture-hosted fluids. We report 3 cases of Re-Os sulphide geochronology from fracture-hosted hydrocarbon-pyrite systems offshore West of Shetland (UK) and in the nearby onshore Orcadian Basin, N Scotland.

Hydrocarbon Re–Os data from the Faroe-Shetland Basin (FSB) show that there are four pulses of increased oil generation at 72 $\pm$ 5 Ma, 64 $\pm$ 4 Ma, 53 $\pm$ 14 Ma and 42 $\pm$ 6 Ma. These dates remove the need for large scale oil collection within fractured basement and Late Cretaceous reservoirs before re-migration into later Cenozoic reservoirs and agree with more recent models in which oil generation has been retarded by over pressure and that multiple pulses of generation are associated with regional inversion events that occurred during the Late Cretaceous, Paleocene and Oligocene/Miocene.

The Clair oil field lies on the SE side of the FSB and a major part of the reservoir lies in Lewisian basement where hosting fractures are infilled with pyrite, calcite and bitumen. The pyrite contains low abundances of Re and Os, with Re-Os isotope compositions that are too similar to yield an isochron, whilst the associated bitumen is enriched in both Re and Os. Regression of the Re-Os data from other parts of the Clair field with the new pyrite Re-Os data obtained here yields a more precise generation age of 72 $\pm$ 5 Ma. The texturally later bitumen in the basement gives a generation/migration age of 64 Ma. The results provide a minimum age of fracturing within the basement of 72 $\pm$ 5 Ma.

In the Devonian rocks of the onshore Orcadian Basin, N Scotland, two distinct groups of faults and associated structures are recognised. The earlier set display predominantly sinistral strike-slip to dip-slip extensional movements, and are likely to be Devonian based on regional considerations. The later cross-cutting set of faults display predominantly dextral to extensional displacements and are associated with widespread syn-deformational carbonate mineralisation (+/- pyrite and bitumen). Preliminary Re-Os pyrite and bitumen geochronology reveal that this later faulting, mineralization and hydrocarbon generation occurred during the early Mesozoic (Late Triassic). This is likely related to the main phase of rifting responsible for the formation of the West Orkney Basin immediately offshore and to the north.

Given the worldwide association between fracture-hosted sulphides and hydrocarbons, these examples illustrate how Re-Os geochronology can be used to place better constraints on the absolute timing of faulting episodes.