Rare Gas Isotopic and Elemental Constraints on Oil Migration and Hydrogeological Processes: The Statfjord, Snorre and Gullfaks Fields, Norwegian North Sea Oil Province.

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Noble gas isotopic and elemental data obtained from hydrocarbons can provide unique and hitherto often unavailable information on the hydrogeological conditions related to oil migration and subsequent reservoir processes. The solubilities of noble gases in hydrocarbons and water dictate that a source area noble gas signature will be mixed and diluted with noble gases stripped from groundwater in contact with the hydrocarbons. Thus the hydrocarbon phase will retain a record of its evolution from source to reservoir, providing information on (a) the composition and total amount of groundwater that the hydrocarbons interacted with; (b) the presence of any exotic components in the ground water; and (c) the composition and potential presence of multiple source areas.

The research area consists of three oil fields in the Tampen Spur region of the Norwegian North Sea oil province: the Statfjord, Snorre, and Gullfaks fields. The hydrocarbon deposits mainly occur in Jurassic sandstone sequences of the Statfjord Formation and Brent Group, which have been affected by rotational block sliding related to the main phase of rifting and uplift in the Viking Graben. For this study the main point of focus is distinction between several complex and conflicting reservoir filling hypotheses, that can not be unequivocally distinguished between using conventional methods like biogeochemical markers or gas/oil/water ratio changes between the fields.

A total of 13 gas samples for major and trace gas analysis were collected from the gas side of a gas/liquid separator at the production platforms (Statfjord field: 4; Snorre field: 5; Gullfaks field: 4). Noble gas data for the Statfjord and Snorre fields show a strong linear correlation in elemental and isotope space, which to some extent reflects geographical location within the reservoir. Gullfaks data are too scattered to interpret with confidence. For the Statfjord and Snorre fields it can be deduced that both reservoirs were filled with hydrocarbons of similar noble gas composition. This original composition reflects extensive interaction of the oil, at temperatures >80˚ C and oil/water <0.02, with a groundwater that was initially in equilibrium with air (15˚ C saturated water, ASW). Even after interaction with ground water the hydrocarbons still record significant air-derived Xe enrichments, similar to, but much smaller than those observed in the Elk Hills oil field (Torgersen and Kennedy 1999; EPSL 167, pp. 239-253).

After entry into the reservoirs the hydrocarbons evolved along different paths towards different ‘endmembers’. The Snorre hydrocarbons are characterised by a trend of increasing 3He/4He and 40Ar/36Ar ratios. This could suggest the presence of a mantle component, but this can not be substantiated with the current data. The Statfjord hydrocarbons interacted with a component not unlike 15˚ C ASW, but with significant elemental Ne enrichments, and radiogenic He isotope ratios suggesting the presence of a crustal component.