**Temporal evolution of the Brynhild petroleum system, North Sea**

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Petroleum accumulations are the end product of a long-lasting and complex interplay between multiple components, conditions and processes. Improved understanding of petroleum systems requires a holistic approach of integrating local geological knowledge with geophysics, stratigraphy and organic geochemistry data. Inorganic geochemistry is catching up and offers promising novel avenues for practical research. A key question is whether (and how) the inherent complexity of petroleum systems homogenizes and conceals primary inorganic geochemical signatures that can directly identify specific components, processes or times.

Here, we present results from an integrative study on the Brynhild petroleum system, Norwegian North Sea. Re-Os geochronology constrains the timing and initial Os composition of (i) immature and early mature source rocks from the Mandal and Farsund Formations, (ii) free-flowing Brynhild crude oil, and (iii) hydrocarbons extracted from reservoir rocks of the Ula Formation. Supplementary GC-MS, Rock-Eval, TOC, stable isotope and trace metal data are used together with detailed Re-Os results to constrain source rock depositional conditions and the age of reservoir rocks. Importantly, this multi-tool approach enables us to identify and trace in time the interactions between individual components of the Brynhild petroleum system.

Re-Os age results and modeled $^{187}\text{Os}/^{188}\text{Os}$ ratios for key components back in time suggest that uppermost Jurassic-Lower Cretaceous black shales produced hydrocarbons at $\sim$40 Ma. A recent (7-0 Ma) pulse of hydrocarbon generation is identified in extracted hydrocarbons from the reservoir rocks. Initial $^{187}\text{Os}/^{188}\text{Os}$ ratios suggest that younger hydrocarbons are not sourced from the same Jurassic-Cretaceous shale, but may have been formed by further cracking of the early ($\sim$40 Ma) hydrocarbons.

Our Re-Os results are consistent with detailed regional models for petroleum production and provide further insights into the evolution of the Brynhild oil field. We show that complex petroleum systems carry valuable inorganic clues for the origin and timing of oil formation.

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