

Paper Number: 5468

## Disassembling petroleum systems with Re-Os isotope geochemistry

Hannah, J.L.<sup>1,2</sup>, Georgiev, S.V.<sup>1,2</sup> and Stein, H.J.<sup>1,2</sup>

<sup>1</sup> AIRIE Program, Colorado State University, Fort Collins, CO 80523-1482 USA (correspondence: [judith.hannah@colostate.edu](mailto:judith.hannah@colostate.edu))

<sup>2</sup> CEED Centre of Excellence, University of Oslo, Norway

---

Over the past decade, with improvements in mass spectrometry, sampling methods, and wet chemical procedures, Re-Os geochemists mastered the art of Re-Os geochronology for organic-rich sedimentary rocks. At the same time, the community began exploring Re-Os abundances and isotopic ratios in bitumen and oil, with the goal of determining the timing of hydrocarbon generation and/or expulsion. Here we outline our approach to achieving this ultimate goal, and the challenges still before us.

Tracking Re and Os through a petroleum system is best achieved by defining Re-Os concentrations and Os isotopic composition in the source rock and in reservoir oil. A precise source rock isochron yields both the age and initial  $^{187}\text{Os}/^{188}\text{Os}$  ratio ( $\text{Os}_i$ ) at the time of deposition – the starting conditions for the system. Some have approached timing of oil accumulation by fitting an isochron to asphaltene oils collected from multiple wells in a single system. While potentially helpful, the resulting age is typically low precision (e.g.,  $68 \pm 13$  Ma [1] and  $27.5 \pm 4.6$  Ma [2]) for four reasons: (1) the  $\text{Os}_i$  of the source rock may be variable if deposition was prolonged; (2) the calculated  $^{187}\text{Os}/^{188}\text{Os}$  at the time of oil generation depends strongly on the  $^{187}\text{Re}/^{188}\text{Os}$  of the source rock, which can span an order of magnitude and is rarely well known; (3) oil generation may span significant time, during which the  $^{187}\text{Os}/^{188}\text{Os}$  of the source rock increases; and (4) petroleum systems are open systems, subject to mixing of oils of differing ages or sources and to precipitation of asphaltene.

Our approach is to take apart single oil samples, constructing isochrons from different components, much as geochronologists have long generated isochrons from different minerals in a rock [2]. We have found typically higher  $^{187}\text{Re}/^{188}\text{Os}$  ratios in asphaltene precipitated from oils, relative to the  $^{187}\text{Re}/^{188}\text{Os}$  in the residual maltene fraction. The asphaltene, maltene, and original crude oil therefore yield a 3-point isochron. Additional distinct points may be generated from asphaltene fractions precipitated with different solvents; this takes advantage of the fact that “asphaltene” is simply a solubility class that varies chemically depending on the procedure used for precipitation. Finally, analyses of multiple oils and bitumen tracks in a single petroleum system may reveal several steps in a complex history. Combined with knowledge of local and regional geology, these data lend confidence to interpretation of the Re-Os results.

Given the geologic complexity of petroleum systems, the thermochemical complexity of organic molecules, and the scarcity of published studies, we cannot yet routinely define the timing of petroleum maturation, expulsion, and migration with full confidence. Does an isochron for an oil convey the timing of maturation, expulsion, or accumulation in a reservoir? How are Re and Os partitioned between residual kerogen in the source rock, between oil and asphaltene that may be precipitated during migration, and between oil and formation waters encountered at any stage? Does fractionation of Os isotopes occur at any stage of hydrocarbon maturation and migration? These are questions that the AIRIE Program is exploring both empirically and experimentally. Stay tuned.

*References:*

[1] Finlay et al A (2011) *Geology* 39: 475-478

[2] Georgiev S et al. (2016) *Geochimica et Cosmochimica Acta* 179: 53-75

*This work was supported by the Norwegian petroleum industry under the CHRONOS project.*

