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Unravelling Heavy Oil Systems: A Novel Approach

Sarah J. Porter and Gemma Hildred
sarahporter@chemostrat.com
Chemostrat Ltd. and Chemostrat Inc.

Introduction

The Canadian oil sands are the third largest reserves of hydrocarbons in the world. Comprising three major deposits, Athabasca, Cold Lake and Peace River, the oil sands represent > 95 % of Canada's oil reserves. However, despite being at the forefront of frontier exploration, this complex petroleum system still maintains a large degree of uncertainty as oil-source and oil-oil relationships have yet to be fully defined. To maximize our knowledge of any subsurface petroleum system it is imperative that we have a thorough understanding of the generated hydrocarbons. Detailed evaluation of the chemical composition of heavy oil accumulations provides critical information regarding the temporal and spatial controls on their formation. It can also provide valuable insight into the characteristics of the oils, enabling variations in the asphaltene content and viscosity of the accumulation to be identified. The ability to recognize families of oils in a petroleum system and to relate those families to each other is also essential. However, such understanding is often lacking, and hydrocarbon characterization has so far mostly been restricted to using standard organic geochemical methods.

Rhenium-Osmium Oil Geochronology

Rhenium-osmium geochronology exploits the β decay of ^{187}Re to ^{187}Os. This isotopic decay system provides a very useful and widely used chronometer for the absolute dating of organic rich sediments (Selby and Creaser, 2005a; Kendall et al., 2006). Both Re and Os are highly enriched in organic-rich sedimentary units (due to their organophilic nature), relative to upper continental crust, reflecting the sequestration of Re and Os from the water column during sedimentation and under oxygen-limited conditions. Furthermore, the transferal of Re and Os from the source rock to the generated oil when it enters the oil window allows the Re-Os geochronometer to be used to generate an absolute date for oil generation (Selby and Creaser, 2005b; Selby et al., 2007; Finlay et al., 2011).
Uncertainty regarding the timing of oil generation is a common exploration problem. Constraining the timing of hydrocarbon generation through direct radiometric dating of hydrocarbons provides a robust temporal constraint on the timing of oil formation within the petroleum system. The key advantage of utilizing Re-Os over other traditional organic geochemical techniques is that this proven approach provides a quantitative determination of when the oil was generated, thus also making it possible to assess and quantify charge events within a basin. This isotopic system has been demonstrated to be extremely stable, making it ideal for application to petroleum systems. In addition, Re-Os isotope systematics in hydrocarbons are not affected by biodegradation (eg. Finlay et al., 2011).

Oil Characterisation in Heavy Oil Systems

Oil characterization has traditionally been focused around organic geochemical techniques, such as biomarker analysis (Peters et al., 2007). However, here we describe the use of inorganic elemental geochemistry by ICP-MS and ICP-OES analysis to compositionally categorize oils with a view to identifying oil populations. This technique also enables us to conduct oil-oil correlation, which in turn provides valuable insight into the assessment of reservoir connectivity. The elemental analysis has the advantage of being an inexpensive technique that yields significant compositional information at a high resolution in a short time-frame. This compositional data, in conjunction with the geochronological dataset, also allows conclusions to be drawn regarding charge events and the likelihood of expulsion from a single or multiple source rock units. Inorganic analysis of oils can be conducted on fluids as well as bitumen staining within a reservoir rock (following extraction), making its application ideal to Canada's oil sands. Obtaining a high resolution compositional understanding of the oils within a heavy oil accumulation also allows us to observe changes in the characteristics of the oils throughout the well. The behavior of concentrations of some of the key metals, such as Ni and V enable changes in asphaltene concentration to be observed. This in turn allows assessments to be made regarding changes in oil viscosity and API within the well.

Oil characterization can also be conducted using chemostratigraphy (elemental characterization) through sections of oil sands and heavy oils. This technique is particularly valuable in plays where tar mats pose a significant production problem. Tar mats are notoriously difficult to identify in the sub-surface as traditional petro-physical methods are unable to determine the transition from heavy oils to the tar mat phase. Chemostratigraphic analysis of oils in this setting enables the use of oil compositional data to identify this transition and highlight the presence of tar mats within the well. As with conventional chemostratigraphy, correlations on a multi-well scale can also be conducted if required.

Conclusions

The application of inorganic geochemical techniques to heavy oil systems provides valuable compositional and temporal information on oil formation. By utilizing Re-Os geochronology oil mixing events can be identified and the timing of oil generation can be obtained; something that cannot be achieved using more traditional techniques. This dataset can be further enhanced with the addition of high resolution oil compositional data from ICP-MS and ICP-OES analysis, which allows oil populations to be identified and assessments to be made about charge events and connectivity. Further, the precision offered by ICP analysis of oils versus alternative techniques, enables variations in the characteristics of the oils within the well to be defined.

References

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