Circum-Arctic Petroleum Systems Defined Using Biomarkers, Isotopes, and Chemometrics

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Because petroleum systems involve multiple elements and processes, traditional exploration to find subsurface traps is prone to error. Costly exploration failures, such as the Mukluk well in Alaska, show that large traps may lack oil and gas. Understanding the link between petroleum and the source rock reduces risk. For example, identification of the source rock for accumulations suggests migration pathways and whether nearby structures might have filled. Unfortunately, conventional oil-to-source rock correlation and studies of mixed oils are commonly unreliable because they are based on few parameters and lack statistical evaluation of uncertainty.

This paper describes two new chemometric methods that use geochemical data to define petroleum systems and de-convolute oil mixtures in the circum-Arctic. Source- and age-related biomarker and isotope data were measured for ~1000 oil samples collected above ~55^{o}N latitude. A multi-tiered chemometric decision tree identified 31 circum-Arctic oil families based on a training set of 622 oil samples. 'Decision-tree chemometrics' uses principal component analysis (PCA) and other multivariate statistical tools to classify and assign confidence limits for oil and source-rock extract samples. For example, the method identifies seven oil families in West Siberia, four in East Siberia, and two in the Volga-Ural basin and the corresponding source rocks.

Seventy-four of the above oil samples from the Barrow arch on the Alaska North Slope were studied to assess relative volumetric contributions from different source rocks to the giant Prudhoe Bay Field. Alternating least squares of concentration data (ALS-C) for 46 biomarkers was used to de-convolute the mixtures. ALS-C results for 23 oil samples from the prolific Ivishak Formation reservoir in the field indicate similar contributions from Triassic Shublik Formation and Cretaceous Hue-GRZ source rocks (37% each), and less from the Jurassic Kingak Shale (26%). These results differ from published interpretations that most oil in the field originated from the Shublik Formation. Unlike conventional methods to assess mixtures, ALS-C does not require that pure end member oils be identified prior to analysis or that laboratory mixtures of these oils be prepared to evaluate mixing. Further application of these methods could significantly improve understanding of the origins of crude oil in other areas of the circum-Arctic, thus reducing exploration risk.