

PITFALLS AND POTENTIAL REMEDIES OF THE CURRENT OIL-SOURCE CORRELATION APPROACH: CASE STUDIES IN TWO OF THE WORLD'S LARGEST TERTIARY DELTAIC SYSTEMS

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Biomarkers are used routinely by the oil industry to group genetically related oils, to correlate discovered oils with source rocks and to postulate the probable source rock depositional environments of migrated oils of uncertain origin. Dahl et al. (1994) suggested that biomarker distributions in reservoir oil could be used to monitor lateral facies changes in the underlying source rocks in vertically drained basins. Several case studies showed that this biomarker approach could allow petroleum geologists to constrain source rock quality, one of the key variables in petroleum systems, even when the source rock has not been penetrated. The present study uses geological and geochemical data from two of the world's largest Tertiary deltaic systems to demonstrate the common pitfall of the current oil-source correlation approach and to suggest potential remedies for addressing the problem.

The Beaufort-Mackenzie Basin is a Mesozoic-Cenozoic trough formed by the opening of the oceanic Canada Basin, with sediments prograding northwards across the continental margin from the Late Cretaceous and through the Tertiary period. Molecular, isotopic and elemental data for a set of over 150 oils from the Mackenzie Delta and Canadian Beaufort Sea have been evaluated, and the depositional environment and organic matter characteristics of the potential source units for these oils have been predicted. The deltaic sediments in the Paleogene Aklak, Taglu and Richards sequences of the Beaufort-Mackenzie Basin are molecularly distinctive, containing biomarkers indicative of a major land plant contribution. These include the high C₂₉ sterane abundance relative to other steranes, and high oleananes, 24-norlupanes, 24,28-bisnorlupanes relative to hopanes, and the presence of a battery of partially aromatized, angiosperm and gymnosperm derived polycyclic hydrocarbons. In contrast, biomarker signatures of the marine source rocks in the Upper Cretaceous Smoking Hills/Boundary Creek formations are characterized by little or no oleananoids/lupanoids, abundant C₃₀ 24-n-propylcholestanes, and an almost 1:1:1 ratio of the C₂₇:C₂₈:C₂₉ regular and rearranged steranes.

The Pearl River Mouth Basin also contains a large Tertiary deltaic system developed on the northern continental shelf of the South China Sea, with oils being produced mainly from deltaic-near shore sandstone reservoirs in the upper Oligocene Zhuhai Formation. The

likely source rocks for these oils include the lacustrine shales and mudstones of the Eocene Wenchang Formation and the shallow lacustrine-deltaic coal-bearing sequence of the Eocene-Oligocene Enping Formation. Oils derived from the lacustrine source rocks in the Wenchang Formation typically contain abundant C₃₀ 4-methylsteranes, whereas the deltaic source rocks in the Enping Formation are characterized commonly by high pristane/phytane ratios and significant amounts of C₁₉ tricyclic terpane and bicadinanes.

What is common in both Tertiary deltaic systems is that the chemical compositions across different molecular weight and polarity fractions of a large number of oils in the deltaic reservoirs do not conform to those of the known source rocks, though correlations using the routine m/z 191 and 217 mass fragmentograms would favour one particular source that contains higher biomarker concentrations. For example, the presence of abundant higher plant markers in the Paleogene oils of the Beaufort-Mackenzie Basin appears to suggest a dominant deltaic coaly source with relatively low thermal maturity for these oils. However, GC/MS/MS analyses of the saturate fractions of these oils reveal that the C₂₉ sterane dominance on the m/z 217 mass fragmentograms is in fact a mixture of a group of immature terrestrially-derived C₂₉ steranes superimposed on a group of C₂₆ to C₃₀ steranes with mature structural configurations likely from the Upper Cretaceous marine source. Mass balance calculations indicate that addition of only 5% of the immature intra-reservoir deltaic source rock extract to a mature oil originating from the Upper Cretaceous marine source rocks would turn the mixture into an “immature oil” with an apparent coaly source. This suggests that the presence of abundant higher plant markers in the oil is a necessary but not sufficient indicator for the Paleogene deltaic source. In the Pearl River Mouth Basin, in contrast, laboratory mixing experiments using selected end member oils indicate that even with 50-80% contribution from the deltaic source in the Enping Formation, the mixtures still display biomarker signatures diagnostic of the lacustrine source rocks in the Wenchang Formation. Thus, the presence of abundant 4-methylsteranes in the light oils is also a necessary but not sufficient indicator for the lacustrine source rock in this basin. As mixing is the norm in vertically drained petroleum systems and “source rock” samples are collected commonly from exactly the wrong locations for this purpose, the established paradigms of oil-source correlation in many of the world’s largest Tertiary deltas need to be re-examined.

REFERENCES

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