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Geochemistry as a State of the Art Reservoir Investigative Tool

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Summary

Compositional variations are observed in conventional and unconventional reservoirs worldwide due to various in-reservoir processes. Geochemical characterization of these variations in reservoir fluids provides valuable information regarding baffles and barriers to vertical and lateral fluid communication. The review presented here shows that gas chromatography mass spectrometry (GCMS) allows rapid, accurate, and economical characterization of the numerous geochemical compound classes that comprise reservoir fluids. In the Cretaceous McMurray formation of Alberta, compounds such as alkylnaphthalenes, alkylphenanthrenes, and alkyldibenzothiophenes vary in concentration corresponding to the level of biodegradation in a given reservoir section. Concentration profiles are interrupted and offset by baffles and barriers to fluid communication. Such information allows geoscientists and engineers to make informed decisions about well placement and maximize hydrocarbon recovery. It is possible to access these data through the analysis of legacy core samples by GCMS, as well as helping to show the extent of steam chamber formation. Prevailing economic conditions make it imperative that producers maximize recovery efficiency, and detailed knowledge of reservoir structure and hydrocarbon quality through the use of molecular geochemistry is an important part of working more effectively with the tools at hand.

Introduction

Reservoir characterization employs a number of different tools, including engineering, geophysical, and geochemical data. Variation within reservoirs can take place on scales from kilometers to microns (Stoddart *et al*., 1995). Geochemistry is a tool that allows for a detailed investigation of the organic geochemical composition of reservoir fluids, and the determination of compartmentalization, in terms of baffles or barriers to vertical and lateral fluid flow.

For many years, it has been understood that compositional variation in reservoirs can be due to a number of internal processes, such as gravitational settling, vertical and lateral diffusive mixing, and biodegradation (Bailey *et al*., 1973; England, 1994; Larter and Aplin, 1995; Larter *et al*., 2003). The presence of internal barriers to vertical and lateral fluid flow can produce compartmentalization, producing reservoir fluids with different compositions and fluid properties. Geochemistry, one potential tool among many available to reservoir engineers (Westrich *et al*., 1999), can assist in identifying reservoir compartmentalization. Many elements of geochemistry can be used, including isotope geochemistry, fluid inclusion analysis, and biomarker compositional analysis.

In Alberta, geochemistry is a valuable tool for reservoir characterization, providing detailed information concerning compositional variation within biodegraded reservoirs. Typically, reservoirs within the Cretaceous McMurray formation display decreasing molecular geochemical concentrations of compounds, such as alkylnaphthalenes, alkylphenanthrenes, and alkyldibenzothiophenes with depth, as biodegradation increases towards the oil-water contact (Fustic *et al*., 2011). This knowledge, coupled with geological and geophysical data, can enhance the knowledge concerning in-reservoir elements that might adversely affect production. Knowledge of potential reductions in the thickness of pay intervals along the length of a given well is essential, and the presence of barriers to fluid communication can significantly reduce the quantity of recoverable oil (Strobl, 2013).

Theory and/or Method

Gas chromatography mass spectroscopy (GCMS) is a technique whereby detailed molecular geochemical composition of bitumen can be determined. Compounds in core, cuttings, or produced fluids, separated by gas chromatography, are identified and quantified using a range of analytical standards, which allow for the creation of concentration profiles over a wide range of relevant geochemical compound classes through the target reservoir. The abundance of the analyzed compounds is linked to the level of biodegradation at any given reservoir interval (Bennett *et al*., 2012). Selection of appropriate compound classes for geochemical profiling can indicate the presence of baffles and barriers to fluid communication because these features produce offsets in concentration profiles. Such offsets are known to be associated with variations in fluid properties and can then be correlated with well logs and core photographs (Marcano *et al*., 2012). The advantage of this type of analysis is that features representing baffles or barriers can often be too small to be identified on well logs, but are visible in geochemical concentration plots.

Geochemical profiling can also produce valuable information related to the lateral character of baffles and barriers when adjacent wells are studied. Such profiles can be used in conjunction with engineering and geophysical data to determine the extent of barriers, providing an alternative to 4D seismic studies. This method of analysis is suitable for core samples that have been stored for a significant length of time, proving that legacy material (core or cuttings) contains valuable geochemical data, which can be made available years after having been collected. If at some point in time, fresh samples can be taken and molecular geochemistry and fluid properties determined, these data can be used to construct a geochemical oil viscosity assessment prediction model. Such a model can then be used to predict original viscosities from stored cores and cuttings samples.

Examples

A study by Bennett *et al*., (2012) showed that variations in the concentrations of pentamethylnaphthalenes in a vertically cored well in the McMurray formation of Alberta, Western Canada were linked to increasing biodegradation with depth and proximity to the oil/water contact. These variations were directly related to variations in measured fluid properties. Marcano *et al*., (2012) showed that the relevant chemical compound classes for geochemical profiling are linked to the level of biodegradation in the Peace River and Athabasca bitumens. In addition, the presence of a reservoir barrier was evident from both a gamma ray log and C_0-C_2 alkylphenanthrene concentration data.

Suncor Energy Inc. studied the geochemistry and fluid properties of a number of wells in two different locations in the McMurray formation of Alberta (Sereda and James, 2014), as well as using thermal data from observation wells to estimate steam chamber development rates. Sereda and James (2014) found that geochemical profiling of summed alkylnaphthalenes correlated well with the fluid property and thermal data from observation wells, indicating that even relatively thin nonreservoir intervals can hinder steam chamber development for significant periods of time. Thicker intervals of brecciated material hindered steam chamber development for several months, but did not ultimately act as a barrier. The case study in Sereda and James (2014) clearly highlights the value of legacy core in identifying and understanding in-reservoir baffles vs. barriers. Awareness of such structures can assist in more effective well placement and minimize initial steaming times.

Nexen (CNOOC) are carrying out geochemical profiling studies of multiple wells in the Long Lake region of Alberta, allowing them to identify and track baffles and barriers. These studies correlate well with additional engineering data, providing further evidence that geochemical profiling represents a valuable tool for characterizing intervals that might act as impediments to fluid communication.

Conclusions

Molecular geochemical characterization and fluid property determination are essential tools for the geoscientist and reservoir engineer. Coupled with existing geophysical and engineering data, offsets in molecular geochemical concentration profiles can assist in the prediction and identification of baffles and barriers to fluid communication. Such barriers might not be visible on traditional well logs or in seismic data. It is not a question of which investigative method is better; the nature of a given reservoir environment may perhaps favor one approach over another. For a relatively small financial outlay compared with other investigative techniques, valuable information can be gathered from legacy core and cuttings through GCMS analysis, which allows for making informed decisions regarding effective well placement and production.

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References

Bailey, N.J.L., Krouse, H.R., Evans, C.R., and Rogers, M.A., 1973, Alteration of crude oil by waters and bacteria – evidence from geochemical and isotope studies, AAPG *Bulletin*, **57**, 1276–1290.

Bennett, B., Marcano, N., and Larter, S., 2012, Exploiting the natural variation in fluid properties in oil sands reservoirs: Geochemical fingerprinting supporting heavy oil thermal recovery operations, World Heavy Oil Congress Proceedings, Aberdeen, Scotland, paper WHOC12-252.

England, W.A., 1994, Secondary migration and accumulation of hydrocarbons, in: *The Petroleum System – From source to trap*. L.B. Magoon and W.G. Dow, (Eds.), AAPG *Memoir*, **60**, 211–217.

Fustic, M. Bennett, B., Adams, J., Huang, H., MacFarlane, B., Leckie., D., and Larter, S.R., 2011, Bitumen and heavy oil geochemistry: a tool for distinguishing barriers from baffles in oil sands reservoirs. *Bulletin of Canadian Petroleum Geology*, **59**, 295–316.

Larter, S.R. and Aplin, A.C., 1995, Reservoir Geochemistry: Reservoir Geochemistry: Methods, Applications and Opportunities; in *The Geochemistry of Reservoirs,* Cubitt, J.M. and England, W.A*., eds, Geological Society Special Publication,* No. 86*, 5-32,* Geological Society Publishing House, London, UK*.,*

Larter, S.R., Wilhelms, A., Head, I.M., Koopmans, M., Aplin, A., di Primio, R., Zwach, Z., Erdmann, M., and Telnaes, N., 2003, The controls on the composition of biodegraded oils in the deep subsurface – Part 1: biodegradation rates in petroleum reservoirs, Organic *Geochemistry*, **34**, 601–613.

Marcano, N., Huang, H., Jiang, C., and Bennett, B., 2012, A Review of Some Petroleum Geochemical Tools for the Assessment of Heavy Oil and Bitumen Reservoirs, CSEG, CSPG, CWLS GeoConvention Expanded Abstract.

Sereda, J. and James, B., 2014, A case study in the application of bitumen geochemistry for reservoir characterization in SAGD development. Paper SPE-170109.

Stoddart, D. P., Hall, P.B., Larter, S.R., Brasher, J., Li, M., and Bjorøy, M., 1995, The reservoir geochemistry of the Eldfisk field, Norwegian North Sea, *The Geochemistry of Reservoirs,* Cubitt, J.M. and England, W.A*., eds, Geological Society Special Publication,* No. 86, 257–239, Geological Society Publishing House, London, UK.

Strobl, R., 2013, Integration of steam-assisted gravity drainage fundamentals with reservoir characterization to optimize production, in F. J. Hein, D. Leckie, S. Larter, and J. R. Suter*, eds., Heavy-oil and oil-sand petroleum systems in Alberta and beyond: AAPG Studies in Geology,* **64***,* 639–653.

Westrich, J.T., Fuex, A.M., O'Neal, P.M., and Halpern, H.I., 1999, Evaluating reservoir architecture in the northern Gulf of Mexico with oil and gas chemistry, Society *of Petroleum Engineering Reservoir Evaluation and Engineering,* **2**, 514–519. SPE Paper 59518.