Downhole Fluid Analysis coupled with Asphaltene Nanoscience for Reservoir Evaluation

OLIVER C. MULLINS

Mullins1@slb.com

For condensates, the most important compositional variation is GOR, and the cubic equation of state (EoS) treatment of GOR variations is well developed and successful. Consequently, key reservoir attributes such as vertical and lateral connectivity, extrapolating gradients to obtain contacts for reserves estimation, and properties of the produced fluids are addressed by Downhole Fluid Analysis (DFA) on the MDT measuring GOR and light end compositional variations. In contrast, black oils are generally defined as having low GOR; while black oils can exhibit GOR variations, the most important compositional variation of black oil and heavy is the asphaltene concentration. However, there had been no predictive equation of state for asphaltene gradients because the (colloidal) size of asphaltene particles in crude oils had been unknown. Consequently, the gravity term was unknown. Without knowing the gravity term, modeling of reservoir fluids is precluded.

In recent years, the molecular and colloidal size of asphaltenes in crude oils – from condensates to mobile heavy oil – has been resolved and codified in the Yen-Mullins model. These scientific advances have led to the first predictive equation of state (EoS) for asphaltene gradients, the Flory-Huggins-Zuo EoS. By coupling this new science of the FHZ EoS with the new technology of DFA, a powerful new method of reservoir evaluation has been developed leading to myriad applications. Establishing thermodynamic equilibration of asphaltenes strongly implies reservoir connectivity as proven in published case studies involving light condensates to mobile heavy oil. Huge asphaltene and viscosity gradients are obtained in mobile heavy oil columns around the world in agreement with simple application of the FHZ EoS, and where conventional modeling fails miserably. Two mechanisms of tar mat formation are seen to be a natural process readily accounted for by the FHZ EoS and resolving a long standing enigma in the oil industry. Disequilibrium has become much easier to identify using DFA & the FHZ EoS in conjunction with the cubic EoS. Methods for production optimization and risk management are identified.

The confluence of advanced asphaltene science with the third generation of DFA tools, the IFA, enables a powerful new approach to address many complexities in reservoir dynamics.

A secular solution to a diabolical problem: Porphyry vs. iron oxide-copper-gold deposits

A. HAMID MUMIN[1] AND JEREMY P. RICHARDS[2]

[1]Dept. Geology, Brandon University, Brandon, Manitoba, Canada, R7A 6A9, mumin@brandonu.ca

[2]Dept. EAS, University of Alberta, Edmonton, Alberta, Canada, T6G 2E3 Jeremy.Richards@ualberta.ca

Porphyry Cu±Mo±Au (porphyry) and magmatic-hydrothermal iron oxide-copper-gold deposits (IOCG) are distinct in being dominated by Fe±Cu-sulfide minerals in the former and Fe-oxides in the latter. Most of the largest IOCG deposits formed in the Precambrian, whereas porphyry deposits occur most commonly in late Phanerozoic rocks and are rare in the Precambrian. Despite these major differences, they share many similarities: associated magma composition (calc-alkaline to mildly alkaline); tectonic setting (orogenic to post-orogenic), depth of formation (≤5 km from surface), major metal inventory (Cu, Au), and hydrothermal alteration styles (albeit with wider development of high-T near-neutral alteration, and more restricted development of low-T hydrolitic alteration in IOCG deposits).

We conclude that fundamentally similar tectonomagmatic and hydrothermal processes give rise to these two distinct deposit types. We link the key differences in mineralization style (Fe-sulfide vs. Fe-oxide) and temporal prevalence to oxidation of the deep oceans during the Neoproterozoic Oxidation Event. Following this event, sulfate concentrations in deep ocean waters, seafloor sediments, and seawater-altered oceanic crust increased dramatically, and for the first time in geological history abundant sulfur and sulfate were introduced into subduction zones and arc magmas. Phanerozoic arc magmas were thereafter significantly richer in S than in the Precambrian (Prouteau & Scaillet, 2013) and, combined with their relatively high oxidation state, were ideal transportation agents for Cu and Au into upper crustal magmatic-hydrothermal systems.

In contrast, S-poor Precambrian arc and derivative magmas formed S-poor IOCG deposits in orogenic, and post-orogenic settings, while S-rich conditions were relatively rare (leading to a dearth of porphyry-type deposits). Higher geothermal gradients in the Precambrian, combined with the lower acid-generating potential of S-poor hydrothermal fluids may explain the greater extent of high-T near-neutral pH alteration in IOCG deposits compared to porphyries.

[1] Prouteau & Scaillet, 2013: J. Petrology, v. 54, p. 183–213.

DOI:10.1180/minmag.2013.077.5.13