Origin of Gas in Conductively Heated Reservoirs in SAGD operations – Theories and New Insights from Geomicrobiology

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Summary

During Steam Assisted Gravity Drainage (SAGD) operations, temperature observation wells and Residual Saturation Tool (RST) logging illustrate the top of the associated steam chamber and the occurrence of gas in conductively heated zones above the steam chamber. Steam chamber growth is commonly delayed or halted at the base of mudstone-dominated inclined heterolithic strata (IHS) where thin low-permeable fine-grained (mudstone) layers of IHS act as barriers for steam growth. Post steam core studies shows that (i) low permeable layers remain active seals for upward migration of the steam over the life cycle of the SAGD production (8-10 years); and (ii) bitumen is produced from conductively heated zone via a different production mechanism than emulsion from an expanding steam chamber.

While reservoir properties and connectivity remains relatively constant, the production from conductively heated zone can be attributed to:

- Reduced viscosity and associated increased mobility (by conductive heating)
- Additional increase of mobility by occurrence of gas
- Increased pore pressures (by gas and thermal expansion) that provides drive to push mobilized bitumen along inclined mudstone (IHS) surfaces down to an amalgamated steam chamber.

Although very important for recovery, the origin of the gas remains debatable. Suggested processes commonly deal with changes of reservoir PVT conditions and ranges of water-oil-rock interactions. Theories include gas which is liberated from solution, gas generated by thermal cracking of bitumen, and/or produced by aquathermolysis, decarboxylation, or in-situ coke gasification. Suggested processes require temperatures from 160 to as high as 350C in case of thermal cracking.

Post steam core studies shows that gas is present within most if not all IHS bed-sets within the conductively heated zone (30-100C) and that gas occupies the upper most parts of individual sandy intervals (0.1-0.3m thick) immediately below an upper mudstone barrier (muddy IHS laminae), while lower parts of the bed-set remain occupied by bitumen (referred as “shadow effect”). This pattern resembles reservoir configurations with gas at the top and oil below, as observed at the bed-scale (0.1-0.3m thick). Considering that described pattern is reoccurring in stacked IHS bed-sets (up to 15m thick), the most logical interpretation is that gas is formed in-situ, within each bed-set.

We propose that increased temperature may activate dormant thermophilic microbes in oil sands reservoirs, which in return will produce potentially significant amount of various biogenic gasses that may contribute to total volume of in reservoir occurring free gas. The biogenic gas production rates are controlled by temperature, quality of substrate (bitumen) and availability of nutrients. Ongoing microbiological studies on oil sand samples from various parts of the reservoir include investigation of microbial activities under various conditions. Preliminary results show strong evidence of increased microbial activities at 50C. Although rates of production at reservoir conditions are not yet established, results suggest that thermophiles have likely contributed to the occurrence of the gas in the conductively heated zones. These findings support potential utility of recently proposed Microbial Enhanced Thermally Engineered Technology (METEOR) recovery technology. METEOR may contribute to reducing the cost of production and greenhouse gas emission per barrel of produced bitumen in SAGD operations making oil sands more competitive and environmentally friendly. Additionally, technology shall allow for developing currently uneconomical thin-pay heavy oil reservoirs worldwide.