Improving the Efficiencies of *In Situ* Energy Production The Quick Win on Emission Reduction in Oil Sands

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HOTS (heavy oil and tar sands) oils and bitumens dominate the world petroleum inventory and are becoming significant in world and Canadian production yet current employed recovery technologies (Cyclic Steam Stimulation-CSS, Steam Assisted Gravity Drainage-SAGD, mining) are inefficient in terms of recovery, energy and water intensity and have high cost to the environment. While carbon capture and storage(CCS) will be a partial solution to the emissions issue the “7000 Sleipners” worth of storage needed to accommodate the annual anthropogenic CO2 emission load suggests that CCS will be challenging to implement quickly at the high levels needed to mitigate the extremes of climate change. So in the immediate shorterm what can be done to substantially reduce recovery related carbon emissions in the first place?

Much of the worlds’ and most of the Canadian HOTS resource is only recoverable by *in situ* subsurface recovery processes which have to operate in complex reservoirs with heterogeneous reservoir and reservoir fluid property heterogeneities. These heterogeneities impact the efficiency of current recovery processes that are designed for uniform oil mobility environments, e.g. SAGD, or that are limited to reservoirs that can withstand high pressure processes, e.g. CSS. Concerns about greenhouse gas emissions and water usage, combined with societal pressure to implement more sustainable energy recovery procedures and the increasing need to access poorer quality resources require the very rapid development and deployment of much more effective recovery processes. In the short term, geotolerant recovery processes are needed to cope with adverse geology such as baffle/barrier shales for example, bottom water and ubiquitous vertical and lateral oil viscosity gradients and also result in reduced water usage and carbon dioxide emissions.

Mapping of the geological and fluid heterogeneity typically found across heavy oil and bitumen provinces will assist in the transition from current processes (SAGD, CSS) to Reduced Emission to Atmosphere Recovery (REAR) processes, to Zero Emission To Atmosphere Recovery (ZETAR) processes. Compositional gradients strongly impact the mobility of the oil especially in the high water saturation, residual oil zones where relative permeability effects and the discontinuous oil phase combine with high oil viscosities to greatly limit oil mobility. These vertical and lateral mobility gradients commonly persist to steam temperatures and exert a large effect on performance of thermal recovery processes such as SAGD and CSS as well as cold recovery operations. Also, where oil removed by biodegradation has exceeded the rate of fresh oil charge, reservoirs can have a basal residual oil zone up to 15 m thick characterized by steeper gradients in oil composition and substantially higher viscosities than found in the main oil column. These basal bioreaction or burnout zones may have moderate bitumen content but have very low oil mobility, which adversely affects thermal gravity drainage processes such as SAGD or CSS for which well placement is in the lowest parts of a reservoir.

We discuss REAR processes initially based on optimizing current recovery processes to complex oil mobility distributions (geotailoring) by improving reservoir and fluid description processes and linking this to improved engineering solutions by refining well placement and operating conditions. The next step in recovery process evolution involves processes designed upfront to be geotolerant of complex and discontinuous geological facies but not requiring high pressure steam and reservoir fracturing strategies. Finally we review progress towards achieving more efficient energy recovery from HOTS and possible rapid routes towards ZETAR processes including preconditioning reservoirs for thermal recovery using using mobile water to carry viscosity reducing or gas producing reagents to aid with oil mobility, carbon capture and storage options locally in the oil sands area and in situ upgrading approaches. Carbon emission reductions of 50% are indicated by some simulations of such processes in Albertan reservoirs. Recent advances in understanding the biodegradation process forming heavy oils has shown that the process involves crude oil hydrocarbons reacting with water to produce methane via intermediate hydrogen and carbon dioxide as well as residual heavy oil or bitumen. Thus the acceleration of microbial processes in reservoir to recover energy as methane, or as hydrogen as an intermediate product of biodegradation, may be feasible under special conditions. We review developments in this area.

Carbon capture and storage (CCS) will contribute to solution of the carbon emissions crisis we face but large immediate reductions in emissions are quite feasible using carbon efficient recovery and processing options (CERP) and these can be implemented quickly using existing technology.

References

Adams, J.J., Riediger, C.L, Fowler, M.G. and Larter, S.R., 2006. Thermal Controls on Biodegradation around the Peace River Tar Sands: *Paleo-Pasteurization to the West: Journal of Geochemical Exploration, 89, 1-4*
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Aitken, C.M., Jones, D.M. and Larter, S.R., 2004. Anaerobic Hydrocarbon Biodegradation in Deep Subsurface Oil Reservoirs: *Nature, 431, 291*.

Gates, I.D., Adams, J.J. and Larter, S.R., 2007. The Impact of Oil Viscosity Heterogeneity on the Production Characteristics of Tar Sand and Heavy Oil Reservoirs. *Part II: Intelligent, Geotailored Recovery Processes in Compositionally Graded Reservoirs: CIPC, June 12-14, Calgary, AB.*

Head, I.M., Jones, D.M. and Larter, S.R., 2003. Biological Activity in the Deep Subsurface and the Origin of Heavy Oil. *Nature: 426, 344-352*.

Jones, D.M., Head, I.M., Gray N.D., Adams, J.J., Rowan, A.K., Aitken, C.M., Bennett, B., Brown, A., Bowler, B.F.J., Oldenburg, T., Larter, S.R., 2008. Crude-Oil Biodegradation via Methanogenesis in Subsurface Petroleum Reservoirs: *Nature 451 (7175), 176-79.*

Larter, S.R., Huang, H., Adams, J.J., Bennett, B., Jokanola, O., Oldenburg, T., Jones, D.M., Head, I., Riediger, C. and Fowler, M., 2006. The Controls on the Composition of Biodegraded Oils in the Deep Subsurface: *Part II - Geological Controls on Subsurface Biodegradation Fluxes and Constraints on Reservoir-Fluid Property Prediction: AAPG Bulletin, 90, 921-938.*

Larter, S.R., Adams, J.J., Gates, I.D., Bennett, B. and Huang, H., 2008. The Origin, Prediction and Impact of Oil Viscosity Heterogeneity on the Production Characteristics of Tar Sand and Heavy Oil Reservoirs*: Journal of Canadian Petroleum Technology, 47 (1), 52-61.*

Wilhelms, A., Larter, S.R., Head, I. et al., 2001. Biodegradation of Oil in Uplifted Basins Prevented by Deep-Burial Sterilization: *Nature 411, 1034.*