Application of Petroleum Geochemistry to Monitoring In Situ Upgrading Operations in Oil Sands and Heavy Oil Reservoirs

Marcano, Norka [2]; Bennett, Barry [1]; Huang, Haiping [1]; Larter, Steve [1] (1) Geoscience, University of Calgary, Calgary, AB, Canada. (2) Alberta Ingenuity Center for In Situ Energy, Calgary, AB, Canada.

Biodegradation is the most dominant post accumulation process in petroleum reservoirs, forming the very viscous heavy and extra-heavy oils in the world. Currently used technologies of in situ recovery, such as SAGD (Steam Assisted Gravity Drainage) or CSS (Cyclic steam stimulation), and upgrading require huge consumption of energy and emissions. In situ upgrading is proposed to decrease these effects. This process relies on addition of hydrogen and removal of heteroatoms from crude oils under high temperature conditions in the reservoir. A better understanding of the molecular transformation undergone by heavy oil and bitumen under hot aqueous environment may allow the use of newly formed molecules, present in, as natural tracers to monitor the progression of the upgrading front in the subsurface.

In this study, heavy oil and oil sands core samples are pyrolyzed under hydrous conditions up to 350°C for up to seven days. Pyrolysates are analyzed for bulk and molecular composition with the purpose of characterizing the chemical changes of the bitumen under simulated thermal recovery experiments. The results suggest that the asphaltene fraction is probably the main source of the newly formed hydrocarbons. The principal proposed mechanisms are cracking of side chains from aromatic groups and cracking of aliphatic fragments linked through heteroatoms in cyclic systems present in the asphaltene molecular structure. The generation of bicyclic and tricyclic condensed aromatic molecules, some of which are not originally present in the studied oil sands, such as alkylanthracenes, appears to be good indicators of the progress of the thermal conversion. Biomarkers such as monoaromatic and triaromatic steroids are destroyed or diluted under the most extreme experimental conditions, but look intact at temperatures below 300°C. Variation in some terpane parameters, traditionally used to monitor thermal stress and some recently proposed as proxies for process monitoring, appear to be also good indicators of thermal stress undergone by the bitumen. The production of adamantanes may potentially be good reaction proxies as well. Bitumen reactivity in the aqueous environment at temperatures below 300°C seems to be low; however, we have shown that neoformation of compounds such as alkylanthracenes, not abundant in unaltered oils, at thermal recovery conditions suggests some molecular changes are suitable to monitor steaming effects under current thermal recovery conditions.