Hydrocarbon biodegradation trends related to fluid and mineral geochemistry, Border Plains region, western Canada foreland basin

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The Border Plains region of central Alberta and Saskatchewan contains rich deposits of medium to heavy oil in Cretaceous and Paleozoic age formations. Oil quality varies between formations and within pools, ranging from light alteration to complete removal of low molecular weight saturated and aromatic hydrocarbons. Oil, gas and water geochemistry of fifty-three produced fluid samples from wellheads in the region indicate a heterogeneous distribution of oil quality, gas wetness, and water salinity.

Oil quality variation is the result of numerous processes operating over 50 Ma since initial oil reservoir filling. Oil viscosity ranges from 130 to 98,300 cP (@ 20°C), and 8.2 to 21.8 degrees API Gravity (@ 60°F) in the Border Plains region. Quantitative geochemistry of produced fluids suggests that oil quality is controlled by oil biodegradation, late-stage oil charge and mixing, groundwater flow, and local asphaltene precipitation. Rock thin sections from cores and scanning electron microprobe mineral composition analysis, suggests secondary controls on oil biodegradation based on mineral alteration textures and nutrient limitations of the clastic host-rocks.

The timing, volumes, and flow directions of petroleum and groundwater are especially important aspects of basin analysis in biodegraded oil systems. Multiple oil charge events and groundwater flow systems are related to the Columbian and Laramide Orogenies in this foreland basin over 120 Ma, and are also influenced by Eocene intrusive events and topography around the basin margin. Up-dip compaction drive, petroleum buoyancy drive, and topographic drive forces, create heterogeneous distributions of oil and water geochemistry to depths over 800 meters. Oil families from three source rocks and three major water systems are delineated using fluid composition and isotope geochemistry. The combination of oil, gas, water and mineral data allows for a broad assessment of dynamic fluid flow and geochemical processes that are analogs to other foreland basin systems on Earth.

Study and prediction of mobility of colloids and radionuclides

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Sorption of radionuclides on immobile solid phases play a major role in slowing down their migration in underground and surface waters. It is possible to predict the mobility of radionuclides from data on acid-base properties and sorption behavior of solids towards radionuclides, and from their modeling. Presence of colloidal particles can disturb these predictions. If radionuclides are sorbed on mobile colloids, their mobility is increased, as already observed in natural systems. On the other hand, if colloids adhere on the immobile phases, mobility decreases. We have developed studies and tools to predict the adhesion of colloids in relation to their surface charge. The surface charge depends on pH and ionic strength. Sorption of dissolved species depends on the surface charge, which, in turn, is modified by sorption. Adhesion of oxide particles was studied both in specially designed reactors and recirculating circuits, using turbidimetric measurements to determine the rate of adhesion. The surface charge and the isoelectric point (IEP) of colloidal particles were measured by acid-base titration and zetametry. Moreover, an ampirical relation between surface charge and zeta potential was developed. For surfaces of the immobile phases, the IEP was measured from the adhesion rate of latex particles of known surface charge. In slow water flow, adhesion is essentially controlled by electrostatic interactions between the particles and the immobile phase; it takes place in the pH range between the IEP of both phases, i. e. when the interactions are attractive. In this range, adhesion can be predicted from the DLVO theory. In turbulent flow, adhesion was observed also in repulsive conditions, but these conditions generally do not occur in natural conditions. Finally, by combining acid-base properties of oxide surfaces and their sorption ability towards radionuclides, it is possible to predict the mobility in presence of colloids.