Methanogenic microbial communities and biogas production from severely biodegraded heavy crude oil sands

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Understanding microbial life in subsurface oil reservoirs is central to deep biosphere ecology, and to bioengineering interventions in areas such as souring control and enhanced residual oil recovery. The former can be achieved by stimulating nitrate-reducing bacteria, which combat the activity sulphate-reducing bacteria, and the latter may be achieved by stimulating microbial methane production. We investigated the microbiology of basal water and surface-mined bitumen from an Athabasca oil sands reservoir (Alberta, Canada) in microcosms that were incubated for 3000 days under different redox conditions, with severely biodegraded oil sands as the only organic substrate. In all microcosms that did not receive nitrate, methane was eventually produced reaching maximum values of ca. 8,000 to 40,000 ppm, including in microcosms initially under aerobic or sulfate-reducing conditions. Microbial community analysis of reservoir basal water and 3000-day methanogenic cultures pointed to possible syntrophic partnerships (i.e., different *Proteobacteria* and methanogenic *Archaea*) that may be coordinating to catalyze methanogenesis from heavy crude oil. These results confirm that microbial communities in Athabasca oil sands are capable of utilising organic carbon present in severely biodegraded heavy oil as substrates for further biodegradation and methanogenesis over long (>1000 d) time scales. However, prospects for enhanced and cleaner energy recovery from oil sands via biogas production by one or more of the putative consortia identified might be limited by the already-biodegraded nature of the bitumen ‘feedstock’, since methane production rates were slower than results from other reservoir systems containing less biodegraded oil. The bacteria and archaea identified here may rather highlight the microbial legacy of in-reservoir biodegradation and how biology and “life on oil” created the Alberta heavy oil sands over geologic timescales.