Microbial alterations of sediments and their stratigraphic uses: examples from the Athabasca oilsands of NE Alberta, Canada

Russell P.W. (Stan) Stancliffe

URSA Cleantech.

Lisa M. Gieg

University of Calgary

Introduction

According to Wolff and Benedict 1964, sedimentology includes five fundamental processes defined as weathering, erosion, transportation, deposition, and diagenesis. Of these, only transportation is not attributable to microbial processes in some way. The results of these actions opens up new and often better ways to correlate subsections of reservoirs and understand their productivity.

Microbes (also referred to here as microbiomes) are now known to be active in many hydrocarbon reservoirs around the globe. With the advent of metagenomics, it has become possible to sample and identify these organisms both quickly and cheaply (Stancliffe and Gieg 2023), Figure 1. The next stage in understanding microbes is to determine how they can alter a reservoir and how this effects the sedimentology and stratigraphy found. This talk aims to highlight some of the activities of microbes in clastic oilsands reservoirs and how these can be both beneficial and detrimental to the sedimentology and stratigraphy of the units.

Theory

Microbes can live in reservoirs which are under 100 °C and have available nutrients, space and time. There are a number of life cycles which can be working to produce, for example, carbon compounds (such as acids, alcohols, solvents, or biosurfactants), hydrogen gas, silica cements, sulphides and carbonates (Youssef et al., 2008; Table 1). Different types of microbial metabolism can contribute to these products. For example, fermentative microbes can produce acids that may dissolve and thus alter pore spaces in rock, along with alcohols or other compounds that may help to dissolve hydrocarbons enabling increased oil recovery. Sulfate-reducing microbes produce H_2S as part of their metabolism, which can lead to metal sulfide precipitation and reservoir souring. Additional examples are described below, and overviewed, in Table 2. Thus, understanding the microbes in a reservoir can provide useful information that may help or hinder oil production.

Table 1

Microbial products commonly found in hydrocarbon reservoirs.

Acids	carbonic, sulphuric
Inorganic precipitates	carbonates, silicates, sulphides
Organic precipitates	slimes, polymers, emulsifiers, foaming agents
Gasses	CO_2, CH_4, H_2S, H_2
Chemical concentration	asphaltenes, iron pyrite, trace elements, radioactive minerals

Table 2

Sedimentological properties altered in a reservoir as a result of microbial activity.

Grain morphology	size, roundness, sorting, mineralogy
Porosity	increase/decrease
Permeability	increase/decrease
Wettability	alteration
Laminations	creation, especially at hydrocarbon/water contacts
Cap rock strength:	alteration – often weakening

Results and Observations

Sedimentology

Prior to the formation of rock, microbes can have a significant effect on the sediment. The angle of repose can be altered along with the rate of weathering. Once the rock is formed, the reservoir-associated microbiome has a long timeframe to adapt to the new environment and exploit all the nutrients available. Acid waste products can reduce grain size and also increase the roundness. The acids can remove small grains and thus alter the sorting values. Another resultant can be the increase in porosity and permeability. However, inorganic precipitates such as silica and carbonates may decrease the storage capacity and transmissibility within the sediments. Furthermore, microbe metabolism at oil-water contacts can reduce the °API of the oil, produce gases and deposit carbonates/silicates which could isolate sections of the reservoir from EOR efforts. Within the reservoir microbes can also secrete organic chemicals which alter the wettability of the grains, create new emulsions, and even plug pores with slimes.

The strength of cap rocks depends on their permeability and what can access the rock. Cap rocks are not completely impermeable, and microbes can enter through micropores and microfractures where their metabolites can weaken the rock. This is especially true if the microbes produce gases and acids. All these changes within the reservoir can alter the producibility of the fluids to a greater or lesser extent. This makes the correlation of microbial activity important to map and model when optimising secondary and tertiary recovery schemes.

Stratigraphy and the correlation of microbiomes within oilsands reservoirs

The correlation of microbe activity is now both cheaper and quicker with the advances in sampling and analysis techniques to identify the microbes present. With regards to the oil sands, microbiome correlation can greatly increase the accuracy of the models and which follow up processes are best to use. The hydrocarbons in oil sands have been altered by microbial activity since the Cenozoic, and perhaps whilst being injected into the reservoir rocks. Today there are many gas caps over the bitumen along with bottom, perched and top water zones. At each contact the biome may be conducive for respiration and waste product generation. Top gas zones are commonly mapped with well logs assuming that they are connected. Stand offs are then calculated and significant volumes of bitumen becoming labeled ‘unproducible’. If the microbiomes in gas zones of different wells are not similar then the stand offs can be reduced along with increasing the production potential. Similarly, water zones tend to be avoided (steam thief zones) but if they can be shown to be unconnected (having different biomes) then stand offs may not be needed. All these observations can be then added to the reservoir model to optimize production and generate accurate volumetrics.

Another common problem found in Athabasca and Cold Lake oilsands reservoirs is the presence of carbonate tight streaks. These sometimes meter thick intervals can be a barrier/baffle to steam, though this is not known until steaming occurs. If the biome above and below the tight streak are similar, then the zones are probably not isolated and steam will find a way around the tight streak. Also, steam can weaken and even induce dissolution of the carbonates which opens up new areas to production later in the pad history.

Conclusions

Not understanding what is living in the reservoir can make the work of petroleum engineers difficult. The geological model can alter through the resource life cycle, often to the detriment of production. Understanding the microbiome can potentially optimise the quality of the fluids recovered, rate of production and safe confinement at the steam pressures used. Microbiome data may also explain anomalies such as souring, corrosion and even volumetric errors.

Acknowledgements

The authors would like to thank the many colleagues who have discussed the presence of active microbiota within oilsands reservoirs. However, any inaccuracies are the responsibility of the authors alone.

Figure 1

Bitumen samples being analysed in a microbiology laboratory.

Selected References

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