Advancing oilsands development,

one DNA fragment at a time

by Leah Lawrence

Since the publication of the first full DNA sequence for the bacterium *Haemophilus influenzae* in 1995, determining the DNA sequence of a single species has become almost commonplace — including being a way of identifying root causes of illnesses and working toward possible treatments.

Now scientists have moved on to sequencing whole ecosystems, or "metagenomes," from samples taken from the environment — and the research has relevance for the oil & gas industry's search for better ways to enhance recovery or mitigate pollution.

"In the context of the oil & gas industry, metagenomics is about looking for the undiscovered potential of microorganisms," says University of Alberta microbiologist Julia Foght. "This could have in situ potential whereby we manipulate organisms in place to accelerate or leverage different properties to reduce viscosity, or maybe it's manipulating an organism or its environment so that it reduces greenhouse gas from its own biological process. There are all sorts of places where microbes intersect with the oil industry."

Although looking at that intersect between microbes and the oil industry has been going on "for more than 50 years," Foght says metagenomics presents a whole new concept because researchers can now attempt to generate entire sequences for an environment by capturing fragments of DNA from the millions of microbes present in as little as a gram-size sample of water, soil or oil-bearing rock.

As explained by Dr. Rob Holt, a director at the Genome Sciences Centre in Vancouver, rather than separating and culturing each organism individually (which is not yet possible for the vast majority of microbes), all the DNA is isolated en masse and then sequenced to get a readout of the DNA present in the sample.

"Even though you don't know exactly which DNA fragment comes from which organism, the sequences, once read, can be classified by comparing them to large databases of all known genes and genomes," says Holt. "That way you can get a good idea of their predicted function in the cell and also a good idea of approximately what types of microbial species are present."

So how does that help the oil & gas industry?

The tar sands are "heavy" rather than "conventional" oil because environmental conditions, including lower temperatures, have allowed microbes to degrade the oil over time on a geological scale. Says Holt: "knowing what organisms are present and what genes are present will allow a better understanding of this process. This part is essentially basic research. But beyond degrading petroleum, microbes and the enzymatic systems they contain can also perform useful biocatalytic tasks like desulfurization, denitrification, heavy metal reduction, and viscosity alteration."

The challenge, then, is first to sequence and analyze the tar sands biosphere and then randomly to screen the novel, isolated, physical DNA fragments that encode genes to see whether they implicate such biocatalytic activity.

"Once biocatalysts have been identified, their activity can be enhanced and the isolated enzymes can be manufactured at scale for heavy crude oil upgrading in refineries, including bioreactors," said Holt. "Alternatively, it is conceivable the microbial cells themselves might be modified by adding or altering genes and used in situ."

According to Foght, metagenomics has emerged as a new concept and people are realizing its potential only now because it has taken time to develop the software and sequencing technology that allow researchers to work with large amounts of incomplete information — technology, she says, that grew out of the human genome sequence and related projects.

"My favorite analogy is that (sequencing fragments) is like taking every jigsaw puzzle you could find in a city the size of Edmonton or Calgary, dumping all the pieces out in a pile on a gymnasium floor and then starting to build all those puzzles without the pictures on the boxes. The software now allows us to look for overlaps that will tell us that this is a sky piece and that's a sky piece and maybe they fit together. And it does it very quickly."

Underground refining

But the thinking around possibly modifying biocatalytic reactions in situ is also well advanced. Dr. Steve Larter, Canada Research Chair in Petroleum Geology in the department of Geology and Geophysics at the University of Calgary, thinks reading DNA blueprints of the microbes that live in oilsands reservoirs could herald a new era in oilsands production and processing — so much so that he's working on how a specific group, known as methanogens, might be harnessed to "bio-upgrade" bitumen under ground.

"Biology directly impacts the way reservoirs produce," said Larter, adding that methanogenesis, a widespread form of microbial metabolism, is thought to have been one source of the natural gas overlying oilsands reservoirs. "Maybe we can throw some 'Miracle Grow' in, let (the microbes) work for awhile and produce methane and hydrogen."

Studies show methanogenesis is already occurring, albeit at geologic time scales. At a minimum, Dr. Larter hopes for oxidization of the heavier hydrocarbons (i.e. C_6+ components), but he also sees the potential to speed up methane production. In a world where oilsands producers burn 0.4 thousand cubic feet of natural gas to produce one barrel of synthetic crude oil, Larter sees bitumen being "burnt" by microbes to produce natural gas.

However, methanogens may also be important for reducing the environmental footprint associated with oilsands mining. Foght has been sampling the microbial diversity of tailings ponds at Syncrude Canada's Mildred Lake site, where regulations require tailings waste be stored on site (the Mildred Lake tailings pond covers some 25-square kilometers and is 40 metres deep). But tailings take a long time to settle — 125 to 150 years by one estimate. Faster settling times would mean fewer and smaller ponds and do much to reduce the environmental footprint of oilsands mining operations.

Methanogenesis, though, involves trade-offs. Since 2000, scientists have noticed a significant increase in methanogenic activity in the Mildred Lake Settling Basin and an estimated one hundred thousand cubic metres of methane is to be released at the site daily. On the plus side, methane production seems to correlate with consolidation or compaction of fine tailings — good thing, because compacted tailings take up less space and, importantly, release process water for re-use, thereby reducing water demands. On the minus side, methane is a greenhouse gas and therefore contributes to climate change. A key challenge, then, is to promote densification with minimal release of methane to the atmosphere.

Excitement down under

Nonetheless, whether applications are found in "next generation" bio-upgraders or in reducing the emissions or size of tailings ponds, it's clear that a better understanding of microbiology and metagenomics research is stirring up interest across Alberta.

Genome Alberta, a not-for-profit corporation that directs and funds research and development in the fields of genomics, proteomics and bioinformatics, recently convened a meeting of minds of some 50 researchers from industry, government and academia. The experts spent two days debating how metagenomics research might be brought to bear on the unique challenges of the oilsands.

Dr. Marvin Fritzler, chair of the Alberta Science and Research Authority (ASRA) thinks the payoff could be vast. "We are looking at the next big thing in oilsands research, and that is metagenomics research and the spin-offs thereof," he says. He urged experts to think big, invoking memories of Alberta Oil Sands Technology and Research Authority (AOSTRA). AOSTRA, an Alberta crown corporation created in 1974, has been widely credited as having been instrumental in the development of today's oilsands production technologies.

Key to any localized metagenomics effort, however, will be collaboration between Alberta's universities and colleges since oilsands-based metagenomics touches on aspects of geology, engineering, biology, microbiology, chemistry and genetics. Institutes like the newly minted Canada School of Sustainable Energy (CSSE) – a collaborative effort between the universities of Alberta, Calgary and Lethbridge to further efforts to advance innovation in the oil & gas sector – and a proposed chair at the Institute of Sustainable Energy, Environment and the Economy would seem poised to play key roles.

A brave new world? Maybe. But even Aldous Huxley wouldn't have underestimated the power of these microscopic workhorses: microbes constitute the majority of living matter on earth, are essential players in numerous biological cycles that humans depend upon, turn nitrogen in the air into a form usable by plants, and produce about half the oxygen on the planet.

"Below the surface we are finding biomes," says Holt. "We certainly don't need to go to another planet to discover new ecosystems." AO