Ubiquitous distribution of methanogens and anaerobic methanotrophs in subseafloor sediments and basalts

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The deep subseafloor is the largest and yet one of the least studied biospheres on Earth. Deep subseafloor sediments account for up to one third of global microbial biomass, and play an important role in the global carbon cycle [1, 2]. Little is known about underlying basalts due to the challenge of obtaining contamination free-samples while drilling into rock up to hundreds of meters below the seafloor.

During Integrated Ocean Drilling Program Expedition 301 in 2004, we obtained sediment and basalt samples from the hydrothermally active Juan de Fuca Ridge Flank. Contamination with microbes from drilling fluid was estimated using a chemical tracer added to drilling fluid, and found to be minimal relative to indigenous populations in sediments [4]. Application of a rigorous decontamination method to basalt cores allowed us to demonstrate minimal contamination in the interior of basalt samples [4].

We examined the community composition of methanogenic and anaerobic methanotrophic Archaea by DNA extraction followed by PCR amplification of the alpha subunit of the gene for methyl coenzyme M reductase (*mcrA*), a gene unique to methanogens and anaerobic methanotrophs. A newly designed primer pair allowed us to detect both methanogens and anaerobic methanotrophs throughout the sulfate reduction and methanogenesis zone of sediments, as well as in underlying basalt. This is the first evidence of not only methanogens and methanotrophs but more importantly life in subseafloor basalts that is substantiated by stringent contamination controls and monitoring.

The phylogenetic composition along geochemical, geothermal, and lithological gradients will be discussed during my presentation.

[1] Whitman *et al.* (1998) *PNAS* **95**, 6578-6583. [2] D'Hondt *et al.* (2002) *Science* **295**, 2067-2070. [3] Fisher *et al.* (2005) *Proc IODP*, v**301**. [4] Lever *et al.* (2006) *Geomicrobiol. J.* **23**, 517-530.

Source of heavy oils and tars in the Athabasca Oil Sands based on geochemistry and 4-D basin modeling

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The source of the 1.37 trillion barrels of in-place heavy oil and tar in the Athabasca oil sands of the Western Canada Sedimentary Basin (WCSB) has been controversial, with various Devonian through Lower Cretaceous source rocks being advocated. This study addresses the controversy with a 4-D model of a portion of the WCSB using hydrous-pyrolysis oil-generation kinetics, and geochemical correlation parameters (biomarkers, trace metals, and stable isotopes) of potential source rocks and oil sand extracts. The five main rock units that are possible sources include the Devonian Duvernay Formation, Devonian-Mississippian Exshaw Shale, Triassic Doig Formation, Jurassic Fernie Formation, and Lower Cretaceous Ostracode Zone of the Mannville Group. Thermally immature composite samples representing potential source rocks in each of these five rock units were collected for characterization of their kerogen. The ratio of organic sulfur to carbon of the kerogens was used to determine which source rocks contained Type-IIS kerogen and to derive hydrous-pyrolysis oil-generation kinetic parameters. Samples of Athabasca oil sands collected from outcrops of the Cretaceous McMurray Formation along the Athabasca and Christina rivers have high organic-sulfur contents indicative of a source rock containing Type-IIS kerogen. The only source rock containing Type-IIS kerogen is in the Jurassic Fernie Formation. 4-D modeling with hydrous-pyrolysis kinetic parameters showed that unlike the other source rocks containing Type-II kerogen, oil generation from the Fernie Formation started as early as 109 Ma. This early thermal maturation resulted in large volumes of generated oil from the Fernie source rocks prior to the onset of erosion (~58 Ma), which curtailed thermal maturation of the later-generating source rocks. Calculations within the study area indicate that Fernie source rocks generated more than twice as much oil as all the other possible source rocks combined. The predominance of the Fernie Formation as a source of the Athabasca oil sands is also evaluated with geochemical correlation parameters (i.e., biomarkers, trace metals, and stable isotopes) in bitumens generated in the composited source-rock samples by hydrous pyrolysis at 300ºC after 72 h.