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Cross-Temporal Insights into Oil Sands Bitumen Geochemistry: A Case Study from the Mackay River Valley

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The Western Canadian Sedimentary Basin hosts oil sands deposits that have undergone significant biodegradation, enriching the bitumen with nitrogen-sulfur-oxygen (NSO) compounds and other complex species. This study probes the complex biodegradation and weathering processes affecting oil sands, both ancient and contemporary, utilizing natural outcrops in northeastern Alberta as a case study.

A detailed geochemical analysis of bitumen-saturated sandstone samples from a section of an exposed outcrop in the Mackay River valley included pyrolysis, SARA analysis, Fourier-transform infrared spectroscopy (FT-IR), inductively coupled plasma (ICP), two-dimensional gas chromatography (GC×GC), gas chromatography-mass spectrometry (GC-MS/MS), and matrix-assisted laser desorption ionization-time of flight mass spectrometry (MALDI-ToF).

Findings indicated that the total organic content ranged from 5.8% to 8.2%, with resin and asphaltene fractions accounting for 85%-90% of this content, showcasing extensive degradation. FT-IR analysis showed significant carbonyl stretching intensity. Sulfur and nitrogen contents were observed in the ranges of 1.25-1.53% and 0.30-0.36%, respectively. Molecular fingerprinting techniques unveiled varying degrees of degradation across the samples, suggesting diverse biogeochemical processes. Notably, the differential preservation of biomarkers, with hopanes showing greater recalcitrance compared to steranes, highlighted the variability in compound class transformation. The presence of transformation products of oil degradation will be probed using MALDI-ToF. Possible elemental enrichment due to oil degradation will be assessed based on the ICP analysis of 57 species.

This study attempts to refine our perspective on the biodegradation and weathering of crude oil, integrating geological and microbiological processes across time scales. The insights from this synergistic analytical approach are relevant for both reservoir geochemistry and the environmental implications of oil sands exploitation.