Geochemical Insights into the Oil Charging and Degradation Systematics of the Grosmont Bitumen Accumulation

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Introduction

Heavy oils and bitumen are formed by microbial degradation of crude oils over geological timescales. The role of oil charge/mixing, water, nutrient supply, reservoir architecture and oil source type have been cited as potential controls on the process of degradation (Head et al., 2003). The source(s) that have potentially contributed to the heavy oil and oil sands deposits of Northern Alberta have long been debated using mass balance considerations (Creaney and Allan, 1990) or molecular evidence (Riediger et al., 1999). For example, the presence of C_{28} bisnorhopane (amongst others) is often used to identify a contribution from the Exshaw Formation, while its absence may be attributed to a charge from the Duvernay Formation. However, as is often a feature of the Grosmont bitumen, the steranes and hopanes may have been completely destroyed (e.g. Fig. 1) thereby limiting their application as indicators for oil-source correlation.

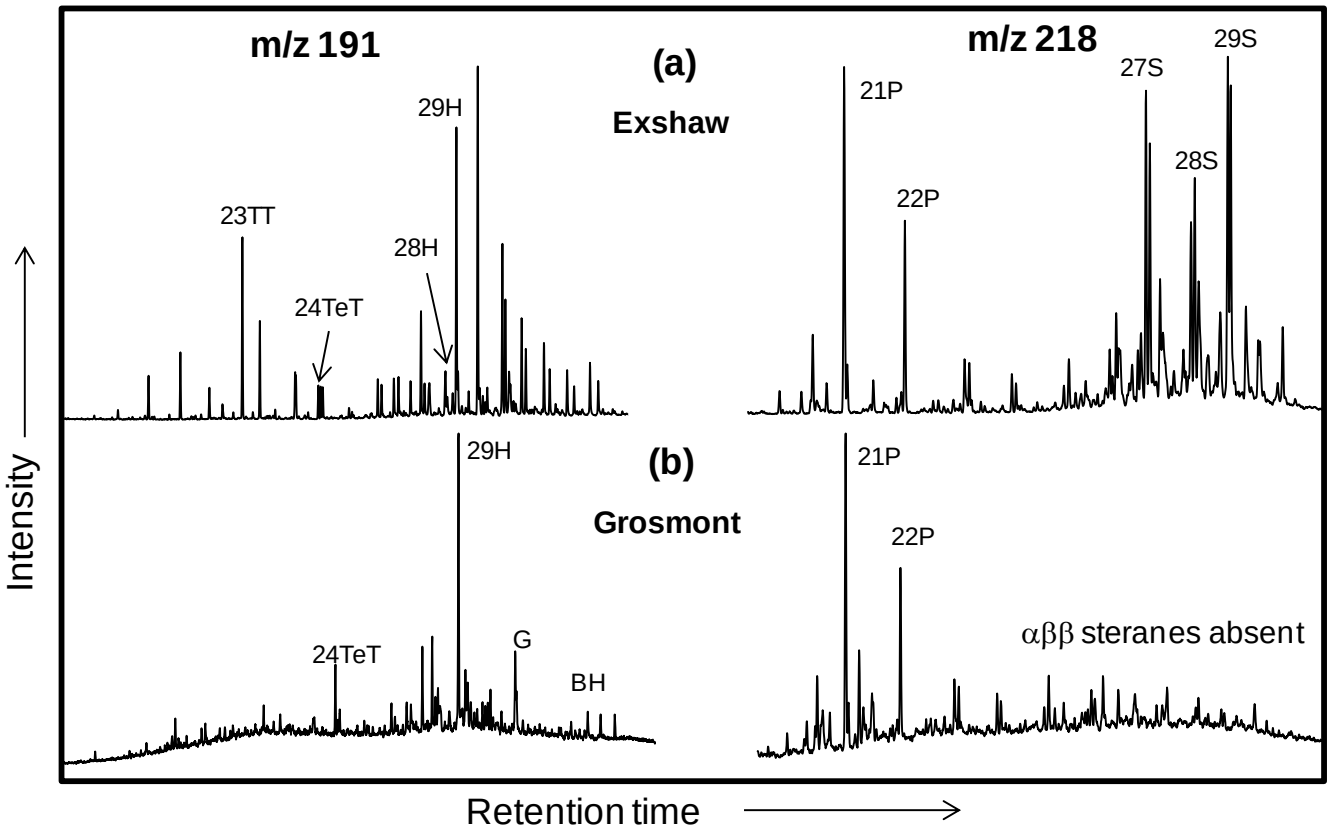

Figure 1. Partial reconstructed mass chromatograms, m/z 191 and m/z 218, representing (a) Exshaw type oil and (b) Grosmont bitumen, displaying the large impact of advanced biodegradation on the distributions of biomarker

compounds. Key: 23TT = C_{23} tricyclic terpane, 24TeT = C_{24} tetracyclic terpane, 29H = C_{29} $\alpha\beta$ 30-norhopane, G = gammacerane, BH = Benzohopanes, 21P = C_{21} $\alpha\beta\beta$ pregnane 27S = C_{27} $\alpha\beta\beta$ sterane.

Results and Discussion

We have investigated the regional source contributions to the Grosmont bitumen from the Gordondale, Exshaw and Duvernay formations. The geochemical fingerprints from the highly resistant aromatic steroid hydrocarbon compounds and the diamondoids possess unique distributions that enable recognition of source charge contributions and also retain valuable information regarding source maturity. The tri-aromatic steroid hydrocarbons extracted from Grosmont Formation bitumen most typically resemble those distributions found in the Gordondale / Exshaw type oils, whereas the distributions from a Duvernay type oil is clearly different. However, Sulfur and Nitrogen whole oil stable isotope data of Grosmont bitumens clearly resolve Gordondale from Exshaw charge components. The degradation resistant biomarkers and isotope proxies provide new insights into oil-source correlations for the carbonate hosted bitumen. Based on the limited inventory of end-member oil types, we can make some assertions regarding the source contributions. The Grosmont bitumen falls within the compositions obtained from a suite of oils that have originated from the Exshaw Formation.

During our studies of the Grosmont bitumen, we have found that molecular parameters based on the abundance of C_{27} 18 α (H)-22,29,30-trisnorneohopane (Ts) relative to C_{27} 17 α (H)-22,29,30-trisnorhopane (Tm), i.e. Ts/(Ts+Tm) and the steroid aromatization parameter (mono-aromatic steroids versus tri-aromatic steroids) display strong resistance to biodegradation. The depth profiles of the molecular parameters (Fig. 2) are remarkably uniform within the UGM2 and UGM3 units and the trends also appear uninterrupted by the presence of the shale break. A similar observation may be seen amongst the quantitative data obtained for the biodegradation resistant C_{24} tetracyclic terpane and Ts, thus molecular ratios and concentration data suggests the oils in UGM2 and UGM3 are genetically related.

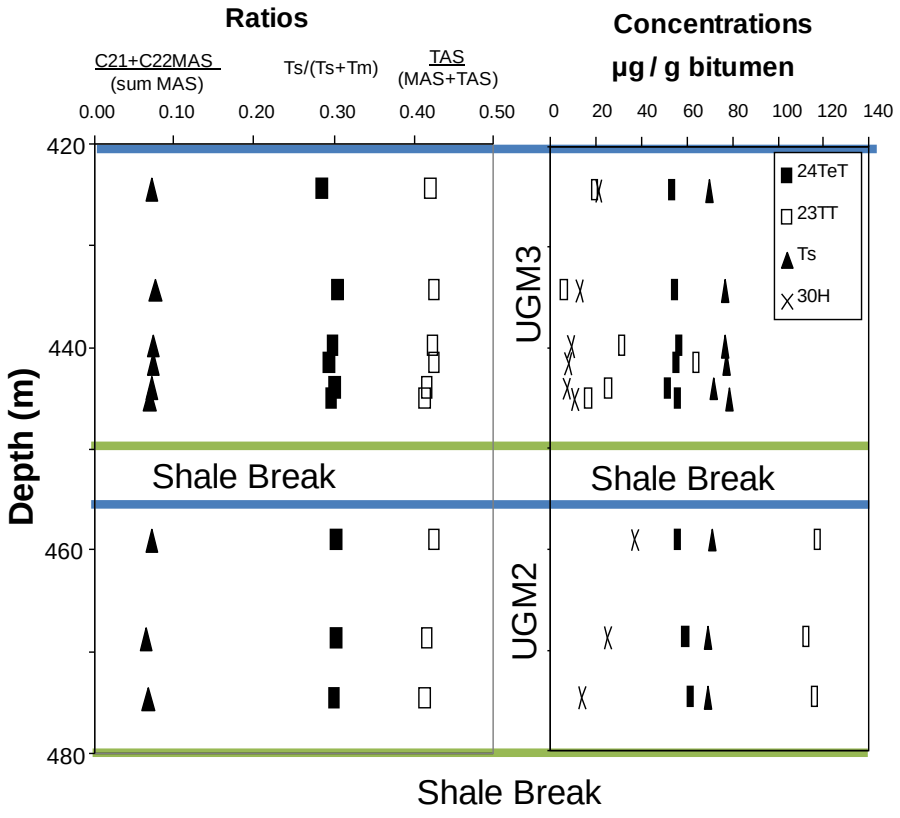

Figure 2. Molecular maturity parameters and molecular concentration (µg/g bitumen) data versus depth (m) for the Upper Grosmont units 2 (UGM2) and 3 (UGM3).

In contrast, the behavior of compounds that appears sensitive to biodegradation under the severe conditions experienced by the Grosmont bitumen exhibit changes within the reservoir units which show very different distributions between UGM3 and UGM2. The concentration data for the C_{23} tricyclic terpane and C_{30} $\alpha\beta$ hopane (Fig. 2) indicate the biodegradation behavior is specific to the reservoir units UGM2 and UGM3. In addition, further evidence for different biodegradation systematics between reservoir units UGM3 and UGM2; is recorded by the relative distributions of hopanes versus 25-norhopanes. In UGM3, the biodegradation of hopanes occurs without the formation of 25-norhopanes, whereas in UGM2 hopane degradation occurs with the formation of 25-norhopanes (Fig. 3). The molecular evidence indicates there are very different degradation systematics operating within the UGM3 and UGM2 reservoir units implying that the laterally extensive shales within the Grosmont Formation represent barriers to vertical fluid communication leading to unique biodegradation processes in the individual reservoir compartments.

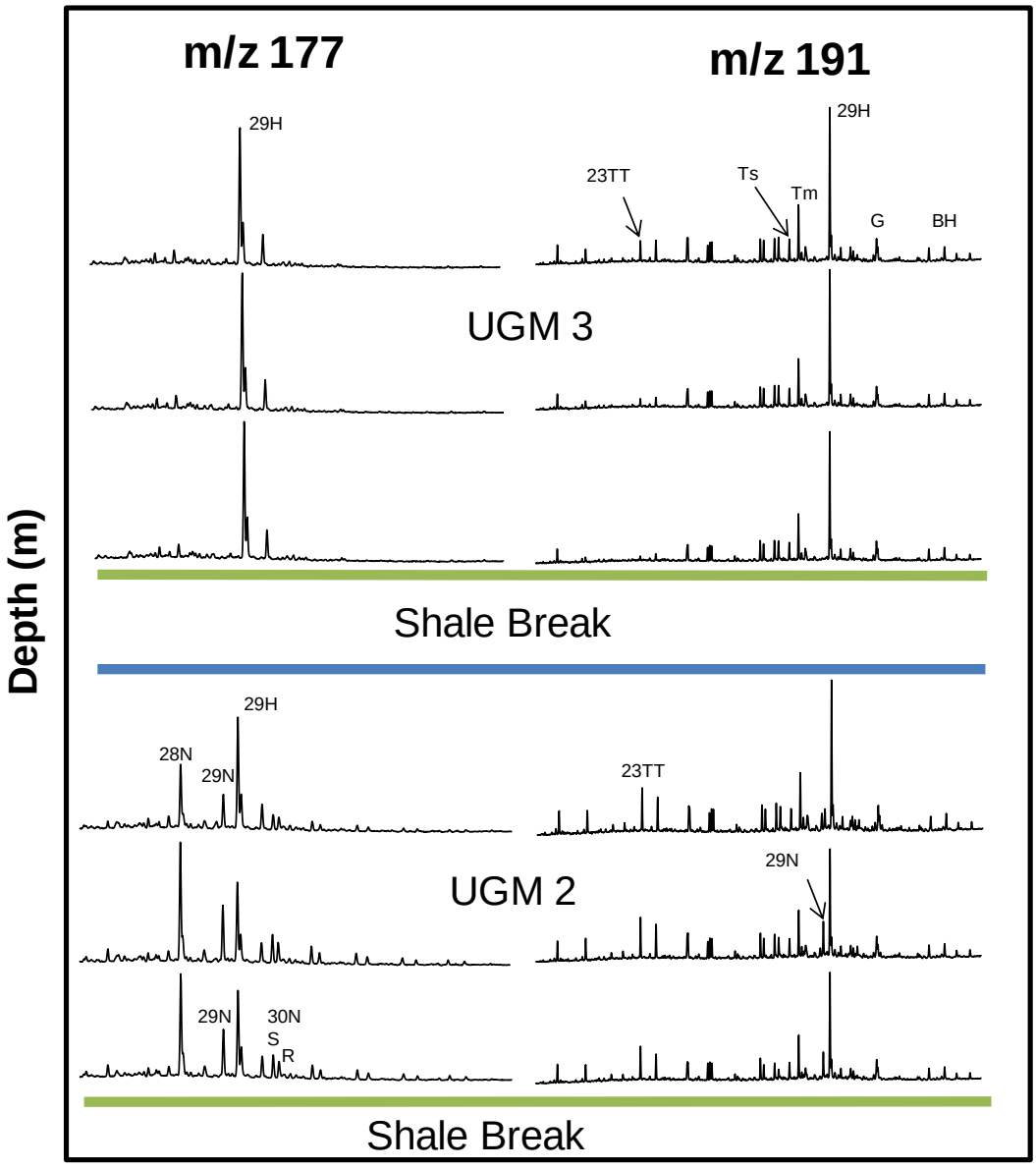

Figure 3. Partial reconstructed mass chromatograms representing 25-norhopanes (left, m/z 177) and tri, tetra and pentacyclic terpanes (right, m/z 191) in the Grosmont bitumen versus depth (m). Key: 29N = C_{29} $\alpha\beta$ 25-norhopane, S = 20S configuration in C_{30} $\alpha\beta$ 25-norhopane (30N); also see legend in Fig.1.

Summary

The molecular evidence based upon the biodegradation resistant compounds and stable isotopes (N and S) suggests the Grosmont bitumen is predominantly charged from the Exshaw Formation derived oils. The uniform profiles exhibited by the molecular parameters (and concentration data) based upon the biodegradation resistant compounds suggests the fluids in reservoir units UGM3 and UGM2 are derived from a genetically related source charge feedstock that filled the reservoir. The open network created by the palaeokarstic weathering system may have provided the migration conduits along the Devonian / Cretaceous unconformity with similar fluids filling downwards either side of the shale barriers into the reservoir units of the Upper Grosmont Formation. Subsequently, within their respective compartments, isolated locally by the shale barriers, the oils underwent biodegradation according to local conditions that are unique to units UGM3 and UGM2.

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References

Creaney, S. and Allan, J. 1990. Hydrocarbon generation and migration in the Western Canada Sedimentary Basin. In: Classic Petroleum Provinces. J. Brooks (ed.). Special Publication of the Geological Society, Blackwell Scientific.

Head, I.M., Jones, D.M. & Larter, S.R. Biological activity in the deep subsurface and the origin of heavy oil. Nature 426, 344-352 (2003).

Riediger, C.L., MacDonald, R., Fowler, M.G., Snowdon, L.R., Sherwin, M.D., 1999. Origin and alteration of Lower Cretaceous Mannville Group oils from the Provost oil field, east central Alberta, Canada. Bulletin of Canadian Petroleum geology 47 (1), 43-62.