

Upper Ordovician hydrocarbon source rock types in North-America – Paleogeographic and paleotectonic control on Type I / II and II-S distribution

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Introduction

Late Ordovician is a time of wide-spread deposition of organic matter-rich mudstones. In North America, these Upper Ordovician hydrocarbon source rocks are present everywhere on the ancient Laurentia continent, their precise age being slightly variable with the oldest and thickest ones (Mohawkian; Sandbian) at the continental margin (Anticosti Macasty shales) and the youngest and thinnest ones (Richmondian; end-Katian) in the central part of the continent (Ontario Collingwood, Yeoman and Boas River and Hudson Bay Red Head Rapids shales) (Fig. 1).

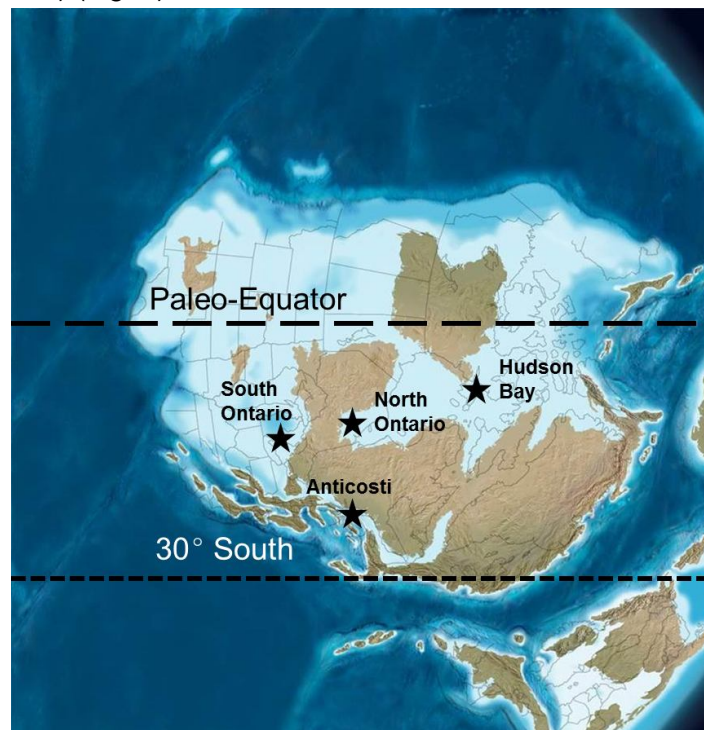


Fig. 1: Distribution of Upper Ordovician source rocks on Laurentia (base map from Blakey; <http://cpgeosystems.com/paleomaps.html>).

The Hudson Bay Basin is an intracratonic basin located in the center of Laurentia; this basin is the largest of the intracratonic basins in North America. The preserved succession covers the Late Ordovician to Late Devonian and is dominated by shallow marine carbonates, evaporites and shales. Three intervals of Upper Ordovician black shales are present in the succession, with a progressive younging and thinning of the shale intervals towards the Late Ordovician paleoequator at the northern margin of the basin. The organic matter rich shale (up to 35% TOC) are found in cyclic succession of peritidal carbonates with evaporites interpreted to record hypersaline conditions. The hypersaline setting is also supported by the shallow water and environmentally stressed conodont association that indicate maximum regression in late Ordovician.

The Upper Ordovician source rocks are markedly different on their petrographic characteristics and biomarker signatures. Upper Ordovician source rocks at or near the continental margins are locally rich in *Gloeocapsomorpha prisca* with biomarker signatures indicative of Type I/II source rocks. To the contrary, the Upper Ordovician source rocks at the northern reach of the Hudson Bay Basin are lacking *G. prisca* and their biomarker signatures indicates sulphur-rich organic matter (Type II-S). Compared to slightly older source rocks at the continental margins, those in Hudson Bay have higher abundances of C19 + n-alkanes and acyclic isoprenoids, and lower pristane/phytane ratios (Fig. 2).

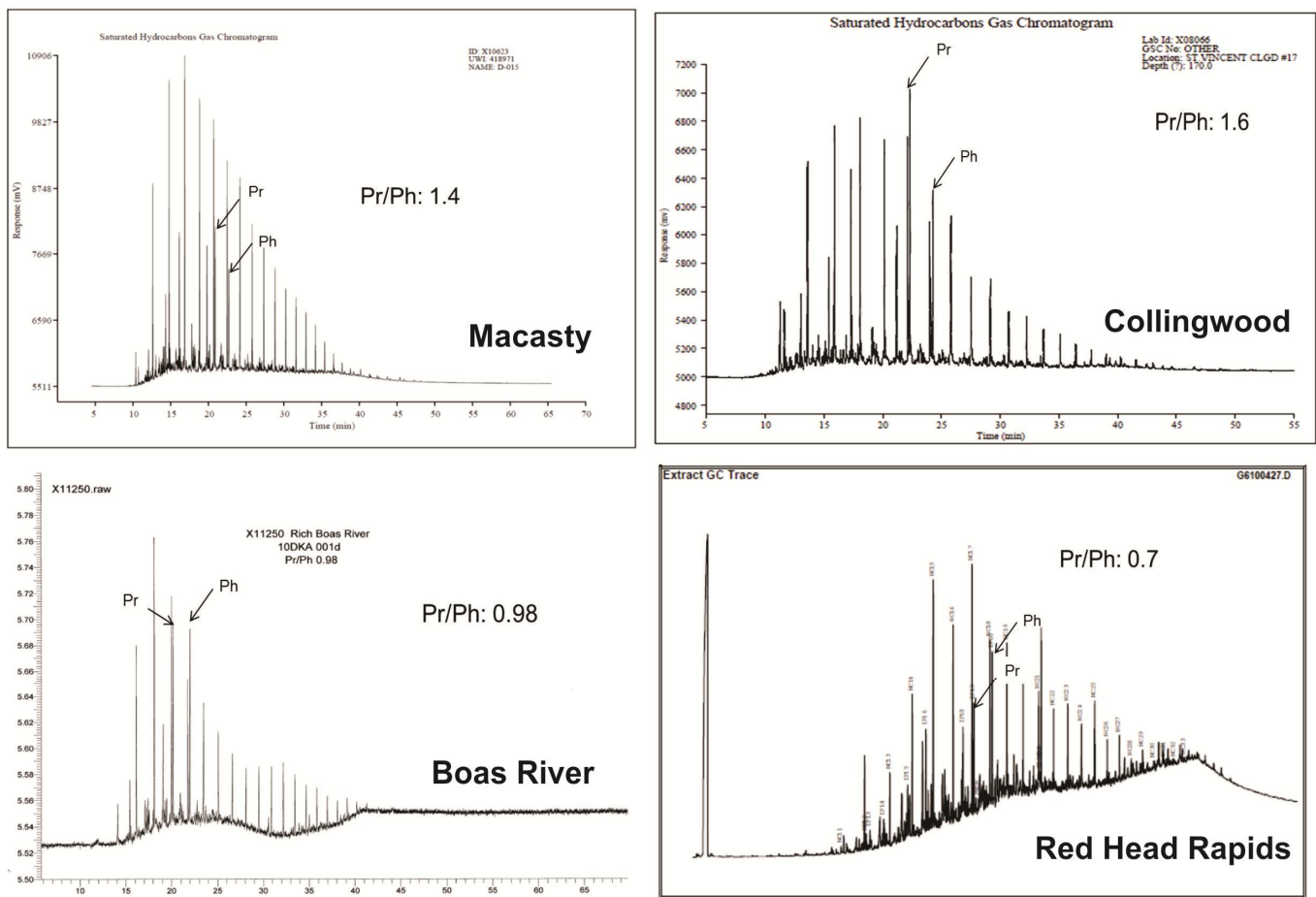


Fig. 2: Representative GC-MS graphs and Pr / Ph values of Upper Ordovician source rocks extracts

These geochemical signatures indicate the Hudson Bay Basin source rocks were deposited in hypersaline and highly reducing environments in which anaerobic bacteria reworked the organic matter. Hypersaline-reducing environments are also indicated by the presence of 1-alkyl-2,3,6-trimethylbenzenes (which form in the presence of sulphur bacteria) in the aromatic fractions of Upper Ordovician units. The Ordovician

source rocks in the Hudson Bay Basin also have low C32/C34 ratios and distributions of 17 α (H) - 21 α (H)-hopanes that are very similar to the Silurian hypersaline source rocks in the intracratonic Michigan Basin in central USA.

The intrinsic character and geochemistry of Upper Ordovician source rocks indicate continental-wide tectonic and environmental controls. The thick succession (up to 600 m) of calcareous black shales at the continental margins of Laurentia (e.g., Utica Shale, Cape Phillips Formation) are present in a succession of deepening-upward open marine facies (carbonate and clastics) capped by flysch in response to tectonic foundering of the margin linked to accretion processes. These are dominated by Type II organic matter. Away from the continental margins, the Upper Ordovician source rocks (e.g., Collingwood and Yeoman formations) are included in open marine carbonate successions, these are dominated by Type I/II organic matter. Finally, in the central part of Laurentia, the Hudson Bay Upper Ordovician source rocks (e.g., Red Head Rapids, Amadjuak and Boas River formations) are younger and thinner (5 to 15 m), they are found in eustatically-controlled, shallowing-upward succession culminating in hypersaline conditions resulting in the presence of various amount of sulphur-rich Type II-S organic matter (Fig. 3).

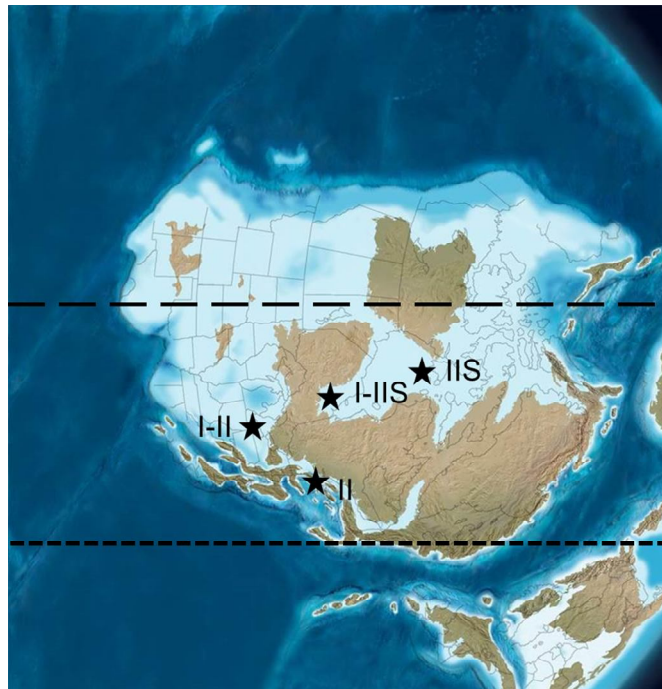


Fig. 3: Distribution of organic matter geochemical types for Upper Ordovician source rocks in North America.

Tectonic, paleogeographic and paleoenvironmental conditions controlled the characteristics of Upper Ordovician source rocks in North America. The presence of Type II-S source rock has economic significance as these will start to generate oil at lower burial temperatures compared to Types I and II.