A Multi-Disciplinary Approach to Unraveling the Mysteries of the McMurray Formation and Associated Strata

Thomas D. Demchuk
ConocoPhillips, Upstream Technology, P.O. Box 2197, Houston, TX 77252-2197
thomas.d.demchuk@conocophillips.com
and
John R. Suter
ConocoPhillips, Oil Sands Development Group, Oil Sand Business Unit, Calgary, AB
john.r.suter@conocophillips.com
and
Graham Dolby
G. Dolby and Associates, 6719 Leaside Drive, Calgary, AB T3E 6H6
gdolby@shaw.ca
and
Courtney Turich, Ronald F. Waszczak,
ConocoPhillips, Upstream Technology, P.O. Box 2197, Houston, TX 77252-2197
courtney.turich@conocophillips.com, ronald.f.waszczak@conocophillips.com

Summary

Much recent study has been devoted to the sedimentological and stratigraphic description of the McMurray Formation, to better interpret the deposit and access the vast heavy oil resource therein. All these studies indicate that McMurray Formation sediments were deposited in a variety of fluvial, estuarine, transitional, deltaic and shallow marine depositional environments: one or all of these depositional settings may be interpreted from a single McMurray Formation outcrop, core, or well log. Such interpretations depend on the particular location of the described section of the McMurray Formation within the broad expanse of Aptian/Albian paleogeography of the Western Interior Seaway of northern Alberta. Typically, no one depositional environment describes the McMurray at any one locality, and the depositional environments and associated facies can change quickly both laterally and vertically within any given area. In order to fully understand these changes, a multi-disciplinary approach is necessary bringing together several geological analytical methodologies and the associated data.

Introduction

The strata of the McMurray Formation are largely devoid of calcareous and siliceous microfossils (i.e. foraminifera, nannofossil, diatoms/radiolarians, silicoflagellates) as well as being barren of calcareous macrofauna (e.g., ammonites and mollusks). This leaves palynology (organic-walled, acid resistant microflora) as the only micropaleontological discipline left to unravel the bio- and chronostratigraphic mysteries of the McMurray Formation. Many studies have been conducted over the decades describing the unique nature of the associated palynofloral assemblages, and the endemic dinoflagellate assemblages for which questions remain regarding their exact paleoenvironmental significance. Multi-disciplinary integrated studies can help constrain these uncertainties.

In addition to the palynology, organic and inorganic geochemical methodologies provide insight to the paleoenvironmental complexity of the McMurray Formation. Organic geochemical proxies such as bulk

C- and N-isotopes, and delta-D hydrogen isotope analyses can give us an indication of paleosalinity: Tex86 isotope analyses provide indications of paleotemperature and hence, paleoclimate. Mineralogy and petrologic information derived from inorganic methodologies such as XRD, chemostratigraphy and QEMScan provide mineralogical and petrologic information may help unravel provenance trends, among other sedimentological concerns. Going forward, integrating these data will lead to an improved sequence stratigraphic and chronostratigraphic framework for the McMurray Formation and associated strata.

Theory and/or Method

McMurray Fm. assemblages are typically dominated by bisaccate and small, inaperturate *Taxodiaceae* pollen. Pteridophyte spores (trilete and monolete) typically comprise 10 – 15% of the assemblage. *Classopollis* spp. can be numerous, especially in the lower parts of the Formation, and while spores of the *Schizaceae* (e.g. *Cicatricosisporites* spp.) are usually present in modest numbers there are occasional abundance peaks. Dinocyst numbers tend to be low (usually <2%) throughout much of the McMurray Fm. but increase markedly near the top. Dinoflagellate assemblages are typically comprised of specimens of *Nyktericysta* spp. and *Hurlandsia rugara* but it is not unusual to find assemblages devoid of dinocysts. Freshwater algae are usually rare. Near the top of the Formation, assemblages can contain very large numbers of *Nyktericysta* spp. and also a few brackish-tolerant marine dinocysts such as *Palaeoperidinium cretaceum* and *Circulodinium brevispinosum*. Certain species of *Vesperopsis* spp. usually make their first appearance in this upper portion of the Formation. The abundance and diversity of marine dinocysts increases through the transition into the overlying Wabiskaw Mbr. (of the Clearwater Fm.) but locally, there can be very large numbers of as yet undescribed species of dinocysts which appear to be of brackish water origin (similar in morphology to *Nyktericysta* group taxa). The Wabiskaw B and A typically yield rich and diverse assemblages of marine dinocysts. The number of specimens of *C. brevispinosum* usually decreases up-section, and is replaced by often super-abundant *Circulodinium deflandrei*.

Although much of the organic and inorganic data remain to be integrated, early interpretations of the XRD and Chemostratigraphy data indicate that the regional flooding “shales” (e.g. A, and C-Shales) are distinct and are characterized by unique clay mineralogy and elemental geochemistry. This leads to a greater understanding of the sequence stratigraphic significance of these shale baffles/barriers. Previous organic geochemical investigations of the hydrogen isotopes indicate that strata of the McMurray Formation may have been deposited within paleoenvironments with paleosalinities as much as 15ppt at Surmont (Brinkhuis et al, 2008). Additional such organic geochemical study will confirm these paleosalinities and reveal regional trends.

Conclusions

The abundance of palynofloral data collected from the McMurray Formation and associated strata has led to a greater understanding of the diverse paleoenvironments of these Aptian/Albian strata. Although a palynofloral characterization scheme has been developed (Figure 1), given the unique nature of the McMurray Formation such understanding will undoubtedly evolve as additional data are compiled from the various oil sands leases, and as associated strata (Wabsikaw and younger) are included in these investigations. Additional understanding of the McMurray Formation paleoenvironments will be gained through geochemical analyses and other sedimentological investigations. Integration of these data will aid in the development of a comprehensive chronostratigraphic and stratigraphic framework for the McMurray Formation and associated strata.

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References

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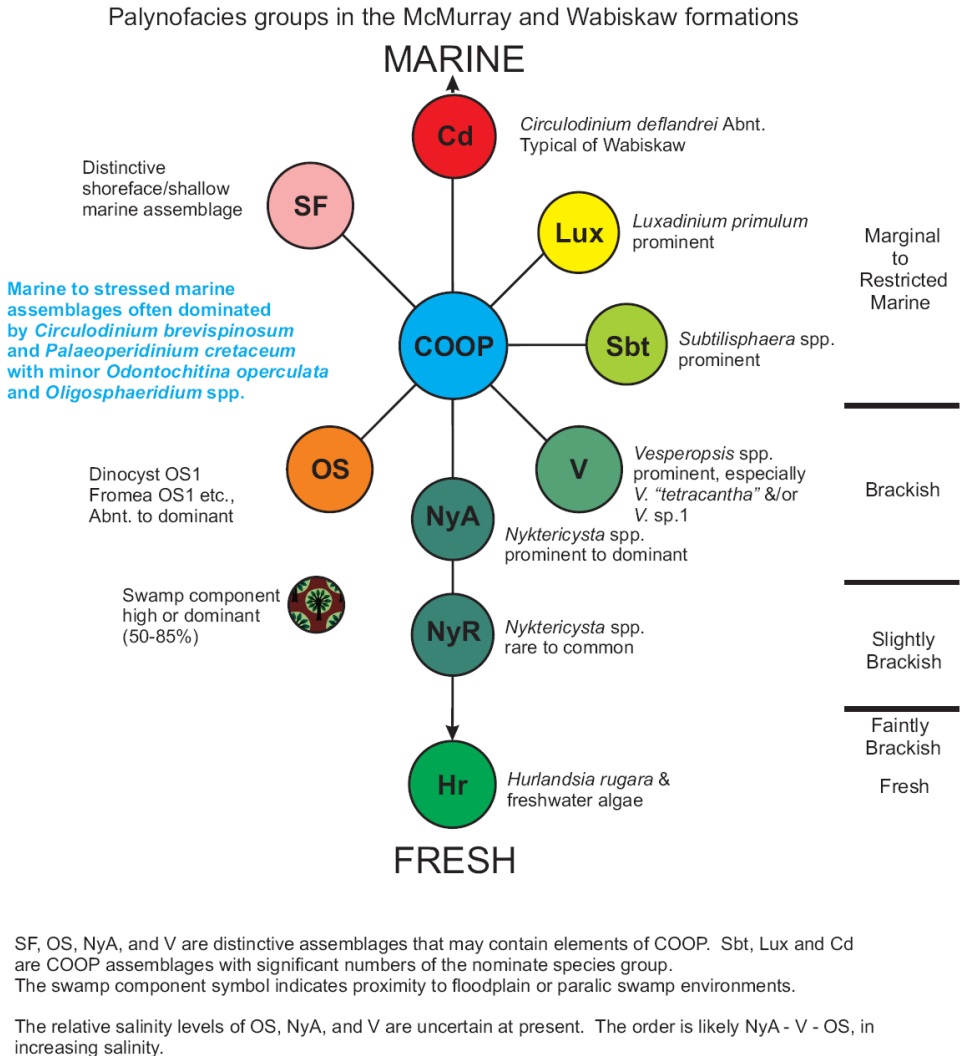

Figure 1. Diagram of the proposed COOP palynofloral designations, illustrating the complex nature of the McMurray Formation palynofloral assemblages, and the proposed gradient from fresh/faintly brackish assemblages up through marginal/restricted marine paleoenvironments. The diagram is meant to be a guide to the understanding of the algal components of the assemblages, and their potential integration into a comprehensive stratigraphic model and understanding of the complex reservoir heterogeneity. This classification is not meant as the final interpretation of these assemblages, but is evolving as more palynology is investigated and additional diverse paleoenvironments are incorporated. Produced through the thorough investigations of G. Dolby.

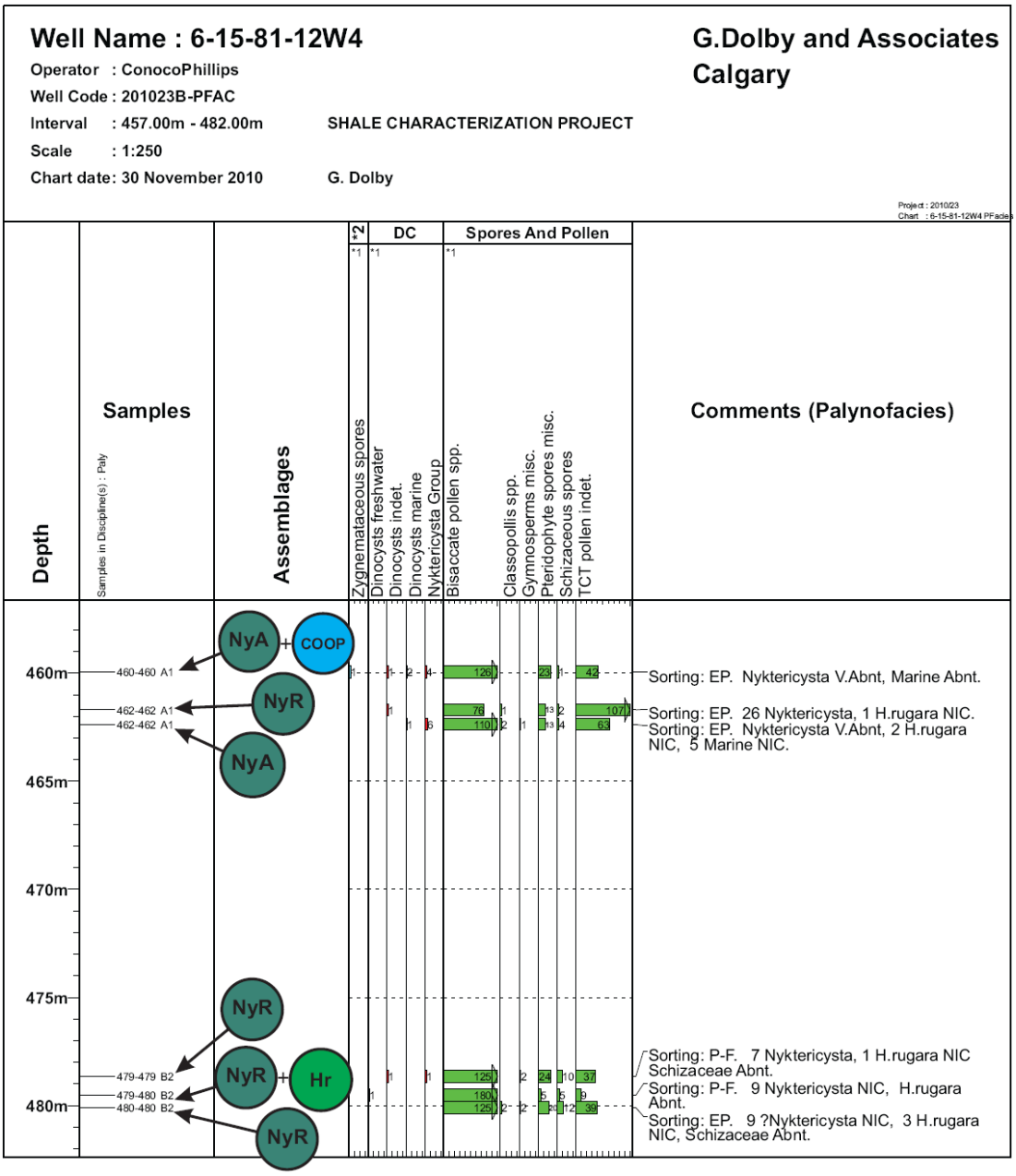

Figure 2. An example of a palynological plot from the 6-15-81-12W4 (Thornbury) well with the COOP designations annotated alongside samples from the B2 and A1 regional flooding shales. Illustrated are *Nyktericysta* "Rare" and the *Hurlandsia rugara* fresh to slightly brackish assemblages corresponding to the lower B2 shale, and *Nyktericysta* "Abundant" and COOP brackish to marginal marine assemblages. Through integration of these palynofloral assemblages with additional sedimentological, stratigraphic and geological data.