THE STRATIGRAPHIC SETTING AND EVOLUTION OF THE MARITIMES BASIN IN EASTERN CANADA: IMPLICATIONS FOR HYDROCARBON EXPLORATION

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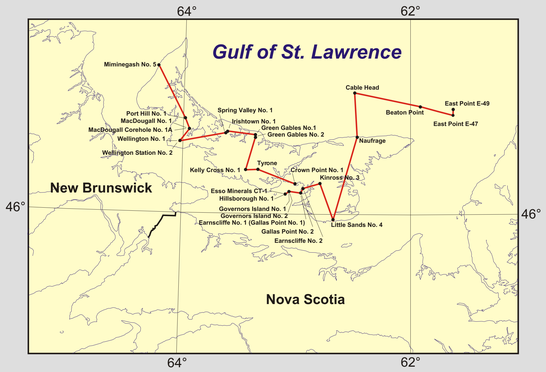
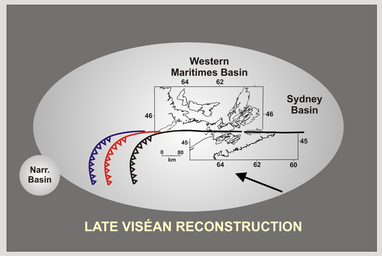
ABSTRACT

The 400,000 km2 Devonian- Permian basin (12 km of sediment) has proven oil and gas potential. However, stratigraphic, structural and thermal maturity complexities, and a small geological database, hinder exploration. Early basinal rifting resulted in deposition of terrestrial redbeds and volcanic rocks. By the mid-Tournaisian, lacustrine/estuarine environments were widespread, and oil-rich mudrocks occcur in the Horton Group, and equivalents. by the late Tournaisian, deposition was mainly fluviatile. The latest Tournaisian to early Viséan, generally, is an hiatus. In the middle to late Viséan (Windsor/Codroy Groups) marine evaporite-dominated rocks provided seals. Lacustrine/fluviatile deposition continued into the mid-Namurian Mabou Group.

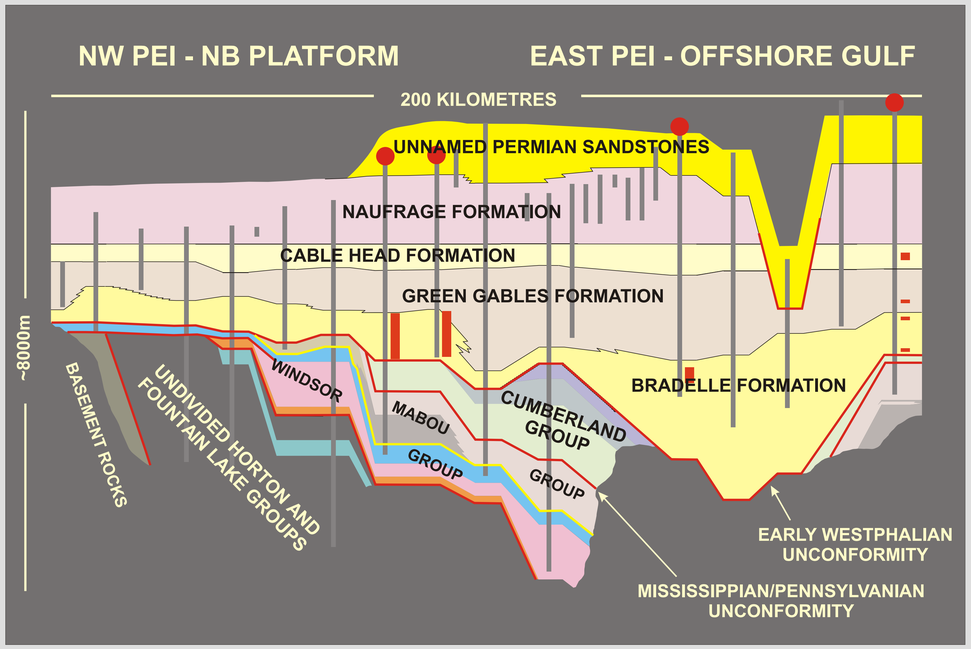
The Mississippian/Pennsylvanian unconformity at the base of the Port Hood Formation, and equivalents, heralds a sedimentological change. Multistoried fluviatile sandstones are widespread. Black carbonaceous shales with coals (gas generators), increase in abundance upwards until the earliest Westphalian. Their distribution is limited to the onshore Maritimes Basin in Nova Scotia, southeastern New Brunswick and southwestern Newfoundland, and to the southern part of the Gulf of St. Lawrence by a second major unconformity at the level of the early Westphalian B (Duckmantian). Duckmantian to early Westphalian D times were dominated by large fluviatile systems, with thick multi-storied sands separated by grey carbonaceous mudrocks with coals (gas generators). These pass upwards into redbed-dominated fluvial successions of the lower Permian.



The western Maritimes Basin remains under- explored in spite of more than thirty years of sporadic exploration activity. Only eight wells have tested the marine portion of the basin. Most available data are for Prince Edward Island and immediately adjacent marine waters. These data have been summarized in the above line of section to provide a regional perspective on the basin fill.

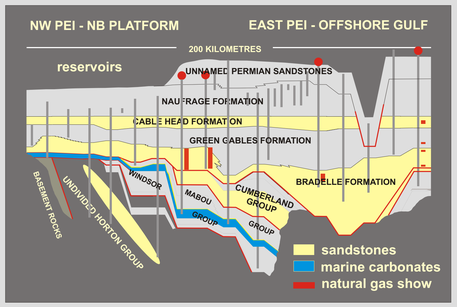


The Westphalian-Permian basin is believed to have been much more extensive than indicated by present outcrop distribution. Regional comparisons suggest that these younger strata can be correlated from the Sydney Basin westerly to the Narragansett Basin, albeit with anticipated regional variations. The tectonic setting of these basins may reflect continuing movements on the Cobequid-Chedabucto fault system resulting in transpressive emplacement of the Meguma terrane over adjacent Avalon terrane as shown schematically on the left.

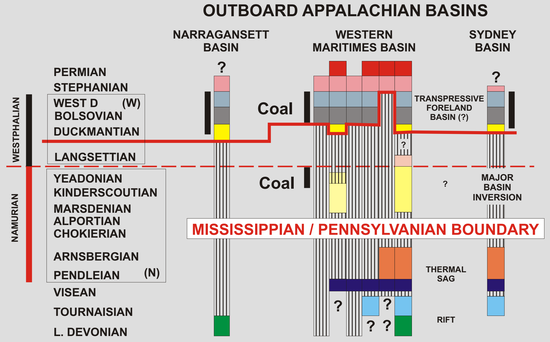


This regional cross-section synthesizes subsurface data representative of the western Maritimes Basin. The stratigraphic architecture is applicable in general terms to all sedimentary basins of late Devonian to Permian age east of the Appalachian Orogen. Two major episodes in basin evolution are apparent, separated by the early Westphalian unconformity. Below this major unconformity, the basin exhibits several older stages in its development, each of which may be genetically distinct.

The Mississippian / Pennsylvanian boundary marks the first basin-wide appearance of major channel sandstones representing far-travelled fluviatile systems. A persistent biostratigraphic gap separates the base-Windsor Group from underlying strata throughout much of the basin, and suggests that for the duration of the Windsor and Mabou Groups, the basin has a separate evolutionary path. Below the Windsor Group, local structural complexity partially obscures regional facies architecture which may be surprisingly consistent over large portions of the Maritimes Basin. In the cross section, few data are available to illustrate the complexities of the early basin fill, and the wells have been simplified for illustrative purposes.



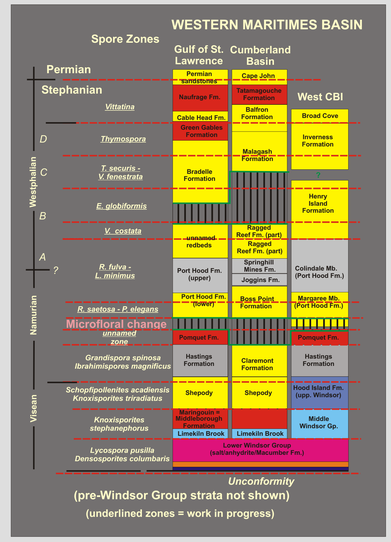
With the exception of relatively thin but laterally extensive carbonate rocks of the Windsor group, reservoirs in the Maritimes Basin comprise sandstones ranging in depositional setting from lacustrine shoreface to fluviatile channels. The former provide attractive reservoirs in the upper portion of the Horton Group. In the Cumberland Group and in the overlying Pictou Group, thick, multi-storied sand bodies, measuring kilometres in lateral extent, are typical. Reservoir quality is variable and is perhaps the weakest component of the hydrocarbon system. Porosities are, however, comparable to those recorded in producing late Carboniferous gas fields in the North Sea region of western Europe.



The stratigraphic framework established for the western Maritimes Basin can be compared and contrasted with that documented in other basins southeast of the Appalachian Orogen. Both the Narragansett and Sydney basins have no apparent record of the earliest Pennsylvanian succession, presumably due to basin inversion at that time. Strata which are preserved in all three areas are generally comparable, attesting to the regional aspect of the major depositional systems.

The early Westphalian unconformity, shown by the heavy red line, merges with the Mississippian / Pennsylvanian unconformity in many areas of the Maritimes basin. The true Mississippian / Pennsylvanian boundary is preserved only in the western Maritimes Basin.

The yellow highlight marks the earliest major fluviatile sandstones which comprise potential reservoirs for natural gas generated from associated coal measures.



The predominantly non-marine character of the Maritimes Basin fill makes palynostratigraphy the most valuable regional biostratigraphic tool. Concurrent range zones have been established for the Tournaisian, Viséan and early Namurian, and research is in progress for younger parts of the basin fill. Parts of this effort are illustrated above.

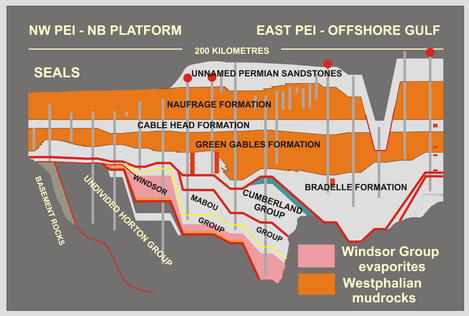
In the younger basin fill, work to date suggests that the coal measures fall into two successions of quite different age. The oldest is represented by coals of the Port Hood Formation which appear to be latest Namurian to Westphalian A (Langsettian) in age. The younger coal measures extend from the Westphalian B (Duckantian) to the highest Westphalian D. Recognition of these contrasting ages is critical to recognition of the early Westphalian and Mississippian / Pennsylvanian unconformities.

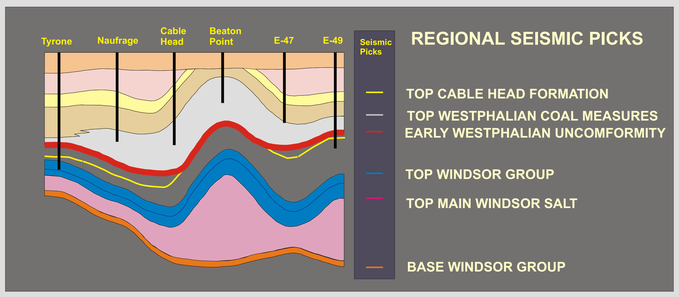
Pronounced facies changes in the western portion of the basin where terrestrial rocks replace even the characteristic marine rocks of the middle and upper Windsor Group present a continuing challenge for palynological study. This problem is heightened by the dominance of redbeds in basin-margin areas.

Thick evaporite units low in the Windsor Group provide attractive seals for hydrocarbons generated from the Horton Group. Less appreciated are thick mudrock sections higher in the succession which have a demonstrated capacity to function as effective seals for both oil and natural gas, as proven by the natural gas encountered in the East Point E-49 well at the eastern extremity of the regional cross-section.

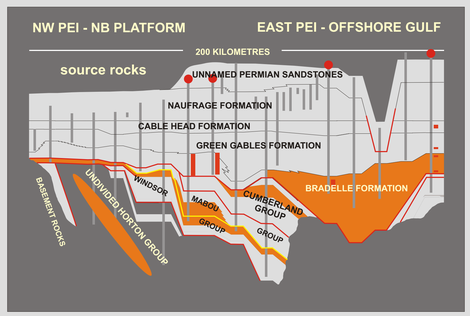
Grey mudrocks with coals in the upper portion of the Cumberland Group may also have potential as seals for natural gas generated within the same succession. These are shown in green in the diagram on the right.

Additional seals may be linked to regional unconformities such as the Mississippian / Pennsylvanian boundary and the early Westphalian unconformity. Local seals may be provided by faults.





More than 40,000 kilometres of seismic reflection data have been acquired in the Maritimes Basin over a thirty-year period. Much of this seismic data-set is available to assist in regional exploration. Some lithostratigraphic horizons can be traced seismically throughout the basin (for example, the base-Windsor reflector). Others have more local utility. Efforts to synthesize these data have been hampered by a lack of regional understanding of upper Carboniferous to Permian rock units and their lateral continuity, and by limited exposure of the youngest basin fill in on-shore areas of the basin.



Historically, most exploration in the Maritimes Basin has been driven by perceived potential for both oil and natural gas sourced from organic-rich black shales and mudstones in the Horton Group. Windsor Group carbonate rocks comprise a second regionally extensive interval where liquid hydrocarbons have locally been generated. Coal measures have received more current attention due to their documented potential to source natural gas, and their association with major sandstone reservoirs.

On the left, in orange, the stratigraphic distribution of source rocks within the basin fill is schematically illustrated using the regional cross-section shown above. Wells which encountered significant natural gas are highlighted.