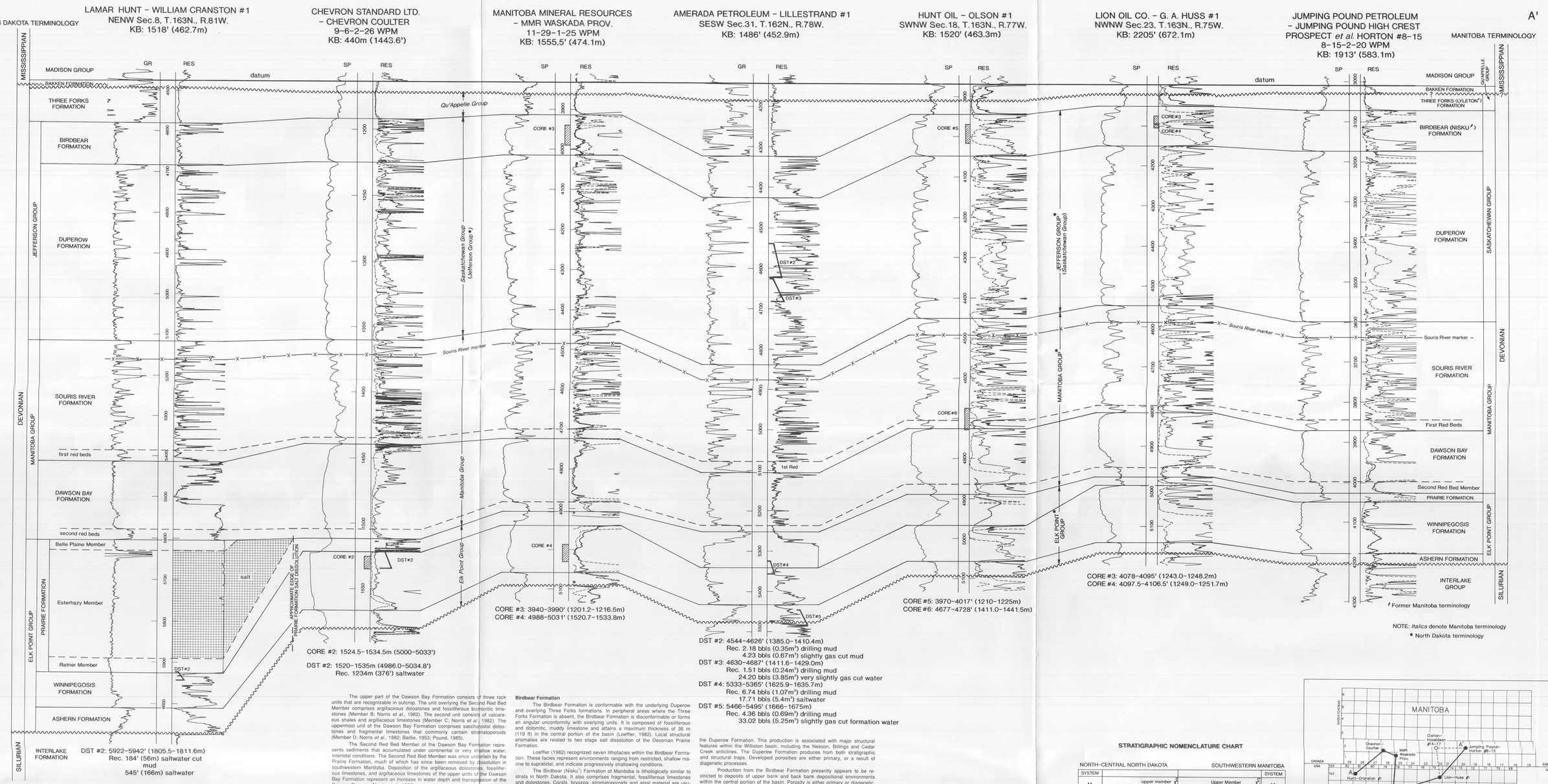


STRATIGRAPHY

The Devonian System in North Dakota and Manitoba is divided into four major lithologic units (Baillie, 1953; Bluemle *et al.*, 1986). These are, in ascending stratigraphic order, the Elk Point, Manitoba, Saskatchewan and Qu'Appelle groups.

ELK POINT GROUP

The Elk Point Group is divided, in ascending order, into the Ashern, Elm Point (Manitoba only), Winnipegosis, and Prairie formations.

Ashern Formation

The Ashern Formation attains a maximum thickness of 55 m (180 ft) in the central portion of the basin. It unconformably overlies the Silurian Interlake Formation in North Dakota. In North Dakota, Lobdell (1984) informally subdivides the Ashern into a lower red member and upper grey member, both comprising argillaceous, microcrystaline dolostones containing minor amounts of quartz silt. Anhydrite is present in both members, however, it is more abundant as nodules in the lower red member. Bedded halite may also be present and is noted in two areas of North Dakota, eastern Williams and western Mountrail Counties.

The lower red member is present in North Dakota as a north-trending, weakly positive feature. It is believed to have been deposited as a peninsula or large island (Lobdell, 1984). Coastal sabkas developed on this feature, and are represented by red microcrystalline dolostones and local anhydrites. This feature was later inundated by the Middle Devonian restrictive sea. Subtidal sediments formed at this time became the microcrystalline dolostones of the upper grey member.

In Manitoba, the depositional thickness of the Ashern Formation ranges from approximately 3 to 12 m (10 to 39 ft). The Ashern Formation unconformably overlies the Middle Silurian Interlake Group and is overlain with slight unconformity by the Winnipegosis Formation, or the Elm Point Formation where it is developed. Its lithology consists mainly of interbedded red and green dolomitic shales and red argillaceous dolostones (Baillie, 1953).

The Ashern Formation constitutes the basal part of the Devonian succession throughout a large part of the Elk Point basin of Manitoba and Saskatchewan. The sediments of the Ashern Formation represent, in part, the reworking of residual soil formed during the later Silurian to early Devonian erosional interval (Norris *et al.*, 1982).

Elm Point Formation (Manitoba)

The Elm Point Formation is identified only in Manitoba. It overlies the Ashern Formation with possible unconformity and ranges in thickness from approximately 5 to 20 m (16 to 66 ft). The Elm Point Formation in outcrop typically consists of medium yellowish-brown, very fine-grained, variably dolomitized, mottled high-calcium limestone. It grades laterally in the subsurface to a dolostone that is generally indistinguishable from the overlying Winnipegosis Formation. It is essentially equivalent to the Lower Member, platform carbonate facies of the Winnipegosis Formation (Norris *et al.*, 1982).

Winnipegosis Formation

The Winnipegosis Formation disconformably overlies the Ashern Formation in North Dakota and Manitoba. It attains a maximum thickness of 105 m (344 ft). The Winnipegosis Formation is subdivided into a lower member, platform facies, consisting generally of a mottled dolostone, and an upper member, carbonate mound, reef, or inter-reef facies (Norris *et al.*, 1982). Argillaceous-bituminous or laminated beds separate the two units. The subdivisions of the Winnipegosis Formation are recognized in North Dakota and Manitoba, but are formally defined only in Manitoba. In Manitoba, a transition zone occurs locally at the top of the Upper Member that consists generally of limestone-shale breccias and coarsely crystalline limestone (Norris *et al.*, 1982).

A transgression and regression of the Devonian sea into the Elk Point basin is represented by sediments of the Winnipegosis Formation. Widespread, normal marine carbonates represent the initial deposits of the formation (Norris *et al.*, 1982; Perrin, 1982; Ehrets and Kissling, 1987). These are, in turn, overlain by sediments representing two distinctly different environments, a shallow shelf environment, and a deeper basin environment with scattered pinnacle reefs. The shelf environment is represented by a fringing bank built up around the perimeter of the basin. Shoreward of this bank exists a sequence of either thin bituminous, laminated, inter-reef carbonates, or thick mound or reef carbonate complexes. Basinward from the bank, the pinnacle reefs and deeper basinal facies developed. The two environments represent a "decoupling" of the deeper basin environment from the shelf environment in response to varying rates of carbonate production.

Regression of the Devonian sea began during the initial deposition of the upper portion of the Winnipegosis Formation. At this time, supratidal deposition occurred on both the shelf and pinnacle reefs. The pinnacle reefs were probably periodically exposed. Shallow water sediments, dolostones, stromatolites, and anhydrites were deposited around the emergent reefs. The basin was eventually filled by salt of the overlying Prairie Formation (McCabe, 1987).

Prairie Formation

The Prairie Formation conformably overlies the Winnipegosis Formation completing the sequence of the Elk Point Group. The evaporites of the Prairie Formation attain a maximum thickness of 198 m (650 ft) with variations occurring locally and regionally due to dissolution and the differential accumulation of salt during deposition (Oglesby, 1988). Four members are recognized in the Prairie Formation of North Dakota; these include, in ascending order, the Ratner, Esterhazy, Belle Plaine, and Mountrail.

The Ratner Member consists principally of anhydrite and is transitional with the underlying Winnipegosis Formation. The Ratner Member is overlain by a transition zone. Interbeds of the anhydrite occur within the overlying halite (Oglesby, 1988; Bannatyne, 1960). These interbeds reflect a periodic recharge of the Elk Point basin. Overlying this transition zone are the remaining three members of the Prairie Formation, the Esterhazy, Belle Plaine, and Mountrail. These are regionally correlative upward brining sequences of halite capped with halite dominated potash beds. The potash represents the shallowest brine depth and the highest level of salinity. The final, unnamed halite cycle is capped by a red to green, nonfossiliferous dolostone to calcareous shale, known informally as the "second red beds". These beds probably protected the Prairie salt from dissolution during the Dawson Bay transgression. Generally included in the Dawson Bay Formation, Oglesby (1988) includes the "second red beds" as the uppermost member of the Prairie Formation.

In Manitoba, the Prairie Formation comprises a sequence of halite beds with minor anhydrite, and a potash-rich interval near the top. The present extent of the Prairie Formation in Manitoba represents a salt dissolution edge (see cross-section A-A'). The formation originally extended north and east of the present salt edge. The Prairie Formation thickens from a zero edge, due to dissolution, to approximately 125 m (410 ft) (Norris *et al.*, 1982; Manitoba Energy and Mines, 1980). The main body of evaporite is restricted primarily to an area west of the Winnipegosis fringing bank along, or near, the Manitoba/Saskatchewan border. A tongue of anhydrite beds extends eastward from this main body, over part of the Winnipegosis fringing bank (McCabe, 1971).

MANITOBA GROUP

The Manitoba Group in North Dakota and Manitoba comprises the Dawson Bay and Souris River formations.

Dawson Bay Formation

The Dawson Bay Formation attains a maximum thickness of 48 m (157 ft). In Manitoba, four rock units are recognized in the Dawson Bay Formation; these include, a basal unit termed the Second Red Bed Member, and three upper units. The Second Red Bed Member (Mafeking Member; Norris *et al.*, 1982) consists of red to green, noncalcareous, fissile shale that grades upward to argillaceous and dolomitic limestone and argillaceous dolostone. These beds are recognizable in the subsurface and in outcrop. Where underlain by Prairie Formation evaporites, the lower contact of the Second Red Bed Member is disconformable (McCabe, 1971).

The upper part of the Dawson Bay Formation consists of three rock units that are recognizable in outcrop. The unit overlying the Second Red Bed Member comprises argillaceous dolostones and fossiliferous biomicritic limestones (Member B; Norris *et al.*, 1982). The second unit consists of calcareous shales and argillaceous limestones (Member C; Norris *et al.*, 1982). The uppermost unit of the Dawson Bay Formation comprises saccharoidal dolostones and fragmental limestones that commonly contain stromatoporoids (Member D; Norris *et al.*, 1982; Baillie, 1953; Pound, 1985).

The Second Red Bed Member of the Dawson Bay Formation represents sediments that accumulated under continental or very shallow water, intertidal conditions. The Second Red Bed Member was once underlain by the Prairie Formation, much of which has since been removed by dissolution in southwestern Manitoba. Deposition of the argillaceous dolostones, fossiliferous limestones, and argillaceous limestones of the upper units of the Dawson Bay Formation represent an increase in water depth and transgression of the Dawson Bay sea (Norris *et al.*, 1982).

Deposition of the Dawson Bay Formation in North Dakota occurred on a low relief platform with slightly restricted marine waters (Dean, 1982). Environments range from subtidal to supratidal. Diagenesis, primarily dolomitization, destroyed much of the original texture.

Souris River Formation

The Souris River Formation conformably overlies the Dawson Bay Formation and generally consists of a sequence of dark grey and brownish-grey, argillaceous, anhydritic, or silty limestones or dolostones (Baillie *et al.*, 1986). Interbeds of siltstones, shales and evaporites are also present. These sediments represent an influx of clastics and supratidal carbonates into the basin in Devonian time. The formation attains a maximum thickness of 107 m (350 ft) in the central portion of the basin.

In Manitoba, the lower contact of the Souris River Formation is transitional. The Souris River Formation, as defined by Norris *et al.* (1982) is comprised of a lower unit, the Point Wilkins Member, and an upper unit, the Sagamace Member, both of which are recognized in Manitoba outcrop. The Point Wilkins Member consists of four rock units, in ascending sequence; the First Red Beds (only unit recognized in the subsurface); a red and green calcareous shale; a fossiliferous, argillaceous limestone; a dense, micritic and fragmented limestone (original Point Wilkins Member of Baillie, 1951); and a yellowish-brown, finely crystalline dolostone and dolomitic limestone. The Sagamace Member consists of variably fossiliferous, micritic limestone grading in part to laminated and pelletal limestone and saccharoidal dolostone. The Souris River Formation ranges in thickness, in Manitoba, from 66 to 95 m (216 to 312 ft) (McCabe, 1971; Manitoba Energy and Mines, 1980).

Recent standardized correlations established by McCabe and Bezys (pers. comm.) for the latest edition of the Western Canadian Atlas (in prep.) and the Lexicon of Canadian Stratigraphy (Canadian Society of Petroleum Geologists, 1990) have redefined the top of the Souris River Formation to correspond with its type section. The previous top of the Souris River Formation in Manitoba was defined as the top of a shale break roughly 15 m (50 ft) below the established top of the Souris River Formation. This pick has been retained in Manitoba as the "Souris River marker" (see cross-section A-A').

Deposition of the Souris River Formation represents an alternating cycle of marine transgression and regression. The First Red Beds and argillaceous and micritic limestones of the Point Wilkins Member represent a transgressive phase. The dolomitic limestone represents the initial phase of a regressive phase. The Sagemace Member represents the transgressive phase of a second cycle (Norris *et al.*, 1982).

JEFFERSON GROUP (North Dakota) / SASKATCHEWAN GROUP (Manitoba)

The Duperow and Birdbear formations represent two different groups. The Jefferson Group was proposed by Sandberg and Hammond (1958) for use in North Dakota. The Saskatchewan Group was proposed by Baillie (1953) for equivalent strata in Manitoba.

Duperow Formation

The Duperow Formation conformably overlies the Souris River Formation. The formation consists of up to 152 m (500 ft) of microcrystalline limestone, fine-grained argillaceous dolostone and anhydritic limestone, and cryptocrystalline dolostone with lesser amounts of bedded anhydrite and caliceous shale (Hoganson, 1978). Terrigenous clastics are scattered throughout the section. Numerous complete and incomplete shoaling upward sedimentary cycles are represented by the Duperow Formation (Wilson and Pilatzke, 1987; Burke and Heck, 1988). The Duperow Formation represents the maximum advance of the late Devonian sea. Environments of deposition range from subtidal to supratidal. A stromatoporoid bank environment is also represented.

In Manitoba, the formation is characterized by a cyclical sequence of strata similar to that of the underlying Souris River Formation. The lowermost cycle consists of dark brown limestone interbedded with black, argillaceous limestone and dark grey shale. The second phase consists mainly of fragmented, saccharoidal dolostone and lesser amounts of limestone. Corals, stromatoporoids, bryozoa and algal material are commonly present. The third and final phase is composed of massive anhydrite. An argillaceous zone marks the top of the Duperow Formation. The depositional thickness of the Duperow Formation in Manitoba ranges from approximately 122 to 195 m (400 to 640 ft).

Birdbear Formation

The Birdbear Formation is conformable with the underlying Duperow and overlying Three Forks formations. In peripheral areas where the Three Forks Formation is absent, the Birdbear Formation is disconformable or forms an angular unconformity with overlying units. It is composed of fossiliferous and dolomitic, muddy limestone and attains a maximum thickness of 36 m (119 ft) in the central portion of the basin (Loeffler, 1982). Local structural anomalies are related to two stage salt dissolution of the Devonian Prairie Formation.

Loeffler (1982) recognized seven lithofacies within the Birdbear Formation. These facies represent environments ranging from restricted, shallow marine to supratidal, and indicate progressively shallowing conditions.

The Birdbear (Nisku[1]) Formation of Manitoba is lithologically similar to strata in North Dakota. It also comprises fragmental, bioclastic limestones and dolostones. Corals, bryozoa, stromatoporoids and algal material are usually abundant. The depositional thickness of the formation ranges from 12 to 43 m (39 to 141 ft) (Manitoba Energy and Mines, 1980).

Three Forks Formation

The Three Forks Formation is conformable with the underlying Birdbear Formation and the overlying Bakken Formation, except along the basin margin where it is unconformably overlain by the Lodgepole Formation. A series of interbeds of greenish-grey and reddish-brown micrite and dolomicrite with anhydrite nodules and subordinate amounts of biomicrite and argillaceous material comprise the formation. There are local accumulations of coarse-grained siltstone to fine-grained sandstone in the upper few feet of the Three Forks Formation, informally referred to as the "Sanish sand". In the central portion of the basin, the Three Forks Formation reaches a maximum thickness of 81 m (265 ft).

In North Dakota, Dumonceaux (1984) divided the Three Forks Formation into five lithofacies that showed considerable vertical and lateral variability due to the degree of onlap and offlap between adjacent depositional environments. Depositional environments ranging from sublittoral to supralittoral have been interpreted by Dumonceaux for these lithofacies.

QU'APPELLE GROUP (Manitoba)

Three Forks Formation

The Qu'Appelle Group, as proposed by Baillie (1953), consists of a single formation in Manitoba, the Three Forks (Lyleton[1]) Formation. It is comprised predominantly of red, dolomitic siltstones and silty shales and argillaceous dolostones and ranges in thickness from 11 to 55 m (36 to 180 ft) (McCabe, 1971). It conformably overlies the Birdbear Formation and is unconformably overlain by the Middle Member of the Bakken Formation. Locally in areas of the late Devonian to early Mississippian salt dissolution, the Three Forks Formation is overlain by the Lower Member of the Bakken Formation.

[1] Former Manitoba stratigraphic terminology

PETROLEUM POTENTIAL

The predominantly marine strata of the Devonian sequence contain many stratigraphic features that are considered to be favourable for the accumulation of oil. The lithofacies relationships, together with the tectonic and environmental features of certain stratigraphic intervals, are more favourable than others for the generation and accumulation of oil. Two Devonian formations are nonproductive; these are, the Ashern and the Prairie formations.

The Winnipegosis Formation of the Elk Point Group has potential to be a suitable oil reservoir. The reefs of the Winnipegosis Formation show excellent porosity and permeability and, where developed along the basinward edge of the fringing bank, have reservoir potential. Production has been obtained from dolomitized reefs of the upper Winnipegosis Formation in the southwestern portion of the Elk Point basin in the Tablelands area of Saskatchewan (Martindale, 1987). Economic production from the pinnacle reefs has not been found in North Dakota and Manitoba. Temple and Hamlet fields in North Dakota produce from the platform margin argillaceous slope facies. The Round Prairie field produces from a small patch reef on the platform.

The Dawson Bay Formation in North Dakota produces along, or adjacent to, the Nesson anticline and along the Cedar Creek anticline. Production from diagenetically enhanced vuggy or intercrystalline porosity. Porosity development (enhancement) is controlled by primary porosity trends. Evaporites commonly plug porosity.

The stromatoporoid zone occurring near the top of the Dawson Bay Formation of the Manitoba Group also has potential as a reservoir. These beds, where exhibiting good porosity, could be a potential reservoir zone as it is capped by impermeable beds of the basal Souris River Formation. Potential exists, as well, within the upper dolomitic unit of the Point Wilkins Member.

Production from the Souris River Formation is limited and restricted to the central portion of the basin. Production along the Nesson anticline is not differentiated from the Duperow Formation.

Fields scattered about the central portion of the basin produce from the Duperow Formation. This production is associated with major structural features within the Williston basin, including the Nesson, Billings and Cedar Creek anticlines. The Duperow Formation produces from both stratigraphic and structural traps. Developed porosities are either primary, or a result of diagenetic processes.

Production from the Birdbear Formation presently appears to be restricted to deposits of upper tract and back bank depositional environments within the central portion of the basin. Porosity is either primary or diagenetic, related to dolomitization. The Birdbear Formation also produces in Montana from structures associated with two stage salt dissolution.

The Three Forks Formation produces from isolated deposits of the "Sanish sand" in the central portion of the basin. Interpreted to be either beach sand deposits, or shallow water sand bars, the sands produce where tension fracture systems are present.

REFERENCES

Baillie, A.D.
1951: Devonian geology of Lake Manitoba - Lake Winnipegosis area, Manitoba: Winnipeg, Manitoba, Manitoba Mines and Natural Resources, Mines Branch, Publication 49-2, 72 p.
1953: Devonian System of the Williston basin area: Winnipeg, Manitoba, Manitoba Mines and Natural Resources, Mines Branch, Publication 52-5, 105 p.

Bannatyne, B.B.
1960: Potash deposits, rock salt, and brines in Manitoba: Winnipeg, Manitoba, Manitoba Mines and Natural Resources, Mines Branch, Publication 59-1, 30 p.

Bluemle, J.P., Anderson, S.B., Andrew, J.A., Fischer, D.W., and LeFever, J.A.
1986: North Dakota stratigraphic column: Grand Forks, North Dakota, North Dakota Geological Survey, Miscellaneous Series No. 66, 3 sheets.

Burke, R.B., and Heck, T.J.
1988: Reservoir characteristics of the Duperow Formation at Tree Top field, North Dakota, in Goolsby, S.M., and Longman, M.W. (eds.), Occurrence and petrophysical properties of carbonate reservoirs in the Rocky Mountain region: Denver, Colorado, Rocky Mountain Association of Geologists, p. 303-316.

Canadian Society of Petroleum Geologists
1990: Lexicon of Canadian stratigraphy, volume 4, western Canada including eastern British Columbia, Alberta, Saskatchewan and southern Manitoba: Calgary, Alberta, Canadian Society of Petroleum Geologists, 772 p.

Dean, K.
1982: Devonian Dawson Bay Formation in North Dakota, in Christopher, J.E., and Kaldi, J. (eds.), Fourth International Williston Basin Symposium: Regina, Saskatchewan, Saskatchewan Geological Society, Special Publication No. 6, p. 89-93.

Dumonceaux, G.M.
1984: Stratigraphy and depositional environments of the Three Forks Formation (Upper Devonian), Williston basin, North Dakota: Master's thesis, University of North Dakota, Grand Forks, North Dakota, 189 p.

Ehrets, J.R., and Kissling, D.L.
1987: Winnipegosis platform margin and pinnacle reef reservoirs, northwestern North Dakota, in Fischer, D.W. (ed.), Second Symposium of the Williston Basin - Billings Basin Symposium: Grand Forks, North Dakota, North Dakota Geological Survey, Miscellaneous Series No. 69, p. iv-31.

Hoganson, J.W.
1978: Microfacies analysis and depositional environments of the Duperow Formation (Fransnian) in the North Dakota part of the Williston basin, in Estelle, D., and Miller, R. (eds.), The economic geology of the Williston Basin, 1978 Williston Basin Symposium: Billings, Montana, Montana Geological Society, p. 131-144.

Lobdell, F.K.
1984: The Ashern Formation (Middle Devonian) in the Williston basin, North Dakota: Master's thesis, University of North Dakota, Grand Forks, North Dakota, 187 p.

Loeffler, P.T.
1982: Depositional environment and diagenesis, Birdbear Formation (Upper Devonian), Williston basin, North Dakota: Master's thesis, University of North Dakota, Grand Forks, North Dakota, 268 p.

Manitoba Energy and Mines
1980: Manitoba stratigraphic map series.

Martindale, W., and Orr, N.E.
1987: Middle Devonian Winnipegosis reefs of the Tablelands area of southeastern Saskatchewan (abs.), in Marchant, T. (ed.), Second International Symposium on the Devonian System, program and abstracts: Calgary, Alberta, Canadian Society of Petroleum Geologists, p. 156.

McCabe, H.R.
1971: Stratigraphy of Manitoba, an introduction and review, in Turnock, A.C. (ed.), Geoscience studies in Manitoba: Geological Association of Canada, Special Paper No. 9, p. 167-187.
1987: Preliminary Manuscript - a tentative model for Winnipegosis (Middle Devonian) "Reefs", Manitoba outcrop belt: Winnipeg, Manitoba, Manitoba Energy and Mines, Geological Services Branch.

Norris, A.W., Uyeno, T.T., and McCabe, H.R.
1982: Devonian rocks of the Lake Winnipegosis - Lake Manitoba outcrop belt, Manitoba: Geological Survey of Canada, Memoir 392, 280 p.
1982: Devonian rocks of the Lake Winnipegosis - Lake Manitoba outcrop belt, Manitoba: Winnipeg, Manitoba, Manitoba Energy and Mines, Mines Branch, Publication 77-1, 280 p.

Oglesby, C.A.
1988: Deposition and dissolution of the Middle Devonian Prairie Formation, Williston basin, North Dakota and Montana: Master's thesis, Colorado School of Mines, Golden, Colorado, 79 p.

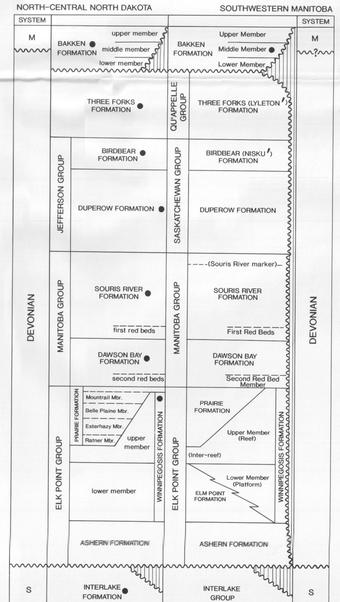
Perrin, N.A.
1982: Environments of deposition and diagenesis of the Winnipegosis Formation (Middle Devonian), Williston basin, North Dakota, in Christopher, J.E., and Kaldi, J. (eds.), Fourth International Williston Basin Symposium: Regina, Saskatchewan, Saskatchewan Geological Society, Special Publication No. 6, p. 52-67.

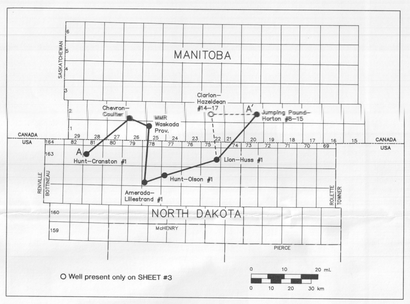
Pound, W.R.
1985: The geology and hydrocarbon potential of the Dawson Bay Formation carbonate unit (Middle Devonian), Williston basin, North Dakota: Master's thesis, University of North Dakota, Grand Forks, North Dakota, 320 p.

Sandberg, C.A., and Hammond, C.R.
1958: Devonian System in Williston basin and central Montana: American Association of Petroleum Geologists Bulletin, v. 42, p. 2293-2334.

Wilson, J.L., and Pilatzke, R.H.
1987: Carbonate-evaporite cycles in Lower Duperow Formation of Williston basin, in Longman, M.W. (ed.), Williston basin - anatomy of a cratonic oil province: Denver, Colorado, Rocky Mountain Association of Geologists, p. 119-146.

STRATIGRAPHIC NOMENCLATURE CHART





LINE OF CROSS-SECTION

METRIC CONVERSION TABLE

1 metre (m)	= 3.28 feet (ft)
1 cubic metre (m^3)	= 6.29 barrels (bbls) (oil)
	= 220 imperial gallons
	= 35.49 cubic feet (gas)
1 hectare (ha)	= 2.47 acres
1 kilometre (km)	= 0.62 miles (mi)

SHEET # 4: DEVONIAN

CORRELATION CROSS-SECTIONS ALONG THE UNITED STATES–CANADA INTERNATIONAL BORDER (NORTH DAKOTA–MANITOBA)

Prepared by:

Julie A. LeFever
(North Dakota Geological Survey)

Carol D. Martiniuk
(Manitoba Energy and Mines) Petroleum

Sidney B. Anderson
(North Dakota Geological Survey)

Drawn by:
M. E. McFarlane N. Barton B. Lenton
(Manitoba Energy and Mines)

December, 1991

NORTH DAKOTA GEOLOGICAL SURVEY
REPORT OF INVESTIGATION 92

MANITOBA ENERGY AND MINES
PETROLEUM OPEN-FILE REPORT POF 12-91