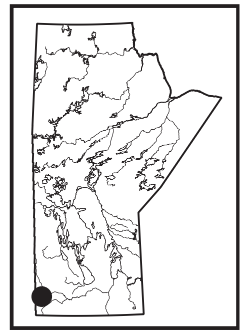
GS-15 Sedimentology of the Wymark Member (middle unit) of the Upper Devonian Duperow Formation, southwestern Manitoba (NTS 62F14, 15, 16)

by L. Eggie[1], N. Chow[1] and M.P.B. Nicolas



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Summary

Present in the subsurface of the Williston Basin, the Upper Devonian (Frasnian) Duperow Formation is a carbonate-evaporite succession, which is interpreted to have been deposited in a shallow back-reef setting. In southwestern Manitoba, the Duperow Formation can be subdivided into the Saskatoon, Wymark and Seward members, with the Wymark Member further subdivided into informal lower, middle and upper units. Relatively little work has been done recently on the Duperow Formation, but current economic interest in the formation in Manitoba is driven by the success of petroleum exploration in the Duperow Formation in Montana, North Dakota and Saskatchewan. The middle unit of the Wymark Member has been identified as the primary unit of interest, and characterization of the sedimentology and reservoir potential of this unit is important in order to facilitate future exploration.

The middle Wymark Member is composed of 10 individual lithofacies, which can be grouped into three lithofacies associations. The subtidal lithofacies association (LA 1) comprises lithofacies A (nodular to bedded lime mudstone), B (mottled to nodular lime mudstone to intraclast-peloid packstone), C (stromatoporoid-coral floatstone to framestone), D (fossiliferous wackestone to packstone) and E (peloid-intraclast grainstone). The intertidal lithofacies association (LA 2) comprises lithofacies F (massive dolostone) and G (laminated mudstone). The supratidal/sabkha lithofacies association (LA 3) comprises lithofacies H (intraclastic to laminated dolostone and gypsum), I (massive gypsum) and J (patterned dolostone). These lithofacies are interpreted to have been deposited in an arid peritidal setting in the interior of a rimmed shelf. The lithofacies associations are typically arranged in metre-scale, shallowing-upward cycles with LA 1 at the base of a cycle, overlain by LA 2 and then LA 3 at the top.

Intervals composed of lithofacies B, C, D, E, F and G, up to 14 m thick, are identified as potentially excellent reservoir units. These lithofacies have intercrystalline, interparticle and microvuggy porosity ranging from 10 to 40%, permeabilities ranging from 0.1 to 210.00 mD and oil saturations up to 19.6%.

Introduction

The Upper Devonian (Frasnian) Duperow Formation is a succession of carbonate and evaporite rocks, up to 260 m thick, present in the subsurface of the Williston Basin of western Canada and the northern United States (Wilson, 1967). The formation extends through southern Saskatchewan, southwestern Manitoba, northern Montana and northern North Dakota. The Duperow Formation in Saskatchewan and the United States contains proven and significant conventional oil and gas pools, making the formation of significant interest in Manitoba. No commercial discoveries have been made in Manitoba to date and no recent work has been done on the formation in the province, which significantly hinders any evaluation of reservoir potential. The middle unit of the Wymark Member of the Duperow Formation (herein referred to as the middle Wymark Member) is considered to be the most likely reservoir unit in the Duperow Formation of Manitoba (Martiniuk, 1992) and a better understanding of the fundamental characteristics of this unit is needed to facilitate future exploration.

Regional geology

The Devonian Elk Point Basin, an intracratonic sub-basin of the Western Canada Sedimentary Basin, extends 1700 km from northwest to southeast and 700 km from west to east, covering parts of Alberta, Saskatchewan, Manitoba, Montana and North Dakota (Moore, 2001; Figure GS-15-1). Deposition in the basin was dominated by carbonate sedimentation and was centred in south-central Saskatchewan (Baillie, 1953). The Devonian sedimentary package, up to 610 m thick, is subdivided into five disconformity-bounded transgressive-regressive sequences, which, in ascending order, are the Delorme, Black Rock, Hume-Dawson, Beaverhill-Saskatchewan and Palliser sequences (Moore, 1988). The Duperow Formation is part of the Saskatchewan Group in the Beaverhill-Saskatchewan sequence. The region was tectonically stable during the Devonian Period and the sequences are attributed to eustatic sea-level change (Moore, 1988).

The Duperow Formation was deposited during the Frasnian in the interior of the Eastern Platform at the southern extent of the Elk Point Basin (Moore, 1988).

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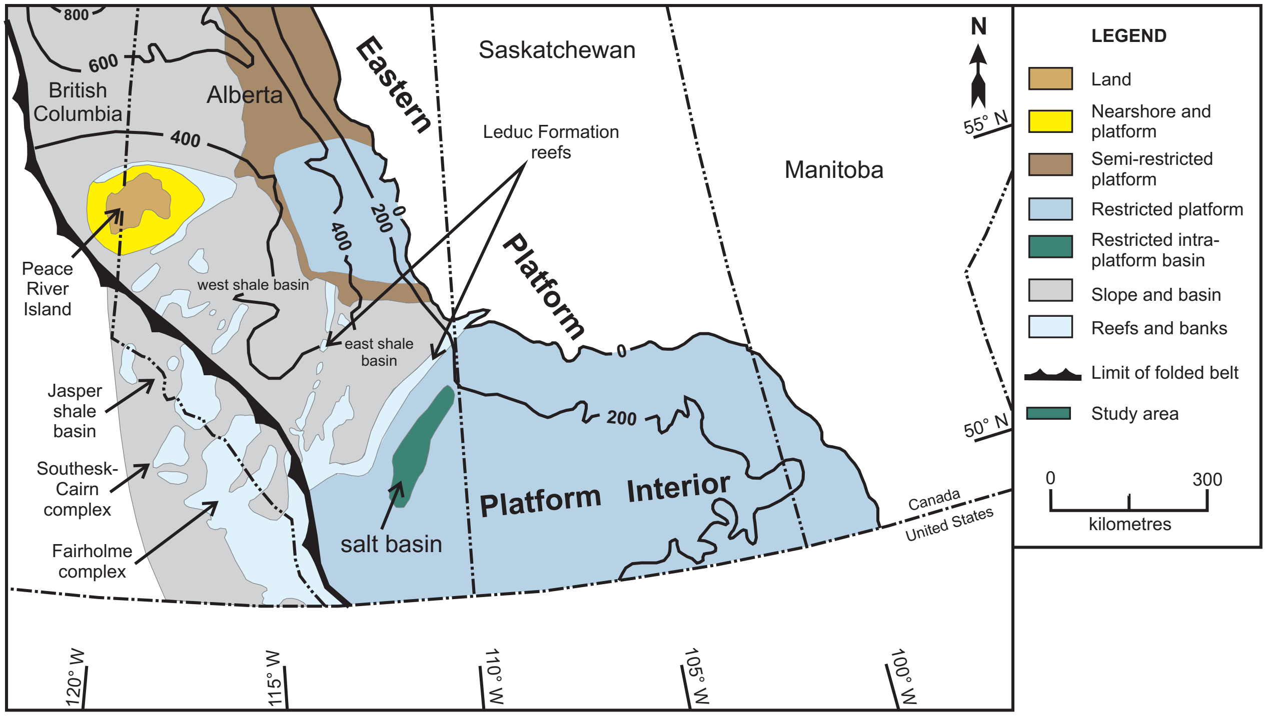

Figure GS-15-1: *Paleogeography of the Elk Point Basin during deposition of the Saskatchewan Group; the Duperow Formation was deposited in the interior of the Eastern Platform (modified from Moore, 1988). Contour lines indicate the water depth in metres. Canadian Society of Petroleum Geologists© 1988, reprinted by permission of CSPG whose permission is required for further use.*

The Eastern Platform was an epicontinental, shallow marine, rimmed shelf sheltered to the west by the Leduc Formation reefs of central Alberta (Figure GS-15-1). Water circulation in the Eastern Platform was variably restricted due to both its distance from the open ocean and the obstruction of the Leduc Formation reefs. The platform was situated approximately 15° south of the equator in an arid climatic zone, where environmental conditions ranged from normal marine to restricted lagoonal and resulted in deposition of open to restricted marine carbonate and evaporite units in the Duperow Formation (Dunn, 1975; Witzke and Heckel, 1988).

Study area

The study area extends west to east within the area of Twp. 10 to 12, Rge. 20 to 28, W 1st Mer., encompassing approximately 250 km^2. The area lies between the Saskatchewan-Manitoba border and the city of Brandon, Manitoba, and includes parts of the Daly Sinclair and Virden oil fields (Figure GS-15-2). Of the wells in the study area, five with Duperow Formation core were examined to describe the stratigraphic interval of the formation as completely as possible. This work was completed during the summer of 2011 for a Natural Sciences and Engineering Research Council (NSERC) Undergraduate Student Research Award project, and descriptions of these cores are summarized in Eggie (2012b).

Methodology

Core examination

The Duperow Formation has been cored in only 29 wells in Manitoba. Three cores of the middle Wymark Member were studied in detail: Dome Harding [4-27-11-22W1] (L.S. 4, Sec. 27, Twp. 11, Rge. 22, W 1st Mer.; 644.04–661.42 m), Daly Gas #1 7-18-10-27W1 (914.4–951.43 m) and Peacock Kemnay 13-4-10-20W1 (573.02–610.51 m). Standard core logging techniques were used to describe lithology, textures, structures, macrofossils, porosity, oil staining and visible diagenetic features. Rock names were assigned using the limestone classification of Dunham (1962), as modified by Embry and Klovan (1972). Oil staining in core was observed by placing pieces of core from regular intervals under ultraviolet (UV) light and the colour, brightness and distribution of the fluorescence were described. Presence of oil was confirmed by placing chip samples of core in acetone under UV light and observing the colour, brightness and type of emission of fluorescent fluids from the chip. 'Streaming' oil occurs when relatively large amounts of free oil are present in the chip. Representative core photographs were taken using a Canon PowerShot S5 IS. A total of 30 samples for thin section preparation was selected to fully represent all lithofacies and to show unusual features.

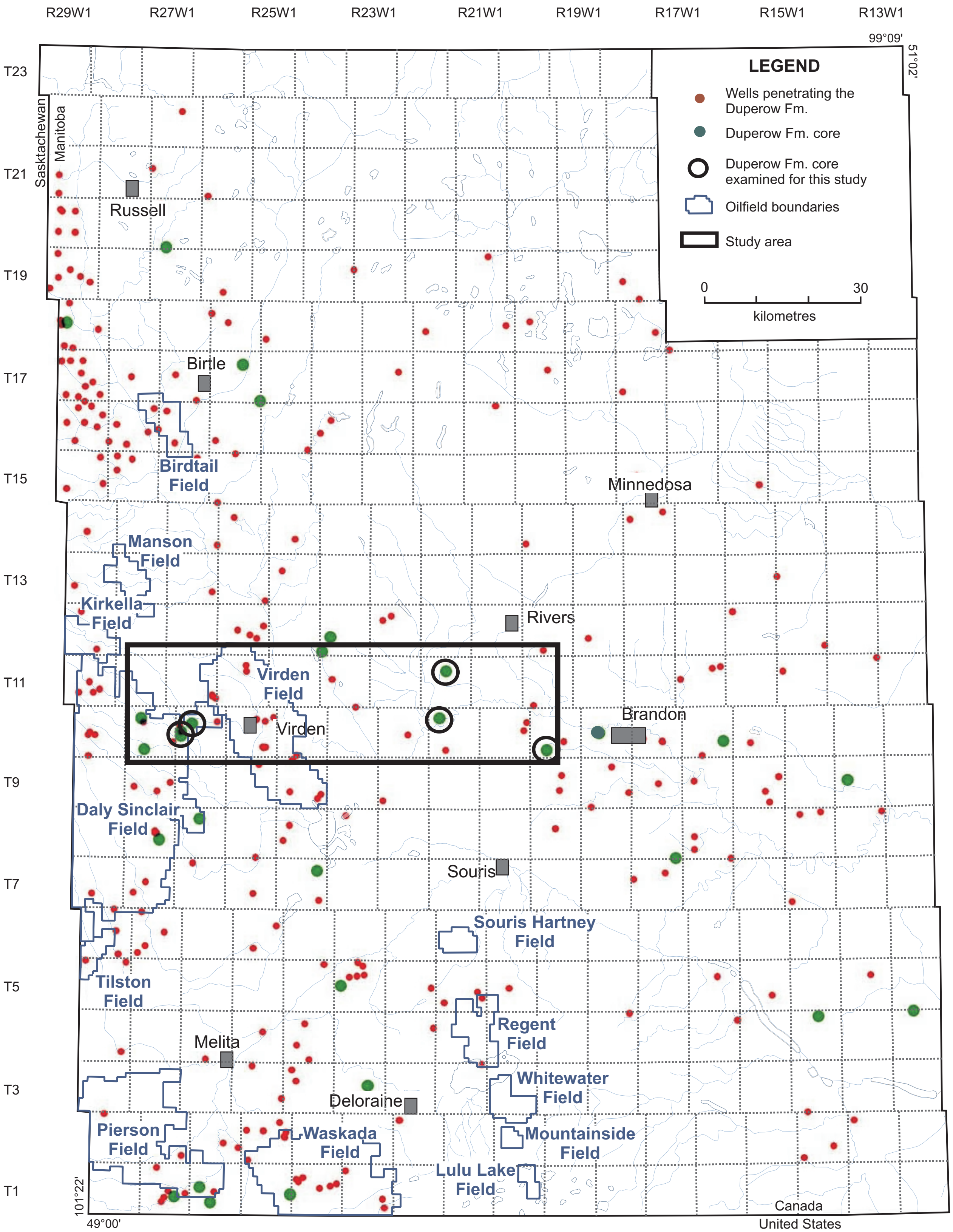

Figure GS-15-2: *Study area in southwestern Manitoba with Duperow Formation well and core locations.*

Thin-section petrography

Thirty thin sections were prepared by Calgary Rock and Materials Services Inc. (Calgary, Alberta). Samples were impregnated with blue epoxy in order to highlight porosity. In order to differentiate calcite from dolomite and to identify ferroan calcite and dolomite, all thin sections were stained with a 50/50 solution of Alizarin Red-S and potassium ferricyanide (Dickson, 1966). Gypsum was stained bright blue-green by this process (Friedman, 1959). Structure, texture, allochems, matrix, cement, porosity, dolomite and other diagenetic features were described. Porosity terminology follows the classification system of Choquette and Pray (1970), and the term microvuggy porosity is used to describe pores less than 0.8 mm size, while vuggy porosity is used for any pores greater than or equal to 0.8 mm size. The fabric of crystalline sedimentary rocks was described using the crystal size terminology of Folk (1974). Dolomite textures follow the classification system of Sibley and Gregg (1987). Data from core analyses of porosity, permeability and oil saturation for Daly Gas #1 7-18-10-27W1 well (Norcen Energy Resources Limited, 1976) were also examined; refer to Eggie (2012a) for details.

Stratigraphy of the Duperow Formation

The Duperow Formation is 125–260 m thick in Saskatchewan and thins laterally to 122–195 m thick in southwestern Manitoba, where it is truncated by erosion at the eastern edge of the Williston Basin (Martiniuk, 1992; Cen and Salad Hersi, 2006). It is stratigraphically equivalent to the Cooking Lake and Leduc formations in Alberta (Figure GS-15-3). The formation conformably overlies the Souris River Formation (Cen and Salad Hersi, 2006; Eggie, 2012b) and is sharply and conformably overlain by the Birdbear Formation (Cen and Salad Hersi, 2006; Nicolas and Barchyn, 2008). In the Williston Basin, the Duperow Formation is generally subdivided into four members, which are, in ascending order, the Saskatoon, Elstow, Wymark and Seward members (Figure GS-15-4; Ehrets and Kissling, 1985; Switzer et al., 1994). The members are typically delineated by laterally persistent key marker beds observed on geophysical logs and correlated to cores (Wilson, 1967; Cen and Salad Hersi, 2006; Eggie, 2012b). In eastern Saskatchewan and southwestern Manitoba, however, the Elstow Member cannot be differentiated from the Saskatoon Member and only the Saskatoon Member is identified (Dunn, 1975; Cen and Salad Hersi, 2006). The Wymark Member is further subdivided into informal lower, middle and upper units. A discontinuous evaporite unit called the Flat Lake Evaporite is rarely observed in the Seward Member in this region.

In the study area, the Saskatoon Member is 7–14 m thick and conformably overlies the Souris River Formation along a sharp, hardground surface. The member is primarily composed of nodular lime mudstone with numerous organic-rich seams, and is interbedded locally with skeletal wackestone and crinoid-intraclast packstone.

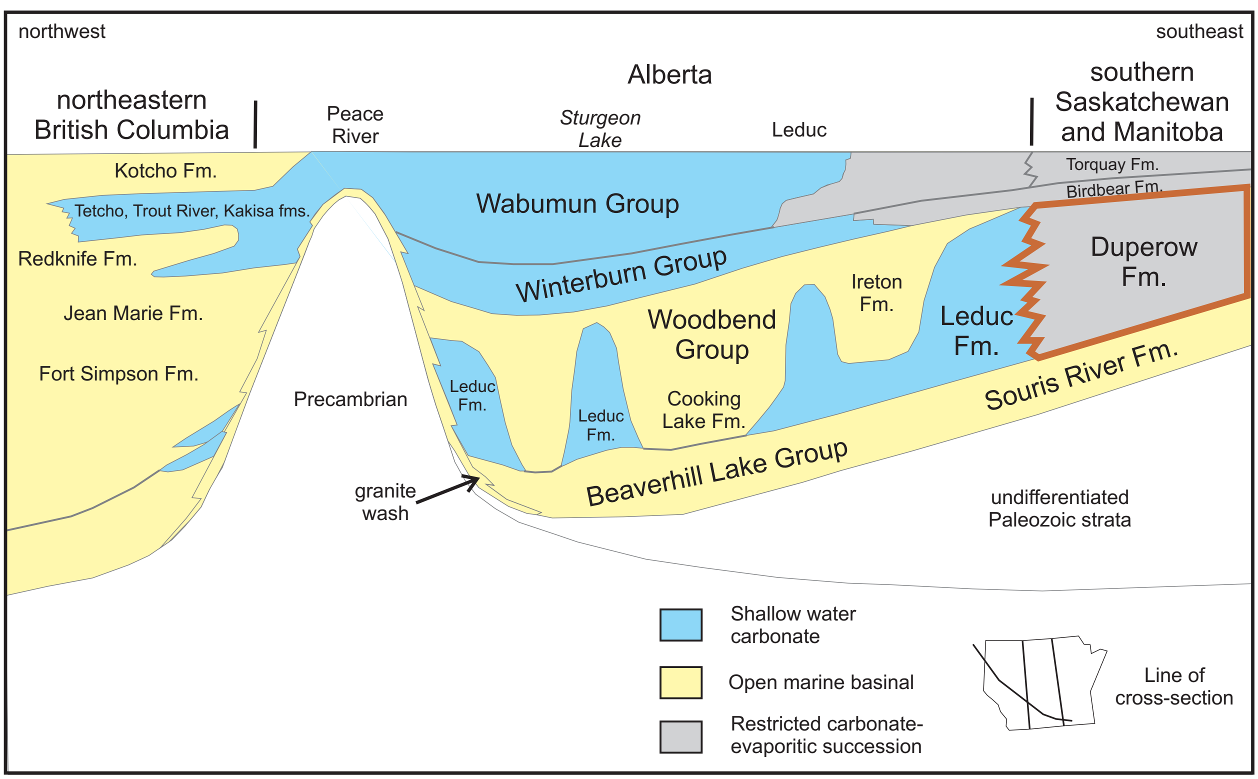

Figure GS-15-3: *Devonian stratigraphy in British Columbia, central Alberta, Saskatchewan and Manitoba (modified from Stoakes, 1992).*

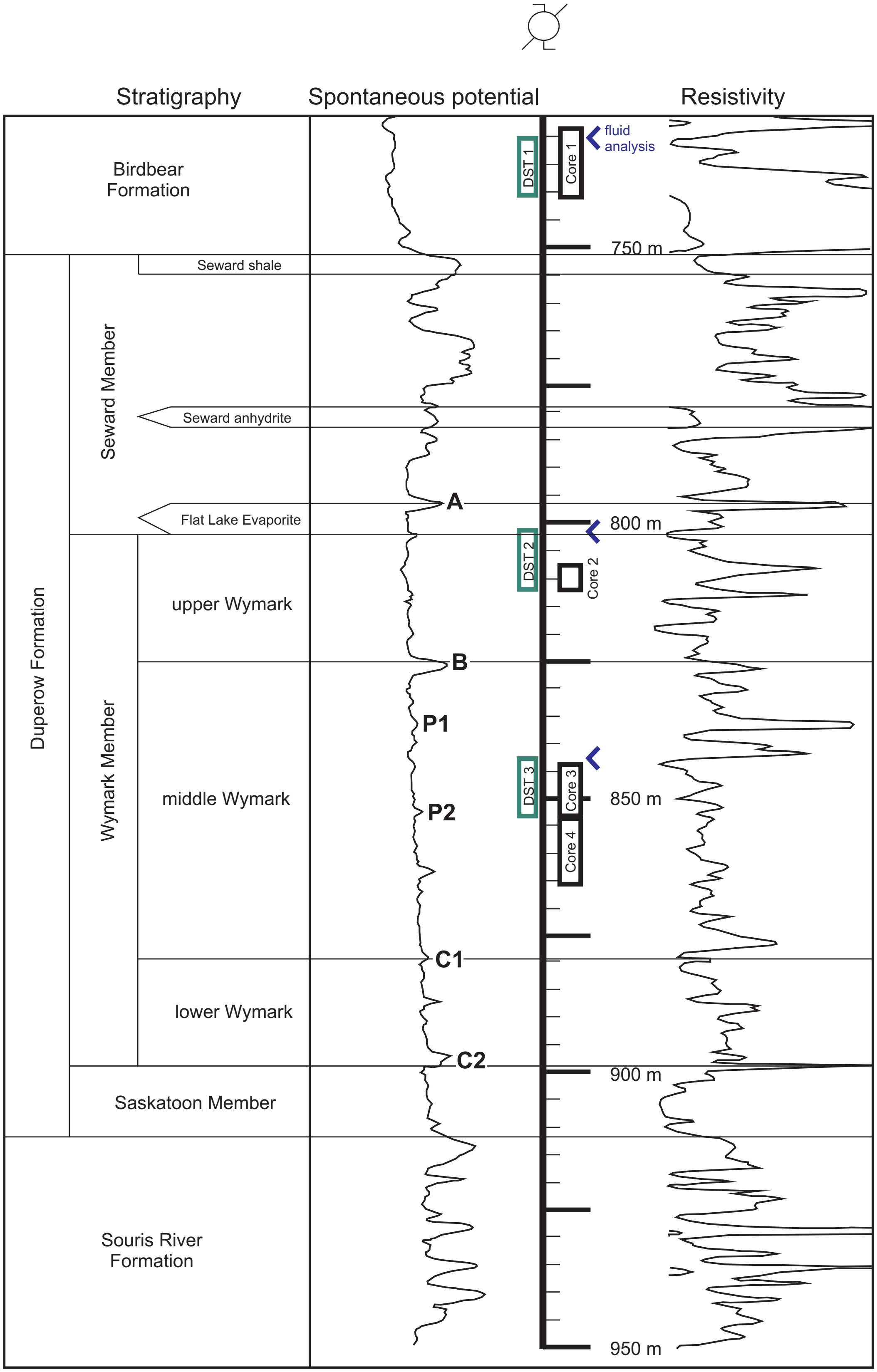

Figure GS-15-4: *Stratigraphy and typical spontaneous potential and resistivity log signature of the Duperow Formation from the B.A. Union Grose Virden SWD 7-27-10-26W1 well, southwestern Manitoba. Marker beds defining unit contacts are labelled C2, C1, B and A, with minor marker beds in the middle Wymark Member labelled P2 and P1. Stratigraphic units are from Nicolas and Barchyn (2008). Abbreviation: DST, drill stem test.*

The Wymark Member is 80.1–107.6 m thick in the study area and conformably overlies the Saskatoon Member. The lower contact is defined at the base of the C2 marker bed, but was not observed in core in this study. The lower unit of the Wymark Member is 13.4–22.6 m thick and comprises thick beds of lime mudstone, brachiopod wackestone to packstone, and coral-intraclast floatstone, with rare thin beds of patterned dolostone and massive anhydrite. It is capped by a thin bed of massive anhydrite.

The middle Wymark Member is 48.8–57.7 m thick in the study area and conformably overlies the lower unit. The lower contact is defined at the base of the C1 marker bed. The member comprises interbedded lime mudstone, fossiliferous wackestone to floatstone, dolomudstone, massive dolostone, patterned dolostone and laminated, nodular and massive anhydrite. The units are highly variable in thickness and are typically arranged in cyclic, metre-scale sedimentary packages.

The upper Wymark Member is 17.9–27.1 m thick in the study area and conformably overlies the middle unit. The contact is defined at the base of a thin siltstone bed, called the B marker bed. The siltstone bed is composed primarily of quartz, calcite, microcline, anhydrite and muscovite. The upper unit comprises lime mudstone, fossiliferous wackestone to floatstone, dolomudstone, patterned dolostone, and laminated dolostone and anhydrite.

The Seward Member is 42.1–48.2 m thick in the study area and conformably overlies the upper Wymark Member. The contact is defined at the base of the A marker bed, but was not observed in core in this study. The member comprises highly argillaceous dolomudstone interbedded with thin intervals of fossiliferous wackestone to floatstone.

Lithofacies associations

Three lithofacies associations are recognized in the middle Wymark Member: 1) subtidal, 2) intertidal and 3) supratidal/sabkha (Figure GS-15-5). These lithofacies associations are interpreted to represent an arid peritidal setting in an overall rimmed shelf environment (Figure GS-15-6). Lithofacies in each association are summarized in Table GS-15-1, and further details can be found in Eggie (2012a).

Lithofacies association 1: subtidal

Lithofacies association 1 consists of lithofacies A, nodular to bedded lime mudstone; lithofacies B, mottled to nodular lime mudstone to intraclast-peloid packstone; lithofacies C, stromatoporoid-coral floatstone to framestone; lithofacies D, fossiliferous wackestone to packstone; and lithofacies E, peloid-intraclast grainstone. All five were not observed together, nor are they arranged in a systematic vertical succession. The lithofacies commonly have gradational contacts. Lithofacies association 1 is interpreted to have been deposited in an open subtidal setting, based mainly on faunal content (Figure GS-15-6).

Lithofacies A occurs both at the base of the lithofacies association, where it is sharply overlain by lithofacies D, and alternating with lithofacies D (Figure GS-15-5). Lithofacies B and C commonly alternate, and both lithofacies locally grade upward into lithofacies D or E. Lithofacies E is the rarest lithofacies in the middle Wymark Member, and is typically found near the top of the lithofacies association. Lithofacies A is considered to be the deepest lithofacies, based on its stratigraphic position at the base of the lithofacies association and its interpreted deposition below storm wave base, indicated by a high proportion of micrite in the lithofacies and the presence of relatively undisturbed organic-rich laminae and seams. Lithofacies B, C and D are interpreted to have been deposited between storm wave base and fair-weather wave base, based primarily on the presence of intraclast and skeletal-fragment–rich beds, interpreted to be storm beds, interbedded with micrite-rich skeletal beds and organic-rich seams and/or laminae. Lithofacies C is interpreted to represent patch reefs based on the presence of in situ stromatoporoids and corals in framestone intervals. Lithofacies E represents localized carbonate sand shoals deposited above fair-weather wave base. High energy conditions are indicated by a paucity of micrite and high proportion of well-rounded intraclasts in the lithofacies.

Lithofacies association 2: intertidal

Lithofacies association 2 consists of lithofacies F, massive dolostone; and lithofacies G, laminated mudstone. Lithofacies F generally underlies lithofacies G, but no interpretation of this relationship can be made. Lithofacies G is typified by thin, crinkly laminations commonly interpreted to result from microbial binding of carbonate sediment. This type of lamination is typical of the intertidal zone in an arid environment (cf. Pratt, 2010). The original lithology of lithofacies F is uncertain, but the lithofacies is included in the intertidal lithofacies association because of its close stratigraphic relationship with lithofacies G and the gradational contacts between the two lithofacies (Figure GS-15-5). Lithofacies association 2 is interpreted to represent an intertidal setting (Figure GS-15-6).

Lithofacies association 3: supratidal/sabkha

Lithofacies association 3 consists of lithofacies H, intraclastic to laminated dolostone and gypsum; lithofacies I, massive gypsum; and lithofacies J, patterned dolostone. Lithofacies H is typically overlain by lithofacies I, which is, in turn, overlain by lithofacies J; however, all three lithofacies are not always present

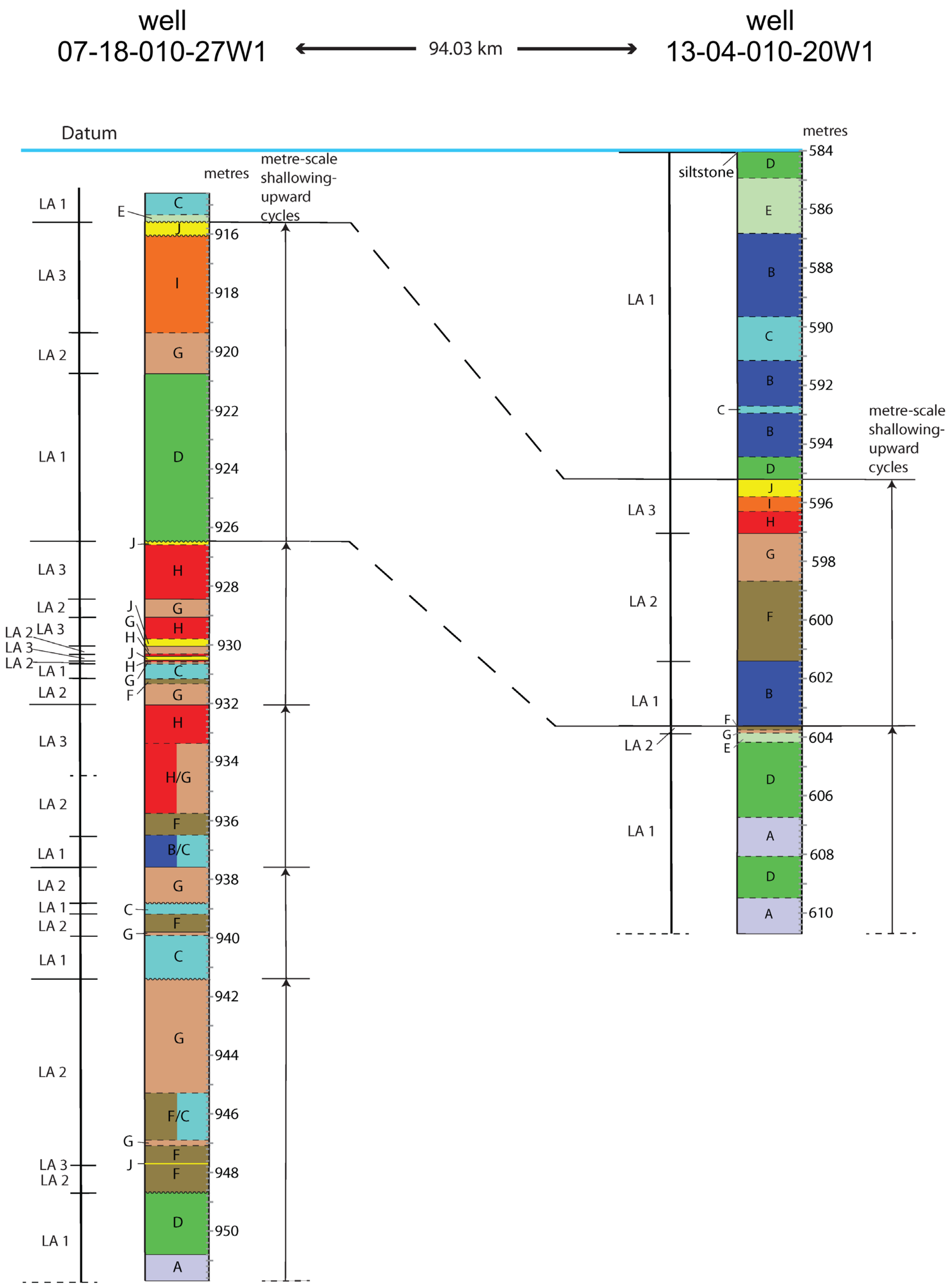

Figure GS-15-5: *Stratigraphic correlation of two cores studied for this project; datum is top of middle Wymark Member, southwestern Manitoba. Lithofacies identified in each core are labelled by colour and letter (A–J) and lithofacies associations (LA 1, 2, 3) are labelled along the left side of the column. Contacts between lithofacies and metre-scale shallowing-upward cycles are indicated. A suggested correlation of one cycle between cores is indicated by dashed lines.*

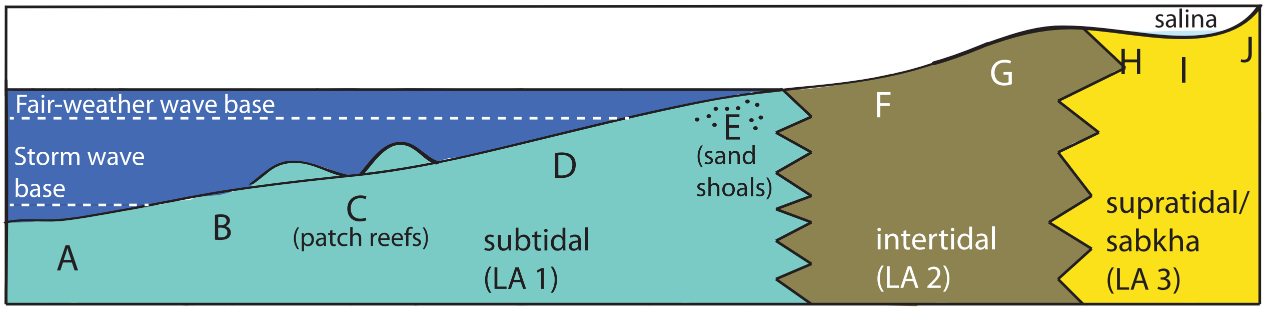

Figure GS-15-6: *Cross-section diagram of an arid peritidal sabkha with Duperow Formation lithofacies indicated by letters A to J and lithofacies associations labelled LA 1 to LA 3.*

together (Figure GS-15-5). Contacts between the lithofacies units are sharp to gradational. Lithofacies association 3 is interpreted to represent an arid supratidal or sabkha environment (Figure GS-15-6; cf. Pratt, 2010).

Lithofacies H is interpreted be upper intertidal to lower to middle supratidal in origin, and lithofacies I is interpreted to be upper supratidal in origin, based on the evaporite mineral composition of each lithofacies; the presence of displacive structures, such as gypsum nodules and chickenwire gypsum, both interpreted to form due to intrasedimentary gypsum growth; observations of V-shaped fractures interpreted to be remnant mudcracks; and the high stratigraphic position of the lithofacies, overlying both subtidal and intertidal lithofacies (Figure GS-15-5). Lithofacies J is interpreted to have formed in the uppermost supratidal zone. This is based on its identification as a patterned dolostone, which has been interpreted in previous studies to form from bacteria-induced sulphate reduction in the subsurface of the upper supratidal zone (Dixon, 1976; Kirkham, 2004).

Metre-scale cyclicity

The three lithofacies associations in the middle Wymark Member are stacked in metre-scale, shallowing-upward cycles (Figure GS-15-5). In an idealized cycle, the subtidal lithofacies association (LA 1) is overlain by the intertidal lithofacies association (LA 2) and the cycle is capped by the supratidal/sabkha lithofacies association (LA 3; Figures GS-15-5 to -7). The cycles do not always include all three lithofacies associations and never include all ten lithofacies. Contacts between lithofacies associations are typically sharp to gradational. Cycle contacts are typically sharp and irregular to planar, commonly with evidence of erosion. Interpretation of the causes of metre-scale shallowing-upward cycles in the middle Wymark Member could not be attempted in this study, due to limited lateral core coverage. This cyclicity may have been caused by either tidal flat island migration, progradation of a coastal tidal flat or aggradation in the basin (cf. Pratt, 2010). The influence of eustatic sea-level change relative to basin subsidence and sedimentation processes is difficult to ascertain.

Dolomite and cements

Diagenetic features have been described more fully in Eggie (2012a), and further details are given in Table GS-15-1. All lithofacies in the middle Wymark Member have been dolomitized to different degrees, varying from trace amounts to complete dolomitization. Dolomitization in lithofacies association 1 (subtidal) is typically limited to the micritic matrix of each lithofacies, while extensive dolomitization is most common in lithofacies associations 2 (intertidal) and 3 (supratidal/sabkha). Dolomite in the middle Wymark Member is typically very fine to coarse crystalline, and varies from planar to nonplanar. Cementation has occluded 5–25% of porosity and typically comprises nonferroan calcite and gypsum cements. Calcite cements are more common in lithofacies association 1, with minor occurrences of gypsum, while gypsum cement predominates in lithofacies associations 2 and 3.

Reservoir potential

Based on visual estimates made in this study and core analysis of the Daly Gas #1 7-18-10-27W1 well by Norcen Energy Resources Limited (1976), good (10–15%) to excellent (15–40%) porosity is present in lithofacies B (mottled to nodular lime mudstone to intraclast-peloid packstone), C (stromatoporoid-coral floatstone to framestone), D (fossiliferous wackestone to packstone), E (peloid-intraclast grainstone), F (massive dolostone) and G (laminated mudstone). Together these units form packages up to 14 m thick. Reservoir-quality porosity is typically intercrystalline, interparticle and microvuggy, and is not facies specific but is rather related to pervasive dolomitization of carbonate lithofacies of the middle Wymark Member (Figure GS-15-8). Porosity in the middle Wymark Member has been reduced by partial cementation (5–25%) by isopachous nonferroan bladed-to-blocky calcite, nonferroan coarse mosaic calcite, nonferroan syntaxial calcite overgrowths, anhydrite and gypsum cements.

All of these lithofacies, except lithofacies E, have analyzed permeabilities greater than 1 mD, and up to 210.00 mD (Norcen Energy Resources Limited, 1976).

Table GS-15-1: Summary of lithofacies of the middle Wymark Member, Duperow Formation, southwestern Manitoba.

Lithofacies		Thickness	Lithology	Dolomite	Cement	Porosity	Lithofacies association
A	Nodular to bedded lime mudstone	0.91–1.83 m	Slightly dolomitic lime mudstone	5–20%, very fine to fine crystalline	<1%, fine to medium crystalline, nonferroan calcite	5–7%, micro-vuggy, moldic, interparticle	
B	Mottled to nodular lime mudstone to intraclast-peloid packstone	0.67–2.83 m	Lime mudstone, fossiliferous wackestone, peloid-intraclast-brachiopod packstone	25–60%, fine to medium crystalline	2–10%, fine crystalline gypsum; 1–2%, medium to coarse crystalline, nonferroan calcite	15–20%, intercrystalline, interparticle, microvuggy, vuggy	
C	Stromatoporoid-coral floatstone to framestone	0.24–2.44 m	Stromatoporoid-rugose coral float-stone, *Amphipora* floatstone, stromato-poroid floatstone, stromatoporoid framestone	2–70%, fine to medium crystalline	12–17%, very fine to medium crystal-line, nonferroan calcite; 1–2%, fine to medium crystalline, ferroan calcite	15–20%, intercrystalline, interparticle, microvuggy, vuggy	LA 1: subtidal
D	Fossiliferous wackestone to packstone	0.76–5.75 m	Echinoderm-peloid wackestone to pack-stone, brachiopod-peloid wackestone to packstone, echinoderm-brachiopod pack-stone, brachiopod-intraclast packstone	20–60%, very fine to medium crystalline	5–10%, very fine to medium crystalline, nonferroan calcite; 0–trace, fine crystalline gypsum	13–17%, intercrystalline, interparticle, intraparticle, moldic, microvuggy, vuggy	
E	Peloid-intraclast grainstone	0.24–1.89 m	Peloid-echinoderm packstone to intraclast grainstone	trace–10%, fine to coarse crystalline	10–12%, fine to very coarse crystalline, nonferroan calcite	10–15%, interparticle, intraparticle	
F	Massive dolostone	0.37–2.71 m	Fine crystalline, sucrosic dolostone	50–60%, fine to coarse crystalline	5–25%, very fine to fine crystalline gypsum	25–40%, inter-crystalline, micr-ovuggy, vuggy, intracrystalline	
G	Laminated mudstone	0.12–3.11 m	Dolomitic lime mud-stone and dolomud-stone; interbedded or solitary; with rare, very thin interbeds of oncoid rudstone, intraclast packstone and intraclast-peloid wackestone	30–75%, fine to medium crystalline	0–10%, very fine to fine crystalline gypsum	15–25%, intercrystalline, microvuggy	LA 2: intertidal
H	Intraclastic to laminated dolostone and gypsum	0.06–1.83 m	a) Intraclast-peloid dolowackestone to packstone interbed-ded with gypsum nodules; b) Lami-nated dolostone and gypsum beds	25–50%, aphano–crystalline to medium crystalline	a) 25–40%, very fine to fine crystalline, gypsum; 1–3%, fine crystalline, ferroan calcite	1–2%, intra-particle, intercrystalline, fracture	
I	Massive gypsum	0.18–3.29 m	Aphanocrystalline gypsum with dolo-mudstone and lime mudstone stringers	1–3%, aphano–crystalline	None	None	LA 3: supratidal/ sabkha
J	Patterned dolostone	0.08–0.49 m	Very fine crystalline dolostone	50–90%, aphano–crystalline to fine crystalline	0–35%, very fine to fine crystalline gypsum; 0–7% very fine to coarse crystal-line anhydrite and celestine	0–15%, intercrystalline, microvuggy	

Figure GS-15-7: *Core photograph of partial shallowing-upward cycle in the Daly Gas #1 7-18-10-27W1 well, southwestern Manitoba. The subtidal lithofacies association (LA 1) is at the base, the intertidal lithofacies association (LA 2) is in the middle and the supratidal lithofacies association (LA 3) is at the top. Arrows indicate the shallowing direction; top at 932.84 m; scale is in centimetres.*

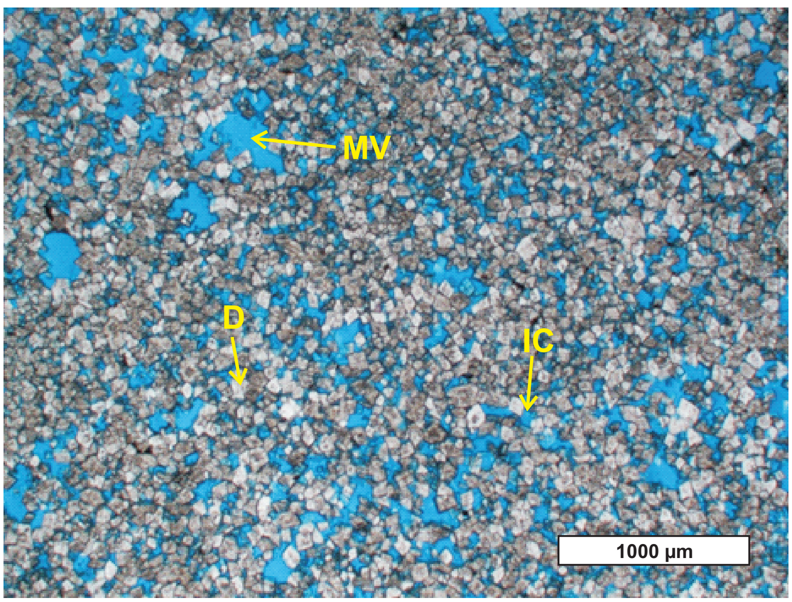

Figure GS-15-8: *Photomicrograph of lithofacies F showing an example of reservoir-quality porosity; intercrystalline (IC) and microvuggy (MV) porosity highlighted by blue epoxy in fine to medium crystalline, planar dolomite (D); plane polarized light; core from the Peacock Kemnay 13-4-10-20W1 well, southwestern Manitoba, at a depth of 600.49 m.*

These values are above current industry cutoffs of 8% porosity and 1 mD permeability. The porous and permeable units are typically visibly stained medium to dark brown by oil and exhibit a moderate to bright, spotty to even fluorescence in core. Chips submerged in acetone exhibit a variable cut, from very faint, pale yellow to bright, streaming, pale yellow-white. Oil saturations from core analysis also vary from trace to 19.6% through these lithofacies (Norcen Energy Resources Limited, 1976). Organic-rich laminae are common in lithofacies A, C and D, where they comprise up to 40% of the lithofacies. Chip tests of organic-rich laminae consistently have a streaming, bright yellow-white cut of live oil, which suggest that the middle Wymark Member passed through the oil window. Potential capping facies include lithofacies H (intraclastic to laminated dolostone and gypsum) and I (massive gypsum). These lithofacies have very little to no porosity and sit at the top of shallowing upwards cycles, above possible reservoir units.

In summary, lithofacies B, C, D, E, F and G are all excellent potential reservoir units, with porosities of 10–40%, permeabilities of 0.10–210.00 mD, and oil saturations of trace to 19.6% As these lithofacies typically occur together and constitute a potential pay thickness up to 14 m thick in the study area. These characteristics are well above industry minimums for economic reservoir units, indicating that the middle Wymark Member in Manitoba has the potential to contain economic petroleum resources.

Economic considerations

Very little exploration has been conducted in the Duperow Formation in Manitoba, and until this study, little was known of its geology and hydrocarbon potential in the province. The Duperow Formation and its stratigraphic equivalents are prolific oil-producing units in western Canada and the north-central United States, and a natural outgrowth of that success is to explore in other jurisdictions to find more reserves. By understanding the geology of this formation on the eastern extent of the sedimentary basin, Manitoba is in a better position to compete for the attention of exploration companies, and provide them with the basic geoscience information needed for decision makers to explore Manitoba's deeper formations. This study is the first look at this formation, with more work still to come. Active exploration into the Duperow Formation would bring economic benefit to the province, as would any successful drilling ventures. Of importance, a new discovery at this stratigraphic level would provide renewed interest not only in the Duperow Formation, but also in deeper horizons as a whole.

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