GS2024-23

Preliminary observations from the Manson Field's Reston-Amaranth-Lodgepole oil reservoir, southwestern Manitoba (part of NTS 62K)

by P.J. Fulton-Regula

In Brief:

- Oil production is predominantly from the Lodgepole and Reston formations, with some production from the Amaranth and Melita formations
- Observations include evidence for enhanced fluid movement in proximity to a north-northwest trending lineament and siliceous breccia zones

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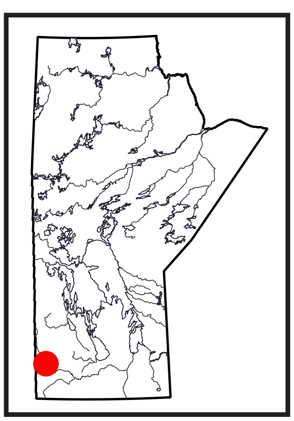

Summary

The Reston-Amaranth-Lodgepole pool in the Manson Field produces oil from a continuous reservoir spanning the Mississippian Lodgepole Formation to the Jurassic Lower Melita Member of the Melita Formation in Manitoba. The Manson Field currently has 101 producing oil wells and a total cumulative production of 888 223 m^3 of oil. Producing formations within this reservoir are primarily the Mississippian Lodgepole Formation and Middle Jurassic Reston Formation mudstone, wackestone and packstone intervals. Other productive intervals include siliceous layers and sandstone sequences.

The rocks in this interval display sedimentary, postdepositional, diagenetic and structural characteristics that suggest enhanced fluid movement and faulting may have influenced the reservoir thickness, composition, sulphide precipitation, oil location and the potential for local oil generation. Unusual features observed in the core include isolated sandstone units, breccia zones, anhydrite dissolution, siliceous layers, sulphide precipitation and enhanced porosity development. Further work will be conducted to better understand this reservoir, the structural regime of the area and the potential for critical minerals and new oil accumulations within the sedimentary succession of Manitoba.

Introduction

The first oil discovery in the Manson Field was in 2009 (oil and gas well licence 7114, Manitoba Economic Development, Investment, Trade and Natural Resources, Winnipeg) in L.S. 12, Sec. 24, Twp. 13, Rge. 29 W 1st Mer. (abbreviated 12-24-13-29W1) in the Bakken Formation to Torquay Formation (Bakken-Torquay oil pools). In 2011, oil was discovered farther to the east and higher in the stratigraphic section in the well at 1-34-12-27W1 (oil and gas well licence 8288). Due to uncertainties in the geophysical log signatures, this productive interval was originally interpreted as the Mississippian Lodgepole Formation. After extensive core examination, the interpretation of the reservoir interval was revised and expanded upsection to include the Triassic to Jurassic Amaranth Formation and the Jurassic Reston Formation. However, it was clear that the reservoir and geology in this area was unusual and complex, and required further study.

There are currently 101 producing wells in the Reston-Amaranth-Lodgepole pools in the Manson Field with a cumulative oil production of 888 223 m^3 (Manitoba Economic Development, Investment, Trade and Natural Resources, unpublished data, 2024).

This study was undertaken to better understand the unique geology of the Reston-Amaranth-Lodgepole pools in the Manson Field. The objectives of this study are to

1) describe the lithological characteristics of the reservoir targets in the eastern extension of the Manson Field;
2) correlate core to geophysical log signatures to map the extent of reservoir units;
3) calibrate geophysical logs and create type sections to inform stratigraphic assignment of the reservoir and field-pool coding designations;
4) understand the depositional and postdepositional history of the Manson Field and how that history translates to other areas of Manitoba; and
5) understand the potential for further oil accumulations and critical mineral deposits.

Methodology

Between 2015 and 2024, 51 drillcore from Twp. 12 to 13 and Rge. 26 to 27W1 were examined (Figure GS2024-23-1). The core came from the Whitewater Lake Member of the Lodgepole Formation to the Lower Melita Member of the Melita Formation. These core were chosen based on the amount of core available within the formations of interest, their location within the study area and their avail-

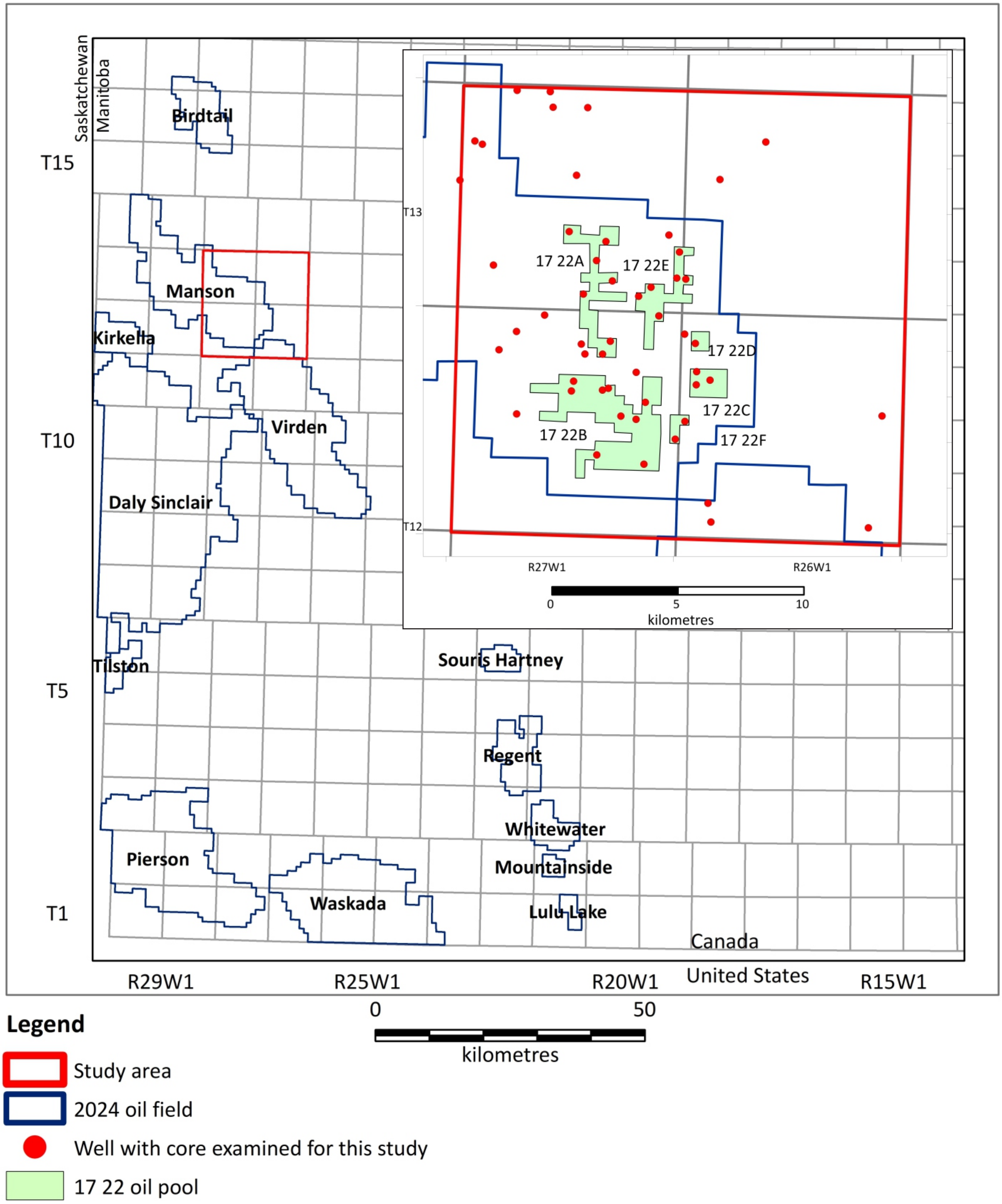

Figure GS2024-23-1: *Locations of the Manitoba oil fields, with the project area outlined in red (P.J. Fulton-Regula,* Manitoba's Designated Oil Fields and Pools 2024 (NTS 62F1–3, 6–11, 14–16, 62K1–3, 6–8)*, work in progress, 2024). Inset map shows the Reston-Amaranth-Lodgepole pools (17 22 field-pool codes; P.J. Fulton-Regula,* Manitoba's Designated Oil Fields and Pools 2024 (NTS 62F1–3, 6–11, 14–16, 62K1–3, 6–8)*, work in progress, 2024) and bottom-hole locations of wells with core examined for this study (geoLOGIC systems ltd., 2024).*

ability for viewing at the Manitoba Geological Survey Midland Sample and Core Library (Winnipeg, Manitoba). Core were thoroughly described and photographed.

Results

Lithological characteristics

Lodgepole Formation

In the study area, the Lodgepole Formation is characterized by the presence of a variably fossiliferous, yellow, pink, maroon and light grey, crystalline, calcareous wackestone to packstone, with occasional fine-grained, black laminations and zoned siliceous layers and nodules. Fossils present include crinoids, solitary corals, gastropods and brachiopods. Rare anhydrite layers occur at the top of the formation; these were identified in the wells at 3-34-12-27W1 and 3-30-12-26W1.

In the well at 13-10-13-27W1, the Whitewater Lake Member underlies the Flossie Lake Member of the Lodgepole Formation. The Whitewater Lake Member consists of a light green, silty, calcareous mudstone and wackestone and light pink and beige calcareous packstone, with anhydrite, dark grey nodular siliceous clasts, white siliceous layers, brachiopods and crinoids. In the well at 6-3-13-27W1, where the overlying Flossie Lake Member is absent, the Whitewater Lake Member is composed of yellow and beige mudstone with zoned white chalky- to black-rimmed siliceous layers, and siliceous fracture infill. It is overlain by pink and grey layered, calcareous mudstone with occasional brachiopods. Porosity is intergranular to intercrystalline and >10% fracture porosity within siliceous layers. Oil staining occurs in the wackestone and siliceous layers.

Where the Flossie Lake Member is present, it is a highly variable, layered, cream, pink, yellow, beige and grey, dolomitic mudstone, wackestone or packstone with anhydrite layers, and includes *Ophiomorpha*, solitary corals, brachiopods and crinoids. Also present are siliceous layers that are yellow with orange rims at the top of the member, with the layers becoming white and more homogeneous with increasing depth. Porosity is intergranular to intercrystalline and fracture oil staining was observed in light beige mudstone to wackestone. No sulphides were noted in the Flossie Lake Member where anhydrite is present. Where the Flossie Lake Member does not have anhydrite, the siliceous layers are generally white to grey with black rims, porosity is >10% vuggy and mouldic with fractures, often with oil staining and sulphides.

The contact between the Lodgepole Formation and the Amaranth Formation in Manitoba is recognized as an unconformable surface; it can be a sharp marker on geophysical well logs.

Lower Amaranth Member, Amaranth Formation

The Lower Amaranth Member of the Amaranth Formation is up to 5 m thick and consists of a nonfossiliferous, grey to beige and red, layered, dolomitic mudstone to siltstone, which contains zoned grey to black siliceous layers and clasts. Rare red siliceous layers occur in places. Porosity is vuggy, fracture and mouldic around siliceous layers; no obvious porosity was recorded in the mudstone of the Lower Amaranth Member. Oil staining around siliceous layers and clasts is common. In certain areas, the Lower Amaranth Member is green, with occasional slickensides on surfaces, and brecciated siliceous layers that occur as rubble in core.

With decreasing red colour and increasing anhydrite upsection, the Lower Amaranth Member has a gradational contact with the Upper Amaranth Member. To maintain consistency across pre-existing stratigraphic datasets and to respect the geophysical log pick in Nicolas (2009), this contact has been placed beneath the first anhydrite layer seen in geophysical logs, where present.

Upper Amaranth Member, Amaranth Formation

The Upper Amaranth Member of the Amaranth Formation is up to 38 m thick, and consists of nonfossiliferous, bedded, beige calcareous to green dolomitic mudstone, with dominantly grey to white, occasionally yellow and orange, crystalline anhydrite or gypsum. The anhydrite and gypsum are massive at the base of the member, becoming beds and nodules in grey to beige calcareous mudstone near the top. This mudstone can have siltstone and fine-grained black laminations; zoned grey to black siliceous layers; dispersed, zoned, grey to black, siliceous clast layers; and pink gypsum. Where anhydrite and gypsum are absent, the mudstone is dolomitic and often appears as green rubble with residual siliceous layers and clasts, and slickensides on surfaces.

Porosity is generally <0.1% intercrystalline to pinpoint, but also <10% vuggy and fracture within and around siliceous layers and clasts. Oil staining occurs in association with vuggy and fracture porosity. Sulphides were noted around interpreted anhydrite clasts, along bedding planes, in nodules and lining vugs and fractures.

For this report, the top of the Upper Amaranth Member of the Amaranth Formation is characterized by the first appearance of evaporitic, massive anhydrite beds. This is a good geophysical log marker, however, this pick becomes difficult to make when evaporites are not present in the section. Current work suggests that there may be a gradational contact between the grey and beige calcareous mudstone of the Reston Formation and the beige calcareous and green dolomitic mudstone of the Amaranth Formation.

Reston Formation

In the study area, the Reston Formation is a 0.3–52.5 m thick, light beige to light grey and green, nonfossiliferous, calcareous mudstone to medium-grained calcareous sandstone. At the base of the formation, it is often dolomitized with zoned grey to black siliceous layers and nodules. These layers and nodules were brecciated and worked to varying degrees upsection to produce breccia, conglomerate with angular to rounded clasts, subangular to subrounded pebble layers (often noted at a distance from the siliceous layers) and grey chert sandstone with rounded grains (at the top of formation).

Porosity in the grey chert sandstone beds is primarily intergranular, <2%, whereas the siliceous layers and breccia exhibit vuggy, fracture and mouldic porosity. Oil staining is associated with 0.01–2% intergranular and <5% fracture porosity. Sulphides were noted within fractures, along bedding contacts and crosscutting bedding. Additionally, slickensides were noted in a green mudstone with siliceous clast rubble.

In the study area, the top of Reston Formation was picked in core at a light beige to light grey and green, nonfossiliferous, calcareous mudstone to medium-grained calcareous sandstone. This core pick corresponds to the geophysical log signature seen in Nicolas (2009). The Reston Formation has a conformable gradational contact with the Melita Formation.

Lower Melita Member, Melita Formation

In the study area, the Lower Melita Member of the Melita Formation is 46–205 m thick and is composed of greenish-grey to brown, beige and black, calcareous mudstone or shale with conchoidal fractures, as well as bivalve packstone, calcareous siltstone, and brown and grey sandstone. The mudstone can contain occasional bivalves, muscovite mica flakes, wood and swelling clays.

Toward the base of the Lower Melita Member, the grey to white and green sandstone to siltstone and mudstone typically form fining-upward cycles. These cycles show reworking of the siliceous layers from angular siliceous breccia in a mud matrix, through conglomerate to fine-grained, crossbedded sandstone to siltstone (with rounded grains) and mudstone. The siliceous layers, breccia and conglomerate can exhibit <10% vuggy and fracture porosity and in the sandstone, <5% intergranular porosity. Oil staining has been noted in the sandstone.

Higher in the section the variably consolidated, noncalcareous, brown sandstone can contain bivalves, muscovite mica flakes, sulphides, lignite and wood fragments. Porosity is intergranular, <10%, and the sandstone can have a faint petroleum smell. It is uncertain if the brown colour in this sandstone is due to oil staining.

Fining-upward sequences in the Lower Melita Member were recorded in 12 wells. The full sequence was not always observed due to core availability and distance from competent siliceous layers, but in general the sequence starts at the base with siliceous layers, breccia and conglomerate, and grades vertically to sandstone and then mudstone. Coarsening-upward sequences, from mudstone to sandstone, were recorded in two wells. Additional work is required to better categorize the units within this formation, map their extent and characterize their relationship with the underlying Reston Formation.

Preliminary observations from core

Siliceous layers

In the study area, five siliceous layers were identified from the Lodgepole Formation to the Lower Melita Member. These siliceous layers, which are chalky in places, exhibit colour zoning from black (or rarely red) to grey and brown (when oil stained), orange, yellow and beige to white. The colour zoning noted was typically observed as a light core to a darker rim. Where anhydrite was present in the Lodgepole Formation, siliceous layers and nodules were yellow with orange rims. Where the anhydrite was absent from the Lodgepole to Melita formations, the siliceous layers and nodules were typically white to grey with dark grey or black rims.

These siliceous layers exhibit varying degrees of brecciation. Where anhydrite is present in the Lodgepole Formation, these layers were not brecciated. Where the anhydrite is absent from the Lodgepole Formation to the Lower Melita Member, the siliceous layers exhibit varying degrees of brecciation. A progression from zoned siliceous layers (base of unit) to breccia with angular fragments, conglomerate with subangular to subrounded clasts, subrounded pebble layers (often noted at a distance from siliceous layers) and grey chert sandstone with rounded grains (top of unit) was noted.

Further work is required to understand their genesis and to map these layers in the study area.

Evidence for dissolution, recrystallization and remobilization

In the study area, there is evidence for enhanced fluid movement throughout the section studied, including

- inconsistent dolomitization, overprinting of the original texture and recrystallization in the mudstone, wackestone and packstone of the Amaranth and Reston formations and some parts of the Lodgepole Formation;
- absence of anhydrite in the Lodgepole and Amaranth formations;
- stylolites in the Lodgepole Formation where anhydrite is absent;
- vuggy and fracture porosity development in brecciated siliceous layers;
- vuggy and mouldic porosity development in the Lodgepole Formation;
- euhedral and crosscutting vein sulphides associated with siliceous layers of the Lodgepole, Amaranth and Reston formations;
- crosscutting sulphides in the light grey, laminated mudstone to siltstone of the Reston Formation; and
- bleaching of the Lodgepole Formation siliceous layers near fractures containing sulphides.

Local structure—evidence for faulting and subsidence

The core in the study area also records

- fining- and coarsening-upward cycles from the Amaranth to Melita formations;
- anhydrite and gypsum missing from the Amaranth Formation and Flossie Lake Member of the Lodgepole Formation;
- local thickening, thinning and nondeposition of portions of the Amaranth, Reston and Melita formations;
- slickensides on core surfaces;
- locally deposited 1 cm thick lignite and paleosol layers in the Lower Melita Formation; and
- green colouration in the mudstone and sandstone of the Amaranth and Reston formations.

Further, core logging results have revealed a north-northwest- to south-southeast-trending lineament between areas where the Amaranth Formation contains anhydrite or gypsum and where the Amaranth Formation is missing anhydrite and gypsum. In Figure GS2024-23-2, this lineament is plotted over the Reston Formation isopach contour map showing a thickened Reston Formation section striking along and to the west of this lineament. This lineament is currently interpreted as a fault. Further work is required to fully understand the extent of this structure and related subsidence and its relationship to other observed structures and core features.

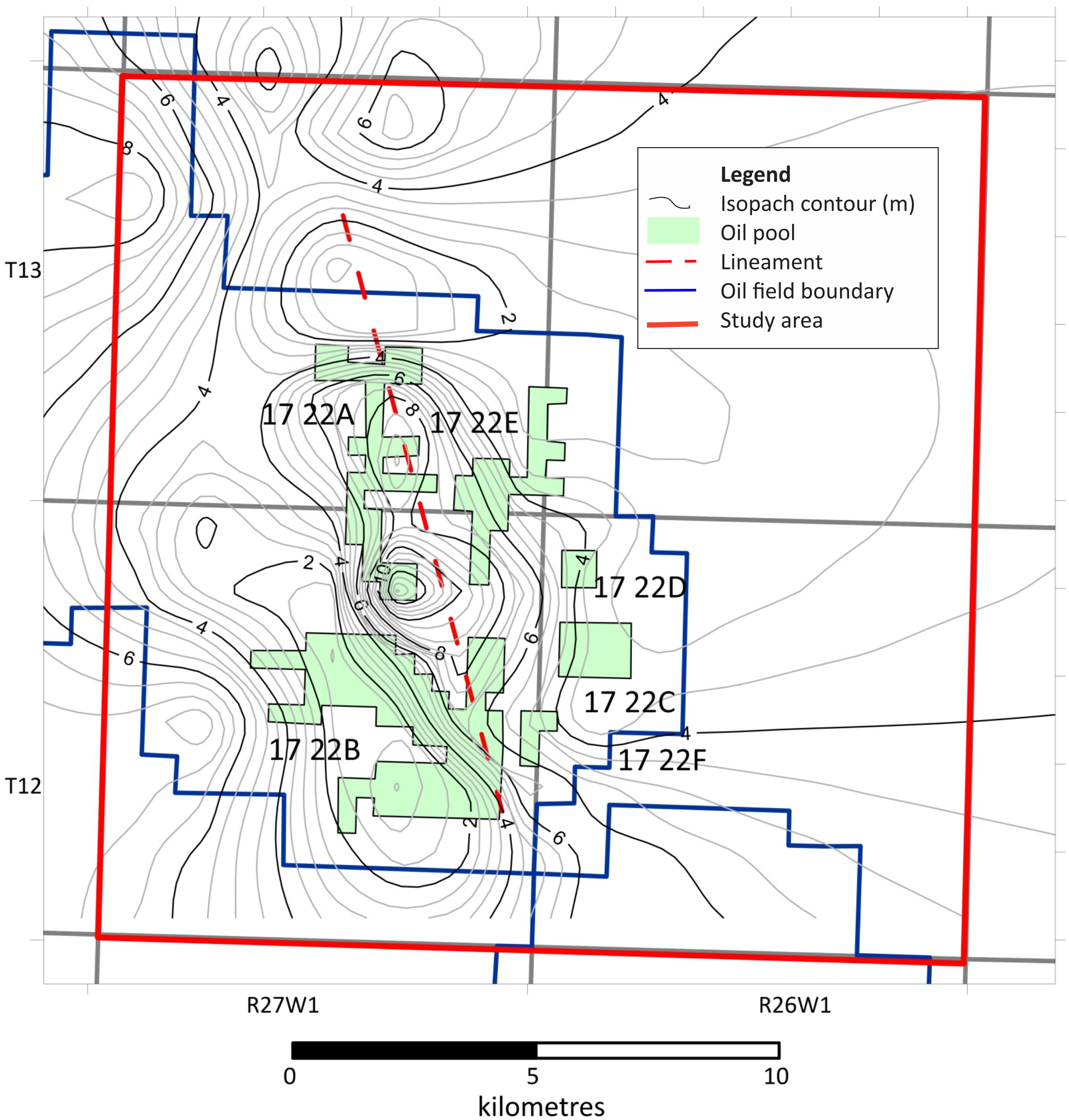

Figure GS2024-23-2: Isopach contour map of the Reston Formation in the study area; contour interval is 0.5 m. Red dashed line indicates location of lineament separating the area where the Amaranth Formation is missing anhydrite and gypsum, on the west side, from the area where the Amaranth Formation contains anhydrite or gypsum, on the east side.

Sulphides

In the study area, sulphides were noted from the Lodgepole Formation to Melita Formation. Preliminary interpretations indicate primary sulphide laminations occur from the Lodgepole Formation to Reston Formation, primary anhedral sulphide nodules occur in the Amaranth Formation, and synsedimentary sulphide layers and anhedral nodules occur in the Lower Melita Member of the Melita Formation. Secondary sulphides crosscut bedding and occur at bedding contacts and in fractures within brecciated siliceous layers in the Lodgepole, Amaranth and Reston formations. Euhedral sulphides were noted in the Amaranth Formation.

Reservoir units and oil production

Three main reservoir units have been identified in the Reston-Amaranth-Lodgepole pools of the Manson Field (Table GS2024-23-1):

1) mudstone, wackestone and packstone layers with intercrystalline to vuggy and mouldic porosity; these include Lodgepole Formation calcareous mudstone, wackestone and packstone intervals and Reston Formation calcareous mudstone with porosities of >2%
2) chert sandstone of the Reston Formation and brown sandstone of the Lower Melita Member of the Melita Formation with intergranular interpreted porosity, >5%
3) siliceous layers in the Lodgepole, Amaranth, Reston and Melita formations with interpreted vuggy and fracture porosity, >10%

The productive oil perforation distribution (Table GS2024-23-1) and faulting suggest that oil is primarily produced in the mudstone, wackestone and packstone intervals of the Lodgepole and Reston formations; and oil is also being produced from siliceous layers in the Amaranth, Reston and Melita formations and from sandstone in the Reston and Melita formations.

Table GS2024-23-2 lists the oil production by pool for the Reston-Amaranth-Lodgepole pools. Most oil production from the Reston-Amaranth-Lodgepole pools occurs in pools 17 22A and 17 22B, where anhydrite is absent from the Amaranth Formation. Limited oil has been produced from pools 17 22C–F where anhydrite is present in the Amaranth Formation.

Discussion and preliminary interpretations

Figure GS2024-23-2 shows the lineament interpreted as a fault between the Amaranth Formation that contains anhydrite or gypsum, on the east side, and the Amaranth Formation where the anhydrite and gypsum are missing, on the west side. This fault coincides with a thickening of the overlying Reston Formation, suggesting the dissolution of Amaranth Formation anhydrite in association with the fault resulted in the overlying Reston Formation infilling a depression on the Amaranth Formation surface.

The productive oil perforation distribution, shown in Table GS2024-23-1, suggests that oil is produced from mudstone, wackestone and packstone intervals of the Lodgepole and Reston formations; siliceous layers in the Amaranth, Reston and Melita formations; and sandstone of the Reston Formation and the

Table GS2024-23-1: Total perforation count in well casing separated by member/unit and oil pool designation for the Reston-Amaranth-Lodgepole pools of the Manson Field (Manitoba Economic Development, Investment, Trade and Natural Resources, unpublished data, 2024).

Formation	Unit	Field-pool code						Total perforations
		17 22A	17 22B	17 22C	17 22D	17 22E	17 22F	
Melita	Brown sandstone	0	0	0	1	0	0	1
	Siliceous layer	0	0	0	1	0	0	1
Reston	Undifferentiated	17	14	1	10	2	3	47
	Chert sandstone	1	0	0	0	0	0	1
	Siliceous layer	9	3	0	7	0	0	19
Amaranth	Upper Amaranth Mb.	0	0	0	0	0	0	0
	Siliceous layer	1	0	0	0	0	1	2
	Lower Amaranth Mb.	0	0	0	0	0	0	0
	Siliceous layer	0	0	0	0	0	0	0
Lodgepole	Undifferentiated	14	47	0	2	0	5	68

Table GS2024-23-2: The cumulative oil production by pool for the Reston-Amaranth-Lodgepole pools as of July 8, 2024 (Manitoba Economic Development, Investment, Trade and Natural Resources, unpublished data, 2024).

Field-pool code	17 22A	17 22B	17 22C	17 22D	17 22E	17 22F	Total
Number of wells	22	57	2	11	7	2	101
Average production by well (m^3)	6 215	11 689	445	5 508	3 315	277	8 794
Total production (m^3)	136 735	666 250	891	60 591	23 202	554	888 223

Lower Melita Member of the Melita Formation. Table GS2024-23-2 indicates that larger cumulative oil production comes from pools 17 22A and 17 22B, both of which occur where the Amaranth Formation anhydrite is absent (Figure GS2024-23-2). Smaller cumulative production has been achieved where the Amaranth Formation anhydrite is present. However, pools 17 22A and 17 22B have also been in production for longer than pools 17 22C–17 22F, so caution is required when interpreting these results. Although oil production from the Lodgepole Formation is common in the surrounding area, rare perforations in the Amaranth, Reston and Melita formations indicate oil production from stratigraphically higher formations may be possible where there is faulting, dissolution and subsidence. Further work is required to assess the source of this oil and its association with potential faulting.

The following characteristics suggest a diagenetic history of enhanced fluid flow in the study area:

- dissolution of anhydrite
- presence of synsedimentary sulphides
- presence of secondary sulphides crosscutting bedding and in fractures within brecciated siliceous layers
- bleaching of siliceous layers around fractures containing sulphides

Further work is necessary to determine the association of enhanced fluid flow with faulting, and if there is an associated increase in heat flow that may have resulted in local oil generation from mudstone and the emplacement of critical minerals.

In general, the depositional and diagenetic features observed in the Manson Field, from the Lodgepole to Melita formations, record a complex history of structural and fluid movement. Missing stratigraphic units, abrupt lithological changes with the deposition of siliceous layers, fining- and coarsening-upward sequences and sudden variations in formation thickness, all suggest a dynamic landscape of collapse, relative uplift and fluid movement during the deposition of the Amaranth, Reston and Melita formations. These processes may have played a role in new oil migration pathways, reservoir development and trapping features within the Manson Field.

Future work

This ongoing study has highlighted the need for the following work:

- update the Reston-Amaranth-Lodgepole pool name to include the Lower Melita Member of the Melita Formation
- correlate core picks of formation and unit contacts to surrounding uncored wells within and outside the study area using core-log correlation
- study the type sections of the Reston and Melita formations and determine how they differ from the sections in the Manson Field
- create updated isopach maps for the Lower Melita Member of the Melita Formation, Reston Formation, Amaranth Formation, Flossie Lake and Whitewater Lake members of the Lodgepole Formation, and map the distribution and thickness of the siliceous layers and sandstone in order to ascertain the extent and timing of faulting and how these relate to diagenetic processes in the study area
- update the Lodgepole Formation subcrop map, review the rock types in the formation and explore diagenetic processes, siliceous layer deposition and sulphide precipitation
- create normalized plots to properly assess oil production in relation to subsidence
- conduct Rock-Eval and total organic carbon (TOC) analyses of the Lower Melita Member mudstone to investigate its oil-generating potential
- conduct X-ray fluorescence (XRF) analysis of sulphides, siliceous layers and white minerals for critical minerals
- analyze thin sections of core samples to understand mineral textures and relationships, and explore the diagenetic history of this reservoir
- review and correlate the available porosity, permeability and oil density data for the oil reservoir, and cross-reference with the described lithologies

Economic considerations

Primary and secondary sulphides were noted in the study area in the Lodgepole, Amaranth, Reston and Melita formations. Further work is required to confirm the type and quantity of this mineralization and identify where critical minerals may be prospective in the sedimentary section of Manitoba.

The Manson Field hosts an oil reservoir that occurs in the youngest identified stratigraphic oil-containing horizon in Manitoba. Though oil in the Reston-Amaranth-Lodgepole pools is primarily produced in the Lodgepole and Reston formations, oil is also being produced higher in the stratigraphic section in proximity to an interpreted fault. This production suggests additional oil resources may be present higher in the section around faults and opens up the possibility of a new oil-play type in Manitoba.

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