Petrography of the Jurassic Lower Shaunavon Member Reservoirs in the Leitchville/Bone Creek Area of Southwest Saskatchewan: Preliminary Results

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Abstract

The introduction of horizontal drilling, together with multi-stage fracturing technology, has significantly increased oil production from the Lower Shaunavon Member carbonate reservoirs within the last several years. The preliminary petrographic analysis, based on cores, thin sections, and geophysical well logs from nineteen wells in the Leitchville and Bone Creek pools and surrounding area in southwestern Saskatchewan, indicates that the Lower Shaunavon Member reservoirs are primarily comprised of limestone with variable amounts of dolomite (0 to 95%) and anhydrite (0 to 25%). These carbonate reservoirs occur as shallowing-upward peloidal/oolitic wackestone-grainstone cycles, which are interpreted to be deposited in a warm peritidal environment on a carbonate platform.

Detailed petrographic analysis also enables the reconstruction of the diagenetic history of the Lower Shaunavon Member and its impact on porosity and permeability within these reservoirs. The dominant form of cement in these reservoirs is blocky sparry calcite, which occludes porosity. Micritization locally increased porosity to 15 to 20%, particularly within the oolitic and peloidal facies. Other diagenetic features include: dolomite preferentially replacing calcite within shell fragments; anhydrite replacing coral fragments as well as intergranular cement; and solution-related moldic/vuggy porosity (5 to 20%), resulting in variable permeability (0.1 to 10.0 mD) as noted in Facies 4, 5, and 6. Depositional environment is the primary control on the spatial distribution of reservoirs within the Lower Shaunavon Formation; whereas diagenesis strongly influenced reservoir quality in the Leitchville/Bone Creek pools and surrounding area.

Keywords: *Lower Shaunavon Member, reservoir characteristics, Leitchville, Bone Creek, southwest Saskatchewan, Jurassic, petrographic.*

1. Introduction

In southwestern Saskatchewan, the upper and lower members of the Middle Jurassic Shaunavon Formation have been the target of hydrocarbon exploration since 1952 when oil was discovered in the Upper Shaunavon Member in the Delta and Eastend fields. The Bone Creek pool was discovered in 1954 with the drilling of the 101/06-34-010-19W3/00 well; the Leitchville pool was discovered a few years later in 1960 when the 101/06-18-009-18W3/00 well was drilled. The Bone Creek discovery well was completed in the Upper Shaunavon, and the Leitchville discovery well was completed in both the Upper and Lower Shaunavon members. The Shaunavon Formation is currently the fourth-highest oil producer in Saskatchewan with over 375 MMBbl of oil having been produced to date (geoSCOUT™, May 2011). The oil within the Shaunavon Formation is a medium crude with an average 22°API. The majority of the production is from the mixed calcareous sandstones within the upper member. Oil production from the Lower Shaunavon Member was very limited until 2005. The introduction of horizontal drilling and multi-stage fracturing technology has significantly increased oil production from the Lower Shaunavon Member with 70% of the total oil from this stratigraphic unit being produced within the last several years. The Lower Shaunavon Member is the focus of this paper.

2. Regional Geology

Middle Jurassic sediments in southern Saskatchewan were deposited in an epicratonic setting associated with the rejuvenation of the Williston Basin; sediments were sourced from the low-lying land in the north, east, and south

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(Poulton *et. al.*, 1994). During much of the Middle Jurassic, sedimentation on the northwestern flank of the Williston Basin, where the study area is situated (Figure 1), was dominated by mixed carbonate-clastic deposits. The clastic sediments are considered to be derived predominantly from the Canadian Shield to the north and east (Blair, 2004). The Jurassic Shaunavon Formation (Figure 2) in southwestern Saskatchewan was originally defined by Milner and Thomas (1954) and is correlative to the uppermost one-third of the Sawtooth Formation (Cobban, 1945) or Piper Formation (Imlay *et al.*, 1948) in Montana. The lower two-thirds of the Sawtooth Formation or Piper Formation is equivalent to the Upper Watrous and Gravelbourg formations of Milner and Blakslee (1958).

The Upper Shaunavon Member in southwestern Saskatchewan consists of highly variable facies including shallow marine, tidal flat, and fresh-water deposits that were subject to periods of emergence. Four depositional environments have been identified by Blair (2004): 1) a lagoonal facies consisting of dark grey noncalcareous shale; 2) tidal-flat sediments consisting of fine sheet sandstone and mudstone banks; 3) a basinal facies consisting of a dark grey to greenish shale, mudstone, and marlstone; and 4) a transitional belt between the basinal facies and the tidal flat facies, consisting of beach, bar, and channel sandstone surrounded by extensive shale. Early oil production

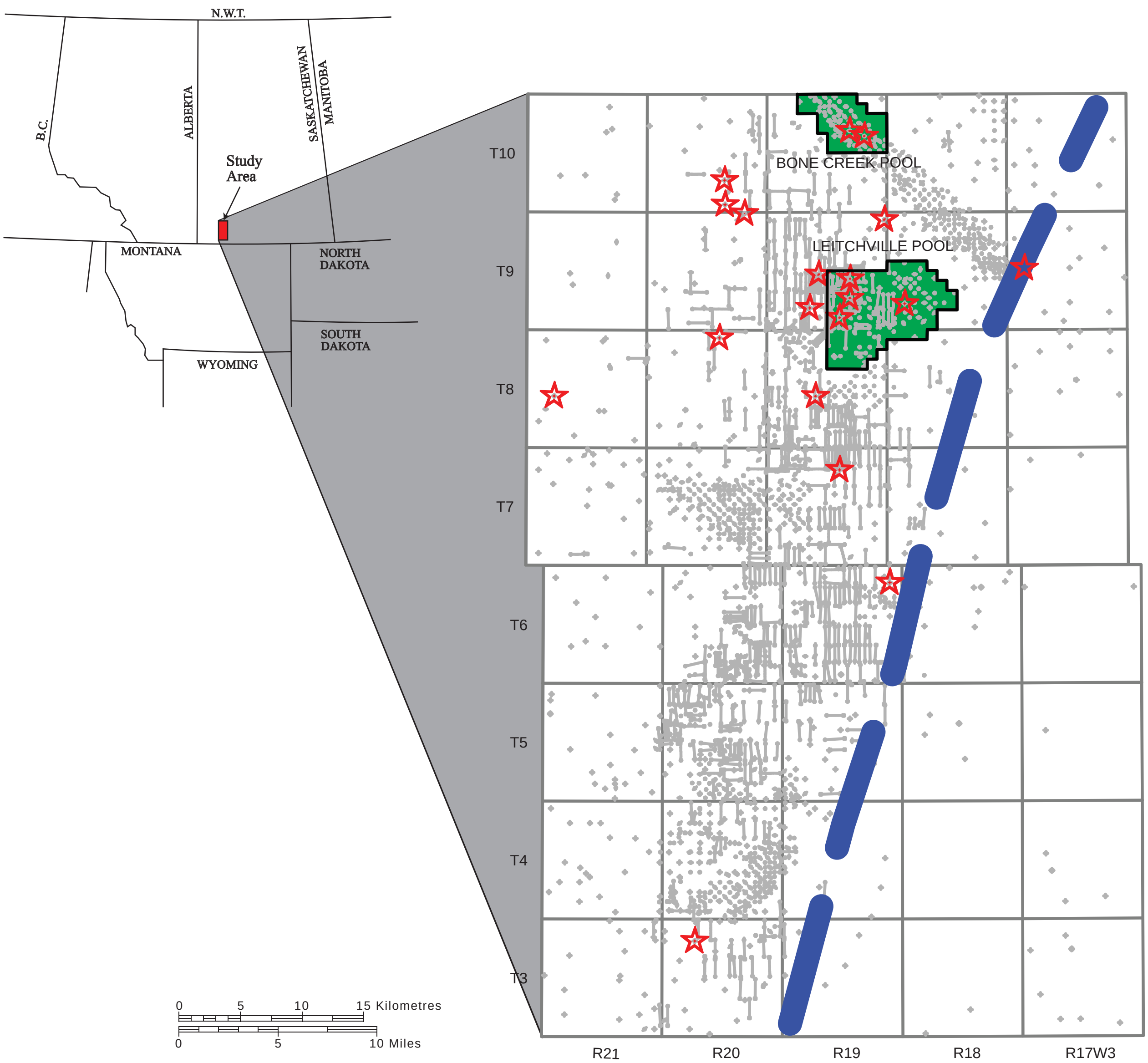


***Figure 1** – Study area (Townships 3 to 10, Ranges 17 to 21W3) highlighted in red within the regional context of southwestern Saskatchewan. The dashed blue line represents the axis of the Shaunavon Syncline or the northern extension of the Cobourg Syncline (Milner and Blakslee, 1958; Christopher, 1964; Gent, 1992). The grey symbols represent the wells currently drilled within the study area, and the red stars indicate the locations of cores examined for the purpose of this paper. The Leitchville and Bone Creek pool areas are shown in green.*

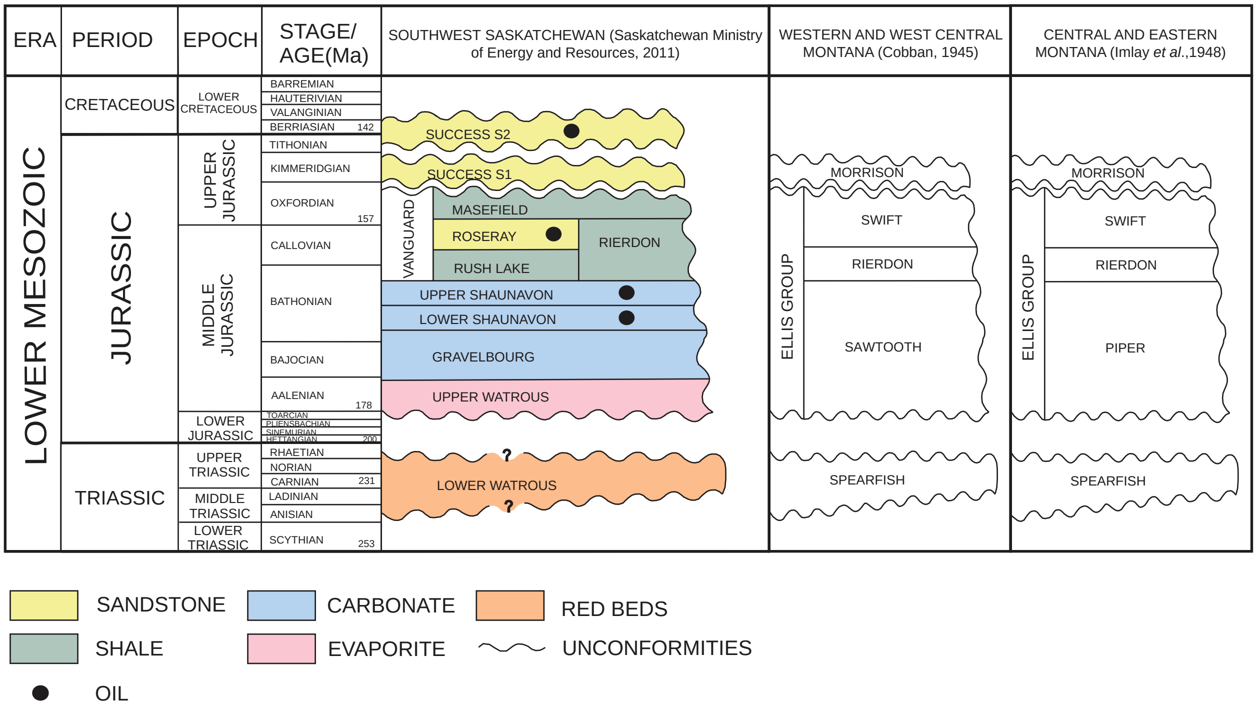


Figure 2 – Stratigraphic correlation chart showing the stratigraphic relationship of the Shaunavon Formation with Lower Mesozoic strata in southwest Saskatchewan and Montana.

in the Upper Shaunavon Member was found in isolated mixed clastic/carbonate shoreline bodies within this transitional belt (Marsh and Jensen, 2010). Within the study area, the Upper Shaunavon Member occurs at an average depth of 1337 m.

The Lower Shaunavon Member has been described as lithographic limestones deposited in a shallowing, mildly restricted and low-angle depositional gradient environment (Christopher, 1964). It is regionally consistent in thickness and is traceable as far east as longitude 104° and trends as far west as 110° on the Shaunavon Shelf, where the formation dips southeast 2.5 to 3.0 m/km as an irregular, step-like or terraced monocline (*ibid.*). In the southeast part of the study area it forms the nearly flat-bottomed Shaunavon Syncline (*ibid.*). The Lower Shaunavon Member is described as being regionally fairly homogenous, comprised mostly of carbonate mudstone with restricted fauna characterized by pelecypods, solitary corals, and gastropods (*ibid.*; Marsh and Yurkowski, 2008). Christopher (1984, p90) described the Lower Shaunavon Member on the Shaunavon Shelf as "distinctly oolitic in its upper 25 ft. (~7.6 m); it is also dolomitized in an area of lesser extent." The Lower Shaunavon Member can be identified throughout the study area at an average depth of 1371 m and an average thickness of 28.5 m (Marsh *et al.*, 2011).

3. Method of Study

This preliminary study was conducted by examining core and thin sections from 19 wells containing the Lower Shaunavon Member. All core and thin sections described and analyzed for this preliminary investigation are from southwestern Saskatchewan within Townships 3 to 10, Ranges 17 to 21W3 (Figure 1). Six of the 19 cores examined are from the Leitchville and Bone Creek pools, while the remaining 13 cores are from wells in the area surrounding the two pools (Figure 1). Eighty-eight thin sections were examined. All of the permeability and porosity values were taken from core analysis data (Accumap® and geoSCOUT™, February 2011).

4. Lithofacies and Petrographic Descriptions

The Lower Shaunavon Member consists of fairly homogeneous carbonate deposits that can be grossly divided into an upper oolitic/peloidal/fossiliferous unit, which is the current primary reservoir target, and a lower cyclic mudstone unit with peloidal wackestone-packstone interbeds. In the study area, the predominantly mudstone unit conformably overlies the Jurassic Gravelbourg Formation and shallows upward into the oolitic/peloidal/fossiliferous beds, which are unconformably overlain by the Upper Shaunavon Member. These two units can be further subdivided into eight facies.

a) Facies 1 – Massive Lime Mudstone

This facies is a white to beige massive limestone mudstone with very limited shell fragments that have been extensively micritized. Facies 1 is present in all the cores within the study area that penetrate the lower mudstone unit. Hardgrounds are present in most of the core containing this facies, and are typically overlain by encrusting algal mats (stromatolites) and burrow structures. These hardground surfaces, along with the stromatolites and burrow structures, appear in cycles in up to 30% of the cores examined for this study. These cycles can repeat themselves up to nine times in a given core (Figure 3). An anomalous brecciated unit is present in this facies in the 101/16-23-010-19W2/00 well (Figure 4A). Micro-intercrystalline, fabric-selective intraparticle porosity as well as non–fabric-selective burrow and fracture porosity are all visible with porosity values ranging between 5 to 20%. Dolomite has replaced calcite in this facies in many of the cores in this study area, making up between 15 to 20% of the facies, although replacement dolomite (Figure 5C) up to 95% was also observed. Up to 15% anhydrite replacement of the limestone was also observed (Figure 5B). Dark beige to pale brown colouration within this facies is due to oil staining.

b) Facies 2 – Peloidal Wackestone

This facies is white to beige wackestone with 5 to 10% peloids, 5 to 10% shell fragments (pelecypods, gastropods, and solitary corals), and 3 to 5% ooids. Facies 2 is also present in all core within the study area that penetrate the lower mudstone unit. Well 121/15-16-009-19W3/00 has approximately 13 m of this facies interbedded with multiple, up to 50 cm thick, beds of Facies 1. Micro-intercrystalline porosity ranges from 5 to 20%. Dark beige to pale brown colouration within this facies is due to oil staining.

c) Facies 3 – Peloidal-Fossiliferous Packstone

This facies is white to beige limestone packstone with peloids (70 to 80%) and shell fragments (pelecypods, gastropods, and solitary corals up to 20%). In some core, rare ooids are visible. Calcareous algae is also present (1360.5 m in well 101/12-14-009-19W3/00, Figure 3). Gastropods range in size from 1 mm to 1 cm. Solitary corals, when present, range in size from <1 mm up to 5 cm. The internal structure of the coral is commonly replaced with either calcite-sparite cement or anhydrite. Facies 3 occurs as a few centimetres to 2 m thick interbeds, within both the lower cyclic mudstone unit and in the lower section of the upper oolitic/peloidal unit. Micro-intercrystalline, intraparticle, and moldic porosity can be up to 18%. Locally, moldic porosity influences porosity within this facies. Some shell material has been replaced by pyrite in this facies. Dark beige to pale brown colouration within this facies is due to oil staining.

d) Facies 4 – Micritic Peloidal-Fossiliferous Wackestone/Packstone

This facies is a light to dark beige wackestone to packstone with peloids (40 to 60%), ooids (up to 20%), and 10 to 15% shell fragments (gastropods, brachiopods, and pelecypods) (Figures 6A and 6B) that have been extensively micritized. This facies appears within the uppermost one-third of the Lower Shaunavon Member. Solitary corals, as seen in well 111/08-07-009-18W3/00, can range in size from <1 mm to as large as 5 cm. Also, commonly the internal structure of shell fragments is replaced with either sparry calcite or anhydrite. Bioturbation is common in most core (Figure 4B) with *Chondrites* burrows being particularly abundant. Hardground surfaces are also present within this facies, but are less common than in Facies 1. Interparticle, vuggy and moldic porosity are common (Figures 5D and 6C), with porosity ranging from 5 to 20% (average 14 to 16%). Moldic porosity results from the dissolution of shell debris and grains. The cement in this facies is a mixture of calcite, dolomite, and anhydrite. Dolomite is present in most cores in beds ranging in thickness from 30 cm up to 1 m and typically varying from 20 to 25% composition, although locally it can vary as much as 5 to 95%. Anhydrite cement is also common within the pore space (well 101/01-19-009-17W3/00); as well, pyrite occurs within this facies (Figure 7C). Irregular oil staining is visible in core and thin section. Micrite envelopes encase the majority of the ooids, peloids, and shell debris and are prevalent in all cores.

e) Facies 5 – Micritic Oolitic/Peloidal-Fossiliferous Packstone/Grainstone

This facies (Figures 5A, 6A, 6B, and 7A) is a light to dark beige packstone to grainstone with equal amounts of ooids and peloids ranging between 70 to 90% of the facies and 10 to 30% shell fragments (gastropods, brachiopods, solitary corals, pelecypods) and organic material. As with Facies 4, this facies is present within the uppermost one-third of the Lower Shaunavon Member. Interparticle, intraparticle, and moldic and vuggy porosities are common, with porosities ranging from 13 to 20%. Moldic porosity is the result of the dissolution of shell material and allochems (Figure 4B). Replacement dolomite is common throughout this facies varying from 5 to 50% selectively replacing cement within the pore space (Figure 7A). Anhydrite is also present (up to 20%) within the pore space (Figure 6A). Oil staining is visible in core and thin section.

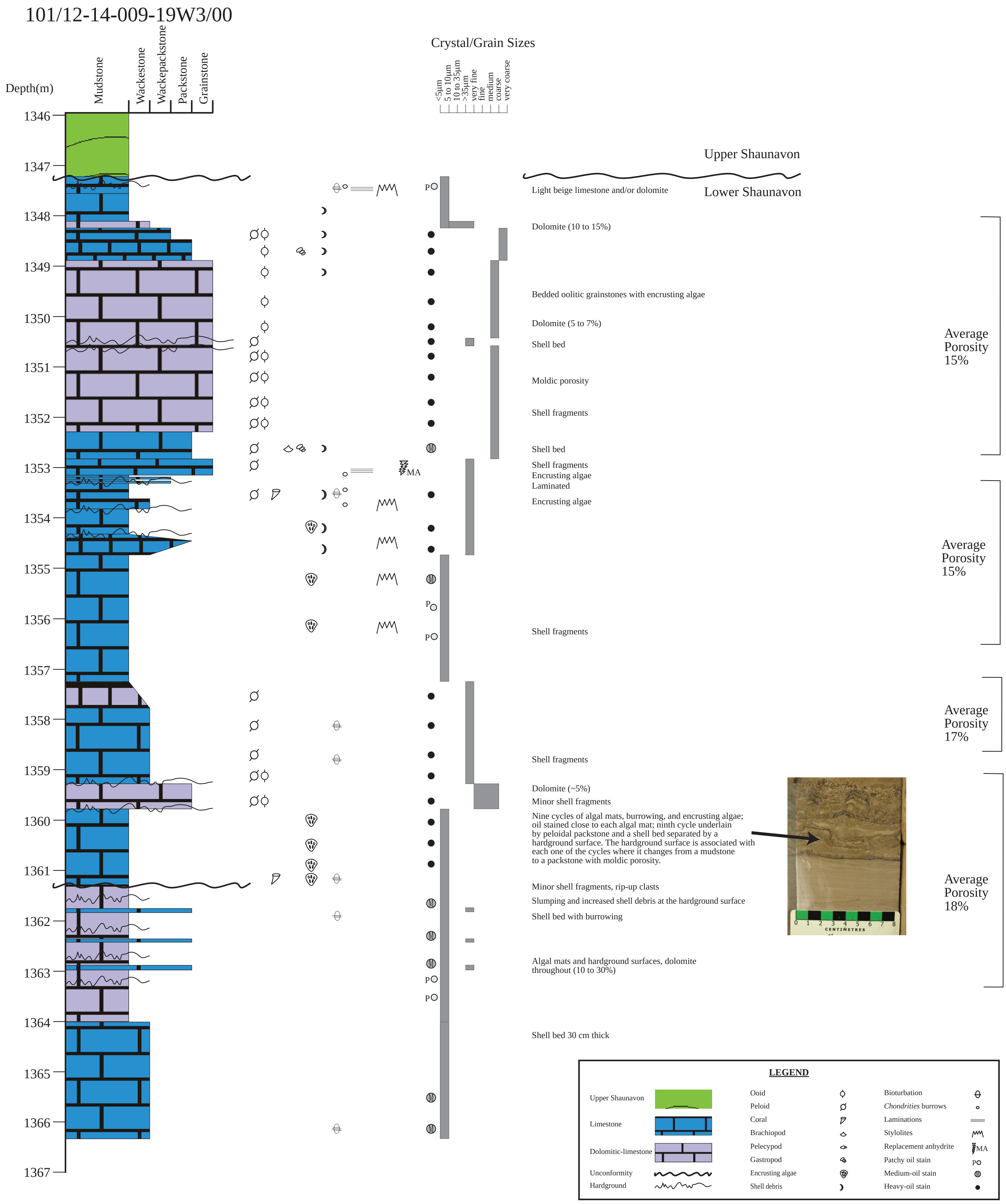
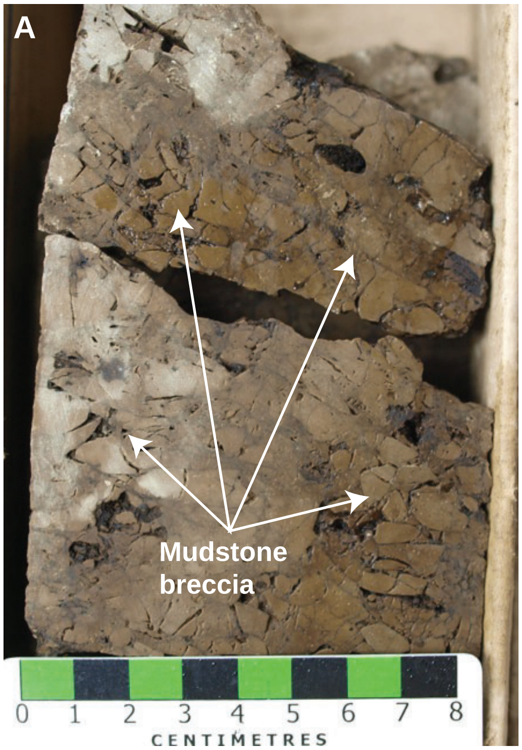


Figure 3–Detailed core description of well 101/12-14-009-19W3/00 of the Lower Shaunavon Member. The lower two-thirds of the core contains Facies 1 with interbeds of Facies 2 and 3. As many as nine hardground surfaces are noted throughout the lower two-thirds of the core. Of note in this core are the nine occurrences of burrowing and encrusting algae associated with the Facies 3 interbeds. Hydrocarbon staining increases within each cycle of Facies 1 through 3, particularly at the hardground boundary relative to the mudstone above and below. The upper one-third of this core consists of Facies 1, and Facies 4 to 6. Minor moldic porosity is present throughout this upper section.



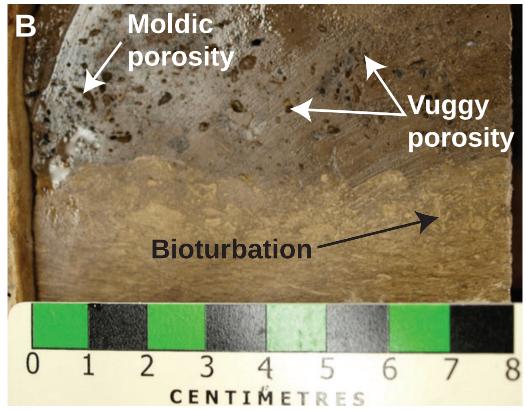


Figure 4 – Core photographs of: A) heavily oil-stained mudstone breccia with 18% porosity and 124 mD permeability within Facies 1 (well 101/16-23-010-19W2/00, 1371.0 m); and B) heavily oil-stained Facies 5 near the top of the Lower Shaunavon Member; vuggy and moldic porosity created by the dissolution of ooids and shell material; Facies 5 is separated by a hardground surface from the heavily bioturbated wackestone/packstone bed (Facies 4) below (well 101/09-10-010-20W3/00, 1392.42 m).

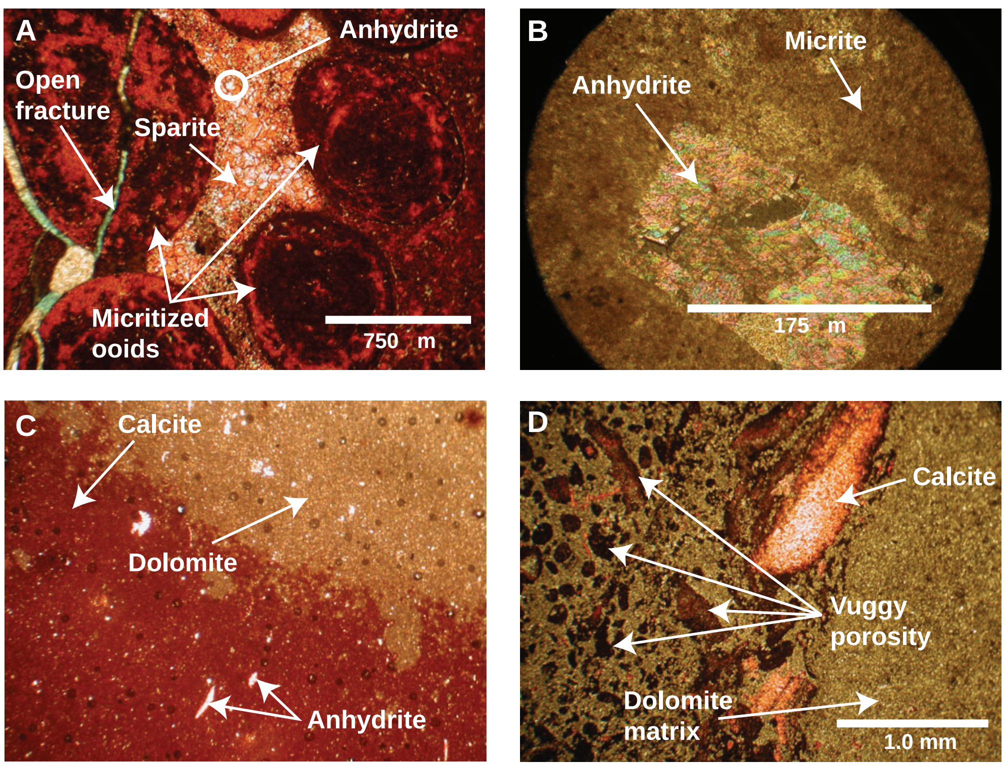
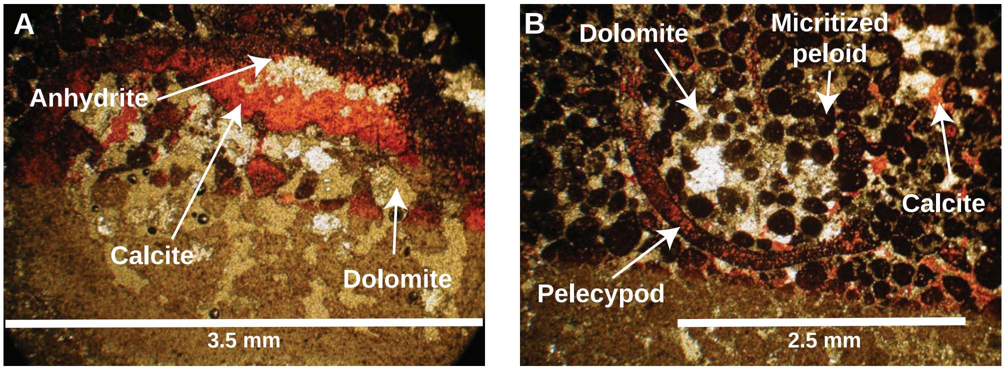


Figure 5 – Thin section microphotographs. A) Dolomite in an open fracture through a micritized ooid (1374.7 m) (Facies 5); the pore throats are filled with sparite and anhydrite; Alizarin red stain; B) large anhydrite crystal in micrite matrix just below laminations within the uppermost few centimetres of Facies 1 (1376.5 m); cross-polarized light; and C) upper section of the microphotograph is 95% micro-crystalline dolomite (crystal size <187 μm) decreasing to 5% micro-crystalline dolomite in micritized calcite in the lower section (plane light); minor anhydrite and dolomite replacing calcite after burial (1388.8 m) (Facies 1); Alizarin red stain. A), B), and C) taken from well 121/15-16-009-19W3/00. D) 20 to 30% calcite within a dolomite matrix (well 101/09-10-010-20W3/00, 1392.92 m) with vuggy peloidal porosity and heavy oil staining (Facies 4); Alizarin red stain.



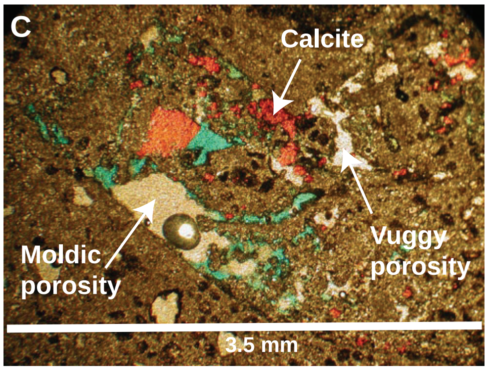


Figure 6 – Thin section microphotographs taken from well 141/16-35-009-20W3/00: A) algae with 50% dolomite, microcrystals of calcite and anhydrite within Facies 5 (uppermost part of photo); a few microcrystals of calcite are also present in lower portion of photo (Facies 4) (1377.3 m); Alizarin red stain; B) micritized peloids, calcite (red stained) cement, and shell material; dolomite is within the pore throats along with 2 to 7% anhydrite (Facies 5); lowermost portion of the photo is Facies 4 (1377.3 m); Alizarin red stain; and C) Facies 4 (1381.6 m); moldic and vuggy porosity in a dolomite matrix with minor calcite cement; heavy oil staining and open porosity (20%) are visible although average porosity in this well for Facies 4 is 13%; Alizarin red stain.

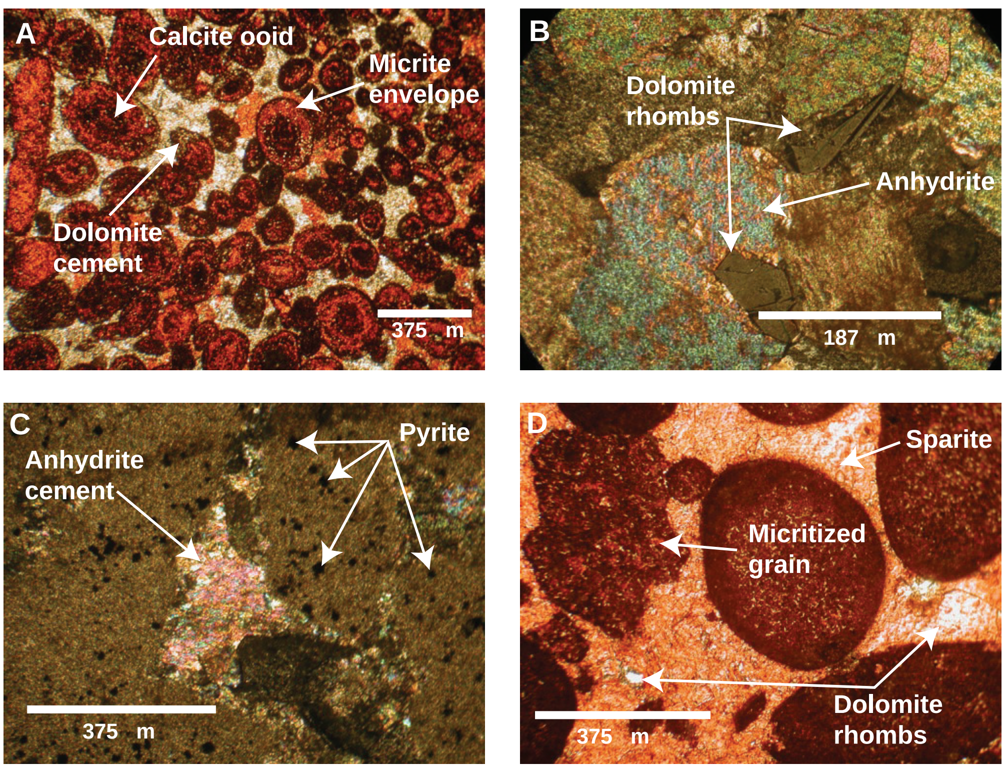


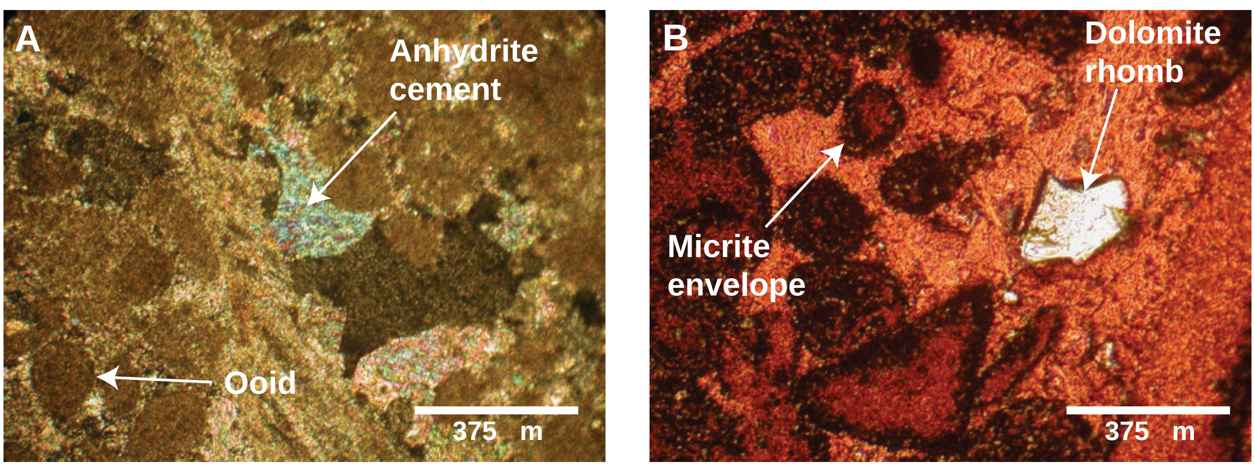
Figure 7 – Microphotographs of: A) heavily oil-stained (inter-particulate) minor dolomite cement patch with a medium-sorted oolitic/peloidal packstone-grainstone (Facies 5) with micrite envelopes (well 111/08-07-009-18W3/00, 1400.2 m); up to 50% dolomite has selectively replaced only the calcite in the pore space; Alizarin red stain, plane light; B) examples of dolomite rhombs and anhydrite that post-dates the dolomite (well 111/08-07-009-18W3/00, 1402.7 m) (Facies 6); cross-polarized light; C) anhydrite development within pore throats with abundant pyrite crystals visible in Facies 4 (peloidal packstone) (well 101/01-19-009-17W3/00, 1397.20 m); cross-polarized light; and D) heavily micritized ooids (Facies 6) with primary blocky sparry calcite, minor interparticulate dolomite, and dolomite rhombs (well 101/10-03-009-19W3/00, 1362.75 m); Alizarin red stain, plane light.

f) Facies 6 – Oolitic Packstone/Grainstone

This facies consists of dark beige, heavily oil-stained packstone to grainstone with primarily ooids (up to 90%), and up to 15% shell fragments (gastropods, brachiopods, and pelecypods). This facies also occurs within the uppermost one-third of the Lower Shaunavon Member. A small percentage of stromatolites and peloids (3 to 5%) are also present. The majority of the allochems and shell fragments have been extensively micritized (Figure 7D). Interparticle, moldic, and fracture porosity ranges from 13 to 16%. The most abundant cement in this facies is blocky sparry calcite (Figures 7D); anhydrite cement is also present (Figure 8A). Dolomite is rare (5 to 7%) within this facies (Figure 8B), but can be up to 0.5 m thick and comprises 50 to 95% of the matrix locally (Figure 7B). Locally, dolomite has replaced calcite in shell fragments (Figure 8C). Anhydrite is visible within the oolitic grains where, in some cases, the anhydrite is partially replacing dolomite rhombs. The dolomite and anhydrite are replacing oolitic grains that were initially aragonite or calcite (Figure 7B). This facies can be up to 2 m in thickness, but when it is present near the top of the Lower Shaunavon Member, it is often truncated by the regional unconformity that separates the Upper and Lower Shaunavon members.

g) Facies 7 – Bioturbated Lime Mudstone

This facies consists of white to beige lime mudstone that lies within the uppermost few centimetres of the Lower Shaunavon Member (Figure 9A), typically directly below Facies 8. Often this facies has been heavily bioturbated as in well 101/12-14-009-19W2/00 (Figure 3). *Chondrites* burrows are identifiable along with some very minor fracturing. Hardgrounds have also been noted. In some instances the mudstone has been partially dolomitized. Porosity is negligible as can be observed in thin section.



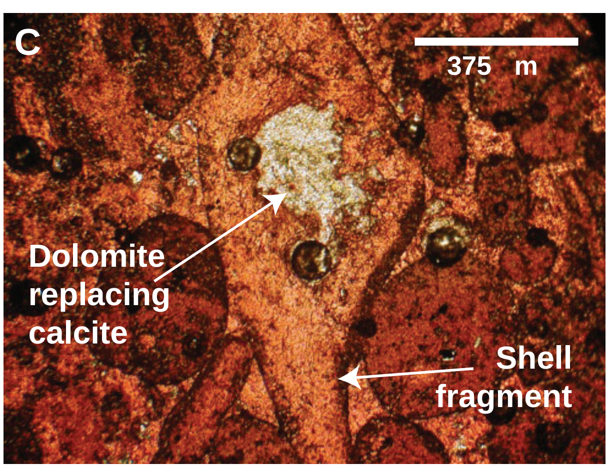


Figure 8 – Thin section microphotographs of Facies 6 from well 101/12-14-009-19W3/00 at a depth of 1349.7 m: A) oolitic packstone/grainstone with abundant shell fragments, anhydrite in pore throats, and 25 to 30% anhydrite cement approximately 1.5 m below the Lower Shaunavon Formation unconformity surface; cross-polarized light; B) micritic overgrowths on peloids and ooids with secondary dolomite rhomb (5 to 7%); Alizarin red stain; and C) secondary dolomite partially replacing calcite within the internal structure of a shell fragment; Alizarin red stain.

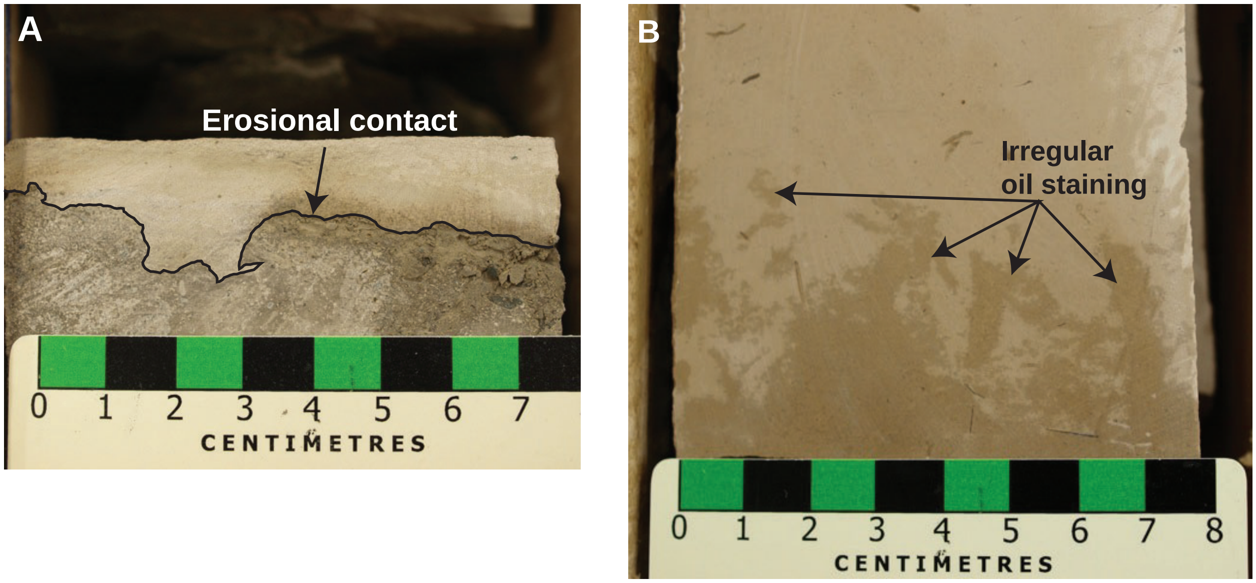


Figure 9 – Core photograph of: A) Facies 7 below erosional contact at the top of the Lower Shaunavon Member (well 101/09-36-009-19W3/00, 1377.2 m); and B) irregular oil staining in Facies 1 (massive mudstone) within lower two-thirds of the Lower Shaunavon Member (well 101/04-09-009-19W3/00, 1369.64 m).

h) Facies 8 – Lateritic Mudstone

This facies is a reddish mudstone that is only found at the top of the Lower Shaunavon Member and marks the unconformity surface. This facies often directly overlies a lime mudstone (Facies 7), and when present is less than 5 mm thick. There is no visible porosity.

5. Discussion

Production is primarily from the upper few metres of the Lower Shaunavon Member from discrete oolitic shoal-type facies (Facies 4 through 6), where porosity typically ranges between 13 to 16%. The different porosity types identified within the reservoir include: micro-intercrystalline, inter-particulate, microfractures, moldic (formed by the dissolution of shell fragments), and vuggy (due to the dissolution of cement and matrix). One of the key factors in the development of a Lower Shaunavon Member reservoir is micritization. Extensive micritization of the ooids, peloids, and shell material within the oolitic facies (Facies 6) and the oolitic/peloidal facies (Facies 4 and 5) appear to form the best reservoir in the Lower Shaunavon Member (Figures 4B and 5D). Moldic and vuggy porosity creates high porosity (up to 28%) within parts of the reservoir, but porosity has been occluded by anhydrite in other portions of the reservoir. Blocky calcite sparite occludes primary intergranular porosity within much of the oolitic shoal complex. Dolomite appears to be a secondary cement that fills the pore space in some instances, but also potentially enhances the development of intercrystalline, vuggy and moldic porosity in other instances (Figure 6C). Replacement dolomite ranges from 0 to 95%, and dolomite rhombs are typically microcrystalline and uniform in size (Figure 7B and 7D). At this point in the study, it is uncertain as to what extent dolomite impacts reservoir quality. Microfracture porosity is also present, but rare. The fractures are visible in both vertical and horizontal orientations, potentially contributing to lateral and vertical permeability. There is open porosity within some fractures, with dolomite developing along the fracture wall (Figure 5A), suggesting that dolomitizing fluid has migrated along these fractures.

Permeability for Facies 4 to 6 is generally between 0.1 and 10.0 mD, although a majority of permeability values statistically fall closer to 0.1 mD, which is generally considered to be a very tight rock. The higher permeability values (*i.e.*, 10 mD), similar to higher porosity values, are associated with moldic and vuggy porosity, as well as fractures.

Currently, the finer lower cyclic mudstone/peloidal wackestone-packstone cycles (Facies 1 through 3) within the lower two-thirds of the Lower Shaunavon Member are considered to be lesser prospective hydrocarbon reservoirs than coarser peloidal-oolitic shoal-type facies (Facies 4 through 6) within the uppermost one-third of the member. This is because of the lower oil saturation levels; however, Facies 1 through 3 are hydrocarbon bearing (Figures 3, 4A, and 9B) and may be productive under the right circumstances (technological advancements together with increased oil prices). The finer mudstone cycles within the lowermost two-thirds of the Lower Shaunavon Member are mainly micritic lime-mudstone as defined as Facies 1, but they can also include up to 20% of Facies 2, and 10% of Facies 3; these cycles were deposited within a quiescent environment such as a lagoon, shoreward of a shoal complex. There are multiple episodes of exposure within the lower, finer mudstone cycles, which may have an impact on reservoir quality, as seen in the nine cycles in well 101/12-14-009-19W3/00 whereby oil saturation levels increase with proximity to the top of each cycle (Figure 3). Lateral continuity of these cycles should be studied further in order to delineate the extent of this potential reservoir. A potential limitation to the extent of the reservoir would be the occurrence of diagenetic anhydrite cement occluding porosity. Anhydrite has also replaced sparry calcite cement within pore throats of Facies 2 (peloidal wackestone), and in some instances it has developed upon the dissolution of dolomite.

Facies 4 through 6 of the Lower Shaunavon Member marine carbonates in southwestern Saskatchewan are interpreted to be deposited as shoal complexes on the margin of a carbonate platform. Orientation and stratigraphic location of these facies within a shoal (*i.e.*, the center of the shoal versus the flanks of the shoal) are the primary contributing factors for reservoir potential, while the diagenetic history of the strata is the key to reservoir quality. Wells such as 101/12-14-009-19W3/00, 121/15-16-009-19W3/00, and 101/10-03-009-19W3/00 have relatively thick (up to 2.0 m) heavily oil-stained oolitic grainstone facies (Facies 6), which would suggest they are within the main body of the shoal; whereas, wells such as 141/16-35-09-20W3/00 and 101/16-23-010-19W3/00 lack this consistently thick facies, rather containing a mixture of ooids and peloids (Facies 4 and 5), suggesting that they are located more toward the shoal flank. Characteristics seen in well 101/15-29-003-20W3/00, such as high percentages of peloidal wackestones to packstones (Facies 2 and 3), suggest quiescent subaqueous off-shoal zones.

6. Summary

Preliminary work suggests that micritization appears to have had the greatest impact on porosity within reservoirs in Facies 4 through 6, with dolomitization contributing to a lesser extent. This will need to be confirmed with further study on a large scale in the study area. Blocky calcite sparite and secondary anhydrite cement occlude porosity, while dolomite appears to increase porosity slightly. Micro-fractures may have a minor impact on permeability within the reservoir. Moldic and vuggy porosity are considered as the primary factor impacting both porosity and permeability. Currently, Facies 1 through 3 are considered to be lesser quality potential reservoirs than Facies 4 through 6, although oil is present within these low-porosity, finer grained facies. The potential of production from Facies 1 through 3 may increase as horizontal drilling completion and fracturing techniques advance further. Future work will entail the correlation of the reservoir characteristics with regional mapping along the Shaunavon Oil Field Trend to determine the occurrence and orientation of hydrocarbon-bearing strata within the Lower Shaunavon Member. Although lateral variations between wells have yet to be established and core permeability values have yet to be correlated with each individual facies, some preliminary observations can be made. Facies 1, 2, and 3 can be placed primarily into the lower cyclic mudstone/peloidal wackestone-packstone unit whereas Facies 4, 5, and 6, can be placed, for the most part, into the upper oolitic/peloidal unit. Facies 7 and 8 cap the upper oolitic/peloidal unit.

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