Sedimentology and diagenesis with respect to the reservoir development of the Mississippian Midale Beds in the Pinto-Roche Percee area, southeastern Saskatchewan

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Introduction

The Mississippian Midale Beds in southeastern Saskatchewan started commercial production in 1953 and contain some of the most productive hydrocarbon reservoirs in the northern part of the Williston Basin (Yang, 2008). Dolostone and limestone reservoirs in the Midale Beds have been a major source of hydrocarbons within the basin and production has had steady growth since the 1980’s. A large amount of the oil is trapped subadjacent to a sub-Mesozoic unconformity surface that truncates Mississippian strata in a northeastward direction (Nimegeers, 2006). Due to this unconformity surface, several major Midale oilfields parallel the west-northwest trending subcrop edge of the Midale Beds (Nimegeers, 2006).

Within southern Saskatchewan in the Mississippian Williston Basin there are several major Midale oilfields. The primary objective of the research is to achieve a better understanding of the reservoir development of the Midale Beds in the Pinto-Roche Percee area (townships 1 & 2 and ranges 6 & 5W2) of southeastern Saskatchewan by looking at the lithology, facies and diagenetic history. A second goal of this project is to compare the nature of the Midale reservoirs in this area which is close to the Canada/US border with those of sub-crop pools such as the Steelman and Weyburn to the North.

The Midale Beds can be subdivided into a basal evaporate unit known as the Frobisher Evaporite and into an upper marine carbonate unit also known as the Midale Carbonates. The base of the Midale Beds is below the lowest bed of the Frobisher Evaporite and defined by the top of a regional bed of argillaceous dolomitic limestone in the uppermost unit of the Frobisher Beds. The upper boundary is capped by the Midale Evaporite of the Ratcliffe Beds which serves as an important cap rock for the reservoirs of the southeastern Saskatchewan Midale Beds (Fusezy, 1960).

There have been many diagenetic phases and features that have been noted (Liu, 2011) to occur in the Midale Beds. These features vary from calcite, dolomite, anhydrite, bitumen, dissolution, deformation features and stylolitization and can be identified based on both core and thin sections.
Map 1. Map of southeastern Saskatchewan showing oilfields in the area. Steelman and Weyburn pools are located further north near the subcrop edge, while Pinto and Roche Perce pool are located further south close to the Canada/US border.

Methods

Initial interpretations and discussion are based off of 11 cores; 6 cores were located in the Pinto Pool and 5 cores were located in the Roche Perce Pool. Cores were logged and described based on lithology, structure, porosity, colour and other noticeable factors. Each core was then separated into facies and two to three rock samples were then cut and taken from each different facies in each core. From the rock samples taken from the 11 cores 43 thin sections were cut, impregnated with blue epoxy and alumina polished.

Throughout the Pinto-Roche Perce area, the Midale Beds can be separated into three main lithology types. Anhydrite, limestone and dolostone. The anhydrite lithology can be separated into three facies; the limestone lithology into six facies; and the dolostone lithology into two facies. Each of these lithologies can be separated into different facies, identified based on the diversity and abundance of trace fossils and skeletal fragments, sedimentary structures, lithology and colour. Based on these factors paleoenvironments can be distinguished while other features such as peloids, oncoids and intraclasts can be helpful for interpreting energy levels and different marine settings and environments. These facies are interpreted to represent a variety of depositional environments. Facies distribution of the Midale Beds throughout the Pinto-Roche Perce study area give insight into the restriction of certain facies and show the development of several transgressive-regressive sequences throughout the areas depositional history.

The Pinto-Roche Perce area can be subdivided into several transgressive-regressive sequences that developed in response to sea level fluctuations. The Midale Beds throughout southeastern Saskatchewan are typically dominated by shallow marine facies which suggests that deposition occurred within an epeiric sea. Interpretations are based off cross sections and core descriptions.
The anhydrite lithology can be divided into three very specific facies throughout the Pinto-Roche Perceee study area. The A1 facies is easily distinguishable by the massive looking nodular mosaic anhydrite located at the base of core. The facies represents the Frobisher Evaporite of the Midale Beds and a sabkha environment. A2 is identified by the characteristic laminated and mottled interbedding of anhydrite near the top core and is representative of the Midale Evaporite of the Ratcliffe Beds and a shallow playa lake. Lastly, A3 is most clearly recognized due to the prominent anhydrite nodules which are located within the surrounding brown limestone. A3 is stratigraphically located at the base of the lower Midale Carbonate, overlying the Frobisher Evaporite and can be interpreted as an algal marsh environment. All three facies can be correlated via wireline logs with distinct density porosity and resistivity log signatures. Porosity and permeability is very poor in the anhydrite facies as a whole and both the A1 and A2 represent evaporitic caps to the underlying hydrocarbon reservoirs.

The limestone lithology is broken down into six different facies with four facies located within the Pinto Pool and two more facies found in the Roche Perceee area. Limestone facies are separated and identified primarily based on abundance and diversity of the skeletal assemblage and trace fossils as well as colour and porosity. As a whole, shallow marine environments are portrayed by the limestone facies and representative of sea level change over time. The limestone facies are challenging to correlate throughout wireline logs as log signatures and characteristics between facies are difficult to distinguish and pinpoint. All limestone facies show some potential reservoir quality with L2 and L4 showing the highest potential in the Pinto Pool with porosity values that continuously exceed 10%. Both limestone facies of the Roche Perceee area have extremely variable porosity and permeability values with certain wells demonstrating porosity as high as 27% and permeability as high as 7.31mD suggesting good reservoir potential and quality.

Two dolostone facies are identified throughout the study area and both reside in the Pinto Pool. The dolostone facies stratigraphically represent the upper Midale Carbonate and are typical of shallow lagoon environments. The two different facies are easily identified either by the distinct lamination of D1 or by the chalky grey colour of D2. Both dolomite rich facies show good potential reservoir quality with favourable porosity and permeability values with D2 showing slightly higher potential than D1.

**Conclusions**

Eleven lithofacies were identified in the three transgressive-regressive parasequences that characterize the Mississippian Midale Beds in the Pinto – Roche Perceee area of southeastern Saskatchewan. The facies represent a variety of depositional environments and facies distribution is primarily controlled by minor sea-level changes. Lithology throughout the Pinto – Roche Perceee area varies from that of the Steelman and Weyburn pools as the vuggy limestone and marly dolostone are not present. This is most likely due to a lack of subaerial exposure in the Pinto – Roche Perceee area, leading to different depositional settings and diagenetic processes.

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Figure a). Well 01/08-16-001-5W2 from the Pinto Pool with facies noted on core.

**Facies:**
A1al/A1bl: Nodular Mosaic Anhydrite/Laminated Limestone
A2al/A2bl: Interbedded Laminated & Mottled Evaporite/Organic Rich Mudstone
A3: Nodular Anhydrite
L1: Crinoidal/Fossiliferous Packstone-Grainstone
L2: Crinoidal Wackestone
L3: Crinoidal Packstone
L4: Peloidal/Intraclastic Wackestone-Packstone
L5: Oncoidal/Intraclastic Wackestone-Packstone
L6: Fossiliferous Wackestone-Packstone
D1: Laminated Dolostone
D2: Dolomitic Mudstone-Wackestone

Figure b). Well 91/16-22-001-6W2 from the Roche Perce Pool with facies noted on core.
References


Nimegeers, A.R., (2006), Stratigraphic relationships and depositional model of the Mississippian Midale beds in the Steelman-Bienfait area, southeastern Saskatchewan, Master’s degree thesis, Department of Geology, University of Regina, 132p.
