DISTRIBUTION OF POROSITY AND FACIES IN THE GAYS RIVER FORMATION, SOUTH-SIDE ANTIGONISH HARBOUR: IMPLICATIONS AS A POSSIBLE HYDROCARBON RESERVOIR

by

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ABSTRACT:

The Gays River Formation is a limestone unit located at the base of the Windsor Group, located adjacent to paleotopographical basement highs. It is in non-conformable contact with the underlying pre-Carboniferous basement rock, which, in the case of the south side Antigonish Harbour outcrop, is a granodiorite. Underlying organic-rich shales of the Horton Group, and overlying evaporite deposits of the Bridgeville Formation, combined with the natural upward slope of the underlying basement provide an ideal environment for a hydrocarbon trap to occur. In this study, the lithological constituents and porosity were examined in hand sample as well as thin section. Four facies were identified, bafflestone, wackestone, mudstone and a mixed wackestone-bafflestone. The porosities ranged from 10%-31% and showed no apparent preference to facies-type. A representative cross-section of the area was made from the combination of measured sections from the field and the lab data, and from this the distribution of these facies and porosity, with respect to the basement rock was studied. The wackestone was found to be the most extensive facies, and the bafflestone was restricted to regions of immediate contact with the granodiorite basement. Porosity values combined with qualitative assessments of reservoir rocks suggest that the Gays River Formation shows good potential as a reservoir rock.

Chapter 1: Introduction:

1.1 Scope and Content

The Gays River Formation lies at the base of the Windsor Group, a widespread stratigraphic unit throughout Carboniferous basins in the Maritimes. The Windsor Group consists of carbonate deposits, large evaporite deposits, and interbedded clastic rocks, and is a very economically important unit for the Maritimes. Interest in the Carboniferous basins in the Maritimes has increased because of knowledge that hydrocarbon reservoirs of potential economic importance have been discovered. Stakes have been claimed in many regions in the Maritimes by oil companies, interested in these units for their hydrocarbon potential. For this reason I am studying at the Gays River Formation South Side Antigonish Harbour outcrop from the perspective of its potential as a hydrocarbon reservoir. By examining at the distribution of facies, as well as the distribution of porosity with respect to the basement rocks, I am trying to show the extent of this units' potential as a reservoir rock.

1.2 Location and Access:

The study site is located on the South Side Antigonish Harbour, at the Ridge Brokers Ltd. Quarry. It is located approximately 5 km north off of the highway 104, and accessed via the quarry access road (fig 1).

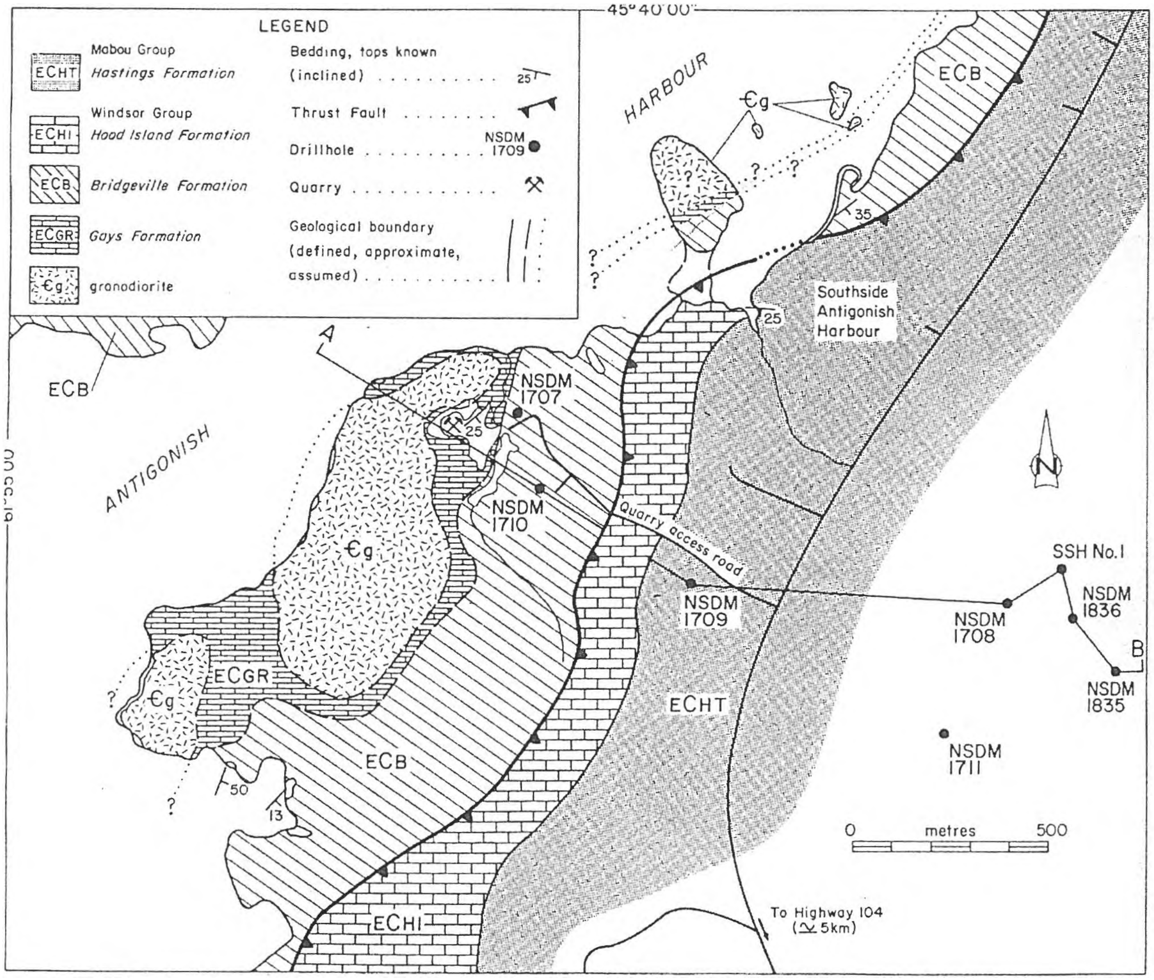


Fig. 1

Road map of Ridge Brokers Ltd. Quarry, with local geology (Boehner and Giles 1993)

Chapter 2: Methods

2.1 Measured Sections:

The first method which I used to gather information was through measuring sections in the field. I chose ten outcrops spaced throughout the quarry that covered the area, and measured each of these sections for lateral relationships, as well as descriptions and thickness of beds.

2.2 Slabs:

From each of these 10 sites I took samples of the representative facies. The samples were then cut using a slab saw, and then each slab was polished to get a fresh face on each of the samples. The process of polishing these slabs consisted of 4 different stages. First, the edges needed to be removed from the face of the cut, and it needed to be flat. In order to accomplish this I used a grinding wheel with a grit applied to produce a level face to polish. After this I used the vibrating lap for three stages of polishing, each with a more fine grit. In between each stage it was very important that the rock was washed clean of all of the previous grit.

2.3 Stereo Microscope:

After these slabs were cut, I performed point counts on each one using a stereo zoom microscope by applying a transparency with randomly placed marker dots on it to the slab. At each point on the transparency I identified the lithological constituent, in order to give an estimation of modal composition as well as percent of macroscopic porosity.

2.4 Transmitted Light Microscope:

Taking samples from each of the sites, I cut 14 of them into smaller blocks for thin sectioning. These thin sections were impregnated with a blue epoxy to emphasize the pore spaces. The thin sections were also stained with Alizarin red S solution, which helps to differentiate between calcite and dolomite crystals by staining the calcite red, while the dolomite remains colorless. I performed point counts on each to get an accurate modal analysis. This was done using a microscope stage that moves in the x-y directions at controlled intervals. I moved the microscope in intervals of 1.5 mm, creating a grid across the thin section, identifying the lithological constituent under the crosshairs of the microscope at each point. Detailed descriptions of the slides were also done to describe relationships between different stages of cementation and porosity. The point counts were also used to identify the different facies within the Gays River Formation using Embry and Klovan's (1971) extension to Dunham's(1962) Classification scheme (fig. 2),

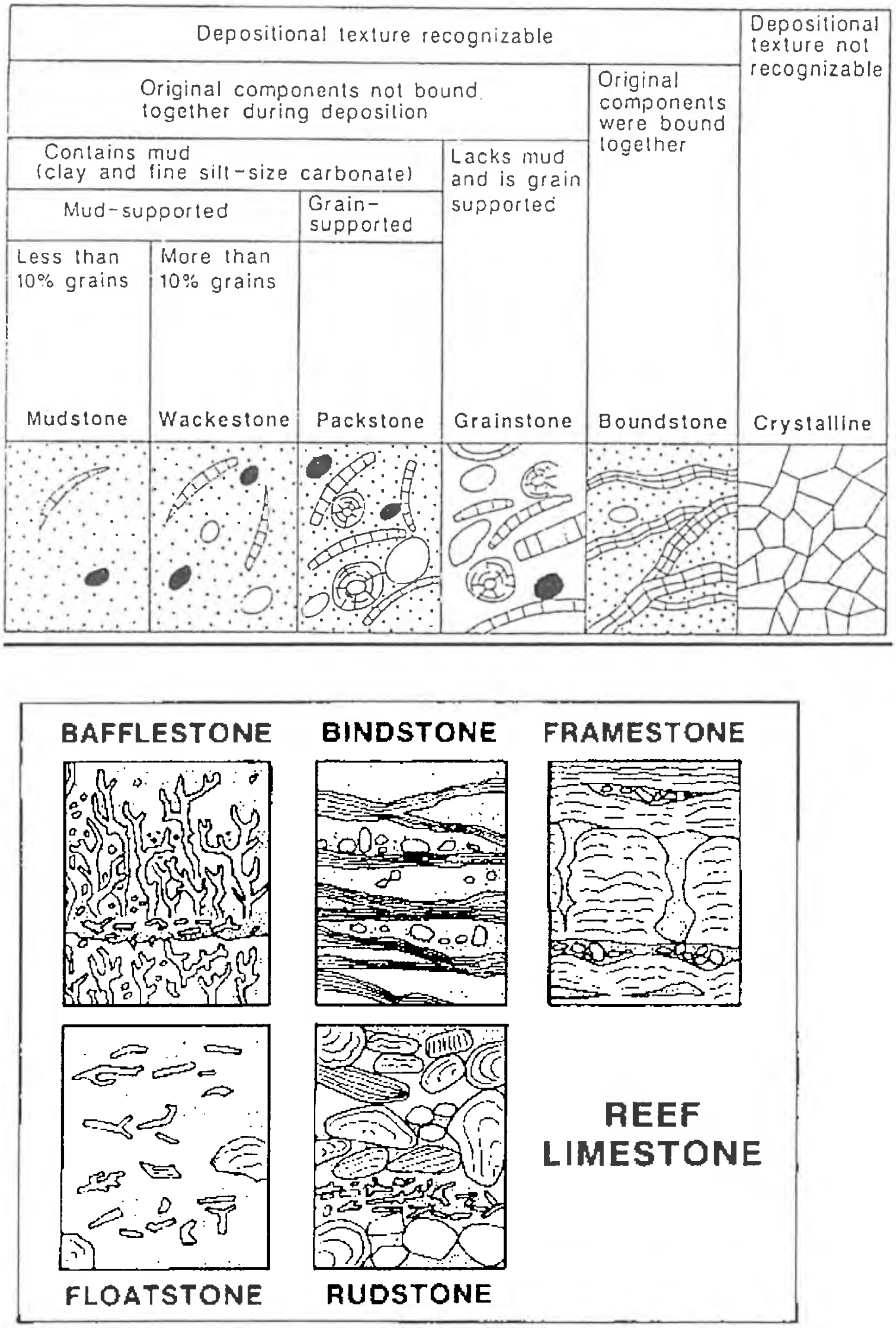


Fig. 2

(Top) Dunham's (1962) classification of carbonate rocks

(Bottom) Embry and Klovan's (1971) extension to Dunham's classification

Chapter 3: Background

3.1 Previous Work:

The first study giving a Carboniferous age for the "Gypsiferous Series" was by Brown and Smith (Halliburton, 1829), but the first to correlate and give a correct description of the Windsor, as well as give it a Carboniferous age using faunal, as well as stratigraphic means, was Lyell (1843). Dawson (1847) then subdivided this series into what he described as a lower estuarine or lacustrine plant-bearing formation, and an upper marine formation, and in 1873 he named these the Horton Series, and the Windsor Series respectively. In 1867, Hartt produced the first detailed description of the Windsor Group at Windsor, which later became Bell's type section (1927). Bell produced a composite section of the Windsor group, which included the Macumber Formation, now thought to be the lateral facies equivalent to the Gays River Formation. In 1979, Boehner and Giles named the formation at the base of the Windsor group the Gays River Formation, and correlated numerous outcrops around the province, including the outcrop that I am studying at the South Side Antigonish Harbor location. More recently Boehner and Giles (1993) produced a description of the Windsor Group in the Antigonish Basin, with a representative cross-section of the area (fig. 2).

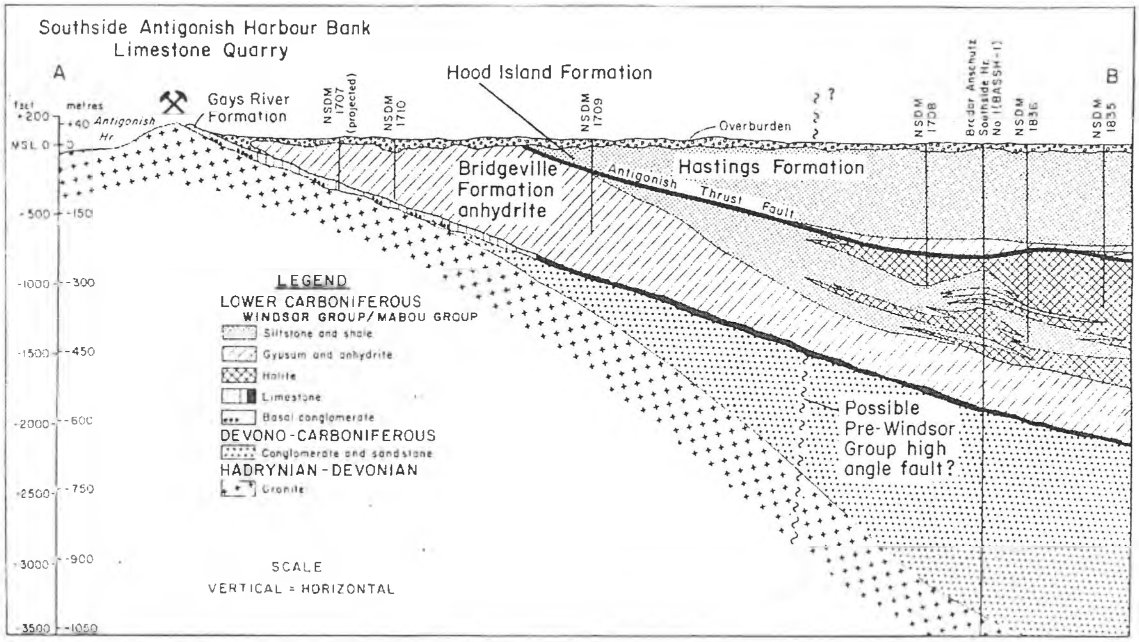


Fig. 3 Cross section by Boehner and Giles (1993) of Geology of South Side Antigonish Harbour.

3.2 Geology of the Windsor Group:

The Windsor Group is mid-to-late Visean in age (Giles and Boehner, 1993), and is widespread throughout Carboniferous basins in the Maritimes. It consists of interbedded carbonate deposits, with evaporitic and siliclastic deposits. It commonly lies unconformably on pre-Carboniferous basement, as well as in nonconformable contact with the clastic rocks of the Horton Group. It is overlain conformably by the mudstones of the Mabou Formation in some areas, and unconformably by younger Carboniferous units in others. The Windsor Group is of great economic significance in the Maritimes because of its large gypsum, salt and limestone deposits. It also hosts industrial metal deposits in the Gays River

Formation. Most recently the Windsor Group has been studied with interest as a possible host to hydrocarbon reservoirs. With impermeable evaporite layers commonly deposited overlying porous carbonate units; in the right conditions it could host significant hydrocarbon reservoirs of economic importance.

3.3 Geology of Gays River Formation:

The Gays River Formation occurs at the base of the Windsor Group, and is mid-Visean in age. It is a mound deposit, which lies non-conformably on the pre-Carboniferous basement, and occurs in areas of paleo-topographical basement highs. The formation consists of a siliclastic deposit or breccia, bank and interbank facies as described by Boehner and Giles (1979). The interbank facies consists of thinly bedded mudstones and wackestones, with some pockets of peloidal packstone. This packstone is the main evidence that the Gays River Formation is the lateral facies equivalent to the Macumber Formation. The shelly fossils are fragmental and sparse, and appear to be transported in from other areas. This unit rarely exceeds 3 meters thickness. This unit is thought to be deposited in sub tidal environment, down slope relative to the bank facies. The depositional environment would have a moderate current, but not enough to remove the fine grained matrix. It is thought that the lateral transition from the Gays River Formation to the Macumber Formation occurs in concordance with overlying of the Horton Group clastic rocks.

The bank facies consists mainly of a bafflestone deposit, formed by the growth of calcareous algae, which both Ryan (1978) and Hatt (1978) assigned to the family

Codiaceae. This unit can be as thick as 3 meters, and lies on the pre-Carboniferous basement. The matrix is described as dolomitic, but in the case of my study this was not found to be true. The matrix also contains peloid rich areas. The porosity is described as low, and the permeability is thought to be low (Boehner and Giles 1979). This deposit is thought to be typical of warm marine waters, in an intertidal, to sub tidal range. Johnson (1961) placed the algae from low tide level, to 10 meters depth, by looking at the typical depths in which this form of calcareous algae is found. The bank facies grades laterally as well as vertically to the interbank facies.

Boehner and Giles (1979) also found that the base of the bank deposits could contain irregularly distributed siliclastic sediments, or breccias. This deposit is limited in its lateral extent and shows poor sorting with very angular clast. This is thought to be deposited in the early stages of the marine transgression, and is the product of marine reworking of detritus, so the environment is an intertidal one with high wave energy and shallow water. Although a breccia of limestone with large blocks of granodiorite was found at one contact site in the South Side Antigonish Harbour location, there was no real siliclastic deposit as described by Boehner and Giles.

Chapter 4: Results

4.1 Facies Types:

One of the main objectives of this study was to classify the different facies types, and their distribution with respect to the inlier. I was able to classify the rocks into 4 main facies, applying Dunham's (1962) classification of carbonate rocks (fig. 4) based on the microscopic point counts performed. The different facies found in the Gays River Formation were mudstone, wackestone, a combined wackestone-bafflestone, and bafflestone. The results of each of the point counts are presented in Appendix 1.

4.1.1 Bafflestone:

Samples 6-B and 8-B were classified as bafflestone, using both the microscopic point counts (Appendix 1), as well as looking at the hand samples. A bafflestone is a defined by Embry and Klovan (1971) as a carbonate rock in which the original components are bound together, causing the deposition of matrix sediment through passive means, by slowing down water velocity. In this case, the mound deposit occurs at a paleotopographic basement high.

Hand Sample:

In hand specimen (fig 4), the bafflestone is dominated by the presence of a calcareous algae, which gives the rock a vertical fabric. The algae are surrounded by lime mud matrix, and fossil fragments are sparsely dispersed. The algae also show a fan shape, which is the result of being cut at an oblique angle. There are larger and more abundant clasts of granodiorite within the bafflestone caused by the erosion of the underlying basement rock, which is in nonconformable contact with the bafflestone. On weathered surfaces this unit is grey-brown in color, with white calcareous algae giving a vertical fabric throughout. On a fresh surface, as seen in figure 5, the bafflestone shows a darker brown color, with prominent calcareous algae growing vertically throughout the facies. In hand sample, a few bivalve fossil fragments are visible, but fossil content is sparse.

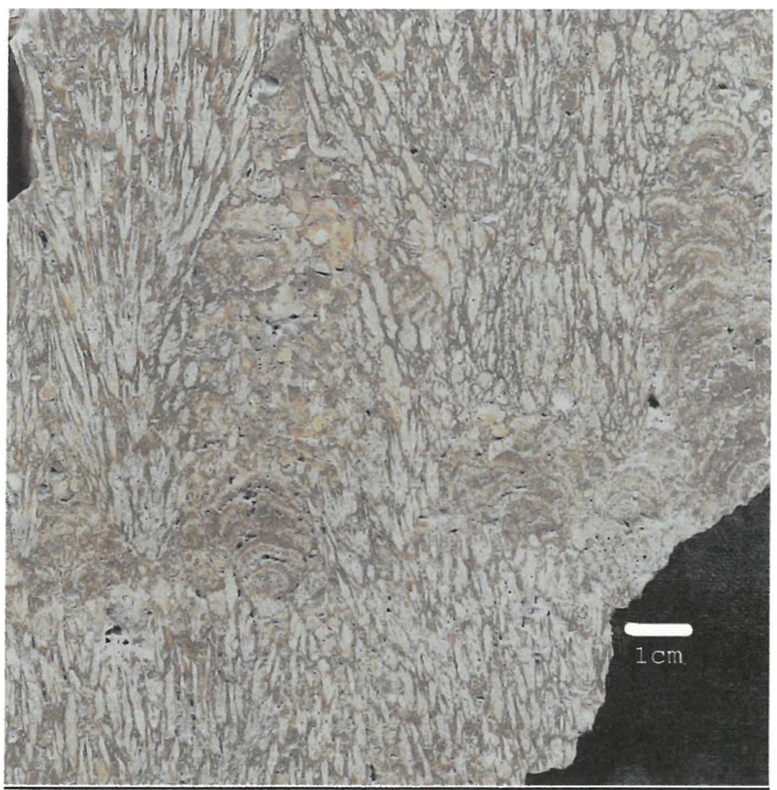


Fig. 4- picture of a polished slab of bafflestone facies

Thin Section:

The most evident microscopic feature of the bafflestone (fig. 6) is that the calcareous algae are very poorly preserved. The internal structure of the algae is recrystallized, and shows a very high intercrystalline porosity, which appears secondary in nature. The distinguishing microscopic characteristic of the calcareous algae is the vertical fabric it produces in the rock. Less obvious characteristic is the circular shape if it has been cut as a cross-section (fig 7). This facies shows little cementation in its pore spaces, and what is there is mostly bladed calcite, typical of shallow burial processes. The shelly fossils in the bafflestone are commonly fractured, similar to those seen in (fig 10), which could be the result of being transported, and deposited out of the original living environment. The lime mud shows an increased crystal size, as a result of the process of neomorphism. The differing sizes of the grains in some areas suggest that the process was a porphyroid neomorphism.

4.1.2 Wackestone-Bafflestone:

The samples 3-B and 8-T were classified as a mixed wackestone-bafflestone facies. I chose this classification because the facies contains pockets enriched in the calcareous algae which are the bafflestone forming component, as well as parts which are defined as a wackestone, which is a mud-supported carbonate rock with greater than 10% grains.

Hand Sample:

In hand sample (fig 5), this facies has two distinct regions. One region is dominated by dark brown lime mud. The lighter grey-brown regions differ because they are enriched in calcareous algae. The algae show a vertical fabric, and are bound together during growth, but this facies only contains pockets of these algae, which are surrounded by dark, sparsely fossiliferous lime mud.

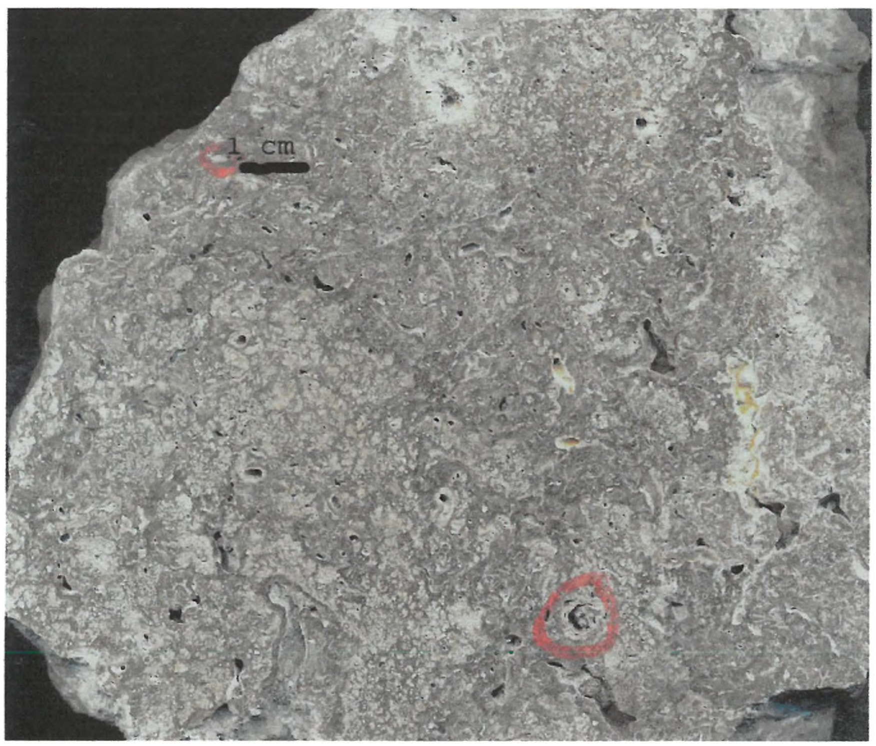
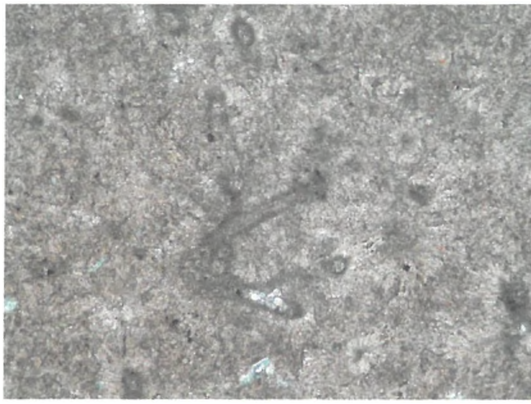


Fig. 5 – polished slab of wackestone-bafflestone facies

Thin Section:

Thin section shown (fig. 7.2) shows a circular shape of the calcareous algae. This indicates that the algae have been cut in a transverse-section. The algae are preserved as a micritic calcite around the edge, with a very porous recrystallized internal structure. There is little deep burial cementation, and the amount of bladed calcite varies from 10%- 4% (Appendix 1). The areas enriched in calcareous algae appear to have very little cementation, similar to the bafflestone facies, whereas areas with more lime mud tend to have increased amounts of cement in the pore space, including some deep-burial, blocky cement. The red colour of the stained area of the thin section shows that the rock consists of calcite, and there is very little evidence of dolomitization.



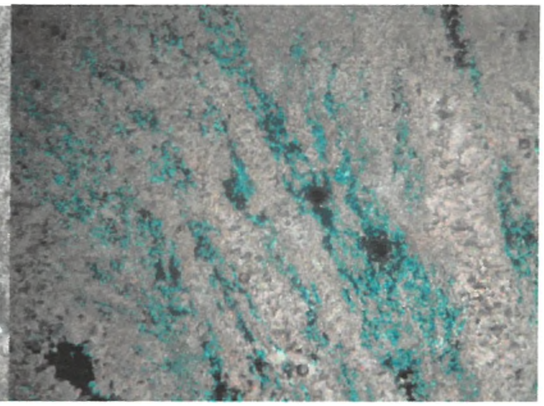
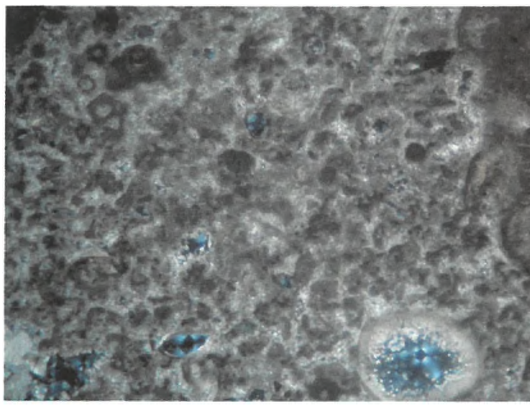


Fig. 6.1 microbial texture entrapping lime mud matrix (plain polarized light)

Fig. 6.2 Thin Section showing poorly preserved calcareous algae



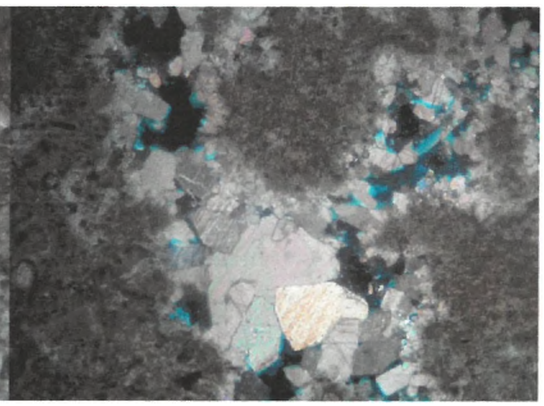
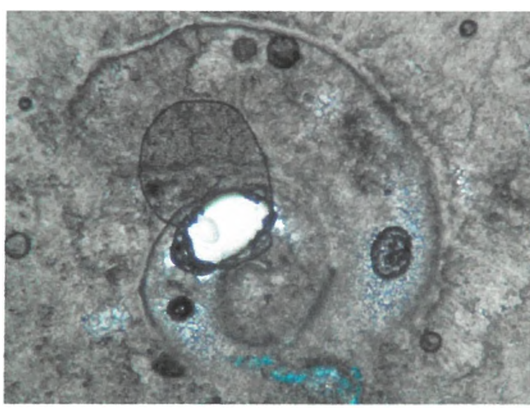


Fig. 6.3 shows thin section of peloidal packstone found in mudstone

Fig. 6.4 – Channel-style pore space showing 2 distinct cementation events



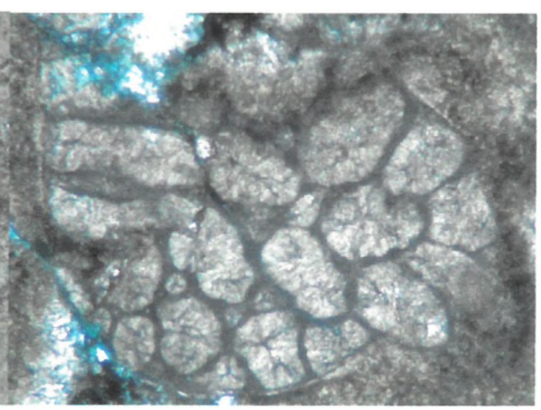


Fig. 6.5 – Gastropod shell showing recrystallization and intragranular porosity

Fig. 6.6 – Thin section of a preserved Bryozoan (both in plain polarized light)

4.1.3 Wackestone:

The most laterally extensive facies in the Gays River Formation is the wackestone facies, defined by Dunham (1962) as a carbonate rock that is mud-supported, and contains more than 10% grains. Samples 10-B, 9-M, 7-B, 4-T, 3-T, 2-T, 2-B, and 1-T were all classified as wackestones using microscopic point counts (Appendix1).

Hand Sample:

In hand specimen (fig. 7), the wackestone is very dark brown, due to the high content of lime mud, and is noticeably fossiliferous. Ostracod, bivalve, and gastropod fossils were all visible in hand sample. The grain sizes ranged from 1-4 mm for the grains, with the matrix lime mud being very fine-grained. The appearance of a polished face of the wackestone is a dark brown matrix, with lighter brown areas created by fossil content, as well as intragranular porosity created be the inside of shells.

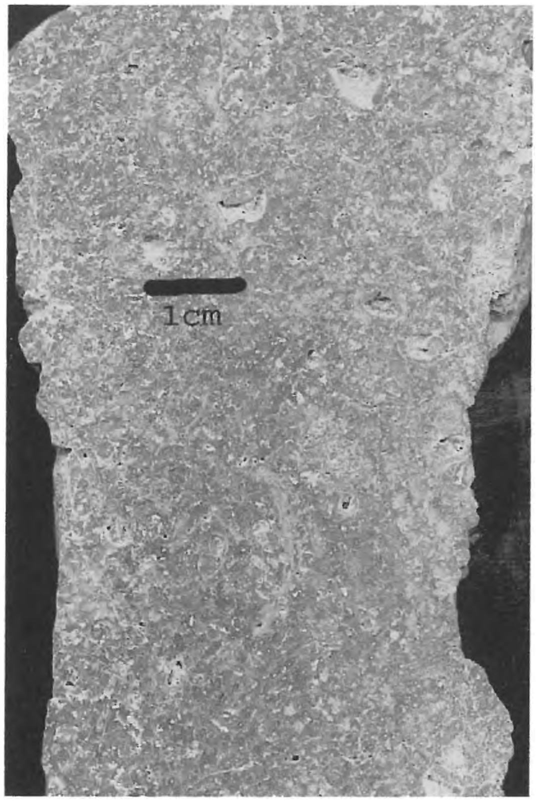


Fig. 7 – polished slab of wackestone, dominated by dark brown lime mud matrix

Thin Section:

In thin section, the wackestone is dominated by microcrystalline lime mud matrix, which accounts for 47-62% of the rocks composition, and a microbial matrix component accounts for 9-22%. The wackestone facies also contains peloids as a consistent contributor to the composition of the rock. The wackestone is the most enriched in shelly fossils of the facies within the Gays River Formation. Most abundantly found are bryozoans, which account for as much as 8% of the rocks composition, but are usually partially dissolved. Also commonly present are bivalves and ostracods. The shelly fossils are commonly fragmented, especially the bivalves which shows that they are possibly out of their habitat, but transported from nearby fossiliferous regions by wave currents. The relationship of different cementation events with each other and the pore space clearly shows 4 different events of cementation (fig. 7.3). The wackestone shows the best relation of these events, and also has the largest blocky calcite cement, up to 3mm.

4.1.4 Mudstone:

Hand Sample:

The only sample that I gathered from the study site that is classified as a mudstone is sample 1-B. Dunham's (1962) classification of carbonate rocks defines a mudstone as a matrix supported carbonate rock with less than 10% grains. The sample is a dark brown, due to the dominant component of the lime mud, as well as the microbial matrix. The mudstone is sparsely fossiliferous, with some bivalve and ostracod shells visible in hand specimen. In hand specimen, this sample is very difficult to distinguish from a wackestone.

Thin Section:

The mudstone is dominated by lime mud matrix, which has undergone neomorphism during burial, resulting in a slight increase in grain size. This rock can be classified using Dunham's classification scheme as a mudstone, because it is a mud-supported rock, with less than 10% grains. This sample also shows pockets of a peloidal packstone (fig. 6.4), which is a grain-supported rock where mud is still present. These pockets often occur in between clumps of microbial matrix. The cementation in this unit occurs as shallow burial, fibrous and bladed calcite cements, as well as deeper granular and late-stage blocky large calcite cement. The fibrous cement occurs as an isopachous cement, coating the outside of grains like peloids, and some shells. Ostracod shells are commonly fractured, but intragranular pore space shows excellent relationship between different cementation events. It shows the fibrous calcite, then bladed, then granular, and finally, large blocky cement.

4.2 Porosity:

4.2.1 Bafflestone:

The porosity of the thin section was found to vary from 17-31% from the point counts. The pore spaces show very little cementation, and what is there is smaller, bladed shallow burial calcite. In the bafflestone facies, one-half to two thirds of the pore space are intercrystalline pores within the algae (fig. 6.1). These pores show very good interconnectedness within the algae columns, but appear to be isolated from the rest of the pores. The other pore space shows moderate interconnectedness, and contains some cementation.

4.2.2 Wackestone:

The porosity of the wackestone facies shows the greatest range of variation from 11%-31%, with the average near 20%. This facies shows variation in the type of pore space, from intergranular and intragranular (fig 8.2), which are both commonly primary porosities and account for up to 9% of the total volume, to the secondary vug and channel-style porosities (fig. 8.3), which can account for as much as 10% and 7% respectively. The primary intragranular porosity is commonly the result of hollow shelly fossils, whereas the intergranular porosity is caused by the contact of two grains, leaving a space between them.

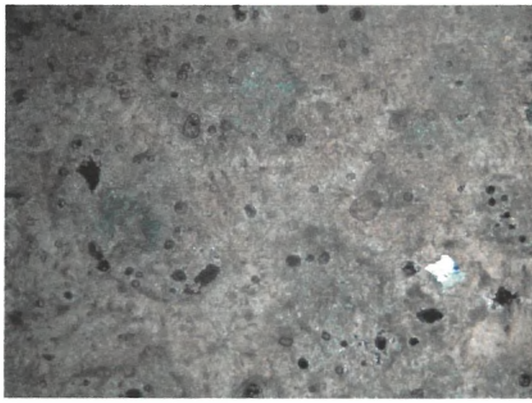
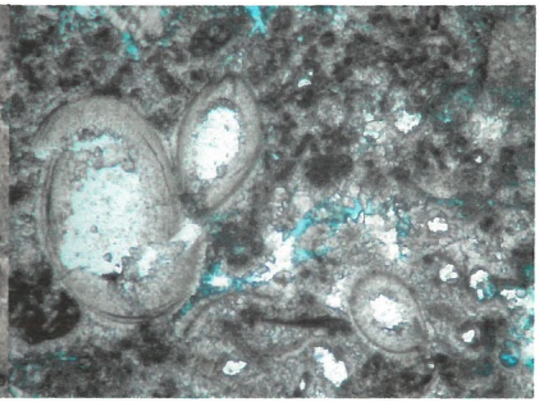



fig. 8.1 – cross-section of calcareous algae in bafflestone, appear more circular, blue epoxy shows the internal structure of the calcareous algae is highly porous

fig. 8.2- fractured ostracod shells showing intragranular porosity (ppl)

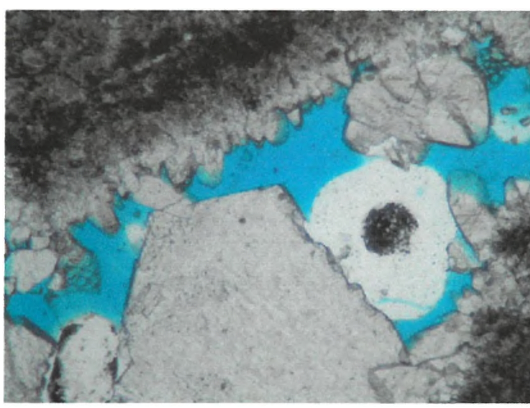
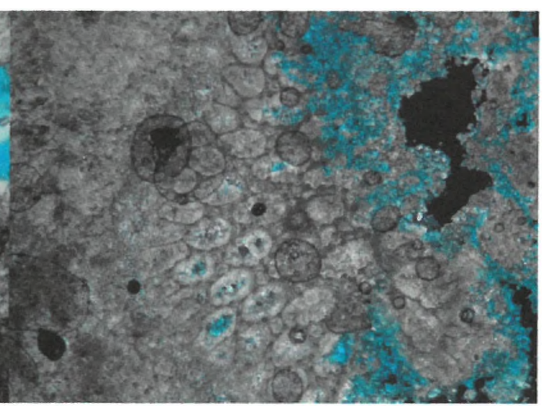



fig. 8.3 – Channel pore space, showing bladed cementation, typical of shallow burial.

Fig. 8.4 – Bryozoan shell that is partially dissolved creating secondary pore space.

4.2.3 Bafflestone- Wackestone:

The mixed facies of bafflestone-wackestone shows some porosity characteristics of both the bafflestone and the wackestone facies. The total porosity for this facies ranges from 19-21%, with the intercrystalline (fig. 6.2) porosity related to the calcareous algae ranging from 5-11%. In this style of pores, there is very little calcite cement, because of the small size, and relative isolation from other pore spaces. The other pore spaces consist mostly of vug-style porosity, which is secondary in nature, and accounts for up to 9% of the rock's modal composition, and to a lesser extent channel porosity, which accounts for up to 2%. The primary forms of porosity in this facies are inter-, and intragranular, the total of which account for up to 4% of the modal composition. The porosity overall, shows a moderate interconnectedness. The algae-related intercrystalline pore space is very interconnected, within the algae, but appears to be isolated from the other pore spaces by the outer wall of the calcareous algae.

4.2.4 Mudstone:

The single mudstone sample (1-B) has a porosity of 19% (Appendix 1), which consists mostly of channel, vug and fracture porosities that appear to be secondary from their relationship with the surrounding rock. Intergranular pore space is primary, and the intragranular is mostly primary, although can be secondary. The mudstone porosity shows moderate to good interconnectedness, possibly due to the secondary nature of most of the pore space.

4.2.5 Discussion:

The microscopic evaluation of porosity increased from macroscopic pointcounts from 5-25%. The greatest difference was in the bafflestone, which can be attributed to the poorly preserved internal structure of the calcareous algae, accounting for as much as 20% of the rock volume. The bafflestone has a porosity of up to 31%, but as much as 20% of this is within the algae, and appears isolated from the rest of the pores. The pore space in the bafflestone shows little cementation, with small bladed calcite around the edges of the pore, but little to no deep burial cementation. This could be the result of a number of things, such as the time at which the pores were created, or the path that the fluids traveled through the rock.

The wackestone facies contains porosities that range from 11-31%, with the average being close to 20%. The pores within the wackestone show the greatest diversity of cementation, with four distinct calicite cementation events. The wackestone appears to have well-interconnected pore space. The wackestone also contains the most primary porosity, due to its higher shelly fossil content. This feature could prove to be important when considering the unit as a reservoir rock, because it shows that the wackestone facies will have more porosity originally, and doesn't depend as much on the secondary events. This primary porosity will also provide the ability to carry fluids, which will then increase the porosity through dissolution. This would suggest that the wackestone could have a good permeability.

The mixed bafflestone-wackestone facies has a porosity that varies from 19-21%. This facies, as shown by the name, shows characteristics of both the bafflestone and wackestone in its porosity. This is because it contains areas of high algae content, and so high amounts of intracrystalline algae-related porosity. There are also areas rich in lime mud, like the wackestone, and these contain more primary pores, with greater cementation. Overall, the bafflestone-wackestone has moderate interconnectedness, with the intra-algal porosity being extremely well interconnected, but isolated from pores outside of the algae.

4.3 Cross Section

I was able to identify four different facies through microscopic point counts, combined with the descriptions of hand samples. By combining these data with the measured sections taken in the field, I was able to produce a representative cross-section of the study site (fig.10). The most notable feature of the area is that the wackestone facies is the most abundant, and has the thickest outcrops throughout the area, and that the bafflestone facies is restricted to the immediate vicinity of the basement highs, in direct contact with the underlying basement rock. The wackestone also produces much thicker outcrops than the bafflestone. The bafflestone-wackestone facies is a transition facies, found between the two during the vertical facies transition to wackestone. The mudstone outcrops only once in the sections that I studied, and could be grouped with the wackestone, although as noted above, there are some significant differences. There also should be a transition to wackestone down dip of the bafflestone, as the basement rocks become deeper, but this is not evident in this cross-section.

The porosity values do not appear to show any preference to facies, although, as discussed above, primary porosity may be more facies-selective.

The reason that only 8 sections are shown is because 9 and 10, were stratigraphically much higher, and did not appear relevant to the rest of the outcrops. Both of these units consisted of Wackestone facies.

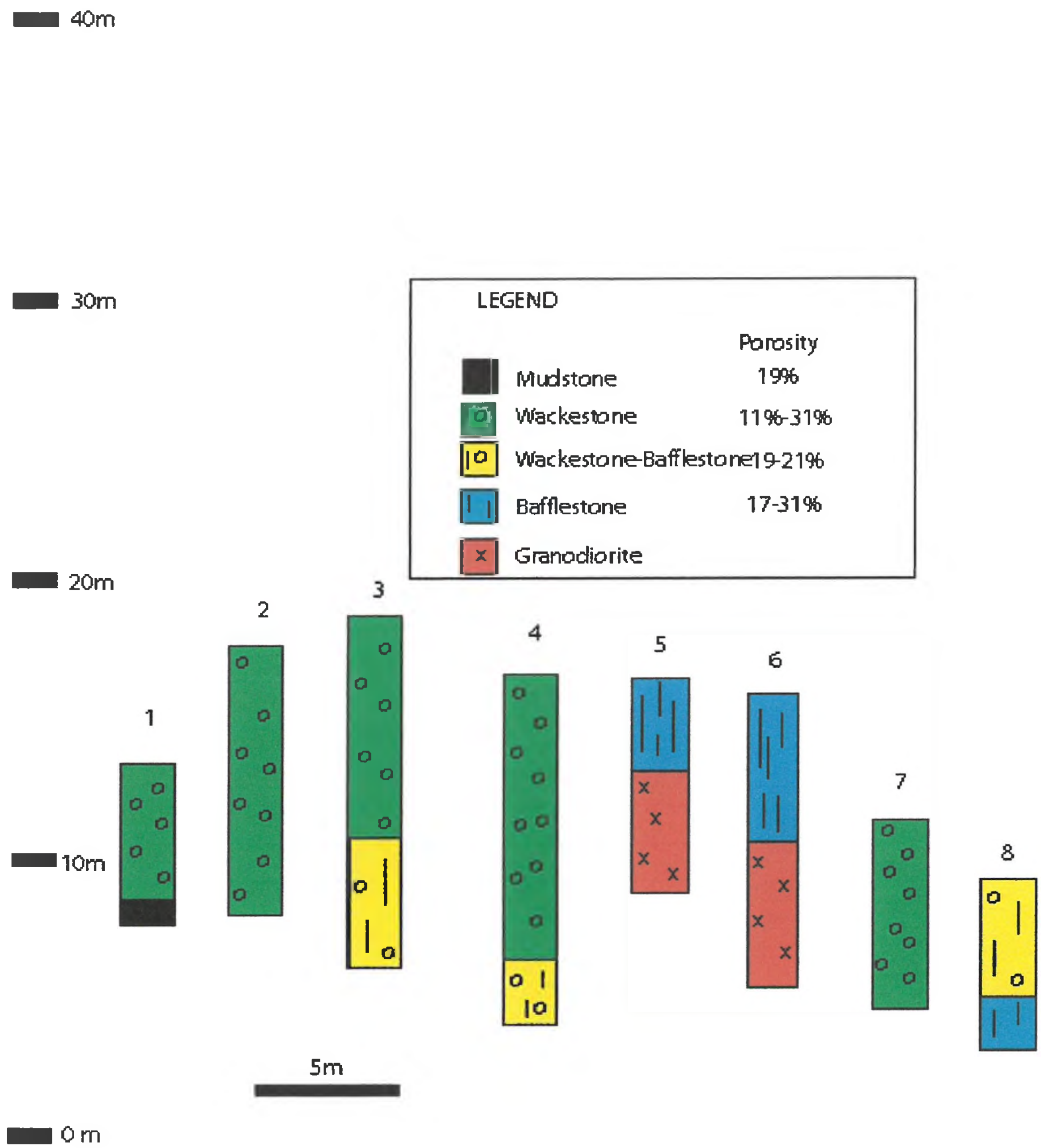


fig. 10

Cross-section showing sites 1-8 at South Side Antigonish Harbour Location

Chapter 5: Conclusions

This examined the distribution of facies and porosity within the Gays River Formation at the South Side Antigonish Harbour outcrop. The Gays River Formation is in the ideal location to form a hydrocarbon reservoir. The cross-section in figure 3 by Boehner and Giles (1993), shows the Gays River Formation is underlain by the Horton Group, which contains organic rich shales that could be a source rock for hydrocarbons. The overlying Bridgeville Formation, which consists of massive Anhydrite deposits, make an excellent impermeable seal. Most importantly, the Gays River Formation is located at the top of a paleotopographic basement high, providing a natural antiformal shape, necessary for hydrocarbon migration, occurring up slopes by density differences, and a place where the hydrocarbon could collect, forming a substantial trap. Within the Gays River Formation, there is a vertical transition from bafflestone to wackestone, with the wackestone being the most abundant facies with the thickest outcrops.

Finally, the values of porosity can be qualitatively assessed through comparison with values from North (1985) (fig. 11). The Gays River Formation shows good to very good reservoir potential (15->20% porosity) through the majority of the samples. This assessment is based purely on percentage of porosity, and does not qualify the formation as a reservoir rock. It does strengthen the view that this formation has good potential as a reservoir rock, and should be studied in further detail.

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APPENDIX 1: Microscopic Point Counts

Sample 1-B

Component	% Composition	Grain Size (mm)
Lime Mud	39	
Stromatolite Matrix	17	
Bladed Cement	11	
Granular Cement	14	
Fibrous Cement	2	
Blocky Cement	8	
Ostracods	3	.5 - 1
Bryozoans	1	1.5
Gastropods		
Bivalve	<1	3
Peloids	5	0.2
Interclasts	<1	
Quartz	<1	
Feldspar	<1	
Porosity	19	

Sample 1-T

Component	% Composition	Grain Size (mm)
Lime Mud	58	
Stromatolite Matrix	7	
Bladed Cement	9	0.2
Granular Cement	10	0.2
Fibrous Cement	4	0.1
Blocky Cement	2	.6 - 3
Ostracods	<1	.5 - 1
Bryozoans	<1	1.5
Gastropods	<1	1.5
Bivalve	2	2.0 - 4
Peloids	5	0.2
Microbial		0.3
Quartz	<1	
Porosity	12	

Sample 2-B

Component	% Composition	Grain Size
Lime Mud	62	
Stromatolite Matrix	9	
Bladed Cement	10	0.1
Granular Cement	6	0.2
Fibrous Cement	1	0.1
Blocky Cement	5	.5 - 3
Ostracods	6	.4 - .8
Gastropods	<1	1.2
Bivalve	<1	1.5 - 2
Peloids	5	.1 - .2
Microbial	1	0.2
Interclasts	<1	0.5
Quartz	<1	.5 - .8
Feldspar	<1	0.5
Porosity	11	

Sample 2-T

Component	% Composition	Grain Size (mm)
Lime Mud	47	
Stromatolite Matrix	19	
Bladed Cement	6	.1 - .3
Granular Cement	5	.1 - .3
Fibrous Cement	7	.1 - .2
Blocky Cement	3	.5 - 2.5
Ostracods	4	.5 - 1.2
Bryozoans	1	1.5 - 3
Gastropods	1	2.5
Bivalve	1	2 - 4.5
Peloids	1	.1 - .2
Microbial		
Brachiopods	1	.5 - 2
Interclasts	<1	0.3
Quartz		
Feldspar		
Porosity	22	
Intergranular	5	
Intragranular	4	
Algal (intercrystalline)		
Vug	10	
Channel	2	
Fracture	1	

Sample 3-B

Component	% Composition	Grain Size (mm)
Lime Mud	45	
Algae	15	
Bladed Cement	10	.1 - .2
Granular Cement	7	0.05
Fibrous Cement	3	0.1
Blocky Cement		
Ostracods	<1	.4 - .5
Bryozoans	<1	2.5
Gastropods	<1	1.5
Bivalve		
Peloids	3	.2 - .3
Brachiopod	<1	1.2
Ooids	<1	1
Calcareous Algae	15	
Interclasts		
Quartz	<1	0.2
Feldspar	<1	0.3
Porosity	19	
Intergranular	3	
Intragranular	0	
Algal (intercrystalline)	11	
Vug	3	
Channel	1	
Fracture	1	

Sample 3-T

Component	% Composition	Grain Size (mm)
Lime Mud	47	
Stromatolite Matrix	22	
Bladed Cement	5	.01 - 0.05
Granular Cement	4	.1 - .2
Fibrous Cement	1	0.01
Blocky Cement	<1	0.8
Ostracods	2	.5 - 1
Bryozoans	8	2 - 2.5
Gastropods	2	1 - 2.3
Bivalve	<1	1
Peloids	5	0.1
Microbial	1	0.1
Brachiopod	<1	1.5
Halite	2	0.05
Quartz	<1	.1 - .2
Porosity		
Intergranular	3	
Intragranular	4	
Algal (intercrystalline)	0	
Vug	13	
Channel	7	
Fracture	<1	
TOTAL	31	

Sample 4-B

Component	% Composition	Grain Size (mm)
Lime Mud	39	
Stromatolite Matrix	13	
Bladed Cement	12	0.05
Granular Cement	12	.05 - 1
Fibrous Cement	3	0.05
Blocky Cement	<1	0.5
Ostracods	2	.8 - 1
Bryozoans	2	1.5 - 3
Gastropods	1	1.5 - 2
Bivalve	8	2.0 - 6
Peloids	4	.2 - .4
Brachiopod	1	4
Ooids	<1	0.7
Interclasts	1	0.9
Quartz	<1	0.2
Feldspar	<1	0.2
Plag	<1	0.1
Porosity	17	

Sample 4-T

Component	% Composition	Grain Size (mm)
Lime Mud	49	
Stromatolite Matrix	15	
Bladed Cement	3	.05 - .1
Granular Cement	7	.05 - .2
Fibrous Cement		
Blocky Cement	1	1 - 1.5
Ostracods	<1	1.2
Bryozoans	5	1.0 - 2
Gastropods		
Bivalve	<1	3.5
Peloids	11	.1 - .3
Microbial	9	0.5
Porosity	%	
Intergranular	3	
Intragranular	2	
Algal (intercrystalline)	2	
Vug	7	
Channel	2	
Fracture	1	
TOTAL	17	

Sample 6-B

Component	% Composition	Grain Size (mm)
Lime Mud	50	
Stromatolite Matrix	3	
Bladed Cement	6	0.1
Granular Cement	<1	0.05
Fibrous Cement	<1	0.05
Ostracods	<1	0.5
Peloids	2	0.1
Calcareous Algae	33	
Interclasts	4	.2 - 5.8
Porosity		
Intergranular	1	
Algal (intercrystalline)	20	
Vug	8	
Channel	2	
TOTAL	31	

Sample 7-B

Component	% Composition	Grain Size (mm)
Lime Mud	59	
Stromatolite Matrix	18	
Bladed Cement	2	.05 - .1
Granular Cement	1	0.01
Ostracods	1	.5 - 1
Bryozoans	3	1 - 2.2
Gastropods	1	.7 - 1.2
Bivalve	<1	2
Peloids	7	.1 - .3
Microbial	2	0.1
Calcareous Algae	4	
Interclasts	<1	0.2
Quartz	1	.1 - .2
Feldspar	<1	0.1
Porosity		
Intergranular	<1	
Intragranular	1	
Algal (intercrystalline)	5	
Vug	6	
Channel	2	
TOTAL	13	

Sample 8-B

Component	% Composition	Grain Size (mm)
Lime Mud	56	
Stromatolite Matrix	3	
Bladed Cement	2	0.1
Granular Cement	1	.1 - .2
Ostracods	1	.2 - .5
Bryozoans	7	2 - 2.5
Gastropods	1	.5 - 1.2
Bivalve	1	1.5 - 2
Peloids	4	.1 - .5
Brachiopod	<1	1
Calcareous Algae	20	
Quartz	<1	0.1
Feldspar	<1	0.2
Porosity		
Intergranular	<1	
Intragranular	2	
Algal (intercrystalline)	8	
Vug	5	
Channel	1	
Fracture	0	
TOTAL	17	

Sample 8-T

Component	% Composition	Grain Size (mm)
Lime Mud	59	
Stromatolite Matrix	9	
Bladed Cement	4	.1 - .2
Granular Cement	1	0.1
Ostracods	1	.5 - .8
Gastropods	<1	2.5
Bivalve	1	1.2 - 2
Peloids	9	.1 - .2
Microbial	9	0.1
Calcareous Algae	4	
Quartz	<1	0.4
Porosity		
Intergranular	1	
Intragranular	3	
Algal (intercrystalline)	5	
Vug	9	
Channel	2	
Fracture	1	
TOTAL	21	

Sample 9-M

Component	% Composition	Grain Size (mm)
Lime Mud	72	
Microbial Matrix	5	
Bladed Cement	5	.05 - .1
Granular Cement	2	0.1
Ostracods	1	.5 - .7
Bryozoans	1	1 - 1.5
Bivalve	1	2.0 - 3
Peloids	6	.2 - .5
Brachiopod	<1	1.5 - 4
Calcareous Algae	<1	
Feldspar	2	0.3
Porosity		
Intergranular	<1	
Intragranular	1	
Algal (intercrystalline)	<1	
Vug	7	
Channel	1	
Fracture	1	
TOTAL	10	

Sample 10-B

Component	% Composition	Grain Size (mm)
Lime Mud	38	
Stromatolite Matrix	11	
Bladed Cement	9	0.2
Granular Cement	6	0.2
Fibrous Cement	<1	1
Blocky Cement	<1	0.5
Ostracods	2	.5 - 1
Bryozoans	3	1.0 - 2
Gastropods	1	1.0 - 2
Bivalve	1	1.5 - 2
Peloids	9	.2 - .5
Microbial	8	.1 - .3
Brachiopod	<1	5
Calcareous Algae	2	
Interclasts	5	0.3
Quartz	1	.3 - .8
Feldspar	2	0.5
Porosity		
Intergranular	2	
Intragranular	2	
Algal (intercrystalline)	3	
Vug	13	
Channel	4	
Fracture	1	
TOTAL	24	