PETROGRAPHIC STUDY OF FIVE SAMPLES RECOVERED FROM THE NAHANNI FORMATION AT WELL LOCATION MURPHY ET AL NETLA M-31 300/M-31-6100-12300/0

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SERVICE BEYOND ANALYSIS

TABLE OF CONTENTS

EXECUTIVE SUMMARY

Five limestone samples collected from the Murphy et al Netla M-31, 300/M-31-6100-12300/0 location were examined by the thin section and SEM petrology, plus by Bulk XRD analysis to determine mineralogy, reservoir quality, diagenetic history and fluid sensitivity. The petrophysical data (Routine Core Analysis) of the core samples was also available for these samples and it has been incorporated into this report as well. All samples belong to the Middle Devonian Nahanni Formation.

An overview of general sample information can be found below within **Table A:**

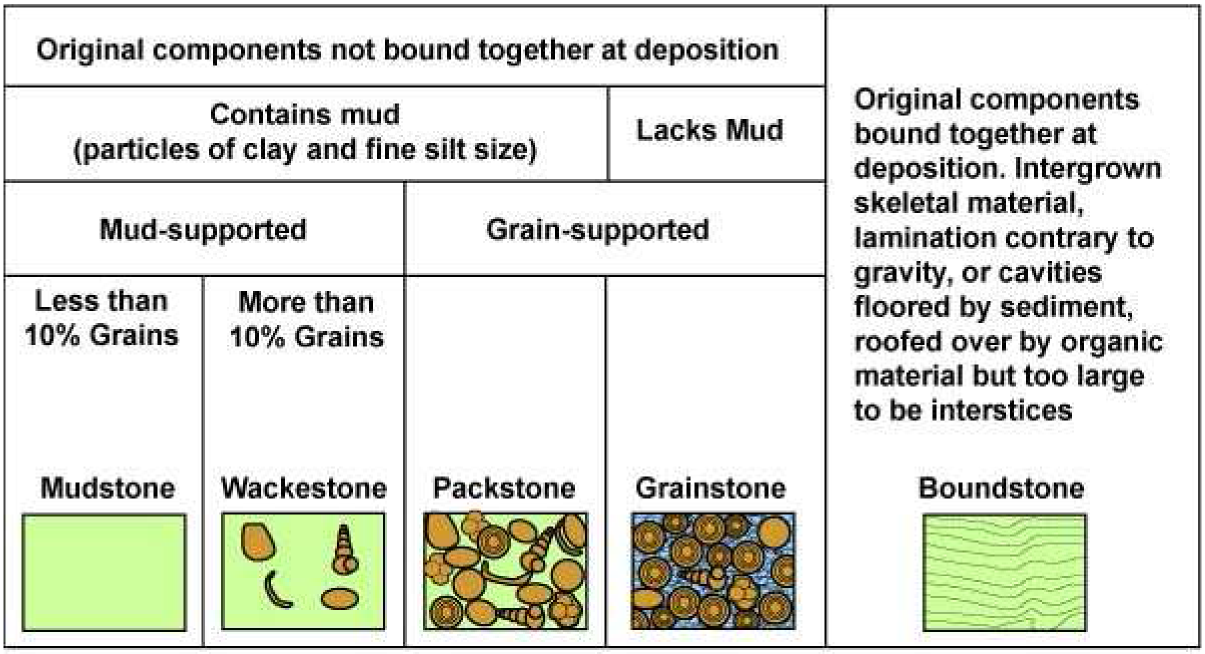
Sample ID (*)	**Depth (ft/m)**	**Formation**	**Rock Classification**	**Analysis (*)**	**RQ (*)**
Location: Murphy et al Netla M-31 300/M-31-6100-12300/0					
T61	4269.00/1301.19	Nahanni	Limestone (Packstone-Wackestone)	TS; SEM; XRD; RCA	P
T60	4302.90/1311.52	Nahanni	Limestone (Packstone-Wackestone)	TS; SEM; XRD; RCA	P
T59	4329.25/1319.56	Nahanni	Limestone (Packstone)	TS; SEM; XRD; RCA	P
T58	4356.00/1327.71	Nahanni	Limestone (Packstone-Wackestone)	TS; SEM; RCA	P
T57	4361.50/1329.39	Nahanni	Limestone (Packstone-Wackestone)	TS; SEM; XRD; RCA	P

(*) TS: Detailed thin section analysis with Images; XRD: Bulk X-Ray Analysis; SEM: Scanning Electron Microscope analysis with images; RCA: Routine Core Analysis

Sample ID: T – thin section sample; X – XRD; S – SEM sample; P – RCA

(*) RQ -Reservoir Quality: VP – Very Poor; P- Poor; M – Moderate; G- Good

To describe the original texture of the rocks the modified Dunham (1962) classifications for carbonate rocks was used (see the figure below).



C. G. St. C. Kendall, 2005 (after Dunham, 1962, AAPG Memoir 1)

Based on the mineralogy, all five samples were classified as limestones. The samples show mainly packstone to wackestone texture, except for sample T59 that is a packstone. Sedimentary structures include discontinued laminae and low amplitude micro-stylolites, plus fractures (see the Petrographic Summary Table 1).

The mineralogy of these five limestone sample is dominated by calcite (96% to 100% of the total rock volume), while pyrite (trace to 3%), dolomite (1% to 2%), clays and organic matter (trace to 2%), pyrobitumen (trace to 1%), and quartz (trace) are the other minerals. Note that quartz occurs as silt sized detrital grains, plus as quartz cement.

The framework components (allochems) include bioclasts (27% to 54%) and carbonate clasts (1% to 35%). Due to poorly preserved morphology and fragmentation, the majority of the bioclast fragments were grouped in the ‘Unidentified’ category (10% to 30%) in the Petrographic Summary Table 1. Other bioclasts were tentatively identified as brachiopod shells and spines (2% to 10%), crinoids/echinoderms (2% to 10%), mollusks (2% to 6%), ostracodes (trace to 1% - only in samples T61 and T60), plus trace stromatoporoid (only in sample T61). The bioclasts are not distributed evenly throughout the study samples. The carbonate clasts are represented solely by peloids. Samples T58 and T57 contain 35% and 30% of peloids respectively. Samples T60 and T59 comprise 1% to 5% of peloids, and sample T61 does not contain peloids at all. Non-carbonate detrital grains were identified as trace amounts of quartz silt in sample T57.

Orthochems are dominated by lime-mud (micrite) that has been point counted between 5% (sample T57) up to 60% (sample T61). It was noted that overall micrite content decreases with depth. Micrite (microcrystalline calcite) consists of 1 to 4 μm crystals and forms as an inorganic precipitate or through breakdown of coarser carbonate grains. Micrite is produced within the basin of deposition and shows little or no evidence of significant transport (Folk, 1959). In the Wentworth division of the carbonate sediments that is mentioned in the following chapters of the report, micrite corresponds to aphanocrystalline size of the crystals. During neomorphism[1] some of the micrite matrix has been recrystallized to microspar (crystal size from 5 to 20 μm) or pseudospar (crystal size larger than 30 to 50 μm). Microspar and pseudospar comprise elongated crystals with irregular and sutured boundaries that usually display patchy distribution and grades into a typical micrite. Note that the recrystallization of primary lime-mud to coarser crystalline micro- or pseudospar usually drastically reduces the amount of micro-intercrystalline porosity. The micro- and/or pseudospar content ranges between trace (sample T58) to 20% (sample T57). Sample T61 does not contain micro- or pseudospar. The other two samples contain 1% (T59) and 6% (T60) of the porosity plugging microspar. Besides the micrite and micro- or pseudospar, trace to minor amounts of clays and organic material were also point counted as a part of the matrix. The total pore filling cements range from 3% (T60) to 5% (T59), whereas the other samples show much higher amounts of cement (10% to 20%). The cements were identified as calcite spar and druse (3% to 11%), dolomite (1% to 2% - only in samples T59 and T57), pyrobitumen (trace to 1% - all but sample T57), trace pyrite (samples T60, T58, and T57), plus trace quartz cement (sample T60). Replacement minerals include trace to minor pyrite (samples T58 and T57), plus trace quartz (sample T60).

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[1] Diagenetic transformation of one mineral and itself or a polymorph, whether the new crystals are larger, smaller or differ in shape from the previous ones or represent new mineral species. Includes both inversion and recrystallization. (Folk, 1965).

Overall, there is no visible porosity in these limestone samples with exception of sample T58 that shows a trace amount of intercrystalline pores. The main porosity plugging factors observed at this location is the abundance of calcite micrite, which has locally recrystallized to tight mosaic microspar, plus the cementation by calcite spar, coarse crystalline dolomite, pyrobitumen, and pyrite. Trace amounts of syntaxial overgrowths observed on the crinoids plates (sample T57) also slightly add to the reduction of interparticle porosity.

Reservoir quality for these five samples is mainly controlled by depositional environment (i.e. sediment texture, abundance and distribution of framework grains such as bioclasts fragments and non-skeletal carbonate grains, abundance and distribution of the matrix, etc.,) and to lesser extent by diagenesis (i.e. mineral diagenesis, recrystallization of micrite to microspar, compaction, and cementation). Reservoir quality is considered to be poor for all the study samples.

Detailed mineralogical composition of each of the study samples are summarized in the tables that can be find in the 'RESULTS' chapter of this report, plus in the **Petrographic Summary Table 1** that is located in the **Tables and Figures** section of the report. Following the tabulated data there are this section and SEM images (with descriptions) that show specific features of the samples.

The reservoir quality rating is based solely on the thin section examination. The following table is the summary of the reservoir quality at the study locations.

Sample ID	Depth (ft/m)	Total Micrite (%)	Total Cement/ Replacement (%)	Total Porosity (%)						Main Porosity controlling factors (*)	RQ (*)
				IP	Int.	Ixl	mV	Fr	M		
Location: Murphy et al Netla M-31 300/M-31-6100-12300/0											
T61	4269.00/1301.19	60	10	-	-	-	-	-	-	Mic; Com; Cc; OM; C	P
T60	4302.90/1311.52	51	3	-	-	-	-	-	-	Mic; Com; Cs; Qc; Py; OM;	P
T59	4329.25/1319.56	36	5	-	-	-	-	-	-	Mic; Com; Cc; Dc; OM; Ms; C	P
T58	4356.00/1327.71	15	23	-	-	TR	-	-	-	Cc;; Mic; Com; Py; C; OM;	P
T57	4361.50/1329.39	27	13	-	-	-	-	-	-	Com; Ms; Cc; Mic; C; Dc; Py	P

Porosity value (%): IP – interparticle porosity; **Int** – intraparticle; **Ixl** – intercrystalline; **Mv** – micro-vuggy; **Fr** – fracture porosity; **M** – micro-intercrystalline porosity
Main Porosity controlling factors: Com – compaction**;** M**ic** – micrite (calcite or dolomite); **Ms** – micro- and/or pseudospar; **Cc** – calcite cement (druse and spar); **Dc** – dolomite cement**; C** – clays and organics; **Ov** – quartz overgrowths; **Py** – pyrite (replacement and/or cement); **F** – fabric: [**CC** – concavo-convex orthochem contacts; **S** – sutured orthochem contacts]
RQ (*) - reservoir quality: VP – very poor; **P –** poor; **M –** moderate; **G –** good
Total cement (*):: includes micro- and pseudospar

Reservoir problems for the samples recovered from the Nahanni Formation at the Murphy et al Netla M-31 300/M-31-6100-12300/0 location may include the following: **(1)** extremely rare and small sizes of intercrystalline pores would restrict the flow and storage of hydrocarbons, **(2)** hydrochloric acid (HCl) treatment of this reservoir has the potential to loosen carbonate fines (calcite micrite) that could migrate and block pore throats, plus cause fabric collapse, **(3)** the sensitivity of calcium carbonate to hydrofluoric acid (HF) in regard to precipitation of calcium fluoride scales, (4) Pore lining pyrobitumen may react with hydrochloric acid (HCl) to create sludges or viscous emulsions, which can restrict permeability potential. Both sludges and emulsions may be removed by using appropriate surfactants (surface active agents), which reduce interfacial and surface tension and result in a more miscible mixture of oil and water (acid). Any drilling, completion or workover must ensure the fluid acid compatibility with the formation pyrobitumen.

METHODS

Petrographic Microscopy

To prepare the thin section samples, the uncleaned end pieces of the core plugs were impregnated with blue epoxy, polished and mounted onto a glass slide. After drying of the epoxy the samples were ground down to a total thin section thickness of 30µm. One half of each thin section was then stained with a combination of Alizarin Red (for calcite) and potassium ferricyanide (for ferroan carbonate) to highlight carbonate mineralogy. The dual carbonate stain helps to differentiate the carbonate components within the samples, and affects them as follows: calcite appear pink to red-brown, ferroan calcite shows mauve to blue, ferroan dolomite colors vary from pale blue to turquoise, while non-ferroan dolomite remains unstained. Finally a second glass slide was glued on the samples to protect the polished surface. The prepared thin sections were point counted. The thin sections were examined in plain and cross polarized light conditions and photomicrographs taken at various magnifications (x12.5ppl; x25ppl; x50ppl, x100ppl, and x200ppl) to document structure, porosity, composition and nature of optically resolvable grains and matrix. Each sample has been described separately and the important features of it that includes framework mineralogy, diagenetic minerals and cements, textures, grain size range and average, porosity, etc., and the results are provided in the tabulated format. Annotated images of the thin sections with descriptions show the important aspects that were observed during the thin section examination. These images are placed after the tabulated data.

Bulk XRD Analysis

Sample Preparation: Each sample, consisting of rock fragments, is manually crushed carefully using a mortar and pestle to reduce the size of the fragments. The sample is then ground with a vibratory disc mill (RS200; Retsch) to further reduce crystallite sizes. Finally, the sample is micronized using a planetary ball mill (PQN04; Across International) and scanned for X-ray diffraction analysis.

X-Ray Data Collection and Analysis:

Diffractometer Name: Bruker D4 Endeavor XRD with a Lynx-Eye detector

Instrumental Parameters: Radiation Source – Cobalt (Co)

Generator settings - 40 mA, 35 kV

Start position [°2θ] - 4

End position [°2θ] - 80

Step size [°2θ] - 0.02

Scan step time [s] - 1

Data Analysis: ICDD PDF-4 Mineral 2020 powder diffraction database

X'PERT HighScore Software for mineral identification

TOPAS Software for quantitative phase analysis

Detection Limit: 0.1 – 0.5 % depending on the type and nature of sample

Quantitative Mineral Phase Analysis: Using the HighScore program, the different mineral phases of the XRD patterns are identified. Once the mineral phases are identified, Rietveld refinements are performed by importing the XRD trace pattern into TOPAS 5. This program (TOPAS 5) is used for Rietveld analysis to quantify the mineralogy. The quantitative mineral phases of all samples are given in **Table 2**. The refined diffractograms and **Table 2** are placed in the **Tables and Figures** section of this report.

SEM Analysis

A representative portion of each sample was adhered onto an aluminum stub specimen mount. The stubs were then sputter-coated with a conductive gold-palladium alloy for detailed Scanning Electron Microscopy (SEM) analysis and imaging. SEM analysis is useful in identifying lithological characteristics such as pore types, framework mineralogy, clay and cement composition, in addition to the potential deportment of clay constituents in relation to pore spaces and pore throats. Energy dispersive X-ray (EDX) was also used in conjunction with SEM observation in order to determine the elemental composition of the observed clay minerals and carbonate mineralogy.

Grain sizes:

The scale for authigenic constituents in carbonates follows the Wentworth division, which is the most useful for dolomites, where transported particles are usually obliterated by replacement and crystal size is one of the few describable characteristic. The carbonate crystal sizes ranges are as follows: very fine crystalline (4 to 16μm), fine (16 to 62 μm), medium (62 to 250 μm), coarse (250-1000 μm), and very coarse crystalline (1000 to 4000 μm). The finest authigenic constituents are called cryptocrystalline (less than 1μm) and aphanocrystalline with the crystal size between 1 and 4 μm.

The following describes a division within the carbonate matrix. Micrite term is used for carbonate mud that consists of 1 to 4 μm diameter crystals and forms as an inorganic precipitate or through breakdown of coarser carbonate grains. Micrite is produced within the basin of deposition and shows little or no evidence of transport (Folk, 1959). Microspar is generally 5 to 20 μm sized calcite produced by recrystallization (neomorphism) of micrite and can be as coarse as 30 μm (Folk, 1965). Microspar is restricted to recrystallization products, not primary precipitates. Calcite fabric crystal size larger than 30 to 50 μm is called a pseudospar.

Abbreviations

The list of common thin section abbreviations in provided in the table below.

NAME	ABBREVIATION	NAME	ABBREVIATION
Anhydrite	Anh	Intragranular Porosity	Intr.
Barite	Ba	Kaolinite	Kao
Biotite	Bio	K-Feldspar	K-Fld
Bioclasts (indistinct)	Biocl	Laminae	Lam
Burrows/Bioturbation	Bur	Metamorphic Rock Frag.	MRF
Bioturbation	Bt	Muscovite	Musc
Calcite	Cal	Matrix	Mtx
Carbonaceous	Carb	Micro-vuggy pore	mV
Chert	Cht	Organic material	OM
Chlorite	Chl	Phosphate	Phos
Concavo-convex	CC	Plutonic Rock Fragments	PRF
Dolomite	Dol	Polycrystalline quartz	PQ
Detrital Calcite	dC	Pseudo-matrix	P-mtx
Detrital Dolomite	dD	Pyrite	Py
Feldspar (plagioclase)	Fld	Quartz	Qtz
Ferroan Dolomite	Fe-Dol	Quartz Cement	Qc
Ferroan Calcite	Fe-Cal	Quartz overgrowths	Ov
Glauconite	Glauc	Sedimentary Rock Frag.	SRF
Grain dissolution pore	GD	Secondary porosity	SP
Heavy minerals	HM	Sutured grain contact	S
Hematite	Hem	Volcanic Rock Fragments	VRF
Illite	Ill		
Intergranular Porosity	IP		
Intercrystalline Porosity	lxl		

RESULTS

In this chapter of the report, the five samples that were recovered from the Nahanni Formation at the Murphy et al Netla M-31 300/M-31-6100-12300/0 location will be described separately. The images that show specific features of each sample will follow the tabulated sample description. Stratigraphic top of the thin section samples has been marked with an arrow placed in the upper right portion of the thin section.

Sample T61 (X76, S61, P36), 4269.00ft/1301.19m

Well Name	Murphy et al Netla M-31	**Location**	300/M-31-6100-12300/0
Sample type	Thin section/SEM grain mount from a core sample	**Depth (m)**	4269.00ft/1301.19m
Stratigraphic Unit	Nahanni Formation	**Reservoir Quality**	Poor
Classification	Limestone (Packstone-Wackestone)	**Stain type**	½ Dual carbonate

MINERALOGY

	Total Bulk mineralogy					
Thin Section Point counting (%)	**Calcite**	**Dolomite**	**Quartz/Cht**	**Pyrite**	**Clays & organics**	**OM**
	99	-	-	-	TR	1
	Framework, Matrix, Cement, and Replacement					
	Carbonate clasts	**Bioclasts**	**Detrital grains**	**Matrix**	**Pore filling cement**	**Replacement**
	-	30	-	60	10	-

ADDITIONAL FEATURES and OTHER COMMENTS

Depositional	The sample shows faintly preserved laminated structure defined by stylolitized laminae, plus by the orientation of some of the bioclasts (see Figure 1.3).
Textures	Based on the mineralogy and proportion between framework components (carbonate clasts and bioclasts) and matrix, the sample was classified as a limestone packstone to wackestone. For the matrix, the crystal texture has been determined as anhedral, while cement shows subhedral to euhedral crystal texture. Some bioclasts have been micritized or replaced by calcite druse, while crinoid fragments often show single-crystal extinction and well-developed calcite twinning.
Framework (Carbonate clasts, Bioclasts)	Petrographic Summary Table 1 shows detailed mineralogy of the sample. This sample contains 99% calcite. Other minerals include pyrobitumen (1%) and trace clays and organics, which are incorporated into stylolitized laminae. The framework components include various bioclasts (mainly unidentified - 20% pf the total rock volume), plus minor brachiopod shell and spines (6%), crinoids/echinoderms (2%), mollusks (2%), plus trace ostracodes and stromatoporoid.
Detrital Grains & Other Non-Carbonate Grains	There are no detrital grains in this sample.

Matrix	Calcite micrite is the main component of the matrix (60% of the total rock volume), while clays and organics are estimated to occur in trace amounts.
Pore Filling Cements	The pore filling cement include calcite (9%) and pyrobitumen (1%). Rare relatively large sized cavity has been partly filled with calcite spar (see Figure 1.2). Pyrobitumen typically fills micro-intercrystalline pores.
Replacement Minerals	There are no minerals that appears to act as a replacement agents in this sample.
Porosity	There is no visible porosity in this sample. Some microporosity could be present in this sample due to the abundance of micrite matrix. The RCA also shows very little amounts of porosity (0.9%) with permeability of 0.02mD, which is affected by fractures.

Annotated microphotographs of the thin section and SEM samples with descriptions are provided below.

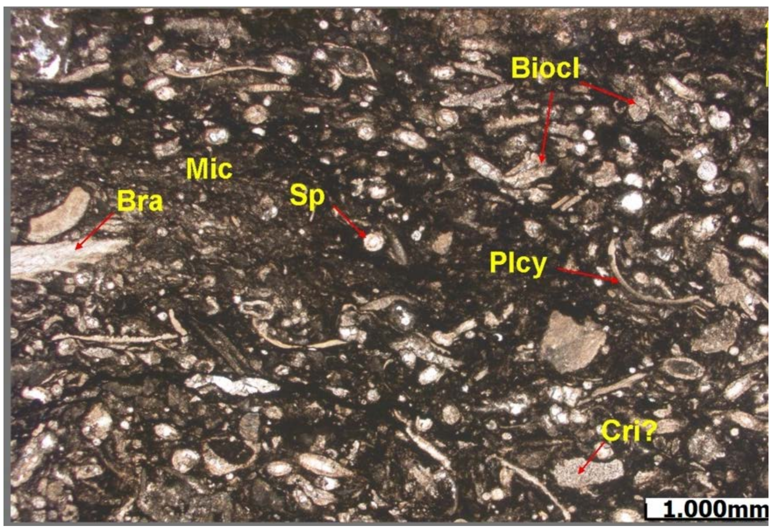

Figure 1.1. Sample T61, 4269.00ft/1301.19m. Low magnification overview of the packstone-wackestone limestone shows the abundance of mainly indistinct bioclast fragments (Biocl) that are floating in a micritic calcite (Mic) groundmass. Some of the bioclasts were tentatively identified as pelecypod (Plcy), brachiopod shell (Bra) and spines (Sp), plus crinoid plates (Cri?). There is no visible porosity in this image. **x25ppl**

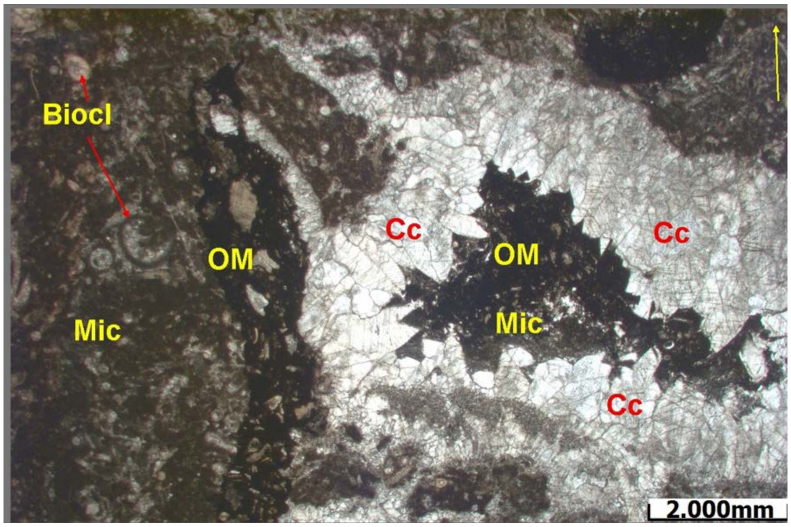

Figure 1.2. Sample T61, 4269.00ft/1301.19m. This image was taken from the unstained portion of the thin section and focuses on a void/cavity that has been primary filled with micritic matrix (Mic) and pyrobitumen (OM), followed by the precipitation bladed calcite spar (Cc). Note the increase in crystal size of the calcite cement from margin to the cavity centre. Finely disseminated indistinct bioclast fragments (Biocl) are part of the matrix of this sample. The pyrobitumen (OM) outside of the cavity appears to plug micro-intercrystalline pores within the matrix. **x12.5ppl**

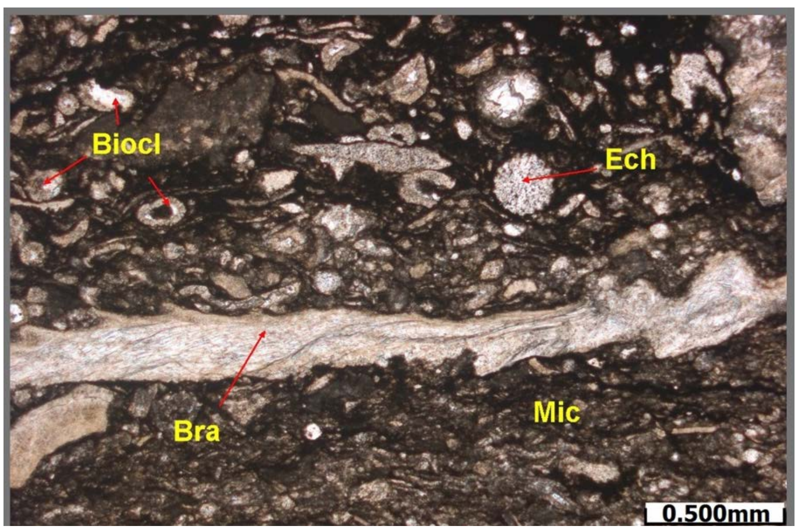

Figure 1.3. Sample T61, 4269.00ft/1301.19m. Moderate magnification image highlights the local presence of large sized foliated brachiopod shell fragments (Bra). Rare echinoderm spine (Ech) with a 'flower-like' pattern produced by the regular, radial arrangement of large pores within the spine, is the other identified framework component. Some of highly fragmented bioclasts (Biocl) are part of the micritic matrix (Mic) of this sample. **x50ppl**

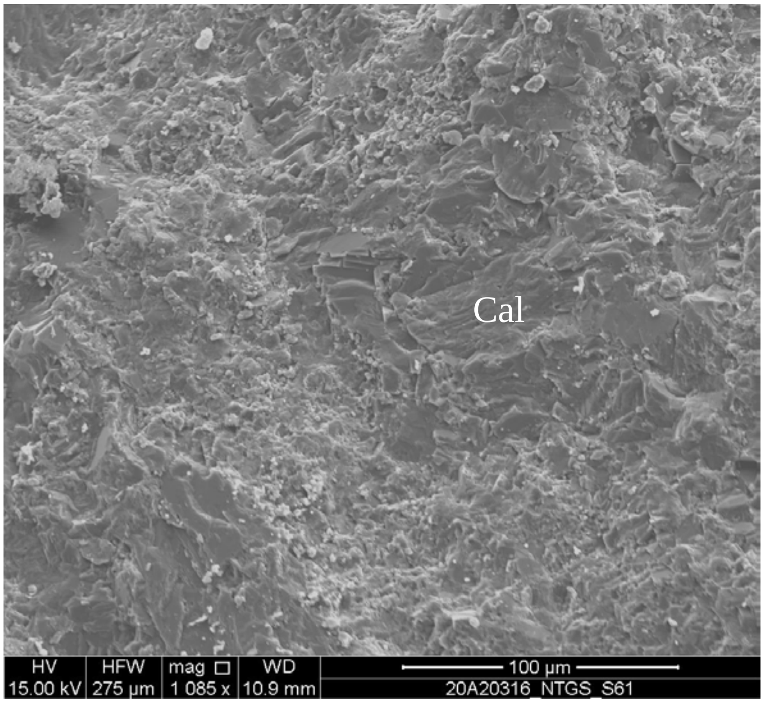

Figure 1.4. Sample S61, 4269.00ft/1301.19m. Overview Scanning Electron Microscope (SEM) image showing patchy, relatively coarse calcite (Cal) cement within a micritic matrix (Mic). No visible porosity. **x1085**

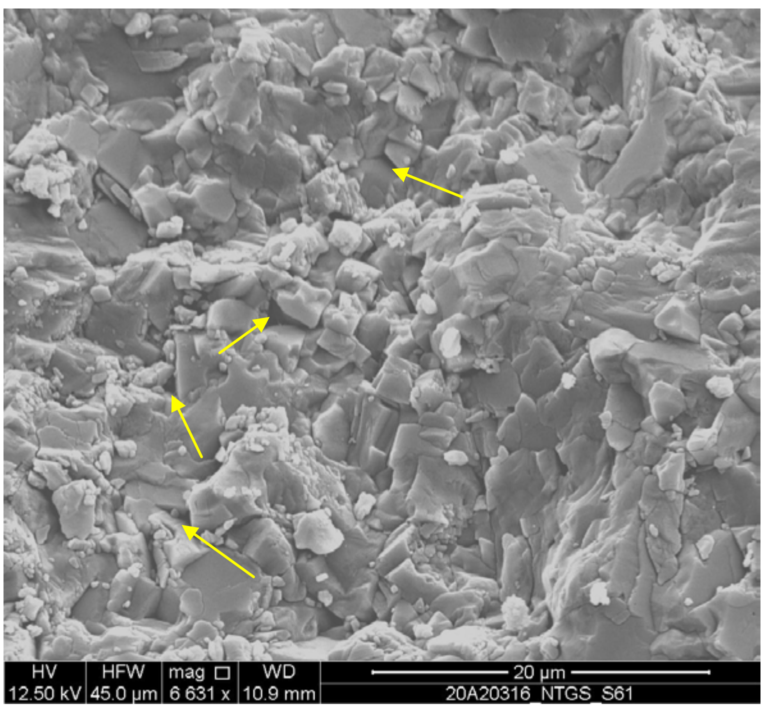

Figure 1.5. Sample S61, 4269.00ft/1301.19m. High magnification Scanning Electron Microscope (SEM) image showing details of the calcite micrite matrix. Scattered micropores (<5µm) are highlighted by yellow arrows. **x6631**

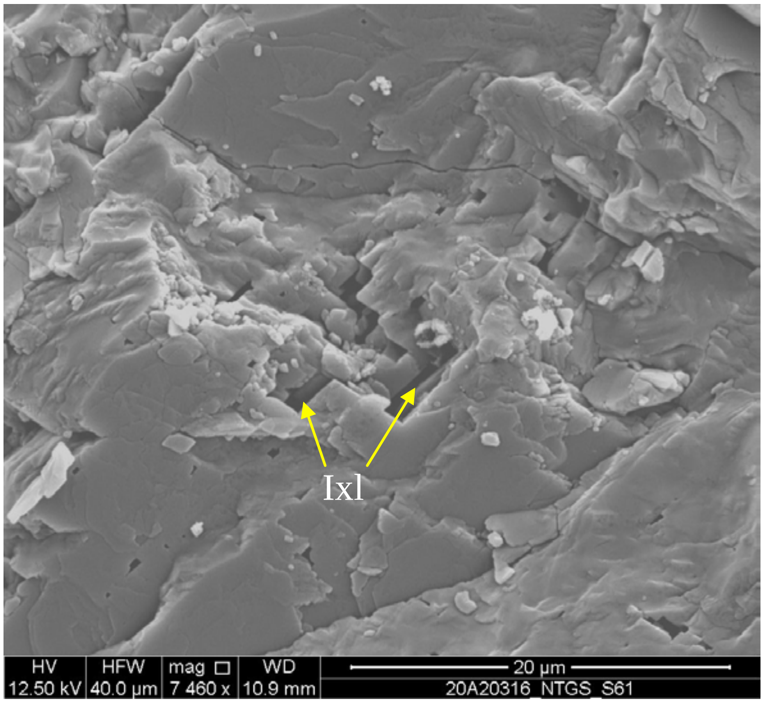

Figure 1.6. Sample S61, 4269.00ft/1301.19m. High magnification Scanning Electron Microscope (SEM) image showing rare intercrystalline pores (Ixl), which range in size from submicron to ~8µm. **x7460**

Sample T60 (X75, S60, P35), 4302.90ft/1311.52m

Well Name	Murphy et al Netla M-31	**Location**	300/M-31-6100-12300/0
Sample type	Thin section/SEM grain mount from a core sample	**Depth (m)**	4302.90ft/1311.52m
Stratigraphic Unit	Nahanni Formation	**Reservoir Quality**	Poor
Classification	Limestone (Packstone-Wackestone)	**Stain type**	½ Dual carbonate

MINERALOGY

	Total Bulk mineralogy					
Thin Section Point counting (%)	Calcite	Dolomite	Quartz/Cht	Pyrite	Clays & organics	OM
	100	-	TR	TR	-	TR
	Framework, Matrix, Cement, and Replacement					
	Carbonate clasts	Bioclasts	Detrital grains	Matrix	Pore filling cement	Replacement
	1	45	-	51	3	TR

ADDITIONAL FEATURES and OTHER COMMENTS

Depositional	At the time of deposition, the sample was most likely massive with abundant amounts of bioclasts and occasional carbonate clasts floating randomly throughout calcite-micrite matrix.
Textures	The sample has been classified as bioclastic limestone (packstone to wackestone). For the matrix, the crystal texture has been determined as anhedral, while cement shows subhedral to euhedral crystal texture. Some bioclasts have been micritized, fragmented and therefore difficult to identify. Occasional crinoid fragments show single-crystal extinction and well-developed calcite twinning.
Framework (Carbonate clasts, Bioclasts)	Petrographic Summary Table 1 shows detailed mineralogical composition of the sample. The sample contains 100% of calcite with only trace amounts of quartz, pyrite, and pyrobitumen. In regards to the framework components, calcite occurs mainly as bioclasts [indistinct - 20%, brachiopod – 10%, crinoids – 8%. Mollusks – 6%, plus ostracode – 1%]. Minor (1%) peloids are the carbonate clasts in this sample.
Detrital Grains & Other Non-Carbonate Grains	There are no detrital grains in this sample.
Matrix	The matrix of the sample comprise mainly calcite–micrite (45%). Note that minor to moderate amounts of the micrite has recrystallized to porosity plugging microspar (6%).
Pore Filling Cements	The pore filling cements within this sample are associated with dissolution and then cementation of bioclasts and formation of tightly packed blocky calcite (3%). Trace amounts of pyrite, quartz, and pyrobitumen also act as cements in this sample.
Replacement Minerals	Quartz is the replacement mineral observed in this sample (trace amounts).
Porosity	There is no visible porosity in this sample. Some microporosity could be present in this sample due to the abundance of micrite matrix. The RCA also shows very little amounts of porosity (0.5%) with permeability less than 0.01mD, which is also affected by fractures.

The annotated microphotographs of the thin section and SEM samples with descriptions are provided below.

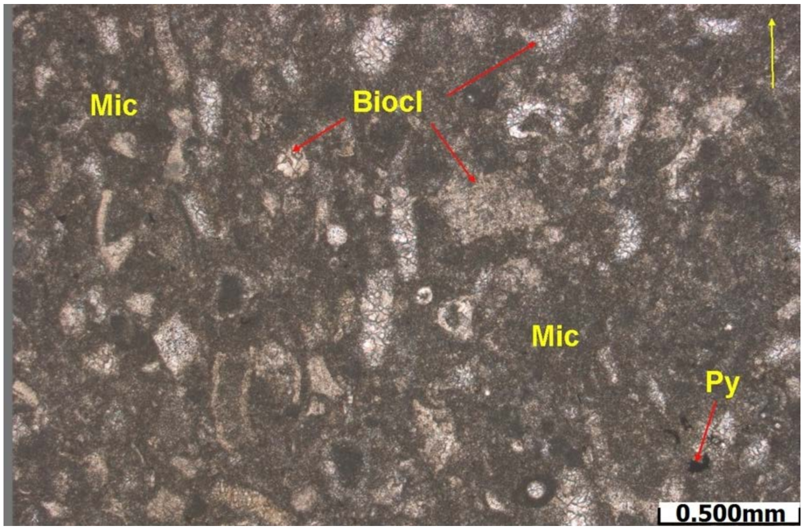

Figure 2.1. Sample T60, 4302.90ft/1311.52m. Moderate magnification image of the thin section shows indistinct bioclast fragments that are randomly distributed throughout calcite-micrite (Mic) matrix. Some of the bioclasts are micritized, while other have been dissolved. The dissolved interior of these bioclasts has been then cemented with calcite druse. Pyrite framboids locally plug micro-intercrystalline pores (Py). There is no visible porosity in this image; however abundance of micrite suggests that this sample could have fair amounts of microporosity. **x50ppl**

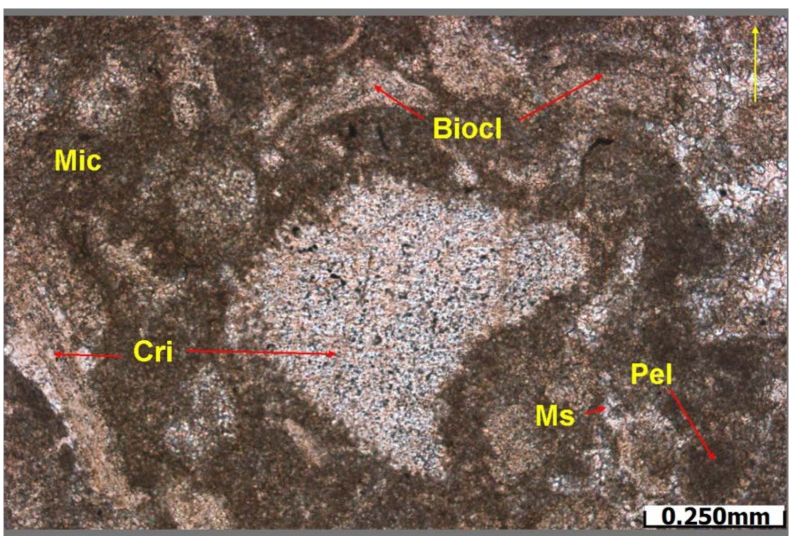

Figure 2.2. Sample T60, 4302.90ft/1311.52m. High magnification image focuses on large sized crinoid plates and stems (Cri). Other framework components in this image include indistinct bioclast fragments (Biocl), and occasional micritic peloids (Pel). The framework grains are surrounded by micrite matrix (Mic) that has locally recrystallized into a microspar (Ms). **x100ppl**

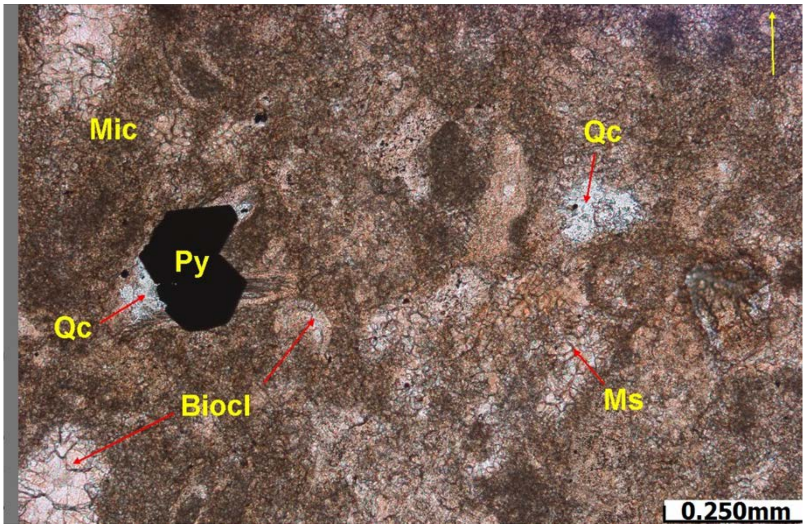

Figure 2.3. Sample T60, 4302.90ft/1311.52m. Alternate high magnification view highlighting localized precipitation of megaquartz (Qc) that acts as either cement or replacement mineral (especially within crinoid debris). Indistinct bioclast fragments (Biocl) are the framework grains. Note that the calcite-micrite (Mic) has been locally replaced (recrystallized) by tightly packed microspar (Ms). **x100ppl**

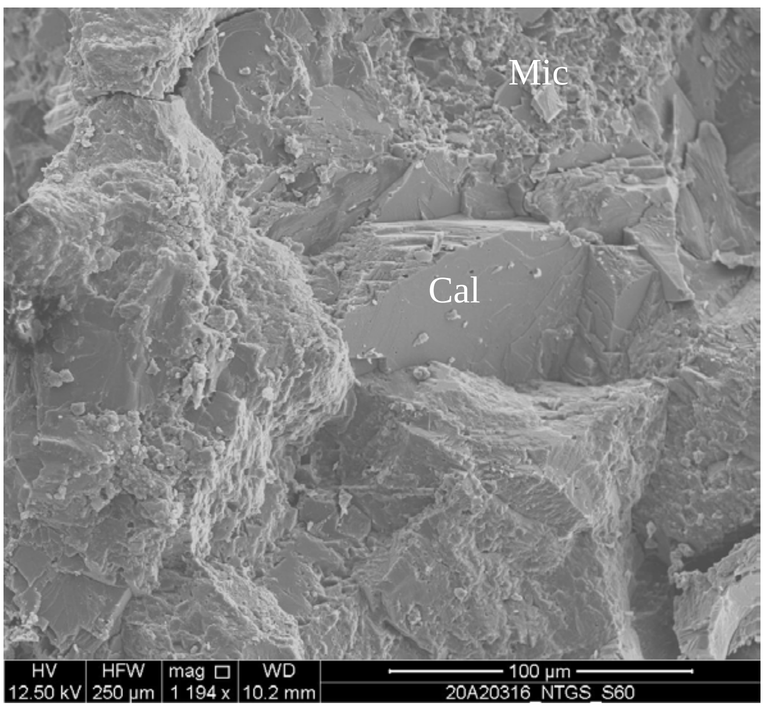

Figure 2.4. Sample S60, 4302.90ft/1311.52m. Scanning Electron Microscope (SEM) image showing the overall crystal fabric that consists predominately of calcite spar (Cal) and micrite (Mic). Porosity within this sample consists of microporosity (see images below). **x1194**

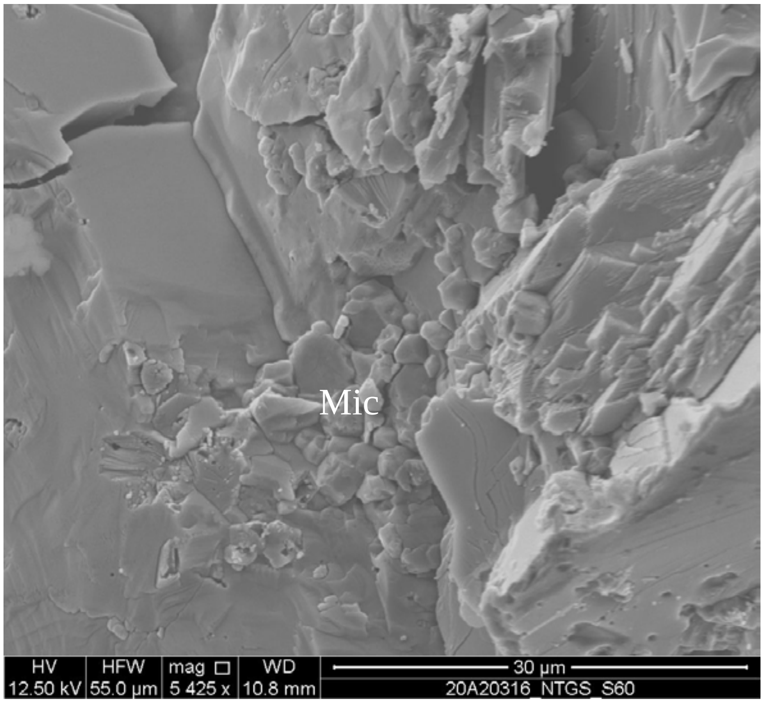

Figure 2.5. Sample S60, 4302.90ft/1311.52m. Scanning Electron Microscope (SEM) image showing a pore between sparry calcite crystals (Cal) is occluded by micrite (microcrystalline calcite). Mic: micrite. **x5425**

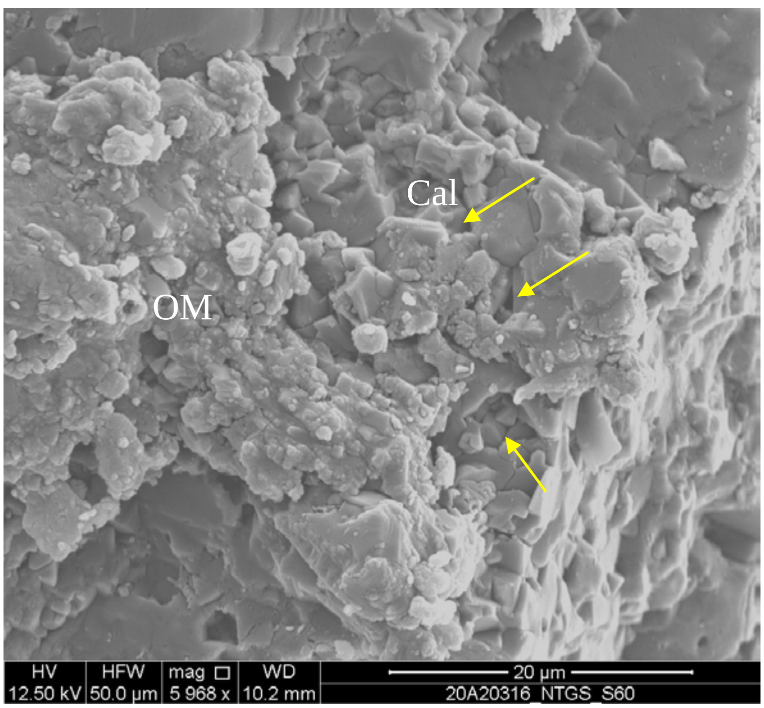

Figure 2.6. Sample S60, 4302.90ft/1311.52m. Scanning Electron Microscope (SEM) image showing submicron micropores (yellow arrows) and an aggregate that consists of organic matter (OM), plus possible indistinct clays. **x5968**

Sample T59 (X74, S59, P34), 4329.25ft/1319.56m

Well Name	Murphy et al Netla M-31	**Location**	300/M-31-6100-12300/0
Sample type	Thin section/SEM grain mount from a core sample	**Depth (m)**	4329.25ft/1319.56m
Stratigraphic Unit	Nahanni Formation	**Reservoir Quality**	Poor
Classification	Limestone (Packstone)	**Stain type**	½ Dual carbonate

MINERALOGY

	Total Bulk mineralogy					
Thin Section Point counting (%)	Calcite	Dolomite	Quartz/Cht	Pyrite	Clays & organics	OM
	98	1	-	-	TR	1
	Framework, Matrix, Cement, and Replacement					
	Carbonate clasts	Bioclasts	Detrital grains	Matrix	Pore filling cement	Replacement
	5	54	-	36	5	-

ADDITIONAL FEATURES and OTHER COMMENTS

Depositional	This sample is a poorly sorted limestone-packstone. The only sedimentary features that are observed are the low amplitude micro-stylolites. Note that stylolites are product of chemical compaction during burial diagenesis.
Textures	Based on the mineralogy and proportion between framework components (carbonate clasts and bioclasts) and matrix, the sample was classified as a packstone. For the matrix, the crystal texture has been determined as anhedral, while cement shows subhedral to euhedral crystal texture.
Framework (Carbonate clasts, Bioclasts)	Petrographic Summary Table 1 shows detailed mineralogy of the sample. This sample contains 98% calcite. Other minerals include dolomite (1%), organic matter (pyrobitumen – 1%), plus trace clays and organics. The majority of the framework builders are indistinct bioclasts fragments (30%), with lesser crinoids (10%), brachiopods (10%), and mollusks (4%). The carbonate clasts occur as micritic peloids (5%).
Detrital Grains & Other Non-Carbonate Grains	There are no detrital grains in this sample.
Matrix	Abundant matrix include calcite micrite (35%), plus trace clays and organic matter. Some of the micrite has been recrystallized to micro/pseudospar (1%).
Pore Filling Cements	Minor calcite spar (3%) and dolomite (1%) are the carbonate cements. Additionally minor amounts of pyrobitumen (1%) was spotted plugging intercrystalline pores.
Replacement Minerals	There are no replacement minerals in this sample.
Porosity	The collected sample does not show visible porosity. The core analysis done on the core plug P34 also confirms this observation. The RCA is very low (0.5%), while the core permeability is less than 0.01mD

Annotated microphotographs of the thin section and SEM samples with descriptions are provided below.

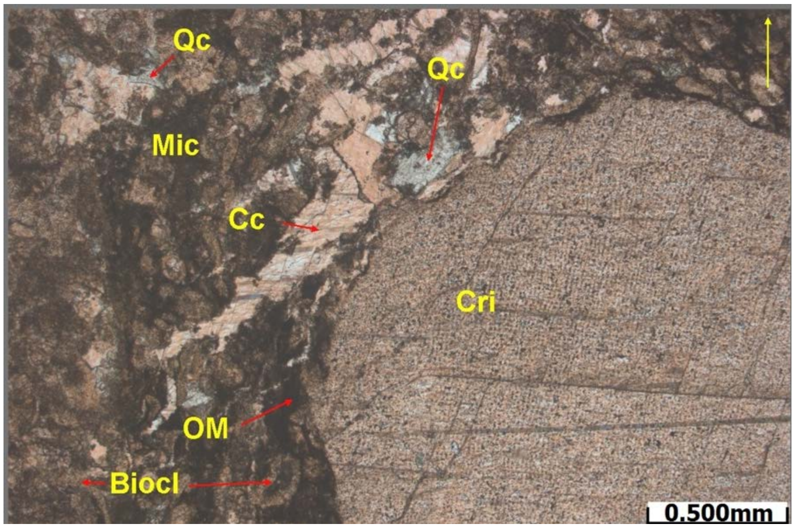

Figure 3.1. Sample T59, 4329.25ft/1319.56m. Moderate magnification overview of the sample shows the framework builders that include large sized crinoid plate (Cri), plus much smaller indistinct bioclast fragments. Interparticle porosity has been filled with calcite spar (Cc) and megaquartz (Qc). Intercrystalline and/or micro-intercrystalline pores within the micritic matrix (Mic) are locally plugged with pyrobitumen (OM) **x50ppl**

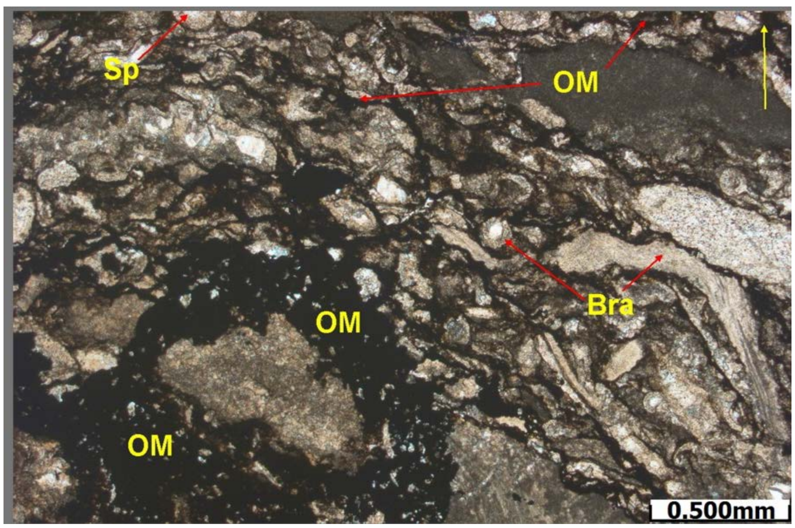

Figure 3.2. Sample T59, 4329.25ft/1319.56m. Another moderate magnification image of the packstone shows possible brachiopod (Bra) shell fragments and spines (Sp), plus highly fragmented indistinct bioclast fragments. Pyrobitumen (OM) fills some of the micro-intercrystalline pores. The sample is tight. **x50ppl**

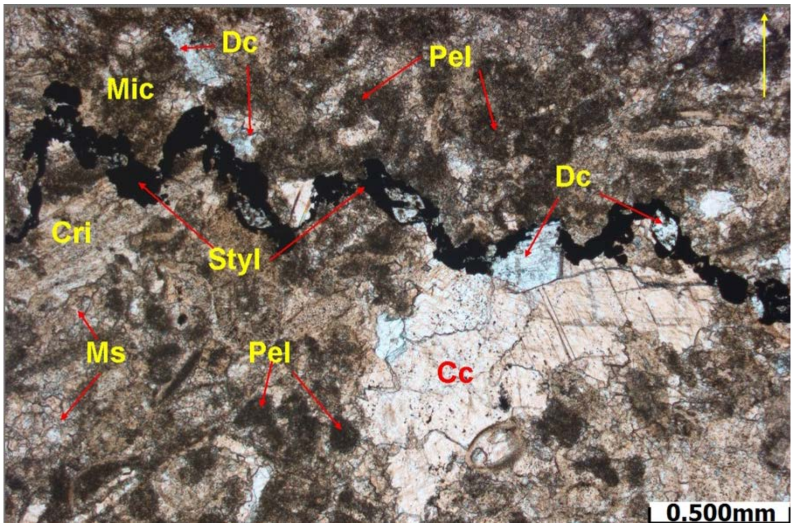

Figure 3.3. Sample T59, 4329.25ft/1319.56m. This image highlights the presence of low amplitude stylolite (Styl) that cuts through this thin section. The stylolite is marked by concentration of insoluble, black material (pyrobitumen?) along its irregular surface. The framework grains are represented by crinoids (Cri) and peloids (Pel). Part of the micrite (Mic) has been replaced by tightly packed microspar (Ms). Calcite spar (Cc) and dolomite (Dc) are the cementing agents of relatively large sized void. Note that dolomite also plugs intercrystalline and/or micro-vuggy pores along the stylolite. **x50ppl**

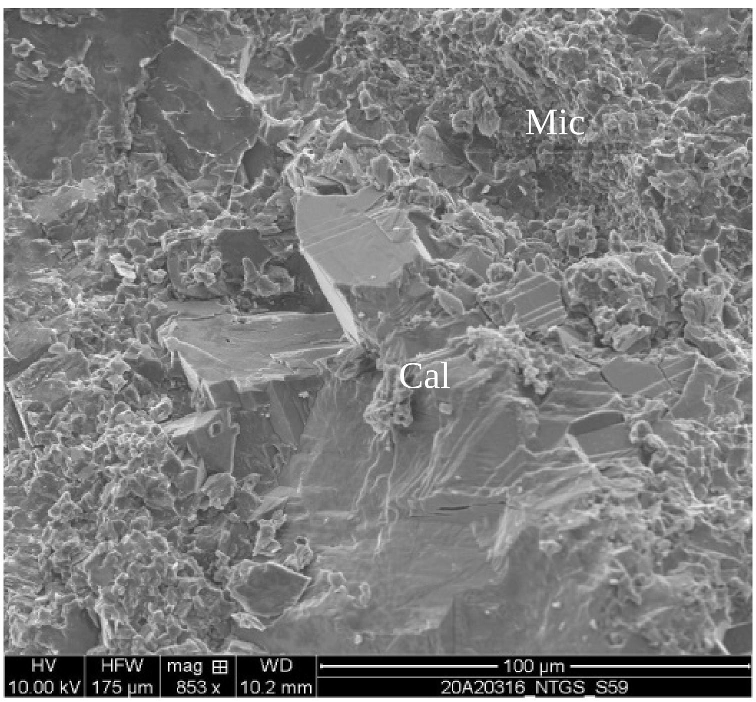

Figure 3.4. Sample S59, 4329.25ft/1319.56m. Scanning Electron Microscope (SEM) image showing the overall crystal fabric that consists predominately of calcite spar (Cal) and micrite (Mic). Porosity within this sample consists of microporosity (see images below). **x853**

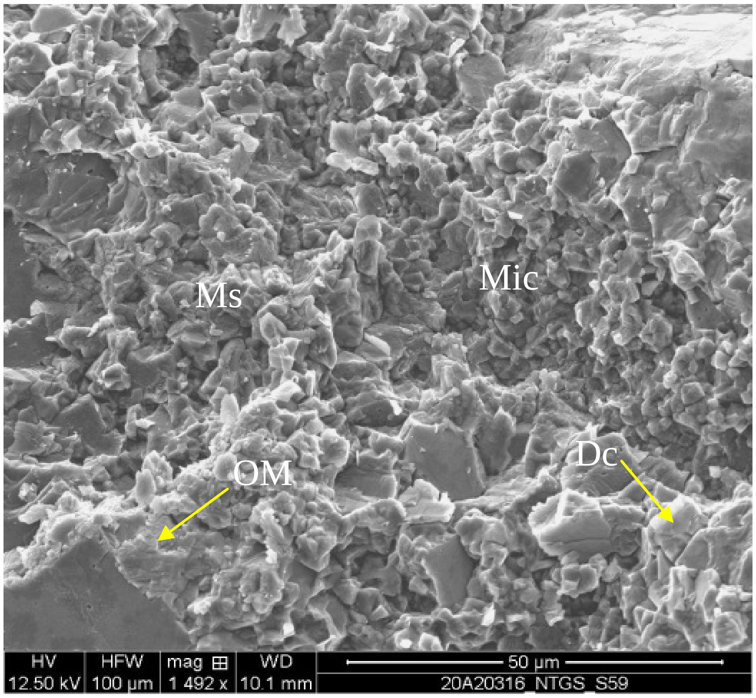

Figure 3.5. Sample S59, 4329.25ft/1319.56m. Scanning Electron Microscope (SEM) image showing details of the calcite micrite matrix (Mic). Submicron micropores are shown by yellow arrows. OM: organic matter; DC: dolomite cement; Ms: microspar. **x1492**

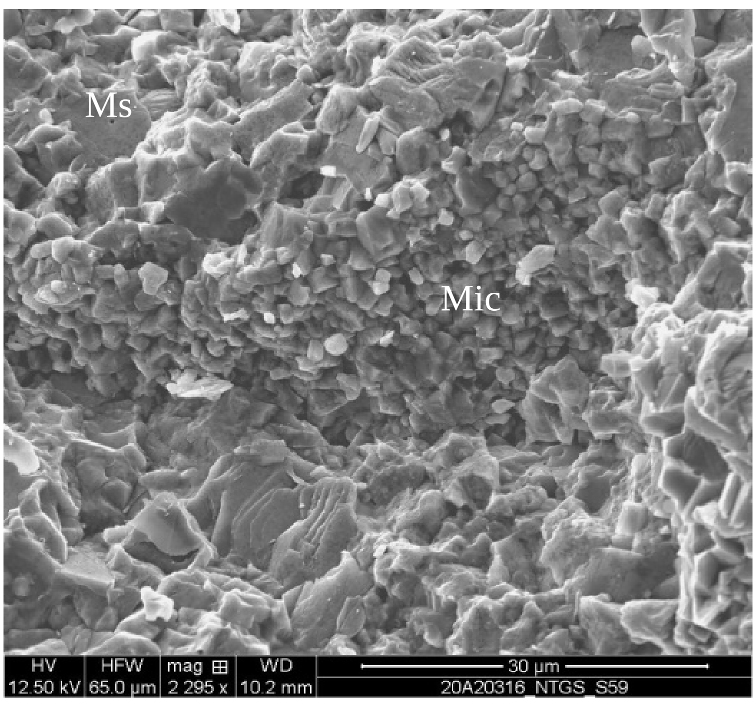

Figure 3.6. Sample S59, 4329.25ft/1319.56m. High magnification Scanning Electron Microscope (SEM) image showing textural differences between microspar (Ms) and micrite (Mic) within the sample. Micrite within the sample locally shows appreciable amounts of submicron pores that may aid in increasing reservoir capacity, but are likely ineffective. **x2295**

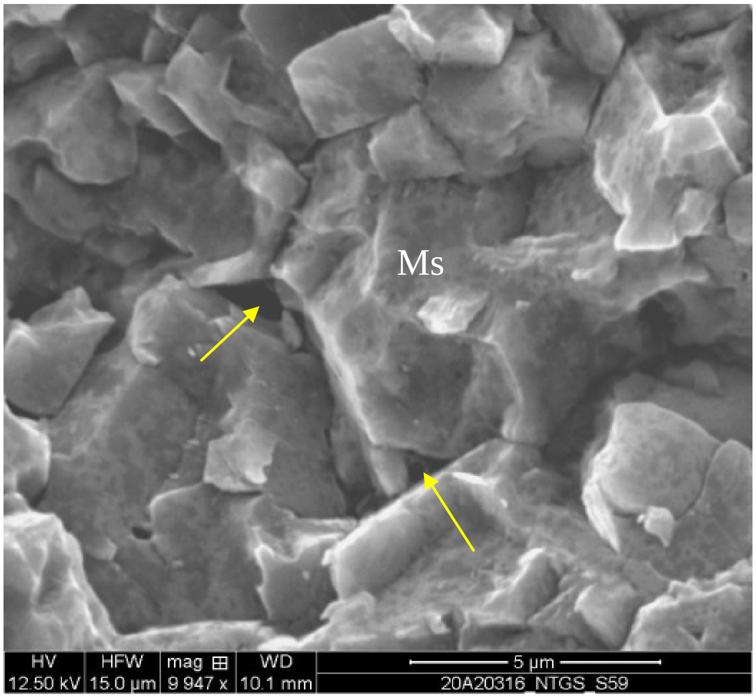

Figure 3.7. Sample S59, 4329.25ft/1319.56m. High magnification Scanning Electron Microscope (SEM) image showing microporosity (yellow arrows) associated with calcite microspar (Ms). **x9947**

Sample T58 (S58, P33), 4356.00ft/1327.71m

Well Name	Murphy et al Netla M-31	**Location**	300/M-31-6100-12300/0
Sample type	Thin section/ SEM grain mount from a core sample	**Depth (m)**	4356.00ft/1327.71m
Stratigraphic Unit	Nahanni Formation	**Reservoir Quality**	Poor
Classification	Limestone (Packstone-Wackestone)	**Stain type**	½ Dual carbonate

MINERALOGY

	Total Bulk mineralogy					
Thin Section Point counting (%)	Calcite	Dolomite	Quartz/Cht	Pyrite	Clays & organics	OM
	97	-	-	3	TR	TR
	Framework, Matrix, Cement, and Replacement					
	Carbonate clasts	Bioclasts	Detrital grains	Matrix	Pore filling cement	Replacement
	35	27	-	15	20	3

ADDITIONAL FEATURES and OTHER COMMENTS

Depositional	At the time of deposition, the sample was most likely massive. Fracturing of the sediment typically happens during burial diagenesis, but may also be associated with later hydrothermal events. Microfractures within the sample have been healed by blocky calcite cement and rarely by pyrite. This sample contains possible stromatactis-type fenestral structures.
Textures	Based on the mineralogy and proportion between framework components (carbonate clasts and bioclasts) and matrix, the sample was classified as lime-packstone to wackestone. For the matrix, the crystal texture has been determined as anhedral, while cement shows subhedral to euhedral crystal texture. Some bioclasts have been either micritized or dissolved and then the mold/cavity was filled with blocky and sparry calcite.
Framework (Carbonate clasts, Bioclasts)	Petrographic Summary Table 1 shows detailed mineralogy of the sample. The sample is composed mainly of calcite (97%), with minor pyrite (3%), plus trace clays and organics, and pyrobitumen. Framework builders are represented by abundant amounts of micritic peloids (35%), with lesser indistinct bioclast fragments (20%), mollusks (5%), plus brachiopods (2%). Note that brachiopods were mainly encountered as tiny spines, while actual shell fragments are rare.
Detrital Grains & Other Non-Carbonate Grains	There are no detrital grains in this sample.
Matrix	Calcite is the main component of the matrix (15%), while clays and organics occur in trace amounts. Trace amounts of microspar has derived from the recrystallization of calcite-micrite.
Pore Filling Cements	This sample contains a 'network' of irregularly shaped voids (possible stromatactis-type fenestral cavities) that have been cemented with calcite spar. Tiny sub-vertical fractures are also healed with blocky calcite cement. Other cementing minerals occur in trace amounts and include pyrite and pyrobitumen.
Replacement Minerals	There are no replacement minerals observed in this sample.
Porosity	There is only a trace amount of intercrystalline pores that can be seen within sparry calcite cement. The core analysis done on the plug P33 reports also very low core porosity (0.5%),

	while the core permeability is less than 0.01mD.

Three annotated microphotographs of the thin section with descriptions can be found below.

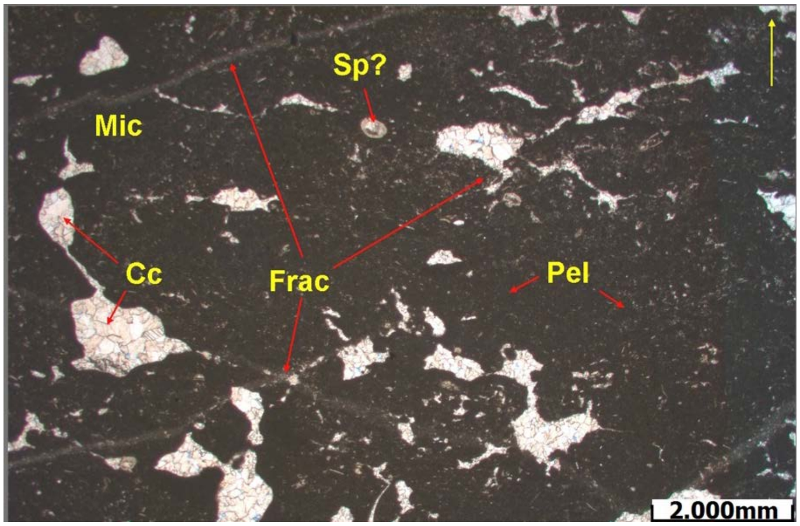

Figure 4.1. Sample T58, 4356.00ft/1327.71m. Very low magnification overview image shows a 'network' of sparry calcite cemented dissolution voids (possible stromatactis-type fenestral structures). The sample is mainly composed of very small peloids (Pel) and lesser amount of bioclasts. Due to low magnification, in this image only rare brachiopod spines (Sp?) can be tentatively identified. Both peloids and bioclasts are suspended in carbonate mud (calcite micrite – Mic). Sub-vertical microfractures (Frac) are healed with blocky calcite cement. There is no visible porosity in this image. **x12.5ppl**

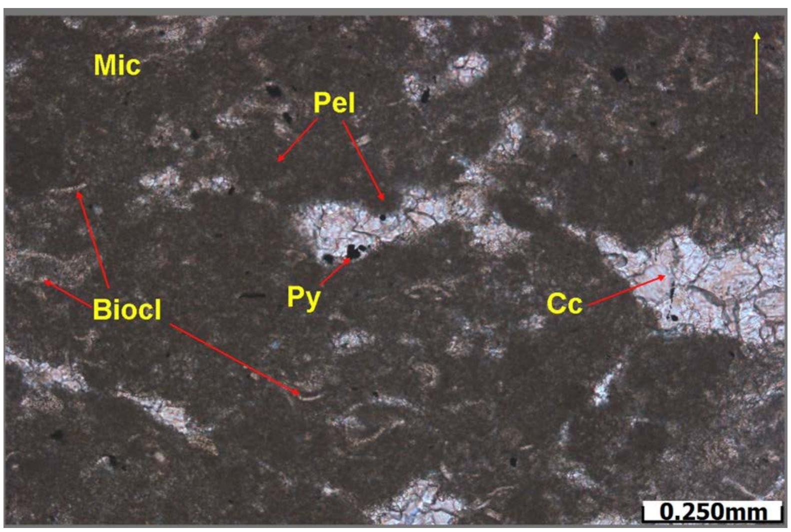

Figure 4.2. Sample T58, 4356.00ft/1327.71m. High magnification image shows micritic peloids (Pel), plus indistinct bioclast fragments (Biocl) within calcite micrite matrix (Mic). Dissolution voids (stromatactis cavity structures) are cemented with calcite spar (Cc). Occasionally pyrite framboids (Py) postdate calcite cementation. **x100ppl**

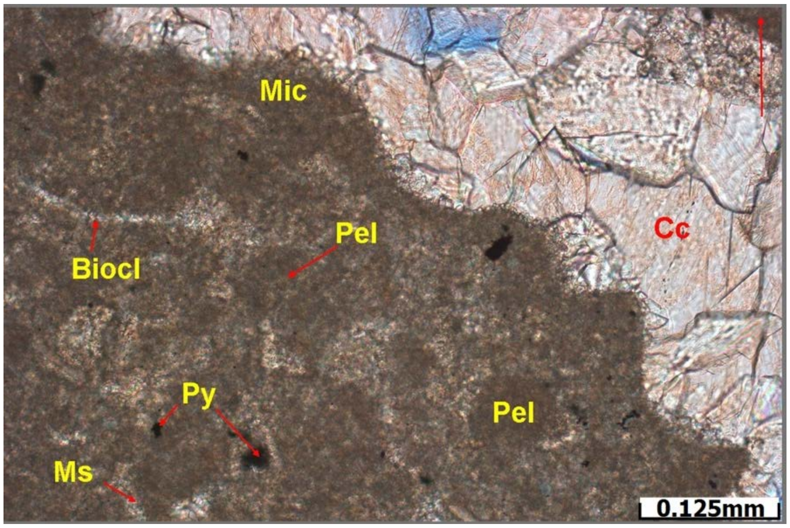

Figure 4.3. Sample T58, 4356.00ft/1327.71m. A very high magnification image shows a wavy boundary between sparry calcite filled void (CC) and underlain peloidal-bioclastic (Pel; Biocl) portion of the sample. The framework grains are floating in micrite matrix (Mic), which has been locally recrystallized to tightly packed microspar (Ms). Aggregates of pyrite framboids and cubes (Py) locally replace microspar and micrite. **.x200ppl**

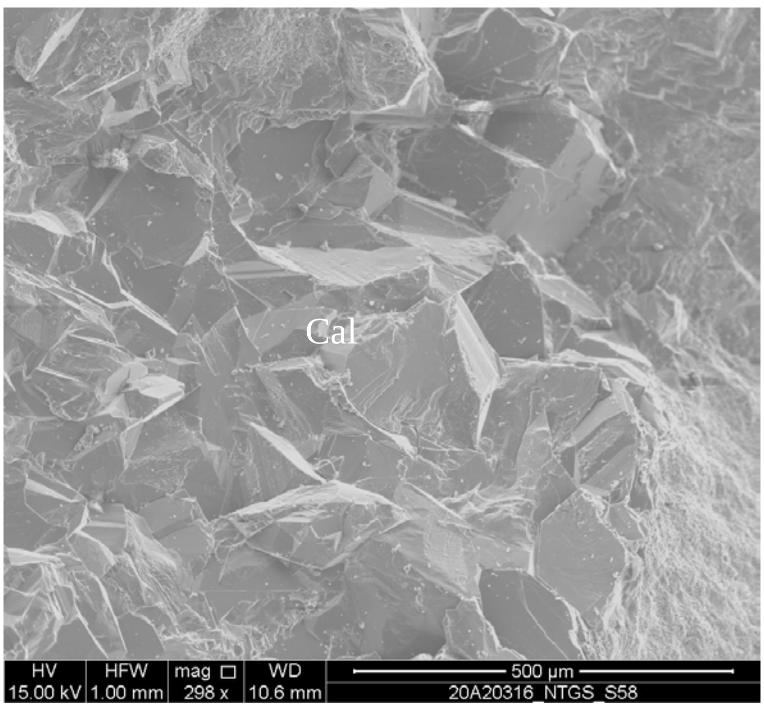

Figure 4.4. Sample S58, 4356.00ft/1327.71m. Scanning Electron Microscope (SEM) image of sparry calcite cement (Cal), which has a tightly interlocking crystal farbric and therefore lacks intercrystalline pore spaces. **x268**

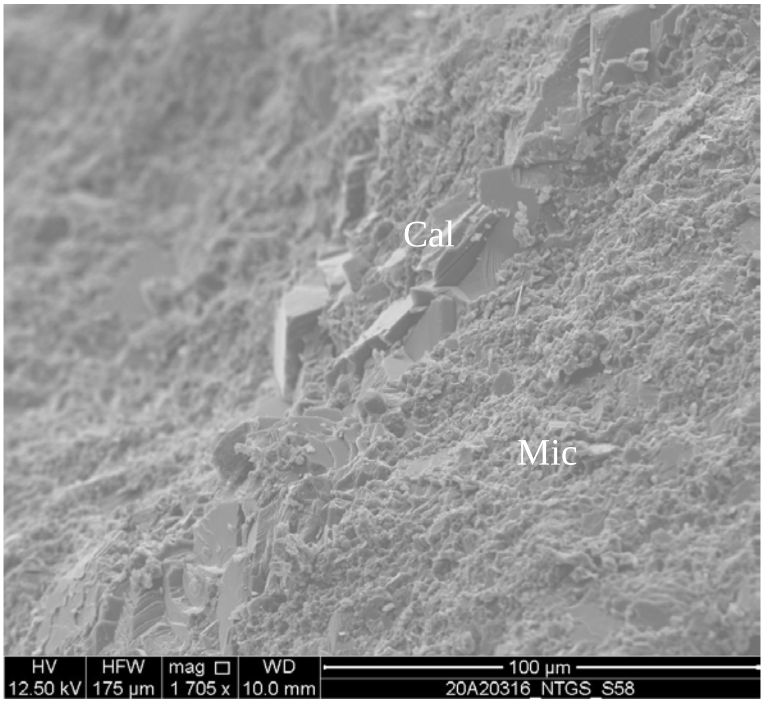

Figure 4.5. Sample S58, 4356.00ft/1327.71m. Moderate magnification Scanning Electron Microscope (SEM) image of calcite spar (Cal) within micrite (Mic). The sample appears tight with no visible porosity. **x1705**

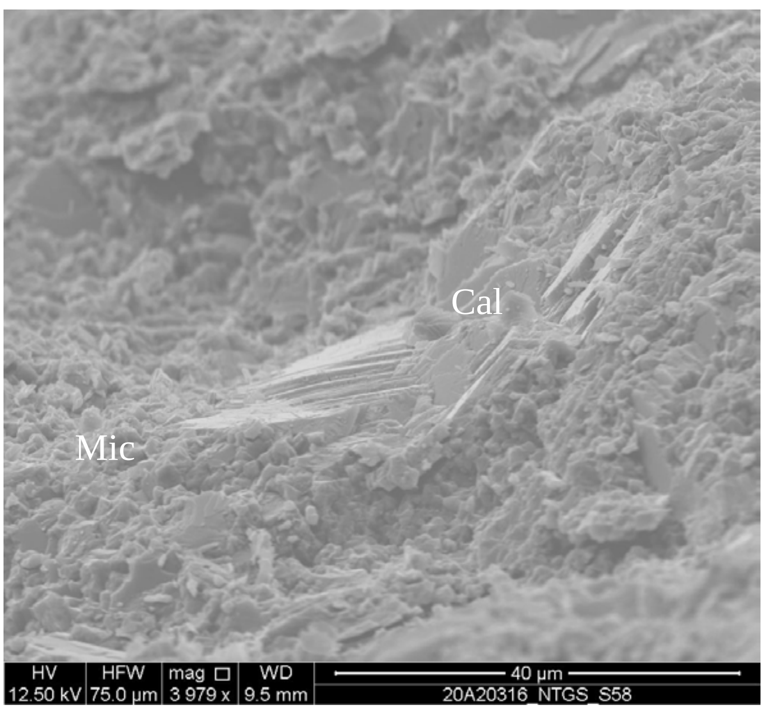

Figure 4.6. Sample S58, 4356.00ft/1327.71m. High magnification Scanning Electron Microscope (SEM) image highlighting the calcite micrite matrix (Mic) which is extremely fine and lacks visible porosity. Cal: calcite cement. **x3979**

Sample T57 (X73, S57, P32), 4361.50ft/1329.39m

Well Name	Murphy et al Netla M-31	**Location**	300/M-31-6100-12300/0
Sample type	Thin section/ SEM grain mount from a core sample	**Depth (m)**	4361.50ft/1329.39m
Stratigraphic Unit	Nahanni Formation	**Reservoir Quality**	Poor
Classification	Limestone (Packstone-Wackestone)	**Stain type**	½ Dual carbonate

MINERALOGY

	Total Bulk mineralogy					
Thin Section Point counting (%)	Calcite	Dolomite	Quartz/Cht	Pyrite	Clays & organics	OM
	96	2	TR	TR	2	-
	Framework, Matrix, Cement, and Replacement					
	Carbonate clasts	Bioclasts	Detrital grains	Matrix	Pore filling cement	Replacement
	30	30	TR	27	13	TR

ADDITIONAL FEATURES and OTHER COMMENTS

Depositional	The sample is laminated and also contains micro-fractures. While laminae formed during the deposition of the sediment, the fracturing typically happens during burial diagenesis.
Textures	Based on the mineralogy and proportion between framework components (carbonate clasts and bioclasts) and matrix, the sample was classified as limestone packstone to wackestone. For the matrix, the crystal texture has been determined as anhedral, while cement shows subhedral to euhedral crystal texture. Some bioclasts have been micritized, while crinoid fragments often show single-crystal extinction and well-developed calcite twinning.
Framework (Carbonate clasts, Bioclasts)	Dominant rock forming elements in this sample include equal amounts of carbonate clasts (30%) and bioclasts (30%). Big portion of bioclasts (10%) could not be identified due to pervasive micritization, fragmentation and/or replacement with calcite or dolomite cements. On the other hand, some of the bioclasts such as crinoids (10%), brachiopod (5%) and mollusks (5%) were still relatively well preserved. This sample contains mainly calcite (96%), while other minerals occur in trace (quartz and pyrite) to minor amounts (dolomite, clays and organics - 2% of each).
Detrital Grains & Other Non-Carbonate Grains	There is only a trace amounts of detrital quartz silt observed in this sample.
Matrix	Calcite, which is the main component of the matrix in this sample consists mainly of micro- or pseudospar (20%), minor micrite (5%), plus clays and organics (2%).
Pore Filling Cements	The pore filling cements within this sample are calcite (spar and druse – 4% and 7% respectively), dolomite (2%), plus trace pyrite.
Replacement Minerals	Besides cementing the framework, trace amounts of pyrite occur as a replacement (mainly micrite) mineral.
Porosity	There is no visible porosity in this sample. The main porosity obstructing factor is the precipitation of micro- pseudospar that has partly replaced micrite, and some of the bioclasts fragments. Additionally, calcite spar and druse, plus dolomite and pyrite cements have also contributed to the porosity reduction. RCA reports the helium porosity as 0.5%, and

	permeability less than 0.01mD.

Annotated microphotographs of the thin section with descriptions can be found below.

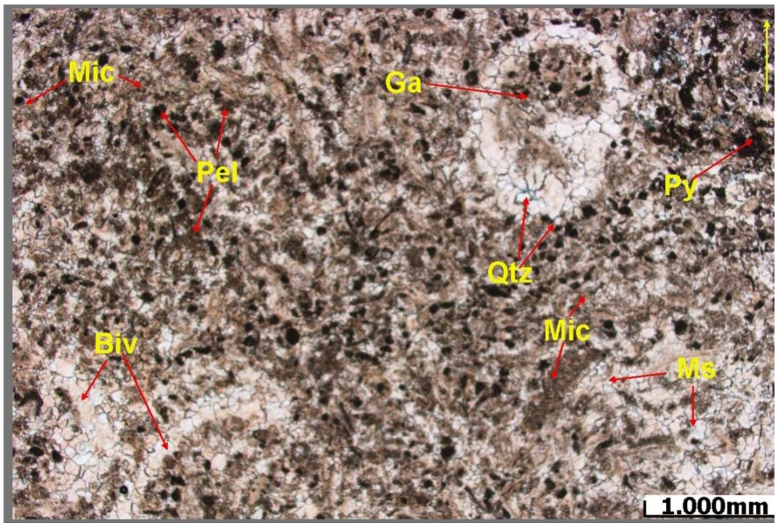

Figure 5.1. Sample T57, 4361.50ft/1329.39m. Low magnification overview of the sample shows abundant amounts of very fine grained micritic peloids (Pel), and occasional mollusks fragments [gastropod (Ga) and bivalve (Biv)]. Micrite matrix (Mic), which is locally replaced by microspar (Ms) Scattered silt sized detrital quartz grains are the only non -carbonate grains (Qtz). Pyrite aggregates (Py) locally replace micrite. The sample is tight. **x25ppl**

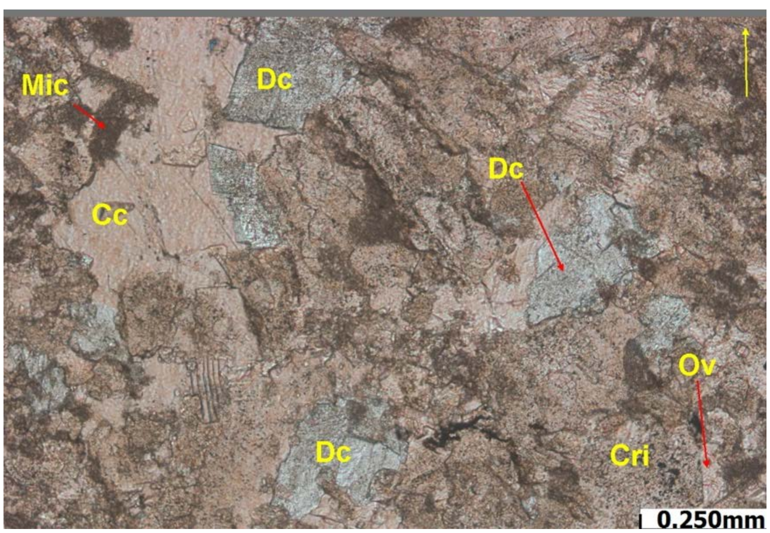

Figure 5.2. Sample T57, 4361.50ft/1329.39m. High magnification image focuses on the presence of both calcite spar (Cc) and dolomite (Dc) cemets. Both these cements fill possible dissolution void. The bioclasts in this view include occasional crinoid plates that show syntaxial overgrowths (Ov). Remnants of calcite micrite (Mic) fills primary interparticle pores. **x100ppl**

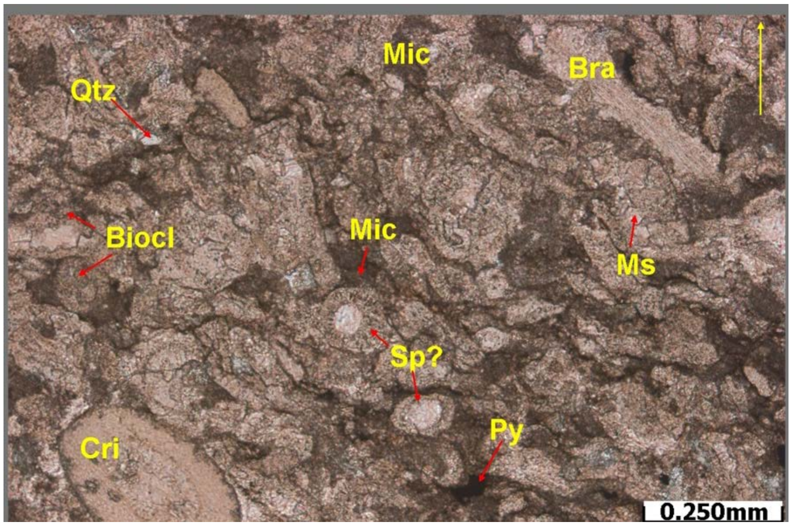

Figure 5.3. Sample T57, 4361.50ft/1329.39m. Another high magnification image shows brachiopod shells and spines (Bra; Sp?), crinoids (Cri), plus indistinct bioclasts fragments (Biocl) that are framework builders of this lime-packstone to wackestone. Micrite (Mic) is arranged into wavy partings that appear to be wrapped around the grains. Some of the micrite has recrystallized to tight microspar (Ms). Quartz silt (Qtz) is the detrital component present in this sample. Pyrite aggregates (Py) locally replace micrite. **x100ppl**

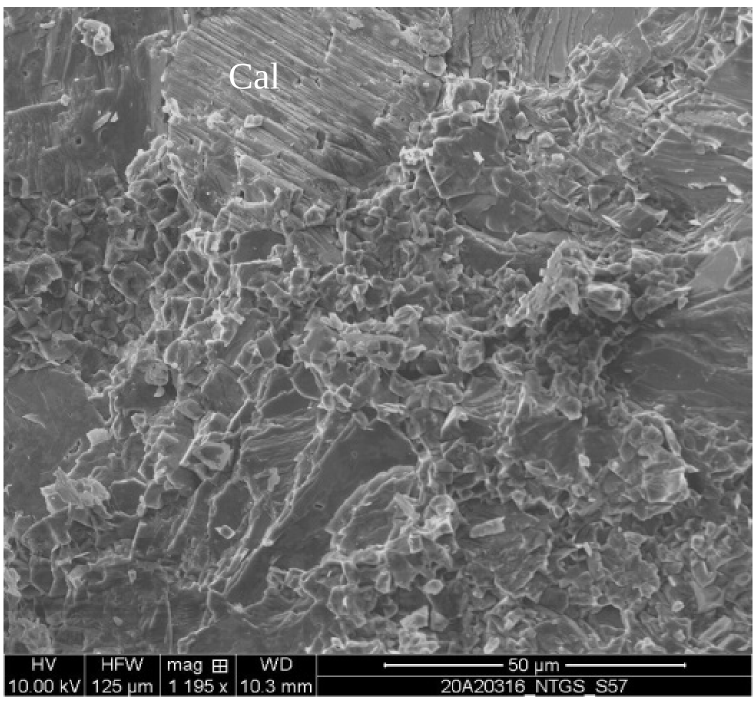

Figure 5.4. Sample S57, 4361.50ft/1329.39m. Scanning Electron Microscope (SEM) overview image showing calcite cement with visible striations (Cal). Calcite micrite and microspar comprise the surrounding matrix and generally lacks visible porosity. **x1195**

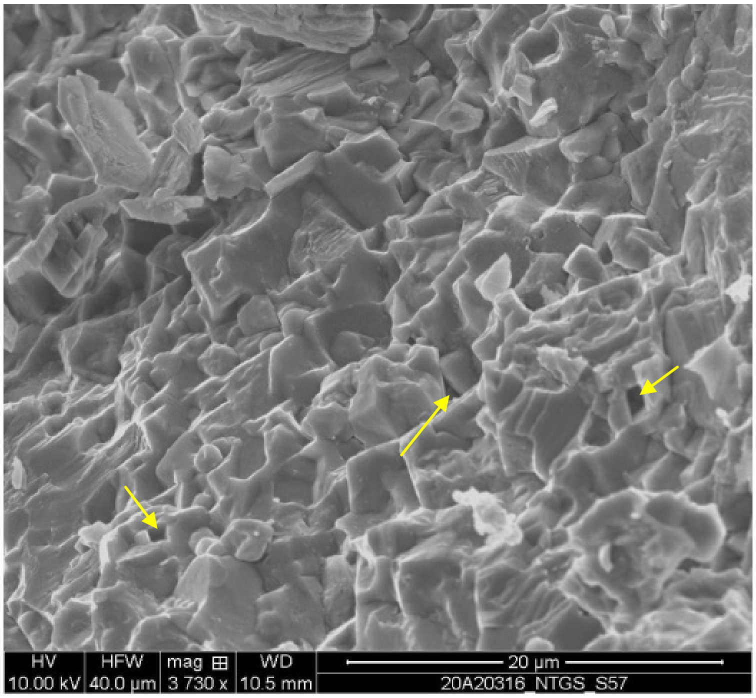

Figure 5.5. Sample S57, 4361.50ft/1329.39m. Scanning Electron Microscope (SEM) image of calcite micrite that shows possible recrystallization textures. Microporosity is denoted by yellow arrows. **x3730**

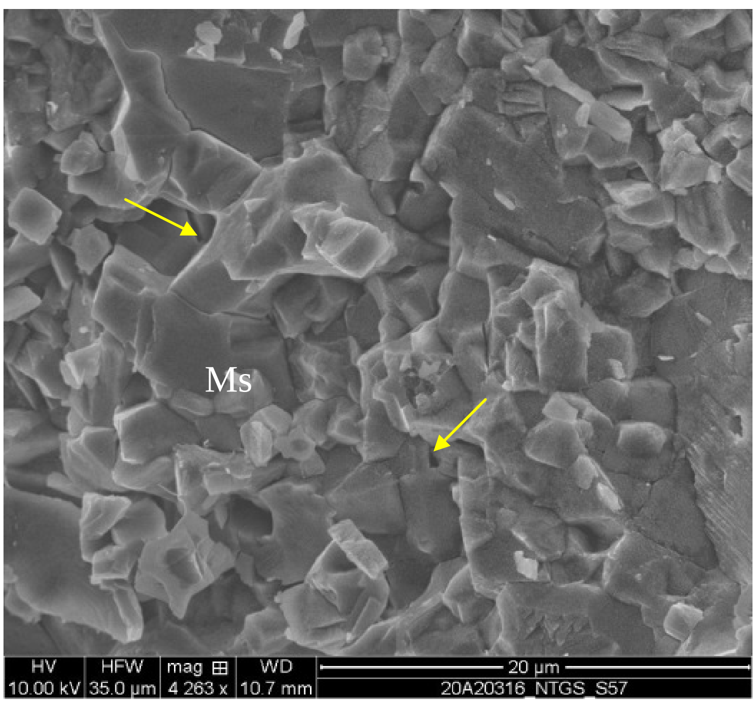

Figure 5.6. Sample S57, 4361.50ft/1329.39m. High magnfication Scanning Electron Microscope (SEM) image of tightly packed microspar (Ms). Trace submicron micropores are denoted by yellow arrows. Dc: dolomite cement. **x4263**

SUMMARY OF PORE SYSTEM, MAIN POROSITY CONTROLS AND RESERVOIR QUALITY

Diagenetic features observed at this location include the following: onset of compaction, micritization of framework grains, recrystallization of micrite to microspar, possible dolomitization (samples T57 and T59) followed by de-dolomitization, cementation of pores (coarse crystalline dolomite), partial replacement of dolomite cement with late calcite spar and pyrite, pressure solution (stylolites), authigenic silica replacements/cement, and pyrobitumen.

Chemical compaction is evidenced through pressure solution features like micro-stylolites. Insoluble bituminous organic matter and possible clays are found along these micro-stylolites. Sample T58 shows stromatactis type fenestral structures. Stromatactis is a cavity structure common in muddy carbonate sediments, which is typically filled with calcite spar. These cavities have been attributed to the decay of soft body organisms.

Note that all mentioned above diagenetic features are not necessarily present in every sample.

Total five samples were recovered from the Nahanni Formation at the Murphy et al Netla M-31 300/M-31-6100-12300/0 location, and all of them were classified as limestones. Except for sample T59 that appears to be packstone, the original texture of the other four samples has been determined as packstone to wackestone. All samples are tight and only trace amounts of intercrystalline pores were observed in sample T58 (see Petrographic Summary Table 1). The main porosity plugging factors is the abundance of calcite micrite, which has locally recrystallized into tight mosaic microspar, plus the cementation [voids – sample T58 or natural fractures in samples T58 and T57] by calcite spar, coarse crystalline dolomite, plus trace pyrite. Additionally pyrobitumen (trace to minor amounts) was spotted in the majority of the samples as intercrystalline and interparticle coatings. Syntaxial overgrowths on crinoid debris also add to the porosity reduction, but these are observed very rarely (see sample T57 – figure 5.2).

Reservoir quality for these five samples is mainly controlled by depositional environment (i.e. abundance and distribution of lime-mud, crystal and grain size of the framework builders, etc.) and to lesser extent by diagenesis (i.e. mineral diagenesis, recrystallization of micrite to microspar, compaction, and cementation). Reservoir quality is considered to be poor for these samples.

The following table summarizes the most important factors that control the reservoir quality of the five samples recovered from the study location. Note that the reservoir quality of these samples is accessed only based on the thin section petrology.

NAHANNI Formation

Sample ID	Depth (ft/m)	Total Micrite (%)	Total Cement/ Replacement (%)	Total Porosity (%)						Main Porosity controlling factors (*)	RQ (*)
				IP	Int.	Ixl	mV	Fr	M		
Location: Murphy et al Netla M-31 300/M-31-6100-12300/0											
T61	4269.00/1301.19	60	10	-	-	-	-	-	-	Mic; Com; Cc; OM; C	P
T60	4302.90/1311.52	51	3	-	-	-	-	-	-	Mic; Com; Cs; Qc; Py; OM;	P
T59	4329.25/1319.56	36	5	-	-	-	-	-	-	Mic; Com; Cc; Dc; OM; Ms; C	P
T58	4356.00/1327.71	15	23	-	-	TR	-	-	-	Cc;; Mic; Com; Py; C; OM;	P
T57	4361.50/1329.39	27	13	-	-	-	-	-	-	Com; Ms; Cc; Mic; C; Dc; Py	P

Porosity value (%): **IP** – interparticle porosity; **Int** – intraparticle; **Ixl** – intercrystalline; **mV** – micro-vuggy; **Fr** – fracture porosity; **M** – micro-intercrystalline porosity
Main Porosity controlling factors: **Com** – compaction (mechanical and chemical)**; Dol** – dolomitization; M**ic** – micrite (calcite or dolomite) and/or micritization; **Ms** – micro- and/or pseudospar; **Cc** – calcite cement (druse and spar); **Dc** – dolomite cement**; C** – clays and organics; **Qc** – quartz/chert cement; **Ov** – crinoid overgrowths; P**y** – pyrite (replacement and/or cement); **OM** – organic matter/pyrobitumen; **Dis** – dissolution; **F** – fabric: [**CC** – concavo-convex orthochem contacts; **S** – sutured orthochem contacts]
RQ (*) - reservoir quality: **VP** – very poor; **P** – poor; **M** – moderate; **G** - good

Reservoir problems for the samples recovered from the Nahanni Formation at the Murphy et al Netla M-31 300/M-31-6100-12300/0 location may include the following: **(1)** extremely rare and small sizes of intercrystalline pores would restrict the flow and storage of hydrocarbons, **(2)** hydrochloric acid (HCl) treatment of this reservoir has the potential to loosen carbonate fines (calcite micrite) that could migrate and block pore throats, plus cause fabric collapse, **(3)** the sensitivity of calcium carbonate to hydrofluoric acid (HF) in regard to precipitation of calcium fluoride scales, (4) Pore lining pyrobitumen may react with hydrochloric acid (HCl) to create sludges or viscous emulsions, which can restrict permeability potential. Both sludges and emulsions may be removed by using appropriate surfactants (surface active agents), which reduce interfacial and surface tension and result in a more miscible mixture of oil and water (acid). Any drilling, completion or workover must ensure the fluid acid compatibility with the formation pyrobitumen.

Comments in regards to the Routine Core Analysis vs Thin Section point counted porosity

Porosity and permeability results derived from the Routine Core Analysis (RCA) can be found in the Petrographic Summary Tables 1 under the header ‘Petrophysical Results’. The information regarding routine porosity and permeability are presented only to compare different methods that could be used to evaluate reservoir quality, plus to see what could possibly affect the results. The table below shows the Thin Section and RCA sample ID, spot depth that they represent (in feet and meters), helium porosity (Φ) and permeability (K_{max}), plus point counted porosity.

Sample ID	**Depth (ft/m)**	**RCA results**		**TS Porosity Φ (%)**	**Rock Classification**
		Φ(%)	**K_{max} (mD)**		
Nahanni Formation					
T61/P36	4269.00/1301.19	0.9	0.02*	Nil	Limestone (Packstone-Wackestone)
T60/P35	4302.90/1311.52	0.05	<0.01*	Nil	Limestone (Packstone-Wackestone)
T59/P34	4329.25/1319.56	0.05	<0.01	Nil	Limestone (Packstone)
T58/P33	4356.00/1327.71	0.05	<0.01	TR	Limestone (Packstone-Wackestone)
T57/P32	4361.50/1329.39	0.05	<0.01	Nil	Limestone (Packstone-Wackestone)

RCA – Routine Core Analysis; TS – Thin section (*) Permeability measurement affected by fractures

The porosity calculated using RCA is similar to the porosity obtained using thin section point counting technique. It should be noted that the Routine Core Analyses measure both effective (visible) and non-effective porosity (microporosity) associated with micrite, and micritized framework grains. On the other hand the thin section petrology only point counts the visible porosity. To summarize, the very slight difference between thin section and core analysis is due to non-visible microporosity, which is associated with micrite, carbonate fines and microporous framework builders, the heterogeneity of core and thin section samples (heterogeneous distribution of cements) and the difference in dimension (aspect ratio) of thin section and core samples[2].

[2] During the thin section examination a two-dimensional representative area is analyzed, whereas petrophysical core analysis reflects the three-dimensional pore volume.

REFERENCES

Scholle, P.A. and Ulmer-Scholle, D.S. 2006. A Color Guide to the Petrography of Carbonate Rocks: Grains, Textures, Porosity, Diagenesis. AAPG Memoir 77. American Association of Petroleum Geologists, Tulsa, O.K.

Welton, J.E. 2003. SEM Petrology Atlas. Methods in Exploration Series No. 4. American Association of Petroleum Geologists, Tulsa, O.K.

DATA TABLES

Table 1

Petrographic Summary of Five Samples recovered from the Nahanni Formation at the Murphy et al Netla M-31 300/M-31-6100-12300/0 Location

Sample ID		**T61**	**T60**	**T59**	**T58**	**T57**
Depth (ft)		**4269.00**	**4302.90**	**4329.25**	**4356.00**	**4361.50**
Rock Type		**LS**	**LS**	**LS**	**LS**	**LS**
Mineralogy	*Calcite*	99	100	98	97	96
	Dolomite	-	-	1	-	2
	Quartz	-	TR	-	-	TR
	Chert	-	-	-	-	-
	Anhydrite/Gypsum	-	-	-	-	-
	Pyrite and Heavy Minerals	-	TR	-	3	TR
	Phosphate	-	-	-	-	-
	Pyrobitumen	1	TR	1	TR	-
	Clays & organics	**TR**	**-**	**TR**	**TR**	**2**
Total Rock Volume (%)		**100**	**100**	**100**	**100**	**100**
Carbonate Clasts	*Peloids*	-	1	5	35	30
	Ooids	-	-	-	-	-
	Intraclasts/Oncolintes	-	-	-	-	-
	Total:	**0**	**1**	**5**	**35**	**30**
Bioclasts/Fauna	*Mollusks*	2	6	4	5	5
	Foraminifers	-	-	-	-	-
	Brachiopod (shell & spines)	6	10	10	2	5
	Bryozoa	-	-	-	-	-
	Corals	-	-	-	-	-
	Algae	-	-	-	-	-
	Echinoderms/Crinoids	2	8	10	-	10
	Trilobites	-	-	-	-	-
	Ostracodes	TR	1	-	-	-
	Stromatoporoid	TR	-	-	-	-
	Unidentified	20	20	30	20	10
	Total:	**30**	**45**	**54**	**27**	**30**
Detrital Grains and Other Non-Carbonate Grains	*Quartz*	-	-	-	-	TR
	Chert	-	-	-	-	-
	Heavy Mineral	-	-	-	-	-
	Total:	**0**	**0**	**0**	**0**	**0**
Matrix	*Micrite (calcite or dolomite)*	60	45	35	15	5
	Micro- and pseudospar	-	6	1	TR	20
	Clays & organics	TR	-	TR	TR	2
	Sutured allochems	-	-	-	-	-
	Total:	**60**	**51**	**36**	**15**	**27**
Pore Filling Cement	*Calcite Spar*	9	-	3	20	4
	Calcite druse	-	3	-	-	7
	Dolomite	-	-	1	-	2
	Quartz/Chert	-	TR	-	-	-
	Pyrite	-	TR	-	TR	TR
	Pyrobitumen	1	TR	1	TR	-
	Total:	**10**	**3**	**5**	**20**	**13**
Replacement	*Calcite*	-	-	-	-	-
	Dolomite	-	-	-	-	-
	Anhydrite	-	-	-	-	-
	Quartz/Chert	-	TR	-	-	-
	Pyrite	-	-	-	3	TR
	Total:	**0**	**TR**	**0**	**3**	**TR**
Total Rock Volume (%)		**100**	**100**	**100**	**100**	**100**
Crystal Texture (Matrix)		Anh	Anh	Anh	Anh	Anh
Crystal Texture (Cement)		Sub-Euh	Sub-Euh	Sub-Euh	Sub-Euh	Sub-Euh
Structure/Fabric		Styl;Lm		Styl	Fracs	Fracs; Lm
Ratio Matrix/Clasts (approximate)		2:1	1:1	1:2	1:4	1:2
Original Texture		PS-WS	PS-WS	PS	PS-WS	PS-WS
Porosity (%)	*Interparticle*	-	-	-	-	-
	Intraparticle	-	-	-	-	-
	Intercrystalline	-	-	-	TR	-
	Fracture	-	-	-	-	-
	Micro-Vuggy	-	-	-	-	-
	Micro- intercrystalline pores	-	-	-	-	-
	Total TS Porosity (%)	**0**	**0**	**0**	**TR**	**0**
Petrophysical Results	*Core Porosity (%)*	**0.9**	**0.5**	**0.5**	**0.5**	**0.5**
	Core Permeability (mD)	**0.02***	**<.01***	**<.01**	**<.01**	**<.01**
Reservoir Quality		**Poor**	**Poor**	**Poor**	**Poor**	**Poor**

LIST OF ABBREVIATIONS (CARBONATES)

SKELETAL GRAINS

Bry	-	BRYOZOAN
Ech	-	ECHINODERMS
Bra	-	BRACHIOPODS
Os	-	OSTRACODS
Cal	-	CALCISPHERES
Moll	-	MOLLUSKS
Plcy	-	PELECYPODS
Biv	-	BIVALVES
For	-	FORAMINIFERA
Strom	-	STROMATOPOROIDS
Cor	-	CORALS
Ga	-	GASTROPODS
Biocl	-	BIOCLASTS

OTHER GRAINS

Pel	-	PELOIDS
Ooi	-	OOIDS

ORIGINAL TEXTURE

GS	-	GRAINSTONE
PS	-	PACKSTONE
WS	-	WACKESTONE
MS	-	MUDSTONE
FS	-	FLOATSTONE
RS	-	RUDSTONE

CRYSTAL TEXTURE

Euh	-	EUHEDRAL
Sub	-	SUBHEDRAL
Anh	-	ANHEDRAL

CRYSTAL SIZE

Cxl	-	COARSE CRYSTALLINE
Mxl	-	MEDIUM CRYSTALLINE
Fxl	-	FINE CRYSTALLINE
Vfxl	-	VERY FINE CRYSTALLINE

CEMENT TYPES

Syn	-	SYNTAXIAL OVERGROWTHS
Blo	-	BLOCKY
Poik	-	POIKILOTOPIC
Dru	-	DRUSY
SD	-	SADDLE DOLOMITE
Lath	-	ANHYDRITE LATHS
Grm	-	GROUNDMASS
Iso	-	ISOPACHOUS RIMS
Spa	-	SPARITE

POROSITY TYPES

Mixl	-	MICRO-INTERCRYSTALLINE
Ixl	-	INTERCRYSTALLINE
Mo	-	BIOMOLDIC
mV	-	MICROVUGGY
mF	-	MICROFRACTURE
IG	-	INTERGRANULAR
IP	-	INTERPARTICLE
INTRP	-	INTRAPARTICLE

QUALITY

G	-	GOOD
M	-	MODERATE
P	-	POOR

Well Name: Murphy et al Netla M-31
Well ID: 300/M-31-6100-12300/0
NT WID # N340

Table 2: Results of quantitative mineral analysis (relative weight %) of X-ray diffraction data for 4 (four) samples using Rietveld method

Geology ID	Depth (ft)	Depth (m)	Core & Box #	NTGS Sample Type & #	**Calcite**	**Dolomite**	**Quartz**	**Muscovite/ Illite**	**Gypsum**	**Pyrite**	**Marcasite**	**Total**
1	4269.00	1301.19	1 & 1 of 12 L	T61, X76, S61, P36	99.7		0.3					100.0
2	4302.90	1311.52	1 & 7 of 12 R	T60, X75, S60, P35	99.6		0.4					100.0
3	4329.25	1319.56	1 & 12 of 12 R	T59, X74, S59, P34	97.8	1.0	0.5	0.6		0.1		100.0
4	4361.50	1329.39	2 & 7 of 8 L	T57, X73, S57,P32	71.7	4.1	1.4	18.4	1.1	2.6	0.7	100.0

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