PETROGRAPHIC STUDY OF ELEVEN SAMPLES RECOVERED FROM THE NAHANNI FORMATION AT WELL LOCATION IMPERIAL SUN ARROWHEAD AURORA M-47 300/M-47-6040-12230/0

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SERVICE BEYOND ANALYSIS

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EXECUTIVE SUMMARY

The purpose of this study is to describe the observed lithological characteristics, associated reservoir quality and fluid sensitivity of eleven petrographic samples collected from the Nahanni Formation at well location Imperial Sun Arrowhead Aurora M-47 300/M-47-6040-12230/0. Petrographic analyses and interpretations are based on the observation of thin section samples generated from core and SEM samples, while XRD analyses were also completed for some of the samples to confirm mineralogy and clay types. An overview of general sample information can be found below within **Table A:**

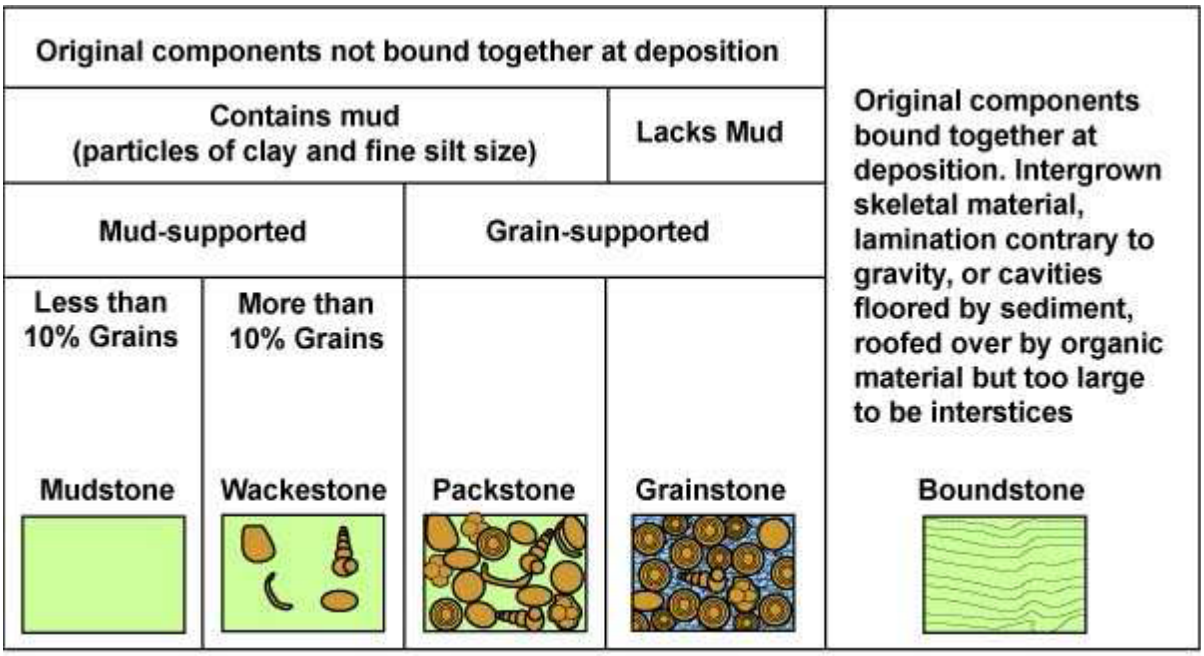
TS sample ID	Depth (ft/m)	Formation	Rock Classification	Analysis (*)	Reservoir Quality (*)
Location: Imperial Sun Arrowhead Aurora M-47 300/M-47-6040-12230/0					
T36, X49, S36, P26	7770.00 ft 2368.30 m	Nahanni	Limestone (Wackestone-Packstone)	TS; SEM; XRD	P
T35, X48, S35, P25	7775.00 ft 2369.82 m	Nahanni	Limestone (Packstone-Wackestone)	TS; SEM; XRD	P
T34, X47, S34, P24	7779.30 ft 2371.13 m	Nahanni	Limestone (Grainstone)	TS; SEM; XRD	P
T33, X46, S33, P23	7784.30 ft 2372.65 m	Nahanni	Limestone (Grainstone)	TS; SEM; XRD	P
T32, S32, P22	7785.50 ft 2373.02 m	Nahanni	Limestone (Grainstone)	TS; SEM	P
T31, X45, S31, P21	7793.10 ft 7375.34 m	Nahanni	Limestone (Wackestone-Packstone)	TS; SEM; XRD	P
T30, S30, P20	7796.10 ft 2376.25 m	Nahanni	Limestone (Grainstone)	TS; SEM	P
T29, S29, P19	7800.70 ft 2377.65 m	Nahanni	Limestone (Grainstone)	TS; SEM	P
T28, X44, S28,	7803.00 ft 2378.35 m	Nahanni	Limestone (Grainstone)	TS; SEM; XRD	P

P18					
T27, S27, P17	7808.10 ft 2379.91 m	Nahanni	Limestone (Grainstone - Packstone)	TS; SEM	P
T26, S26, P16	7814.40 ft 2381.83 m	Nahanni	Limestone (Grainstone - Packstone)	TS; SEM	P

(*) TS- Detailed thin section analysis with Images; SEM _ Scanning Electron Microscope analysis with images; XRD: Bulk & Clay X-Ray Analysis

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 eleven samples are classified as limestones. The samples show mainly grainstone texture, except for samples T26 and T27 which have a grainstone to packstone texture, in addition to samples T31 and T36 which have a wackestone to packstone texture, while T35 has a packestone to wackestone texture. Sedimentary structures include discontinued laminae and low amplitude micro-stylolites, plus fractures. Sutured allochems were also noted in some samples (see the Petrographic Summary Table 1).

The mineralogy of these eleven limestone samples is dominated by calcite (90% to 100% of the total rock volume), while pyrite (trace to 3%), dolomite (trace to 2% - T27, T30, T33-T36), clays and organic matter (trace to 5%), quartz (trace - T34 and T36) and anhydrite (trace - T33 only) are the other minerals.

The framework components (allochems) include bioclasts (7% to 92%) and carbonate clasts (trace to 61%). Bioclasts are dominated by crinoid fragments (2% to 85%). Other bioclasts identified include corals (10% to 45% - T26, T31-T33), stromatoporoids (40% - T30 only) brachiopod fragments (1% to 20% - T26, T30, T31, T33, T36), mollusks (trace to 10% - most samples), trilobite fragments (trace to 5% - T29 and T31) and ostracode carapaces (1% - T3). Bryozoa (trace to 5%) were noted in trace to minor amounts in some samples (T26, T31, T34, T36), while sample T27 is dominated by bryozoan (65%). Trace algae is also noted in sample T38. Due to poorly preserved morphology and fragmentation, some bioclast fragments were grouped in the 'Unidentified' category (trace to 20%) in the Petrographic Summary Table 1. The carbonate clasts are represented by peloids (trace to 60% - T29-T32, T35), in addition to limestone intraclasts (3% - T36). Ooids (1%) were also identifies in sample T35.

Orthochems are dominated by lime-mud (micrite) which occurs in minor to moderate amounts (1% to 15%). 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

[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).

to coarser crystalline micro- or pseudospar usually drastically reduces the amount of micro-intercrystalline porosity. Based on observation of the thin section samples, micro- and/or pseudospar is noted in moderate amounts (15%) in sample T35. However, with detailed observation under the Scanning Electron Microscope (SEM) some degree of recrystallization resulting in microspar is evident in most samples. Besides the micrite and micro- or pseudospar, trace to minor amounts of clays and organic material (trace to 5%) are also present as part of the matrix. The total pore filling cements range from 4% to 13%. The cements were identified as calcite spar and druse (2% to 13%), dolomite (trace to 1% - only in samples T30, T33, T35-T36), ferroan dolomite (trace to 1% - samples T27, T34-T36), plus trace anhydrite (sample T33). Replacement minerals include trace to minor pyrite (trace to 3%), plus trace quartz (samples T34 and T36).

Porosity within the limestone samples includes micro-intercrystalline porosity (trace to 2% - T26, T29, T32, T33) and intercrystalline porosity (trace to 1% - T34 and T35). Trace fracture porosity occurs in samples T30 and T32-T33, in addition to trace micro-vuggy porosity in sample T35, plus trace interparticle in sample T34. The main porosity plugging factors observed at this location include cementation by calcite spar, plus the variable abundance of calcite micrite, which has locally recrystallized to tight mosaic microspar.

Reservoir quality for these eleven samples is mainly controlled by diagenesis (i.e. mineral diagenesis, recrystallization of micrite to microspar, compaction, and cementation) in addition to 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.). 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 **Appendix/Data Tables** 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.

NAHANNI Formation

Sample ID	Depth (ft)	Total Micrite (%)	Total Cement (%)	Total Porosity (%)						Main Porosity controlling factors (*)	RQ(*)
				IP	Int.	Ixl	Mv	Fr	M		
Location: Imperial Sun Arrowhead Aurora M-47 300/M-47-6040-12230/0											
T36	7770.00	15	4	-	-	-	-	-	-	Mic; Cc; Com	P
T35	7775.00	5	19(*)	-	-	1	TR	-	-	Cc; Mic	P
T34	7779.30	2	5	TR	-	TR	-	-	-	Cc; Mic	P
T33	7784.30	1	6	-	-	-	-	TR	1	Cc	P
T32	7785.50	1	9	-	-	-	-	TR	2	Mic; Cc	P
T31	7793.10	10	10	-	-	-	-	-	-	Mic; Cc	P
T30	7796.10	1	5	-	-	-	-	TR	-	Cc; Com	P
T29	7800.70	8	10	-	-	-	-	-	TR	Cc; Mic	P
T28	7803.00	1	10	-	-	-	-	-	-	Cc	P
T27	7808.10	4	9	-	-	-	-	-	-	Cc; Mic	P
T26	7814.40	6	13	-	-	-	-	-	1	Cc: Mic	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; P**y** – 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 Imperial Sun Arrowhead Aurora M-47 300/M-47-6040-12230/0 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.

METHODS

Petrographic Microscopy

To prepare the thin section samples, select portions of the core samples were impregnated wth 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. To determine original texture of dolostone samples, the 'white card' technique has been used. 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. A detailed petrographic summary which includes all samples (**Table 1**) is provided 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 overall mineralogy.

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.

Classification and 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.

To describe detrital grains sizes, the Wentworth divisions will be used. The following is a list of actual size range for each Wentworth grain size: coarse silt (31 to 62.5μm), very fine (62.5 -125μm), fine (125 - 250μm), medium (250 - 500μm), coarse (500- 1000μm), very coarse (1000 - 2000μm), plus granule (2000 - 4000μm) and pebble (>4000μm). The suffix ‘lower’ denotes that the grain size is toward the smaller portion of a specific size range, while the suffix ‘upper’ denotes that the grain size is toward the larger portion of a specific size range.

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 eleven samples that were recovered from the Imperial Sun Arrowhead Aurora M-47 300/M-47-6040-12230/0 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 have been marked with an arrow placed in the upper right portion of the thin section.

Stratigraphic Unit: Nahanni Formation

Sample T36/ X49/ S36/ P26, 7770.00ft/2368.30m

Well Name	Imperial Sun Arrowhead Aurora M-47	**Location**	300/M-47-6040-12230/0
Sample Type	Thin section/SEM grain mount from a core sample	**Depth (m)**	7770.00ft/2368.30m
Stratigraphic Unit	Nahanni Formation	**Reservoir Quality**	Poor
Classification	Limestone (Wackestone-Packstone)	**Stain type**	½ Dual carbonate stain

MINERALOGY

Thin Section Point counting (%)	Total bulk mineralogy					
	Calcite	**Dolomite**	**Anhydrite**	**Quartz**	**Pyrite**	**Clays & organics**
	94	1		TR	2	3
	Framework, Matrix, Cement, and Replacement					
	Carbonate clasts	**Bioclasts**	**Detrital grains**	**Matrix**	**Pore filling cement**	**Replacement**
	18	58		18	4	2

ADDITIONAL FEATURES and OTHER COMMENTS

Depositional	At the time of deposition, the sample was most likely massive. Formation of low amplitude stylolites and fracturing of the sediment typically happens during burial diagenesis (mechanical and chemical compaction).
Textures	Based on the mineralogy and proportion between framework components (carbonate clasts and bioclasts) and matrix, the sample was classified as lime wackestone-packstone. For the matrix, the crystal texture has been determined as anhedral, while cement shows subhedral to euhedral crystal texture. Majority of bioclasts are highly fragmented and micritized
Framework (Carbonate clasts, Bioclasts)	Petrographic Summary Table 1 shows detailed mineralogy of the sample. This sample contains 94% of calcite. Other minerals include clays and organics (3%), pyrite (2%), dolomite (1%), plus trace quartz. Calcite occurs mainly as bioclasts [indistinct 20%, brachiopod (18%), crinoids -15%, plus trace algae and bryozoans] and as carbonate clasts [peloids – 15%, and intraclasts/oncolites – 3%].

Detrital Grains & Other Non-Carbonate Grains	There are no detrital grains in this sample. Trace amounts of microcrystalline quartz is a replacing agent of crinoid plates.
Matrix	Calcite is the main component of the micritic matrix (15%), while clays and organics (associated with stylolites) occur in minor amounts (3%).
Pore Filling Cements	The pore filling cements occur in minor amounts and include calcite spar (3%) and dolomite (1%).
Replacement Minerals	Minor amounts of pyrite (2%) is locally intermixed with organic material, which is one of the main components of stylolitized laminae. Additionally pyrite also replaces micrite within the matrix and micritized framework grains. Microcrystalline quartz locally replaces crinoid debris.
Porosity	There is no visible porosity in this sample; however fair amounts of microporosity is related to micritic matrix, carbonate clasts, and micritic bioclasts.

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

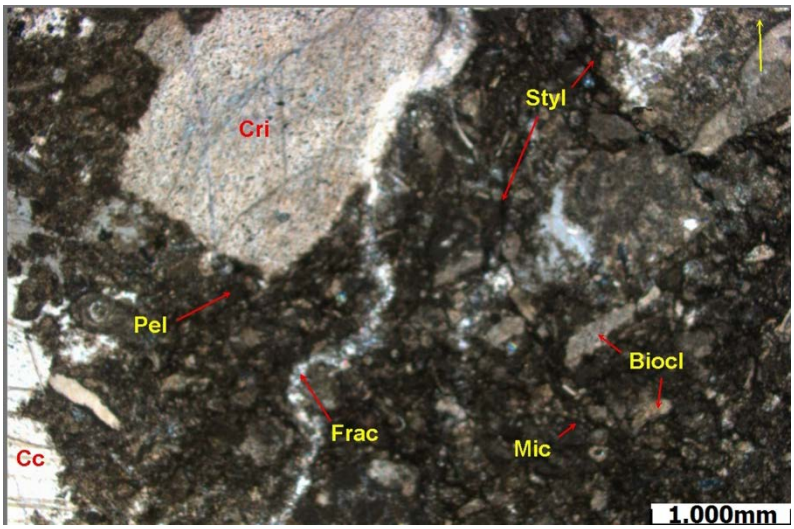


Figure 1.1. Sample T36, 7770.00ft/2368.30m. An overview of the sample shows a few crinoid debris (Cri) that are locally cemented by their syntaxial overgrowths (upper right). The groundmass shown in this image comprise calcite micrite (Mic) with randomly distributed peloids (Pel) and highly fragmented indistinct bioclast fragments (Biocl). Sub-vertical micro-fracture has been healed with calcite druse. Calcite spar (Cc) fills dissolution pores (micro-vugs or biomolds).
x25ppl

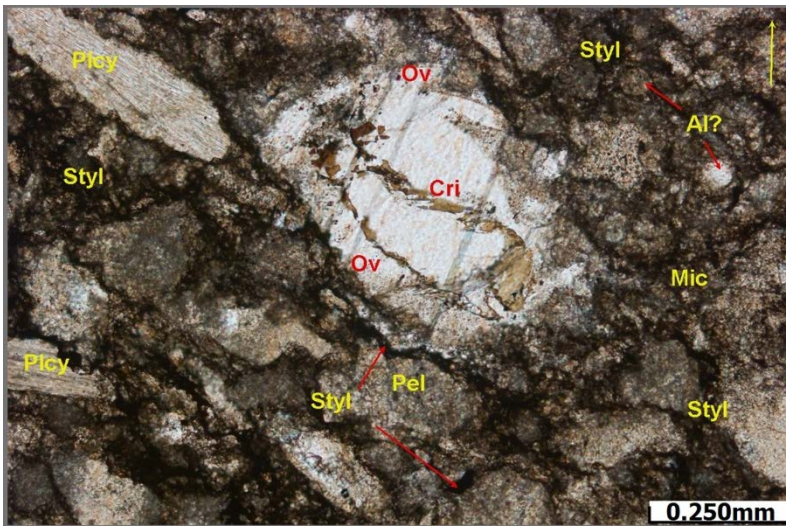


Figure 1.2. Sample T36, 7770.00ft/2368.30m. High magnification image shows tightly packed framework grains that include crinoids (Cri), plus lesser amounts of molluscan (pelecypod - Plcy), and possible algae (Al?). Note sutured (stylolitic – Styl) contacts between some of the grains. Dark brown-black color of the stylolites suggests that their main component is organic matter most likely intermixed with clays. Mic: micrite matrix. **x100ppl**

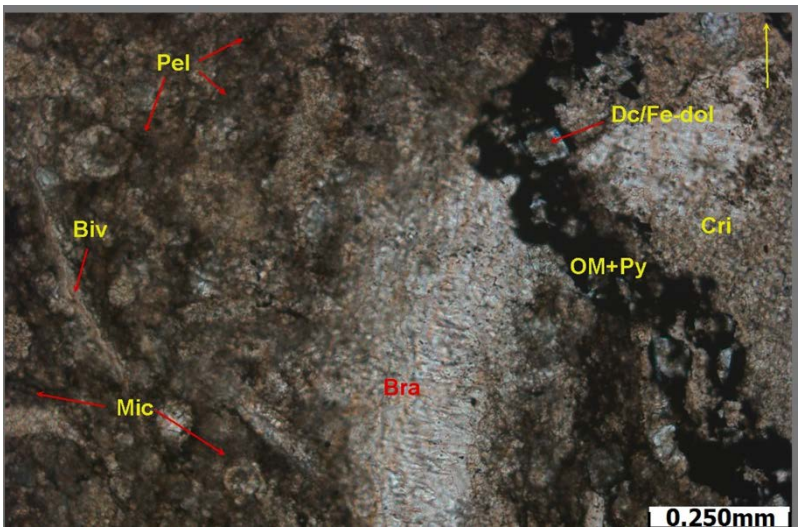


Figure 1.3. Sample T36, 7770.00ft/2368.30m. Another high magnification image highlights the presence of dolomite rhombs within pyritized organic matter (OM+Py). Note that dolomite rhombs have non-ferroan cores and ferroan rims (Dc/Fe-Dol). Highly micritized possible brachiopod shell fragments (Bra) crinoid plates (Cri) and indistinct bivalve shell fragments (Biv) are the bioclasts in this image, while peloids (Pel) are the carbonate clasts. The framework builders are surrounded by calcite-micrite matrix (Mic). **x100ppl**

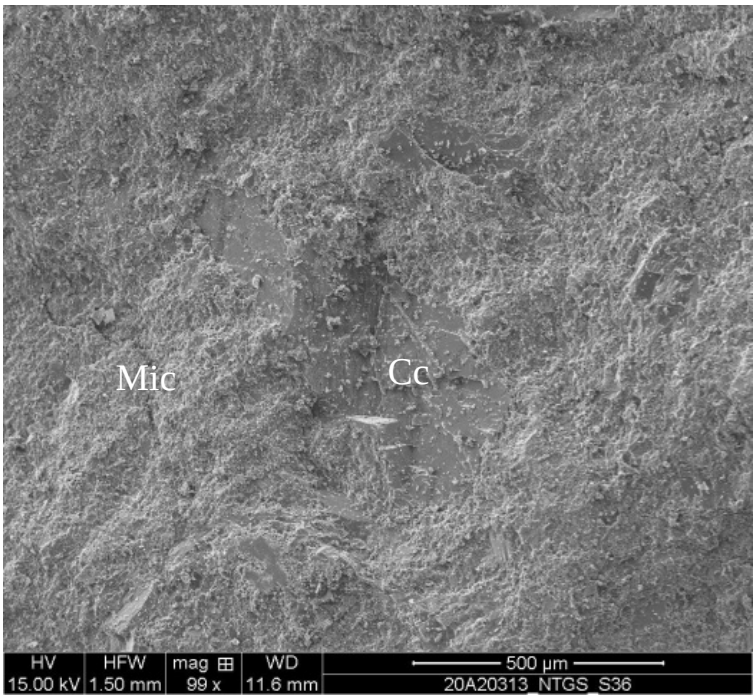


Figure 1.4. Sample S36, 7770.00ft/2368.30m. Low magnification Scanning Electron Microscope (SEM) image showing patchy calcite cement (Cc) within a micrite matrix (Mic). At low magnifications this sample lacks visible porosity; however, in subsequent higher magnification SEM images scattered micropores can be viewed. **x99**

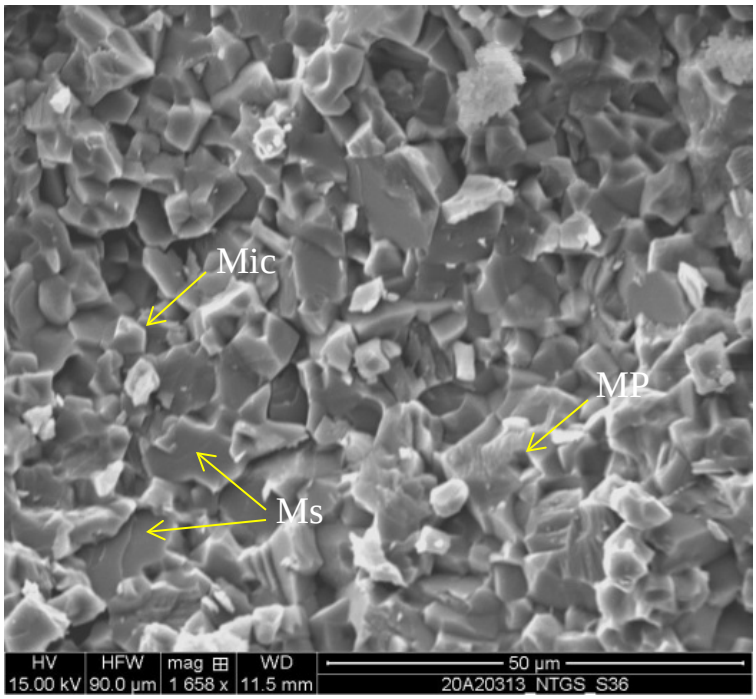


Figure 1.5. Sample S36, 7770.00ft/2368.30m. Scanning Electron Microscope (SEM) image showing scattered microporosity (MP) within the calcite micrite/microspar matrix (Mic/Ms). **x1658**

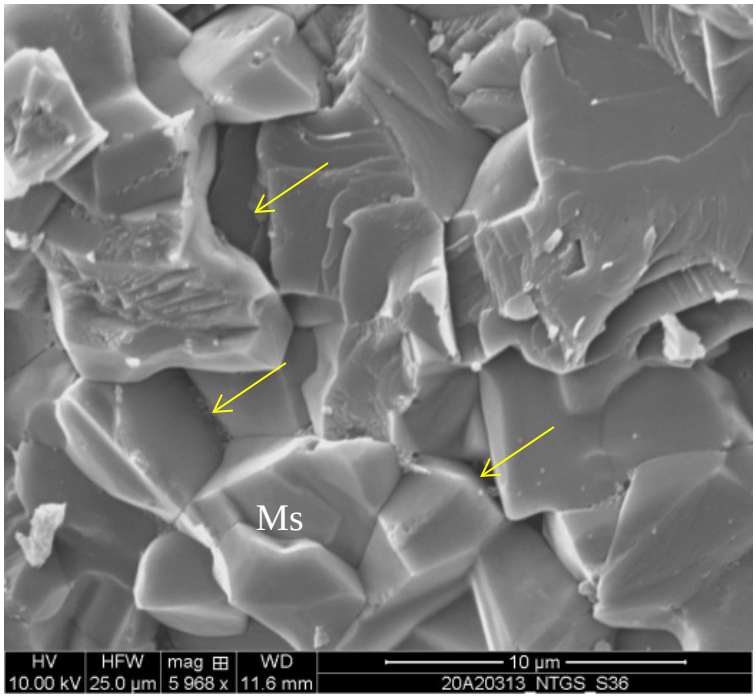


Figure 1.6. Sample S36, 7770.00ft/2368.30m. High magnification Scanning Electron Microscope (SEM) image of scattered micropores (yellow arrows) associated with calcite microspar (Ms). **x5968**

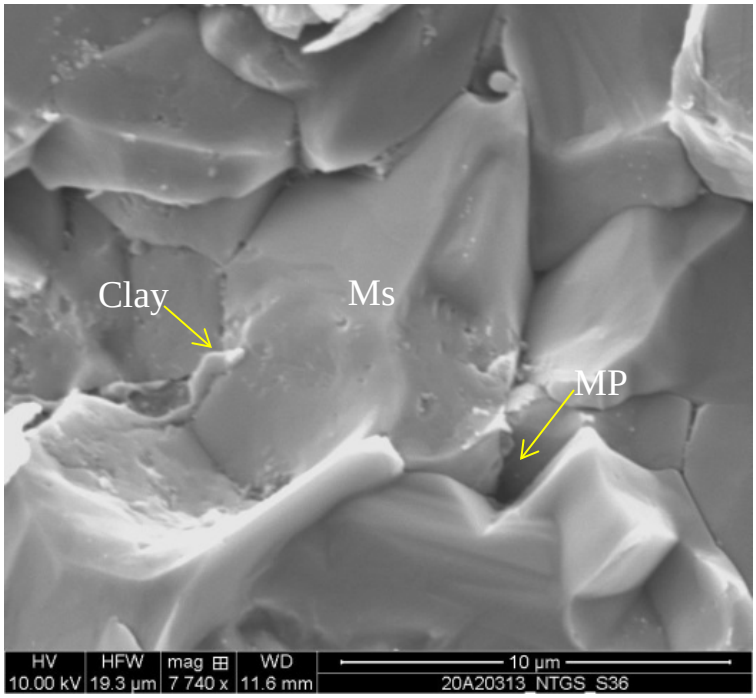


Figure 1.7. Sample T36, 7770.00ft/2368.30m. Alternate high magnification Scanning Electron Microscope (SEM) image of calcite microspar (Ms). A micropore (MP) and interstitial platy clay (Clay) particle, or possible mica flake, are also noted within this view. **x7740**

Sample T35/ X48/ S35/ P25, 7775.00ft/2369.82m

Well Name	Imperial Sun Arrowhead Aurora M-47	**Location**	300/M-47-6040-12230/0
Sample Type	Thin section /SEM grain mount from a core sample	**Depth (m)**	7775.00ft/2369.82m
Stratigraphic Unit	Nahanni Formation	**Reservoir Quality**	Poor
Classification	Limestone (Packstone-Wackestone)	**Stain type**	½ Dual carbonate stain

MINERALOGY

	Total Bulk mineralogy					
Thin Section Point counting (%)	**Calcite**	**Dolomite**	**Anhydrite**	**Quartz**	**Pyrite**	**Clays & organics**
	90	2	-	-	3	5
	Framework, Matrix, Cement, and Replacement					
	Carbonate clasts	**Bioclasts**	**Detrital grains**	**Matrix**	**Pore filling cement**	**Replacement**
	61	7	-	25	4	3

ADDITIONAL FEATURES and OTHER COMMENTS

Depositional	At the time of deposition, the sample was most likely massive. Formation of low amplitude stylolites and fracturing of the sediment typically happens during burial diagenesis (mechanical and chemical compaction).
Textures	Based on the mineralogy and proportion between framework components (carbonate clasts and bioclasts) and matrix, the sample was classified as lime packstone-wackestone. For the matrix, the crystal texture has been determined as anhedral, while cement shows subhedral to euhedral crystal texture. Majority of bioclasts are highly fragmented and micritized
Framework (Carbonate clasts, Bioclasts)	Petrographic Summary Table 1 shows detailed mineralogy of the sample. This sample contains 90% of calcite. Other minerals include clays and organics (5%), pyrite (3%), and dolomite (2%). In regards to the framework components, calcite occurs mainly as carbonate clasts [peloids - 60%, and ooids – 1%], with minor bioclasts [indistinct 5%, and, crinoids - 2%]. Ca
Detrital Grains & Other Non-Carbonate Grains	There are no detrital grains in this sample.
Matrix	Calcite is the main component of the matrix (20%), while clays and organics (associated with stylolites) occur in minor amounts (5%). Fifteen percent (15%) of matrix has been identified as tightly packed micro- and pseudospar. Both micro- and pseudospar are the products of recrystallization of micrite.
Pore Filling Cements	The pore filling cements occur in minor amounts and include calcite spar (2%) and dolomite (2%). Note that dolomite occurs as non- and ferroan phase of this mineral
Replacement Minerals	Minor amounts of pyrite (3%) is locally intermixed with organic material, which is one of the main components of stylolitized laminae. Additionally pyrite also replaces micrite within the matrix and micritized framework grains.
Porosity	The visible porosity includes minor intercrystalline (1%), plus trace micro-vuggy pores .

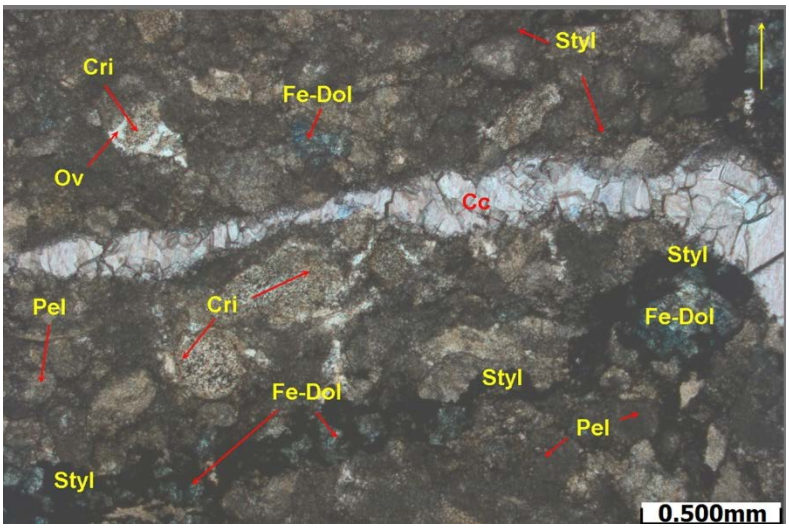


Figure 2.2. Sample T35, 7775.00ft/2369.82m. Moderate magnification image of the sample shows tightly packed framework grains that include peloids (Pel) and crinoids (Cri).Some crinoids show syntaxial overgrowths (Ov). Note a sutured (stylolitic – Styl) contacts between some of the grains. Dark brown-black color of the stylolites suggests that their main component is organic matter most likely intermixed with clays. Calcite spar (Cc) fills either horizontal fracture or dissolution cavity (after indistinct bioclast fragments). Ferroan dolomite (Fe-Dol) cements some of the carbonate grains. **x50ppl**

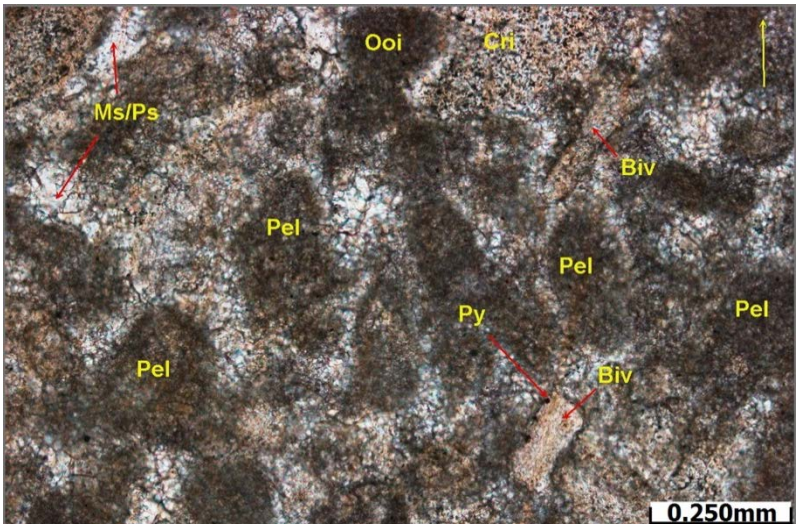


Figure 2.3. Sample T35, 7775.00ft/2369.82m. High magnification image shows micro and pseudospar (Ms/Ps) cemented peloids (Pel), ooids (Ooi), crinoids (Cri), and bivalve (Biv) shell fragments. Pyrite (Py) framboids locally replace bivalve shell fragments. There is no visible porosity in this image. **x100ppl**

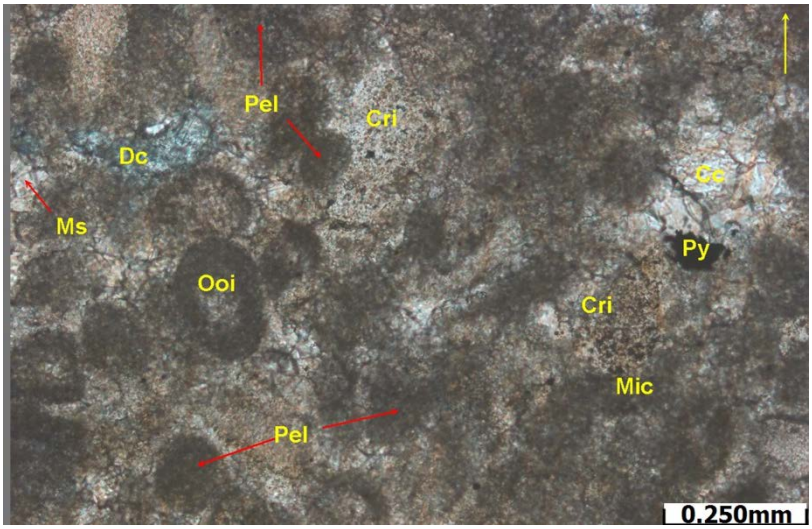


Figure 2.4. Sample T35, 7775.00ft/2369.82m. Another high magnification image of the sample shows the framework grains composed mainly of peloids (Pel), with minor ooids (Ooi) and crinoid (Cri) plates. Micritic matrix (Mic) has been recrystallized to microspar (MS). Possible micro-vugs have been cemented with calcite spar (Cc) and slightly ferroan dolomite (Dc). Pyrite aggregates (Py) appear to replace calcite cement. **x100ppl**

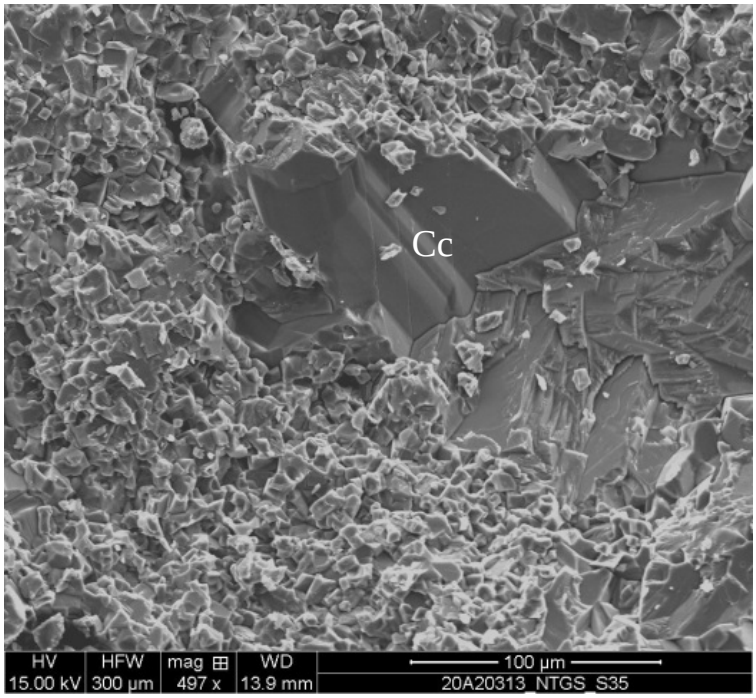


Figure 2.5. Sample S35, 7775.00ft/2369.82m. Scanning Electron Microscope (SEM) image showing patchy calcite cement (Cc) within the calcite micrite/microspar matrix. Details of the matrix are shown in subsequent views. **x497**

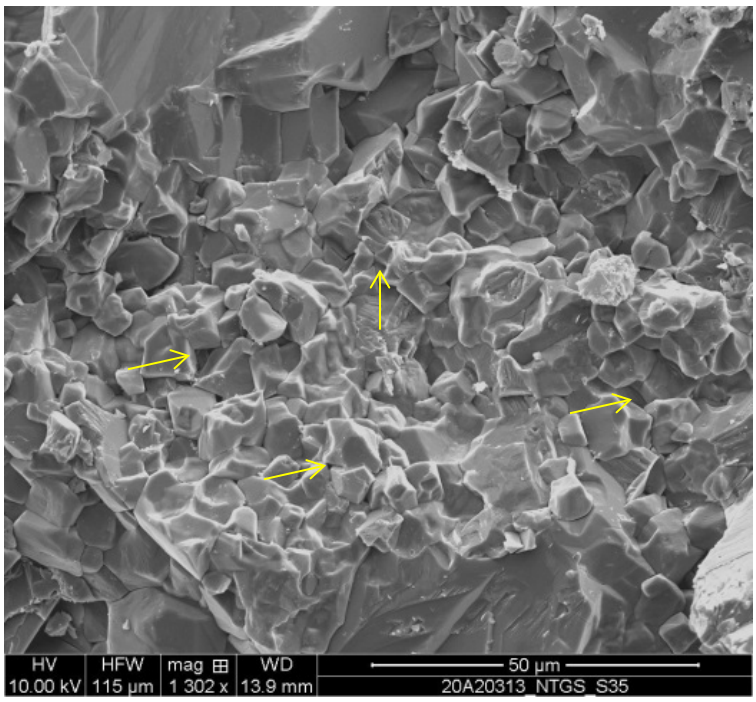


Figure 2.6. Sample S35, 7775.00ft/2369.82m. Scanning Electron Microscope (SEM) image showing that the calcite crystallites which comprise the matrix range in size from micrite (<5µm) to microspar (5-20µm). Scattered micropores (yellow arrows) are predominately submicron (<1µm) in size. **x1302**

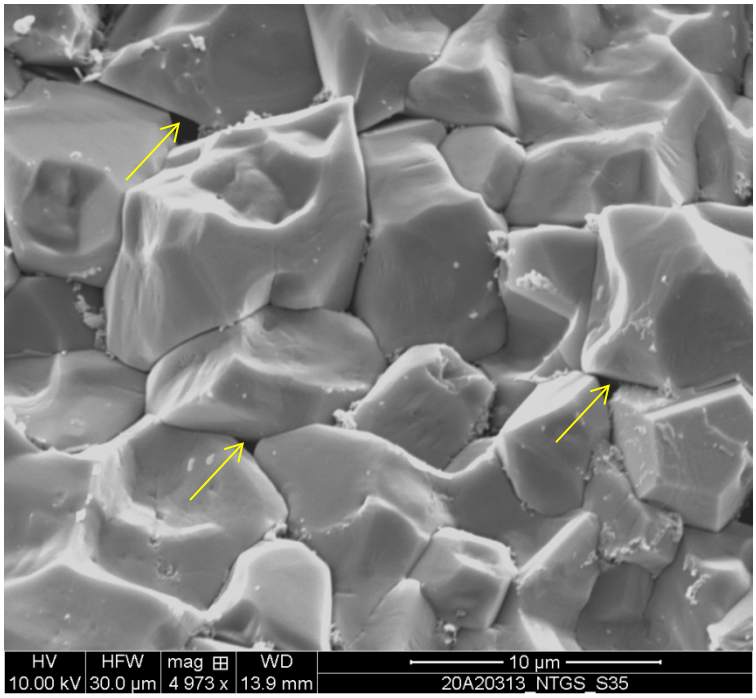


Figure 2.7. Sample S35, 7775.00ft/2369.82m. High magnification Scanning Electron Microscope (SEM) image showing microporosity (yellow arrows) associated with a portion of the sample dominated by anhedral to subhedral calcite micrite (<5µm) to microspar (5-20µm). **x4973**

Sample T34/ X47/ S34/ P24, 7779.30ft/2371.13m

Well Name	Imperial Sun Arrowhead Aurora M-47	**Location**	300/M-47-6040-12230/0
Sample Type	Thin section/SEM grain mount from a core sample	**Depth (m)**	7779.30ft/2371.13m
Stratigraphic Unit	Nahanni Formation	**Reservoir Quality**	Poor
Classification	Limestone (Grainstone)	**Stain type**	½ Dual carbonate stain

MINERALOGY

	Total Bulk mineralogy					
Thin Section Point counting (%)	**Calcite**	**Dolomite**	**Anhydrite**	**Quartz**	**Pyrite**	**Clays & organics**
	99	TR	-	TR	1	TR
	Framework, Matrix, Cement, and Replacement					
	Carbonate clasts	**Bioclasts**	**Detrital grains**	**Matrix**	**Pore filling cement**	**Replacement**
	-	92	-	2	5	1

ADDITIONAL FEATURES and OTHER COMMENTS

Depositional	The sample is massive with no distinct sedimentary features.
Textures	Based on the mineralogy and abundance of crinoids, the sample was classified as crinoidal lime-grainstone. For the matrix (very minor in this sample), the crystal texture has been determined as anhedral, while cement (also minor) shows subhedral to euhedral crystal texture. The fabric of the grainstone locally shows sutured contact between individual clasts.
Framework (Carbonate clasts, Bioclasts)	The framework of this grainstone is dominated by crinoids (85%), with minor bryozoans (5%), and mollusks fragments (2%).
Detrital Grains & Other Non-Carbonate Grains	There are no detrital grains in this sample.
Matrix	Overall minor amounts of matrix (2%) consist of calcite micrite, with trace clays and organics that define sutured contacts between allochems.
Pore Filling Cements	Calcite spar (5%) and trace ferroan dolomite are the pore filling cements.
Replacement Minerals	Minor amounts of pyrite (1%) replaces micrite within the matrix and micritized framework grains, while microcrystalline quartz locally replaces crinoid debris.
Porosity	There is only a trace visible porosity that has been classified as interparticle and intercrystalline pores.

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

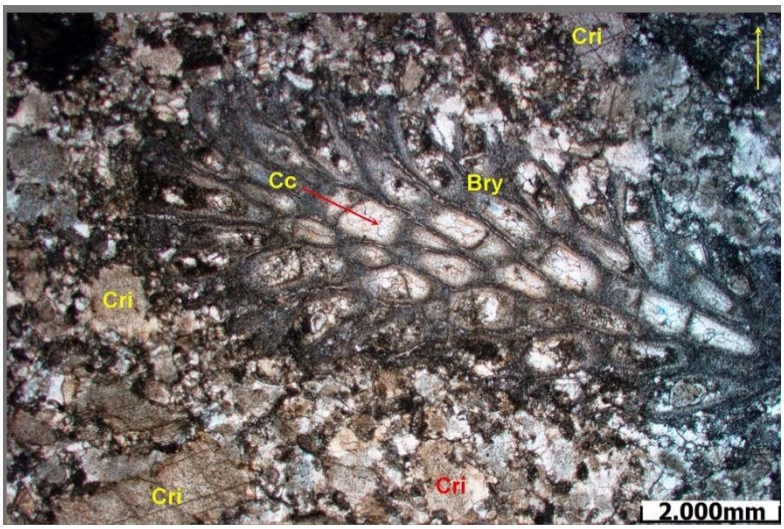


Figure 3.1. Sample T34, 7779.30ft/2371.13m. Low magnification overview of the crinoidal grainstone (Cri) that also contains relatively large sized bryozoans (Bry) fragments. Note that zooecia of the bryozoans are cemented with calcite spar (Cc). The bryozoan is surrounded by crinoids (Cri) with sutured contacts between most adjacent grains. This indicates chemical compaction (pressure solution) produced during burial of the limestone. Note the zooecial walls thicken and bend outwards. **x12.5ppl**

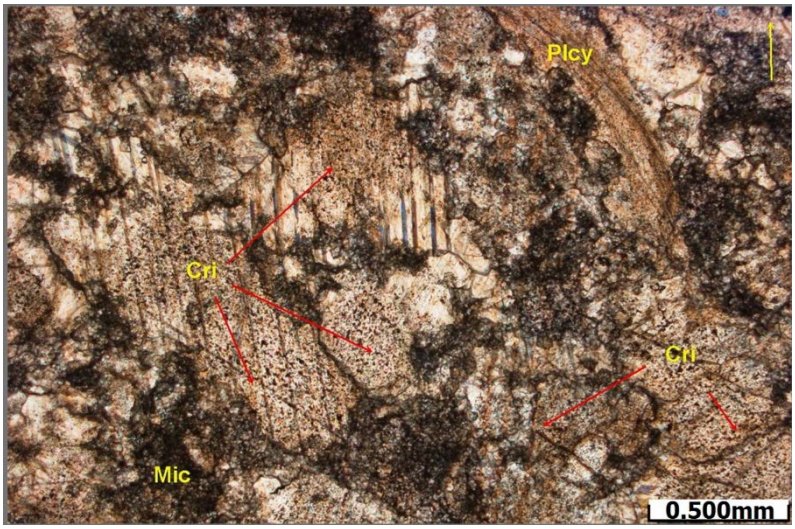


Figure 3.2. Sample T34, 7779.30ft/2371.13m. Moderate magnification image of the crinoidal grainstone with the crinoid plates cemented by their syntaxial overgrowths. Small amounts of micrite (Mic) fills interparticle porosity. Plcy: pelecypod shell fragment. There is no visible porosity in this image. **x50ppl**

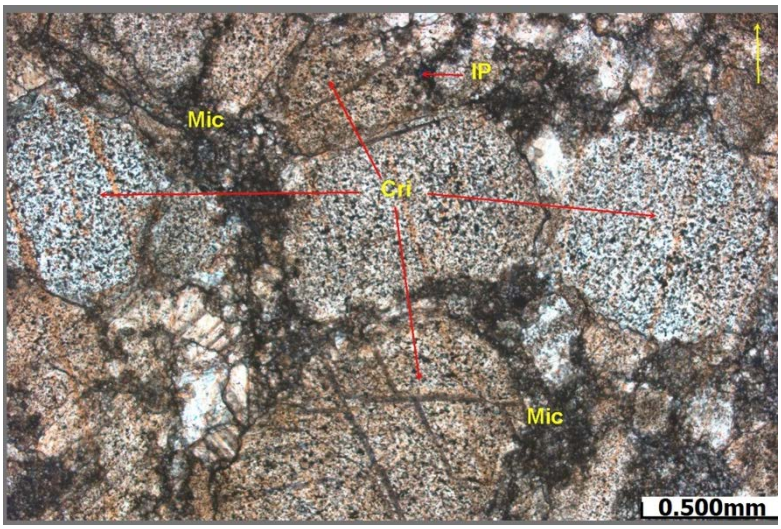


Figure 3.3. Sample T34, 7779.30ft/2371.13m. Another moderate image of the sample shows tightly packed crinoidal plates (Cri) which are often cemented by their overgrowths. Interparticle pores (IP) are almost totally filled with minor calcite-micrite matrix (Mic). **x50ppl**

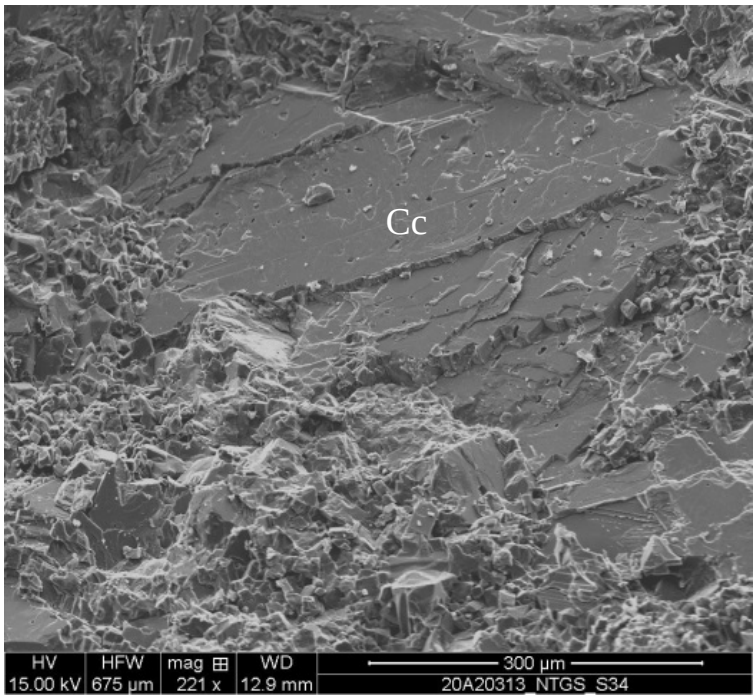


Figure 3.4. Sample S34, 7779.30ft/2371.13m. Low magnification Scanning Electron Microscope (SEM) image of calcite cement (Cc) which displays pinpoint micropores along the crystal surface. At low magnifications the matrix appears tight with no visible porosity; however, at higher magnifications, as demonstrated in the subsequent images, scattered micropores and submicron porosity are visible. **x221**

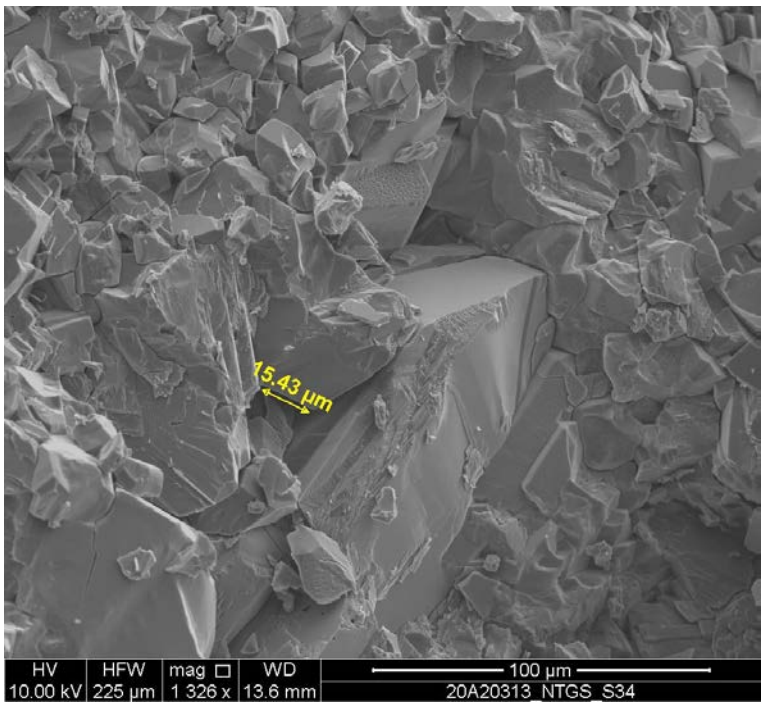


Figure 3.5. Sample S34, 7779.30ft/2371.13m. Scanning Electron Microscope (SEM) image showing a rare intercrystalline macropore measuring ~15µm. **x1326**

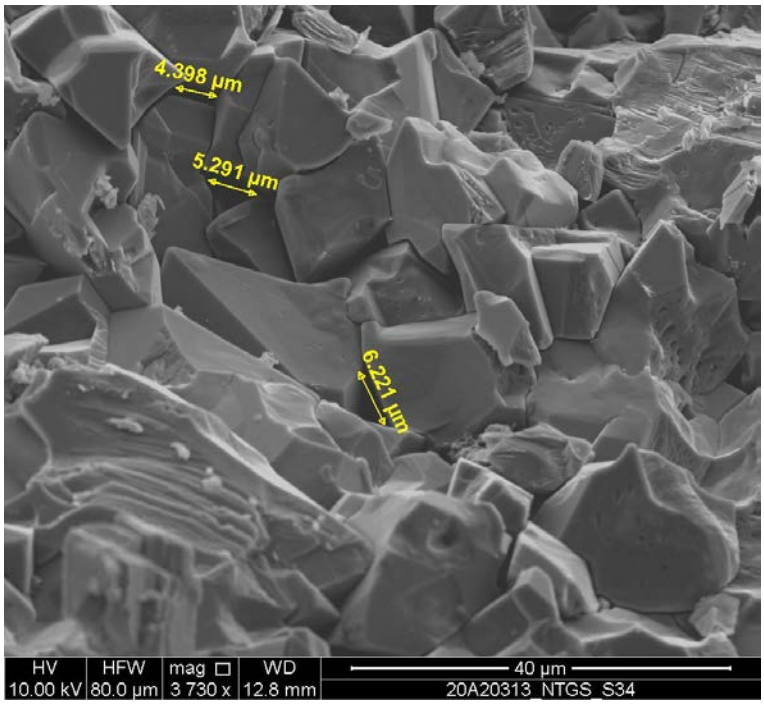


Figure 3.6. Sample S34, 7779.30ft/2371.13m. Scanning Electron Microscope (SEM) image highlighting microporosity (<5µm) within the sample. **x3730**

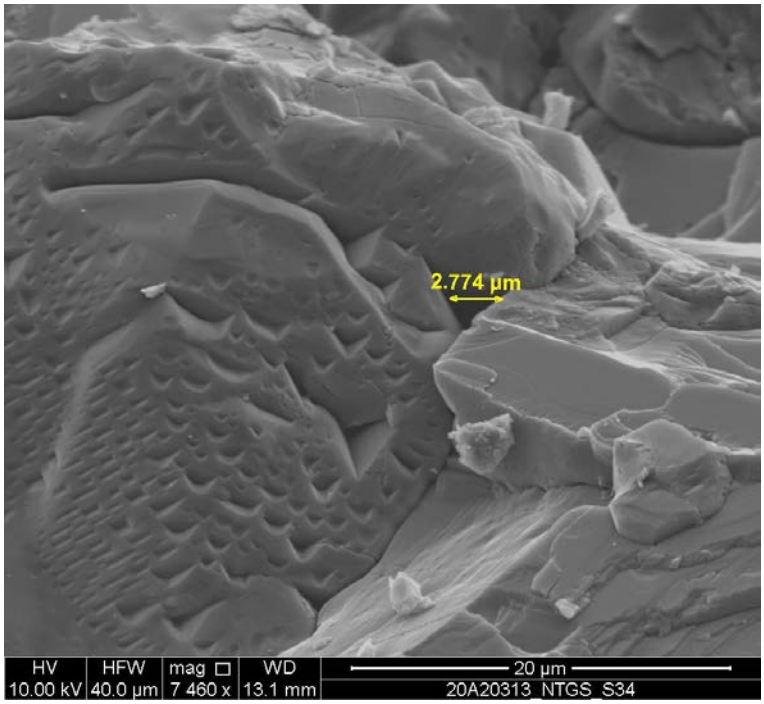


Figure 3.7. Sample S34, 7779.30ft/2371.13m. High magnification Scanning Electron Microscope (SEM) microscope image showing a micropore, plus epitaxial growth patterns within the calcite. **x7460**

Sample T33/ X46/ S33/ P23, 7784.30ft/2372.65m

Well Name	Imperial Sun Arrowhead Aurora M-47	**Location**	300/M-47-6040-12230/0
Sample Type	Thin section/SEM grain mount from a core sample	**Depth (m)**	7784.30ft/2372.65m
Stratigraphic Unit	Nahanni Formation	**Reservoir Quality**	Poor
Classification	Limestone (Grainstone)	**Stain type**	½ Dual carbonate stain

MINERALOGY

	Total bulk mineralogy					
Thin Section Point counting (%)	**Calcite**	**Dolomite**	**Anhydrite**	**Quartz**	**Pyrite**	**Clays & organics**
	99	TR	TR	-	1	TR
	Framework, Matrix, Cement, and Replacement					
	Carbonate clasts	**Bioclasts**	**Detrital grains**	**Matrix**	**Pore filling cement**	**Replacement**
	-	92	-	1	6	1

ADDITIONAL FEATURES and OTHER COMMENTS

Depositional	The sample is massive with no distinct sedimentary features. Some of the observed micro-fractures could be induced during coring processes.
Textures	Based on the mineralogy and proportion between bioclasts (92%) and matrix (1%), the sample was classified as limestone-grainstone. For the matrix (very minor in this sample), the crystal texture has been determined as anhedral, while cement (also minor) shows subhedral to euhedral crystal texture. The fabric of the grainstone locally shows sutured contact between individual clasts.
Framework (Carbonate clasts, Bioclasts)	The framework of this grainstone is dominated by crinoids (50%) and coral fragments (40%), with minor mollusks (1%) and brachiopods (1%), and trace indistinct bioclast fragments. There are no carbonate clasts observed in this sample.
Detrital Grains & Other Non-Carbonate Grains	There are no detrital grains in this sample.
Matrix	Overall minor amounts of matrix (1%) consist of calcite micrite (1%), with trace clays and organics that mark sutured contacts between allochems (mainly between crinoids).
Pore Filling Cements	Calcite spar (5%) and druse (1%), plus trace non-ferroan dolomite and anhydrite are the pore filling cements. Anhydrite was spotted cementing coral septa.
Replacement Minerals	Minor amounts of pyrite (1%) replaces micrite within the matrix and micritized framework grains.
Porosity	There is only minor visible porosity that has been classified as micro-intercrystalline (1%) and trace fracture pores.

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

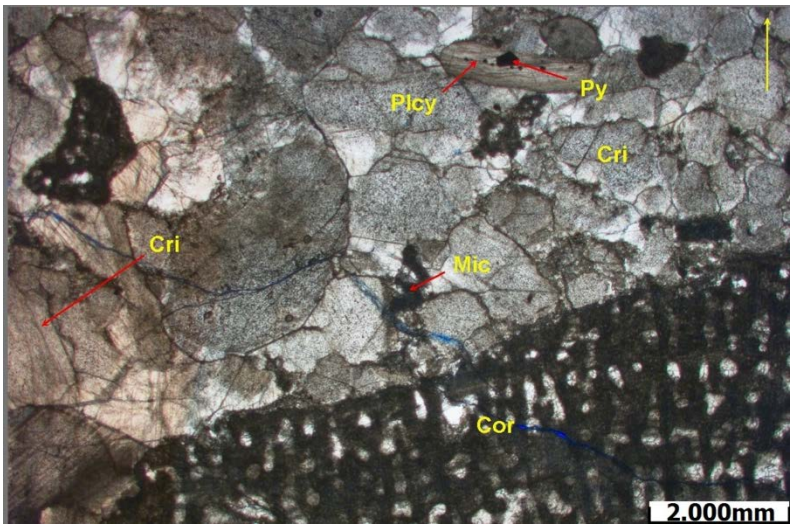


Figure 4.1. Sample T33, 7784.30ft/2372.65m. Low magnification overview image shows the framework of the grainstone composed of crinoid debris (Cri) with and possible tabulate coral (Cor). Rare pelecypod shell fragments (Plcy) are also part of the framework. Crinoids are usually cemented with syntaxial calcite overgrowths, but occasionally interparticle pores are filled with remnants of calcite-micrite matrix (Mic). Note sutured contacts between adjacent crinoid plates. **x12.5ppl**

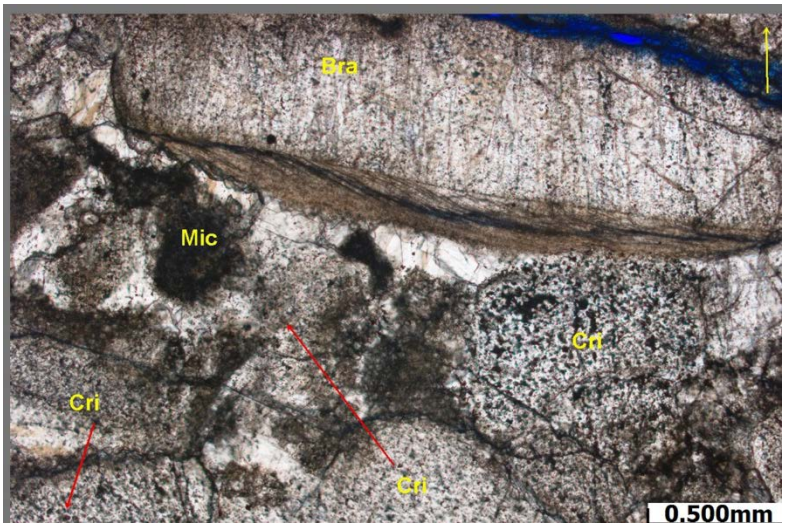


Figure 4.2. Sample T33, 7784.30ft/2372.65m. Moderate magnification image shows tightly packed crinoid plates and abraded brachiopod shell fragments. Minor amounts of calcite-micrite (Mic) fill primary interparticle pores. Blue epoxy indicates induced fracture. **x50ppl**

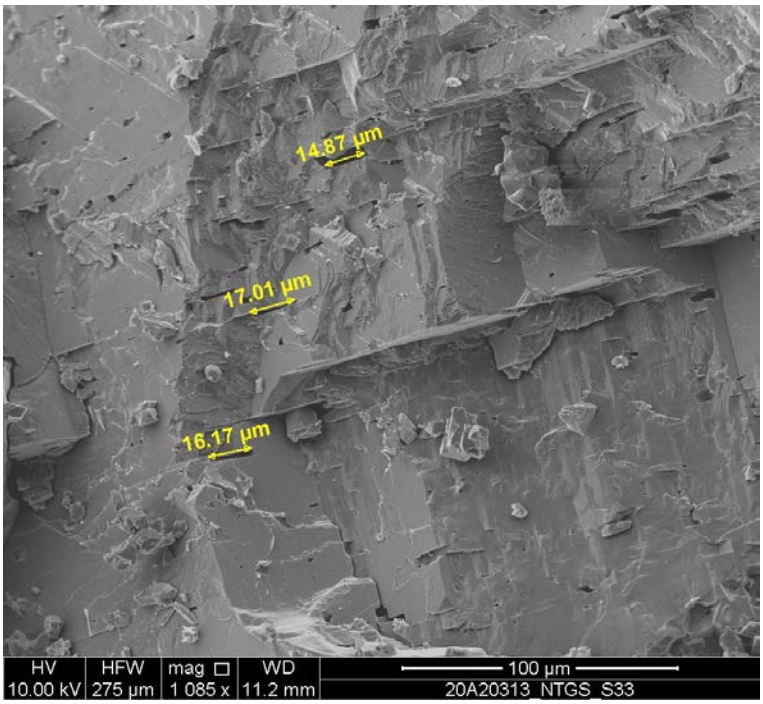


Figure 4.3. Sample S33, 7784.30ft/2372.65m. Moderate magnification Scanning Electron Microscope (SEM) image showing elongate pores that measure ~15µm (long axes) within blocky calcite cement. The pores may aid in increasing fluid capacity within the reservoir, but overall are poorly connected. **x1085**

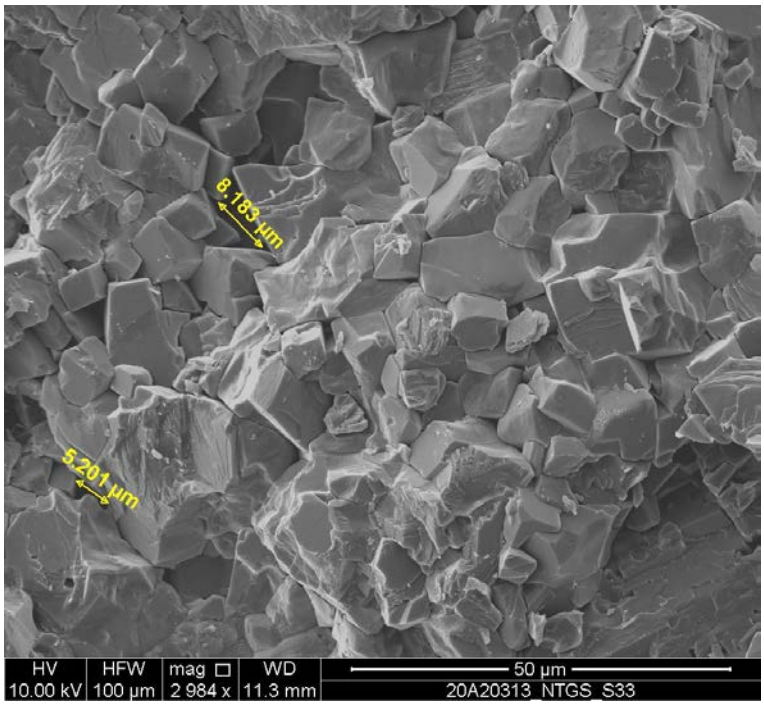


Figure 4.4. Sample S33, 7784.30ft/2372.65m. Scanning Electron Microscope (SEM) image showing micro- to macropores associated with the sub- to euhedral calcite micrite (<5µm)/microspar (>5µm). Increased crystallinity, in addition to the arrangement of the crystallites, appears to locally promote connectivity of the micropores. **x2984**

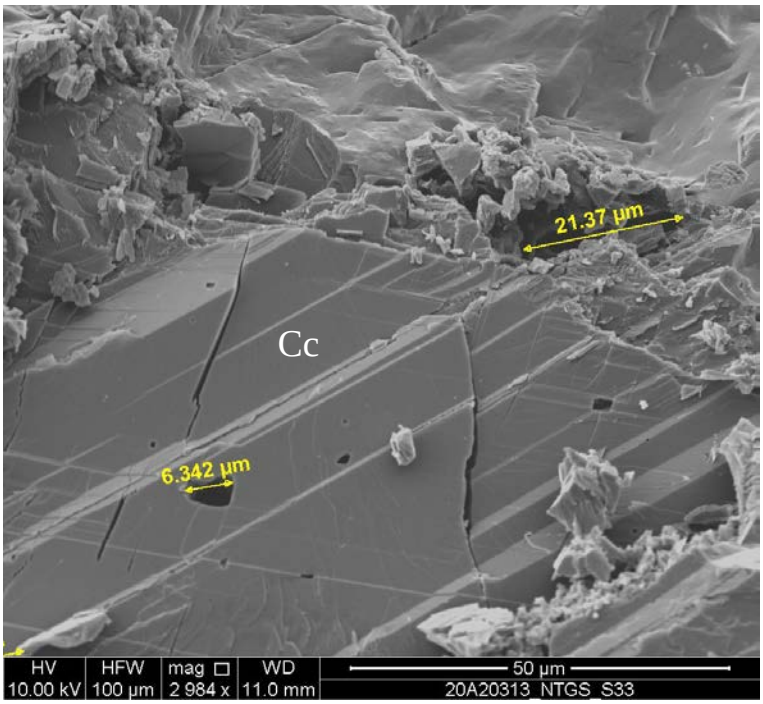


Figure 4.5. Sample S33, 7784.30ft/2372.65m. Scanning Electron Microscope (SEM) image showing calcite cement (Cc). Visible striations on the crystal surfaces reflect internal twinning patterns. A macropore measuring ~21µm is noted between the crystal boundary of the adjacent crystal. Fine calcareous particles line the pore space. An intraparticle pore measuring ~6µm is also noted. **x2984**

Sample T32/ S32/ P22, 7785.50ft/2373.02m

Well Name	Imperial Sun Arrowhead Aurora M-47	**Location**	300/M-47-6040-12230/0
Sample Type	Thin section/SEM grain mount from a core sample	**Depth (m)**	7785.50ft/2373.02m
Stratigraphic Unit	Nahanni Formation	**Reservoir Quality**	Poor
Classification	Limestone (Grainstone)	**Stain type**	½ Dual carbonate stain

MINERALOGY

	Total bulk mineralogy					
Thin Section Point counting (%)	**Calcite**	**Dolomite**	**Anhydrite**	**Quartz**	**Pyrite**	**Clays & organics**
	100	-	-	-	TR	TR
	Framework, Matrix, Cement, and Replacement					
	Carbonate clasts	**Bioclasts**	**Detrital grains**	**Matrix**	**Pore filling cement**	**Replacement**
	TR	90	-	1	9	TR

ADDITIONAL FEATURES and OTHER COMMENTS

Depositional	The sample is massive with no evident sedimentary structures. Some of the observed micro-fractures could be induced during coring processes.
Textures	Based on the mineralogy and proportion between total bioclasts (90%) and carbonate clasts (trace) and matrix (1%), the sample was classified as limestone-grainstone. For the matrix (very minor in this sample), the crystal texture has been determined as anhedral, while cement (also minor) shows subhedral to euhedral crystal texture. The fabric of the grainstone locally shows sutured contact between individual clasts.
Framework (Carbonate clasts, Bioclasts)	The framework of this grainstone is dominated by crinoids (50%) and coral fragments (40%). Trace indistinct bioclasts were also detected during the thin section examination.
Detrital Grains & Other Non-Carbonate Grains	There are no detrital grains in this sample.
Matrix	Overall minor amounts of matrix (1%) consist of calcite micrite (1%), plus trace clays and organics that typically mark sutured contacts between allochems (mainly between crinoids).
Pore Filling Cements	Calcite spar (9%) is the only pore filling cement.
Replacement Minerals	Trace amounts of pyrite locally replace micrite within the matrix and micritized framework grains.
Porosity	The visible porosity occurs as minor (2%) of micro-intercrystalline pores. Trace fracture porosity (most likely due to the presence induced fractures) was also noted.

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

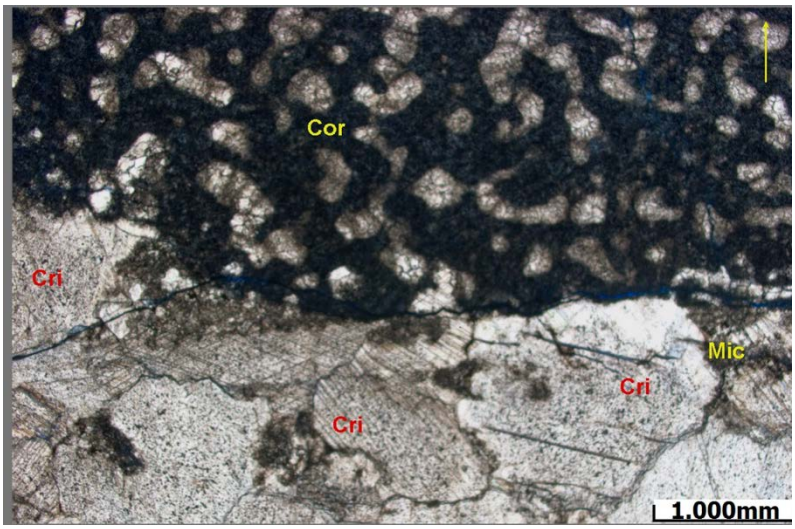


Figure 5.1. Sample T32, 7785.50ft/2373.02m. Low magnification image of the thin section shows possible tabular coral (top – Cor) and tightly packed crinoid plates (Cri – bottom). Note a sutured contacts between bordering crinoid debris. Remnants of micrite (Mic) fills interparticle pores. **x25ppl**

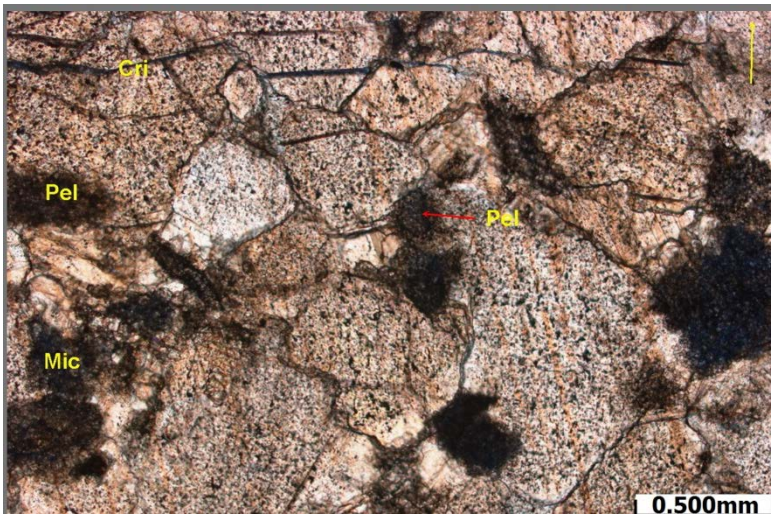


Figure 5.2. Sample T32, 7785.50ft/2373.02m. Moderate magnification image shows crinoid (Cri) dominated portion of the thin section sample. Rare micritic peloids (Pel) are also part of the framework of this grainstone. Minor calcite micrite totally plugs the primary interparticle pores. The crinoid plates are cemented by their syntaxial overgrowths. Note a sutured contacts between individual crinoid plates. **x50ppl**

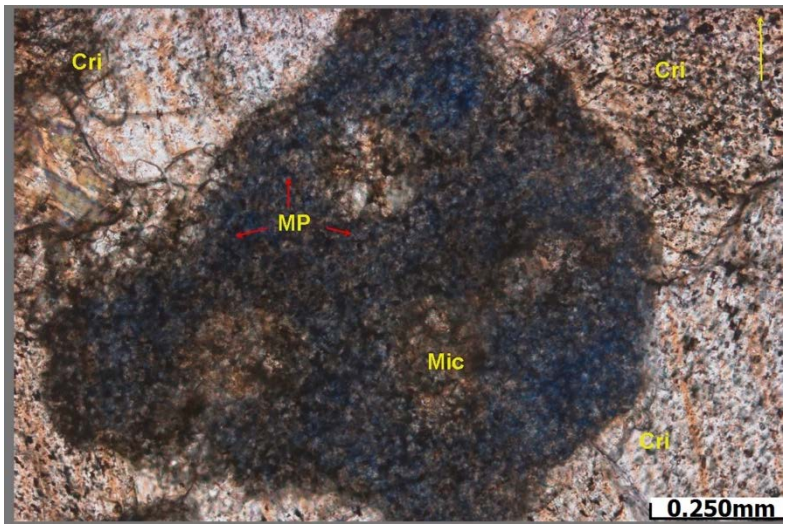


Figure 5.3. Sample T32, 7785.50ft/2373.02m. High magnification image shows a patch of micro-intercrystalline pores (MP) that relate to micrite matrix (Mtx) and micritized bioclast fragments (possibly peloids and/or crinoids plates). The microporous patch is surrounded by tight crinoid debris (Cri). The coarse, single crystal nature of crinoids and echinoderms makes them extremely susceptible to syntaxial overgrowth cementation. Thus, crinoidal limestones are commonly marked by nearly complete porosity destruction. **x100ppl**

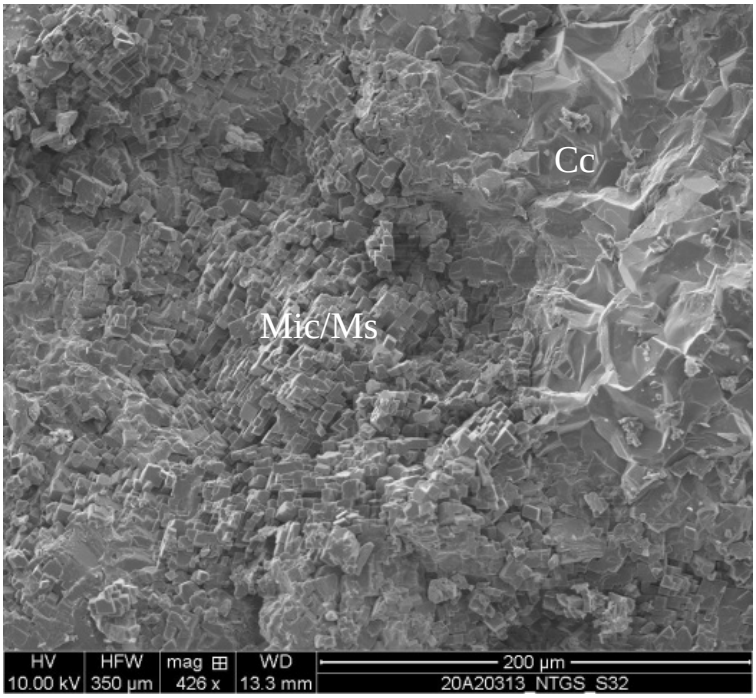


Figure 5.4. Sample S32, 7785.50ft/2373.02m. Low magnification Scanning Electron Microscope (SEM) overview image showing sub- to euhedral micrite/microspar (Mic/Ms) in addition to relatively coarse calcite cement (Cc). **x426**

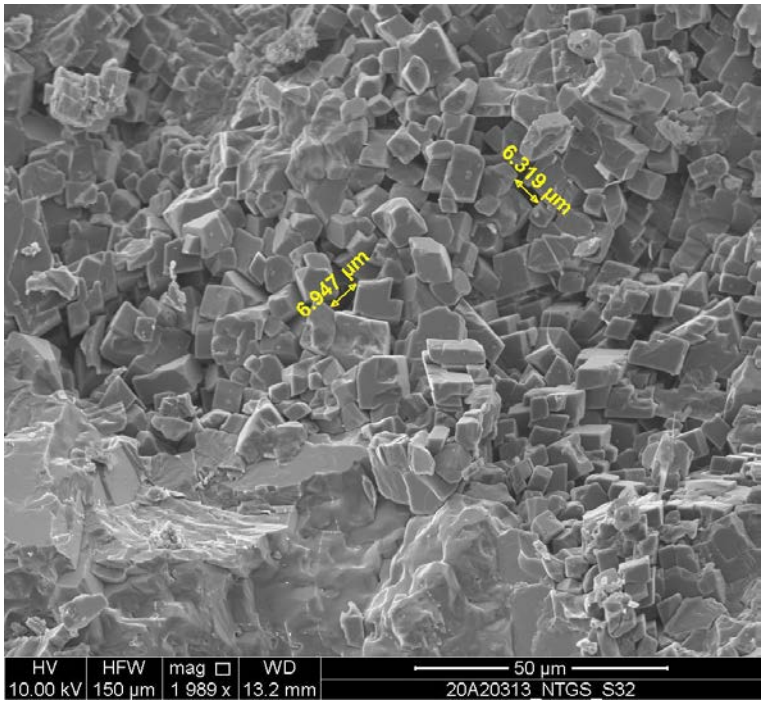


Figure 5.5. Sample S32, 7785.50ft/2373.02m. Moderate magnification Scanning Electron Microscope (SEM) image showing micro- to macropores associated with the sub- to euhedral calcite micrite (<5µm)/microspar (>5µm) matrix. Increased crystallinity, in addition to the arrangement of the crystallites, appears to locally promote connectivity of the micropores. **x1989**

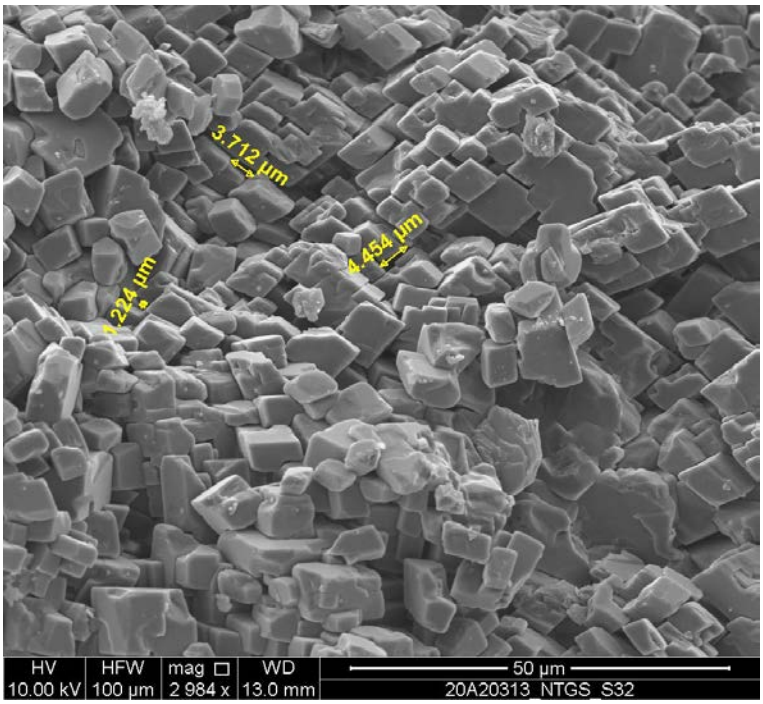


Figure 5.6. Sample S32, 7785.50ft/2373.02m. Alternate Scanning Electron Microscope (SEM) image showing micro- to macropores associated with the sub- to euhedral calcite micrite (<5µm)/microspar (>5µm). Increased crystallinity, in addition to the arrangement of the crystallites, appears to locally promote connectivity of the micropores. **x2984**

Sample T31/ X45/ S31/ P21, 7793.10ft/2375.34m

Well Name	Imperial Sun Arrowhead Aurora M-47	**Location**	300/M-47-6040-12230/0
Sample Type	Thin section/SEM grain mount from a core sample	**Depth (m)**	7793.10ft/2375.34m
Stratigraphic Unit	Nahanni Formation	**Reservoir Quality**	Poor
Classification	Limestone (Wackestone-Packstone)	**Stain type**	½ Dual carbonate stain

MINERALOGY

	Total bulk mineralogy					
Thin Section Point counting (%)	**Calcite**	**Dolomite**	**Anhydrite**	**Quartz**	**Pyrite**	**Clays & organics**
	96	-	-	-	TR	4
	Framework, Matrix, Cement, and Replacement					
	Carbonate clasts	**Bioclasts**	**Detrital grains**	**Matrix**	**Pore filling cement**	**Replacement**
	TR	76	-	14	10	TR

ADDITIONAL FEATURES and OTHER COMMENTS

Depositional	The sample is partly laminated.
Textures	Based on the mineralogy and proportion between framework grains [bioclasts -76% and carbonate clasts – trace] and matrix [micrite – 10% and clays & organics – 4%], the sample was classified as limestone (wackestone to packstone). The crystal texture of the matrix is anhedral, while cement (10% of the total rock volume) shows subhedral to euhedral crystal texture.
Framework (Carbonate clasts, Bioclasts)	Petrographic Summary Table 1 shows detailed mineralogy of the sample. This sample contains 96% of calcite. Other minerals include clays and organics (4%), plus trace pyrite. Framework grains are calcitic, and include mainly bioclasts (76%) and trace peloids. The bioclasts observed in this sample contain mainly brachiopod (shells & spines) and crinoids (205 of each), with lesser mollusks, corals, and unidentified bioclasts (10% of each), minor trilobites (5%), and ostracodes (1%), plus trace bryozoans.
Detrital Grains & Other Non-Carbonate Grains	There are no detrital grains in this sample.
Matrix	Calcite is the main component of the micritic matrix (10%), while clays and organics (associated with stylolitized laminae) occur in minor amounts (4%).
Pore Filling Cements	The pore filling cements occur in moderate amounts of calcite spar (10%).
Replacement Minerals	Trace amount of pyrite one of the main components of stylolitized laminae. Additionally micropyrite also replaces micrite within the matrix and micritized framework grains.
Porosity	There is no visible porosity in this sample; however fair amounts of microporosity is related to micritic matrix, carbonate clasts, and micritic bioclasts.

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

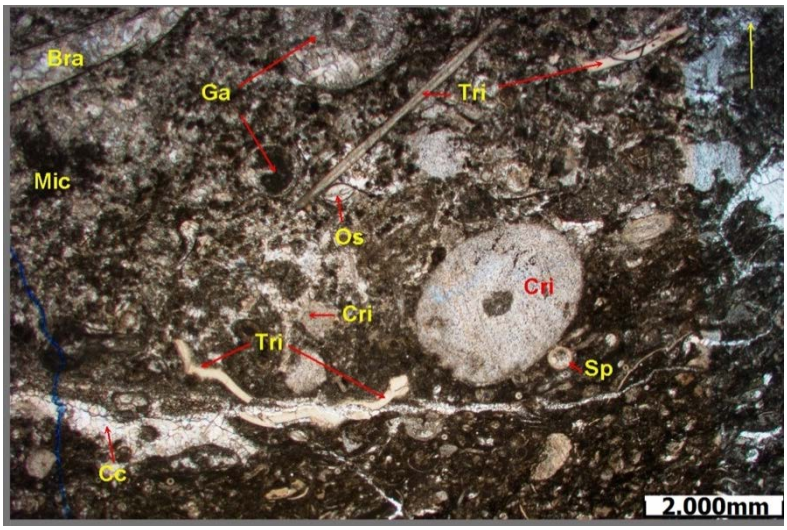


Figure 6.1. Sample T31, 7793.10ft/2375.34m. Low magnification image of the wackestone to packstone limestone shows the framework grains that include gastropods (Ga), crinoids (Cri), brachiopod shell (Bra) and spines (Sp), plus trilobite (Tri), and ostracode (Os). The bioclasts are floating in peloidal-skeletal micritic matrix (Mic). Calcite spar (Cc) cements some of the gastropod chambers (top centre), brachiopod shells and spines, and indistinct bioclast fragments. There is no visible porosity in this image. **x12.5ppl**

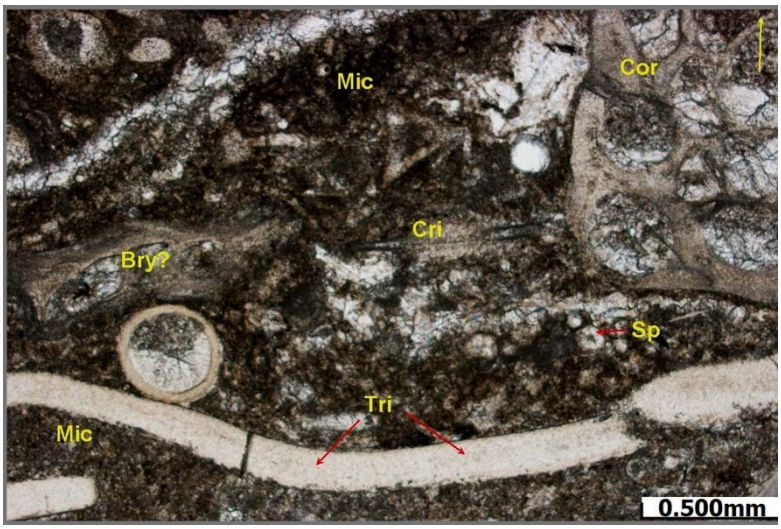


Figure 6.2. Sample T31, 7793.10ft/2375.34m. Moderate magnification image shows in more detail the framework components. Coral (Cor), trilobite (Tri), brachiopod spines (Sp), plus possible bryozoans (Bry?) are the framework builders. Micrite (Mic) is the matrix of this sample. Dark brown color of the matrix implies that there are some clays and/or organic material intermixed with the micrite. **x50ppl**

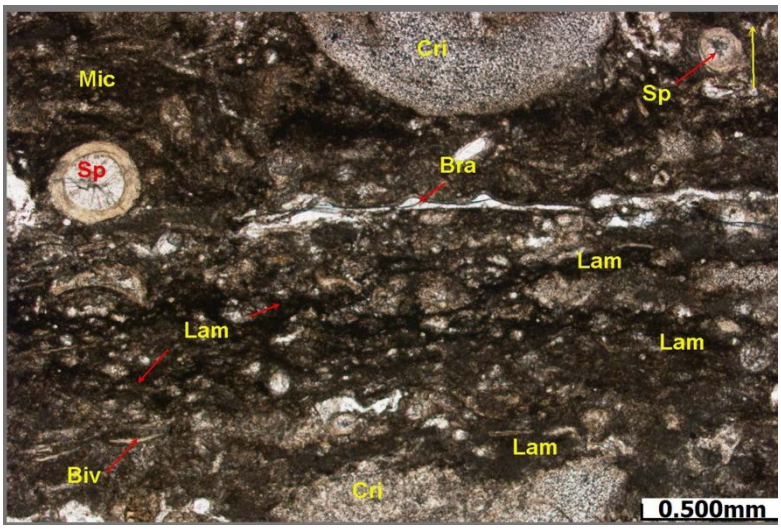


Figure 6.3. Sample T31, 7793.10ft/2375.34m. Another moderate magnification image of the sample focuses on the local presence of dark brown-black, organic rich stylolitized laminae (Lam) that cut through the sample. Calcite micrite (Mic), the laminae, plus fragmented bivalve and other indistinct bioclast fragments are the part of the matrix. Crinoid plates (Cri), brachiopod shells and spines (Bra; Sp) are the framework builders. **x50ppl**

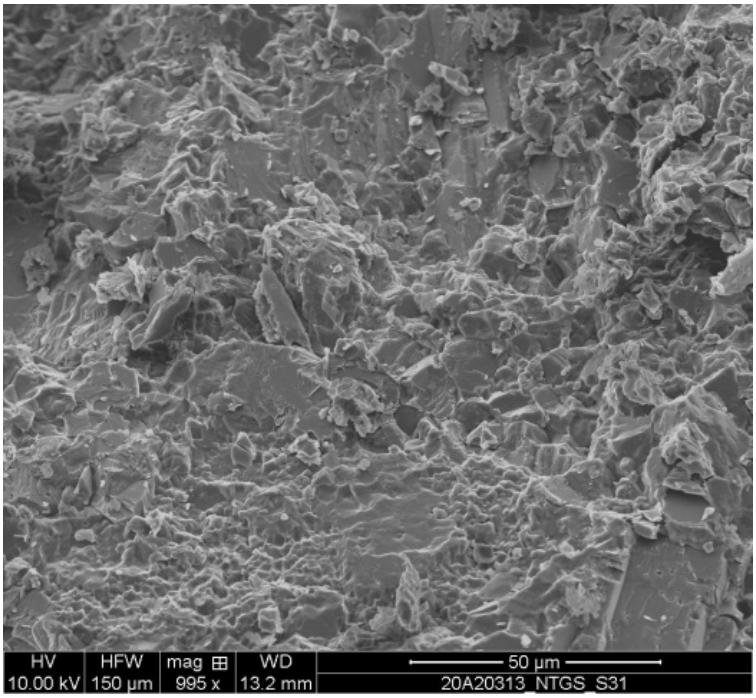


Figure 6.4. Sample S31, 7793.10ft/2375.34m. Scanning Electron Microscope (SEM) image displaying the overall crystal fabric which consists of tightly interlocking calcite micrite and calcite cements. The sample lacks visible porosity. **x995**

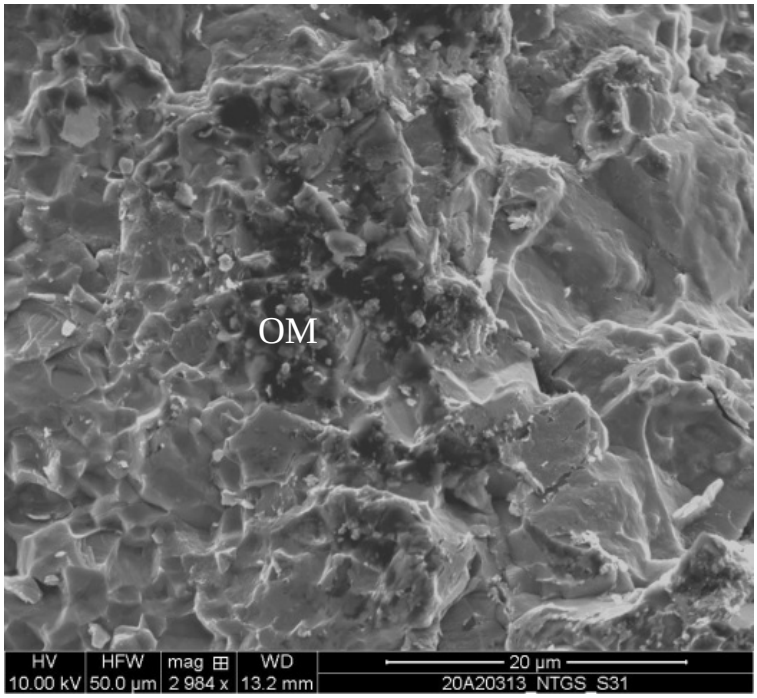


Figure 6.5. Sample S31, 7793.10ft/2375.34m. Moderate magnification Scanning Electron Microscope (SEM) image showing details of the tight crystal fabric. The relatively dark coloured patch in this view reflects organic matter (OM). **x2984**

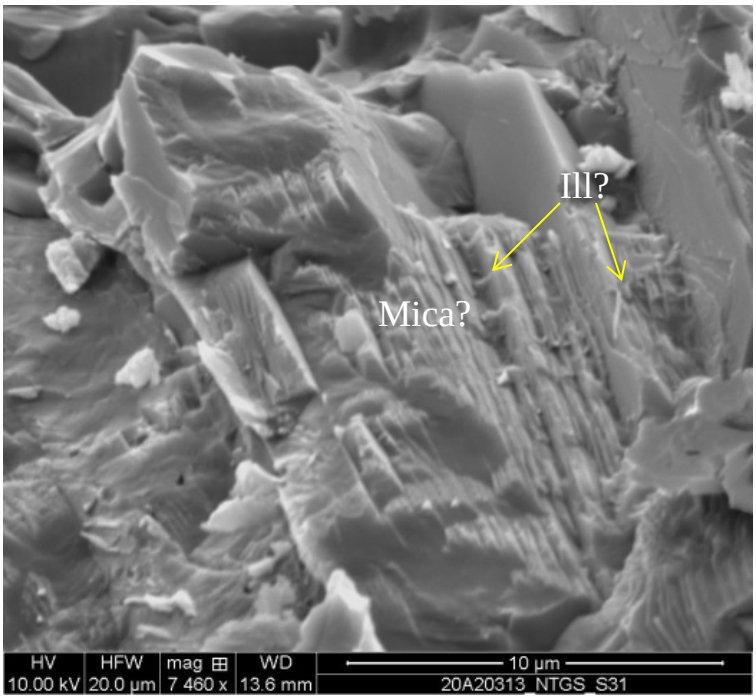


Figure 6.6. Sample S31, 7793.10ft/2375.34m. High magnification Scanning Electron Microscope (SEM) image showing a probable mica flake (Mica?) which displays parallel cleavage. The mica flakes appear fused, possibly as a result of recrystallization. Possible illite filaments are shown (Ill?). **x7460**

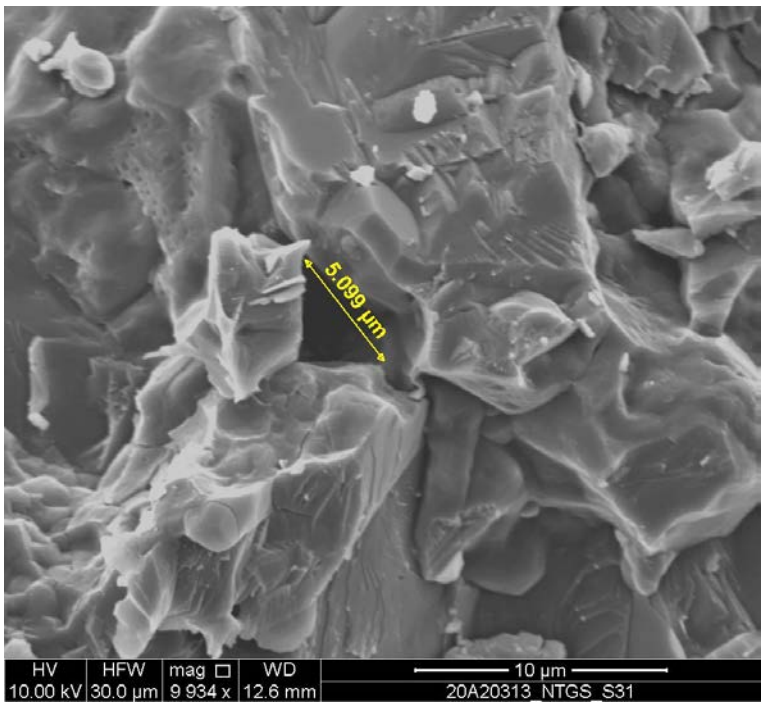


Figure 6.7. Sample S31, 7793.10ft/2375.34m. High magnification Scanning Electron Microscope (SEM) image of a possible micropore (<5µm). However, the pore space may reflect artefact porosity generated by grain-plucking. **x9934**

Sample T30/ S30/ P20, 7796.10ft/2376.25m

Well Name	Imperial Sun Arrowhead Aurora M-47	**Location**	300/M-47-6040-12230/0
Sample Type	Thin section/SEM grain mount from a core sample	**Depth (m)**	7796.10ft/2376.25m
Stratigraphic Unit	Nahanni Formation	**Reservoir Quality**	Poor
Classification	Limestone (Grainstone)	**Stain type**	½ Dual carbonate stain

MINERALOGY

	Total bulk mineralogy					
Thin Section Point counting (%)	**Calcite**	**Dolomite**	**Anhydrite**	**Quartz**	**Pyrite**	**Clays & organics**
	100	TR	-	-	TR	TR
	Framework, Matrix, Cement, and Replacement					
	Carbonate clasts	**Bioclasts**	**Detrital grains**	**Matrix**	**Pore filling cement**	**Replacement**
	2	92	-	1	5	TR

ADDITIONAL FEATURES and OTHER COMMENTS

Depositional	The sample is massive with no evident sedimentary structures. There are a few calcite cement healed vertical fractures (see Fig 7.1 & 7.2), but the horizontal fractures are induced by coring processes (i.e. Figure 1).
Textures	Based on the mineralogy and proportion between total bioclasts (92%) and carbonate clasts (2%) and matrix (1%), the sample was classified as limestone-grainstone. For the matrix (very minor in this sample), the crystal texture has been determined as anhedral, while cement (5%) shows subhedral to euhedral crystal texture. The fabric of the grainstone locally shows sutured contact, especially between crinoid debris.
Framework (Carbonate clasts, Bioclasts)	The framework of this grainstone is dominated by crinoids (50%) and tabular stromatoporoid fragments (40%). Minor (2%) indistinct bioclasts, plus trace brachiopod shell fragments were also detected during the thin section examination.
Detrital Grains & Other Non-Carbonate Grains	There are no detrital grains in this sample.
Matrix	The matrix consists of calcite micrite and occurs in minor amounts (1%) and occurs as interparticle pore fill.
Pore Filling Cements	Minor calcite spar (5%) and trace non-ferroan dolomite are the pore filling cements.
Replacement Minerals	Trace amounts of pyrite locally replace micrite within the matrix and micritized framework grains.
Porosity	Trace fracture porosity is the only pore type noted in this sample.

Annotated microphotographs with description for the thin section and SEM samples are included below.

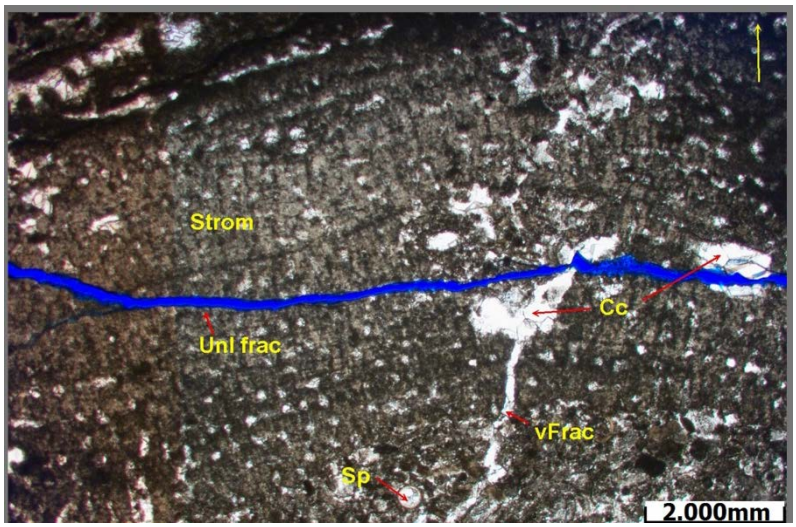


Figure 7.1. Sample T30, 7796.10ft/2376.25m. Low magnification image highlight the presence of tabular stromatoporoid fragment (Strom). Dark grey-brown color of the stromatoporoid is due to the incorporation of organic matter in the skeletal carbonate. This stromatoporoid shows latticework pattern composed of horizontal laminae and vertical pillars. Some of the chambers appear to be filled with micrite, while the other are cemented with calcite spar (Cc). Calcite cement also heals discontinued vertical fracture (vFrac) that cuts through the lower portion of the stromatoporoid. Blue epoxy fills unloading horizontal fracture (Unl frac). Sp: brachiopod spine?. **x12.5ppl**

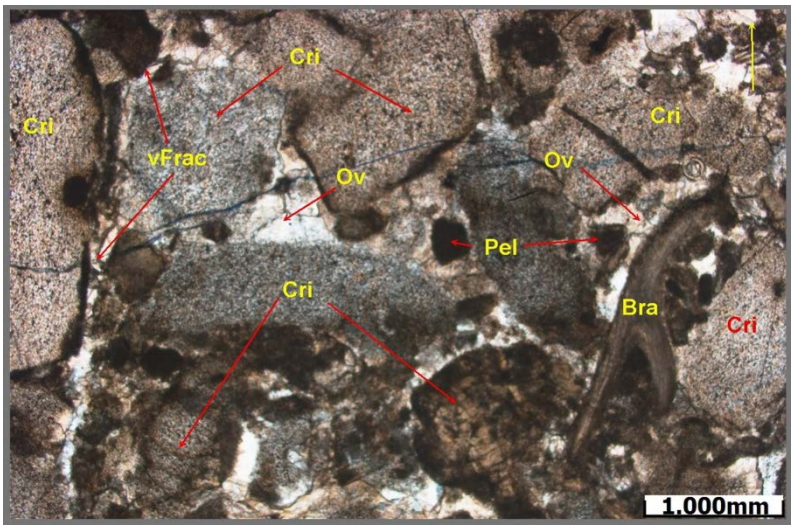


Figure 7.2. Sample T30, 7796.10ft/2376.25m. Another low magnification image of the thin section shows the crinoid grainstone portion of the sample (Cri). Crinoids are cemented with their syntaxial overgrowths (Ov). Other bioclasts in this image includes brachiopod shell fragments with still attached spine (Bra). Carbonate clasts are represented by micritic peloids (Pel). Vertical fracture (vFrac) has been totally healed with calcite spar. **x25ppl**

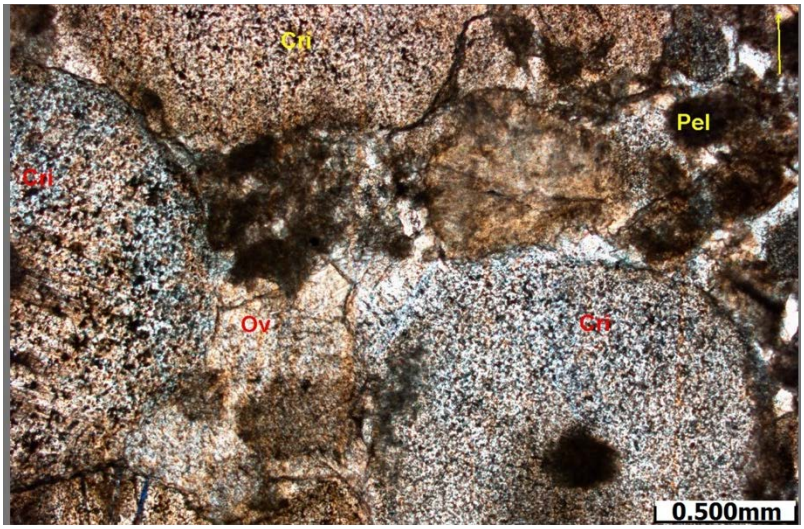


Figure 7.3. Sample T30, 7796.10ft/2376.25m. Alternate moderate magnification image of the crinoidal grainstone (Cri). The crinoids show single crystal extinction, have a speckled texture (perforated with small pores that are filled with contrasting material – micrite or organic matter), plus are cemented by their overgrowths (Ov). Micritic peloids (Pel) are the other framework builders. **x50ppl**

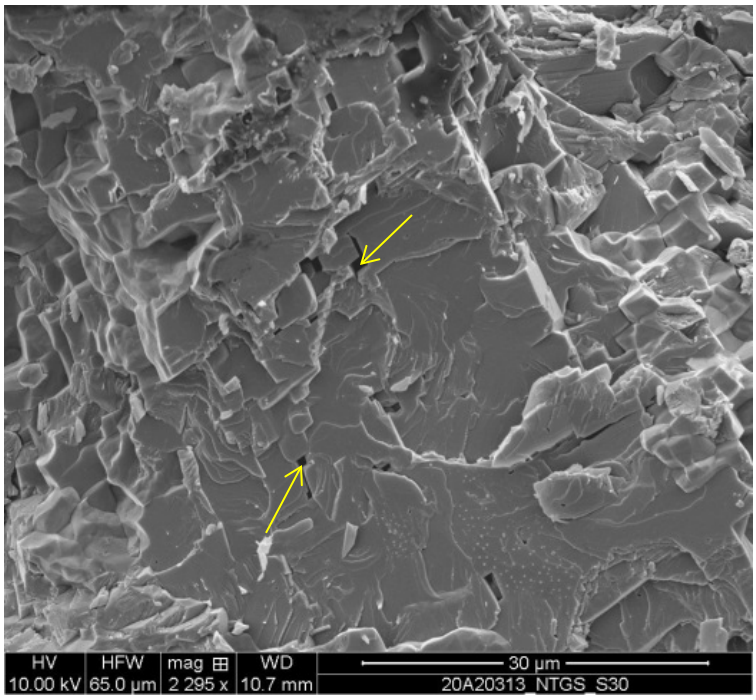


Figure 7.4. Sample S30, 7796.10ft/2376.25m. Moderate magnification Scanning Electron Microscope (SEM) image showing trace intercrystalline micropores (yellow arrows). **x2295**

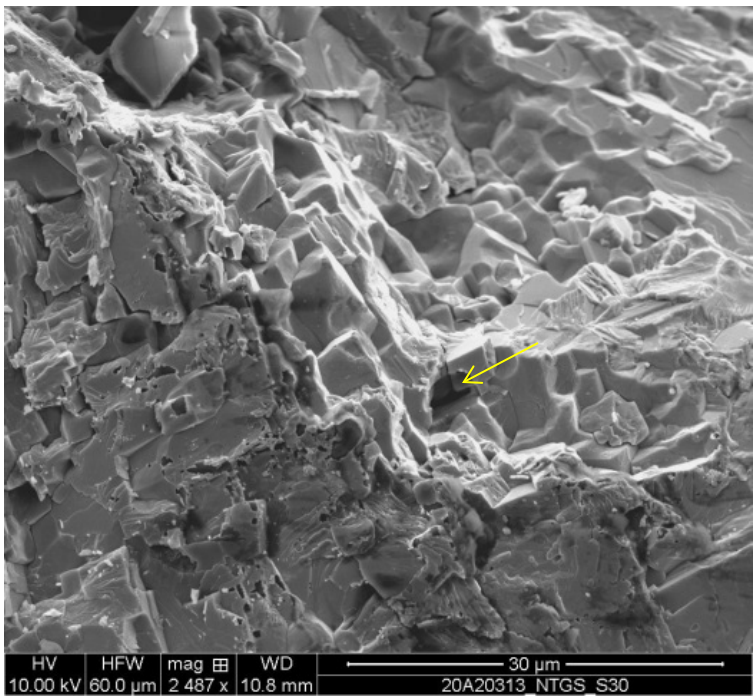


Figure 7.5. Sample S30, 7796.10ft/2376.25m. Alternate moderate magnification Scanning Electron Microscope (SEM) image of an isolated micropore (yellow arrow). **x2487**

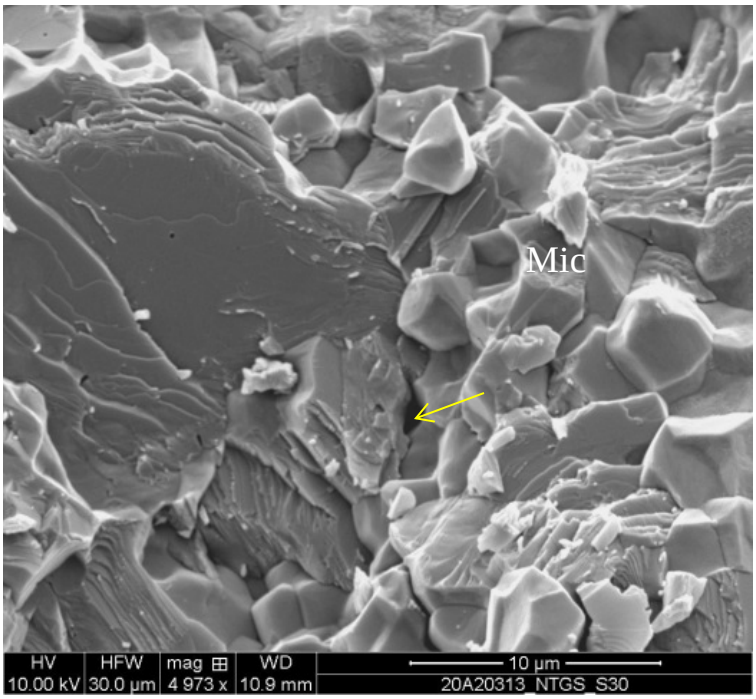


Figure 7.6. Sample S30, 7796.10ft/2376.25m. High magnification Scanning Electron Microscope (SEM) image showing details of the anhedral to subhedral micrite matrix (Mic). A visible micropore (yellow arrow) occurs along the boundary of a relatively coarse calcite crystal and the surrounding matrix. **x4973**

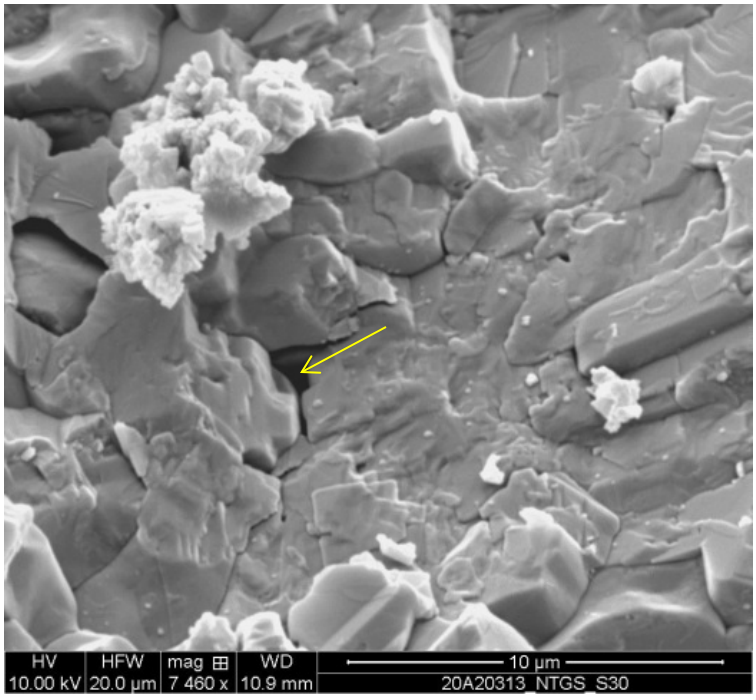


Figure 7.7. Sample S30, 7796.10ft/2376.25m. High magnification Scanning Electron Microscope (SEM) image of an isolated micropore (yellow arrow). **x7460**

Sample T29/ S29/ P19, 7800.70ft/2377.65m

Well Name	Imperial Sun Arrowhead Aurora M-47	**Location**	300/M-47-6040-12230/0
Sample Type	Thin section/SEM grain mount from a core sample	**Depth (m)**	7800.70ft/2377.65m
Stratigraphic Unit	Nahanni Formation	**Reservoir Quality**	Poor
Classification	Limestone (Grainstone)	**Stain type**	½ Dual carbonate stain

MINERALOGY

	Total bulk mineralogy					
Thin Section Point counting (%)	**Calcite**	**Dolomite**	**Anhydrite**	**Quartz**	**Pyrite**	**Clays & organics**
	100	-	-	-	TR	TR
	Framework, Matrix, Cement, and Replacement					
	Carbonate clasts	**Bioclasts**	**Detrital grains**	**Matrix**	**Pore filling cement**	**Replacement**
	5	77	-	8	10	TR

ADDITIONAL FEATURES and OTHER COMMENTS

Depositional	The sample is massive with no distinct sedimentary structures.
Textures	Mineralogy of this sample contains 100% of calcite, plus trace amounts of pyrite and clays & organics. Based on the abundance of framework grains (77% of bioclasts and 5% of peloids) and relatively low amount of micrite matrix (8%), the sample was classified as limestone-grainstone. The crystal texture of matrix is anhedral, while cement (10%) shows subhedral to euhedral crystal texture. The fabric of the grainstone often shows sutured contact, especially between crinoid debris (chemical compaction).
Framework (Carbonate clasts, Bioclasts)	The framework of this grainstone is dominated by crinoids (70%), while mollusks and indistinct bioclasts fragments occur in minor quantities (5% and 2% respectively). Additionally trace amounts of trilobites were also spotted. The carbonate clasts are represented by minor amounts of micritic peloids (5%).
Detrital Grains & Other Non-Carbonate Grains	There are no detrital grains in this sample.
Matrix	The matrix consists of calcite micrite (8%) and trace amounts of clays and organic matter.
Pore Filling Cements	Calcite spar that occurs in moderate amounts (10%) is the pore filling cement.
Replacement Minerals	Trace amounts of pyrite locally replace micrite within the matrix and micritized framework grains.
Porosity	Trace micro-intercrystalline porosity is the only pore type noted in this sample.

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

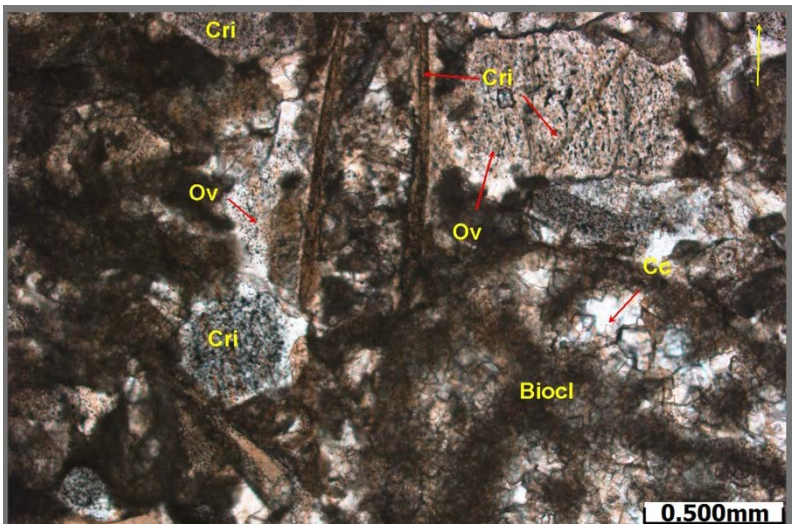


Figure 8.1. Sample T29, 7800.70ft/2377.65m. Moderate magnification overview of crinoidal grainstone. The crinoids (Cri) occur as plates that are perforated with small pores that are filled with contrasting material (possibly micrite or organic material) and rarely as arms fragments. These single-crystal crinoid plates commonly have syntaxial overgrowths (Ov) that totally plug interparticle pores. Indistinct bioclast fragments filled with calcite spar (Cc), while chambers walls are highly micritized. **x50ppl**

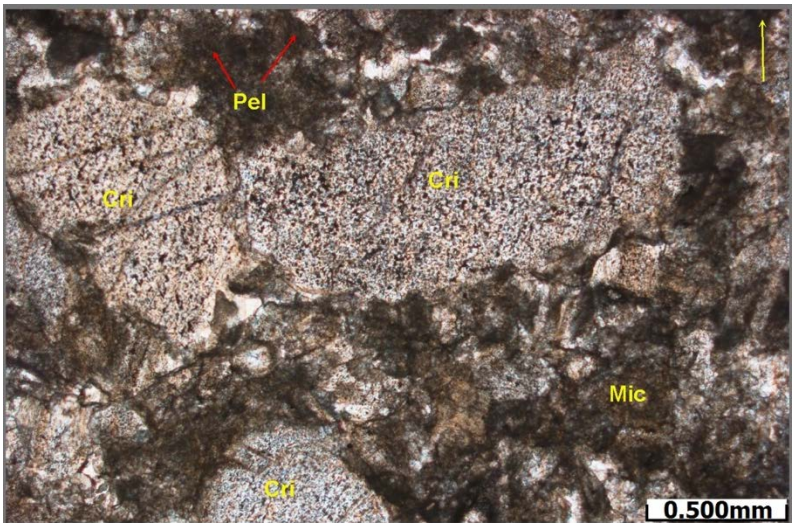


Figure 8.2. Sample T29, 7800.70ft/2377.65m. Another moderate magnification image of the sample of the grainstone shows allochems that were identified as crinoid plates (Cri) and micritic peloids (Pel). Interparticle pores have been filled with micrite matrix (Mic). Some of the crinoids show syntaxial overgrowths. Both overgrowths and micrite seal primary porosity. **x50ppl**

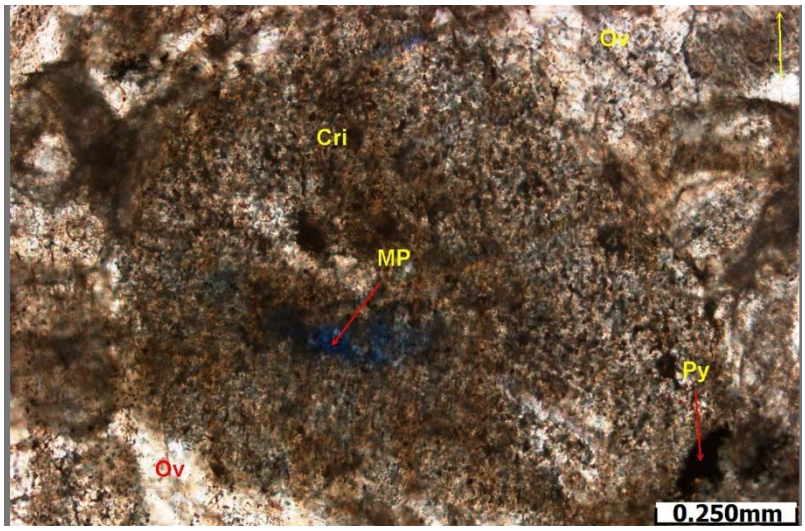


Figure 8.3. Sample T29, 7800.70ft/2377.65m. High magnification image of the sample focuses on microporosity (MP) observed in leached crinoid plate (Cri). Some of the surrounding crinoid debris show syntaxial overgrowths (Ov) that plug primary interparticle porosity. Pyrite (Py) aggregates have locally replaced micrite. **x100ppl**

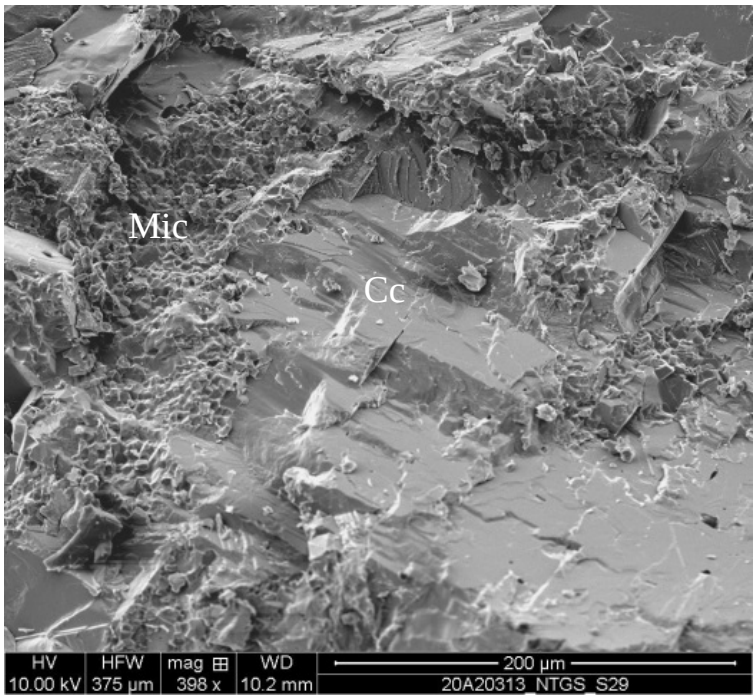


Figure 8.4. Sample S29, 7800.70ft/2377.65m. Low magnification Scanning Electron Microscope (SEM) image showing euhedral calcite cement (Cc) within a micritic matrix (Mic). The sample appears tight and generally lacks visible porosity. **x398**

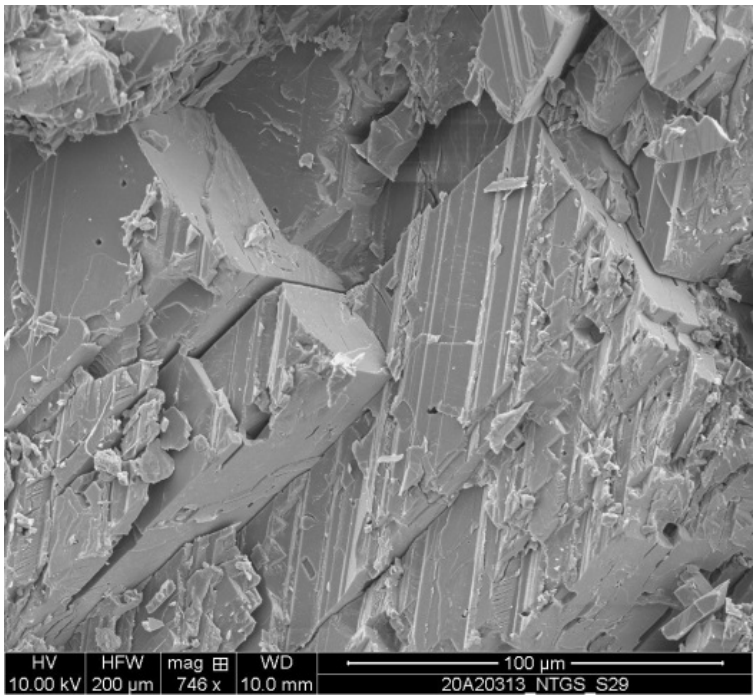


Figure 8.5. Sample S29, 7800.70ft/2377.65m. Scanning Electron Microscope (SEM) image showing blocky calcite cement with visible striations that reflect internal twinning patterns. **x746**

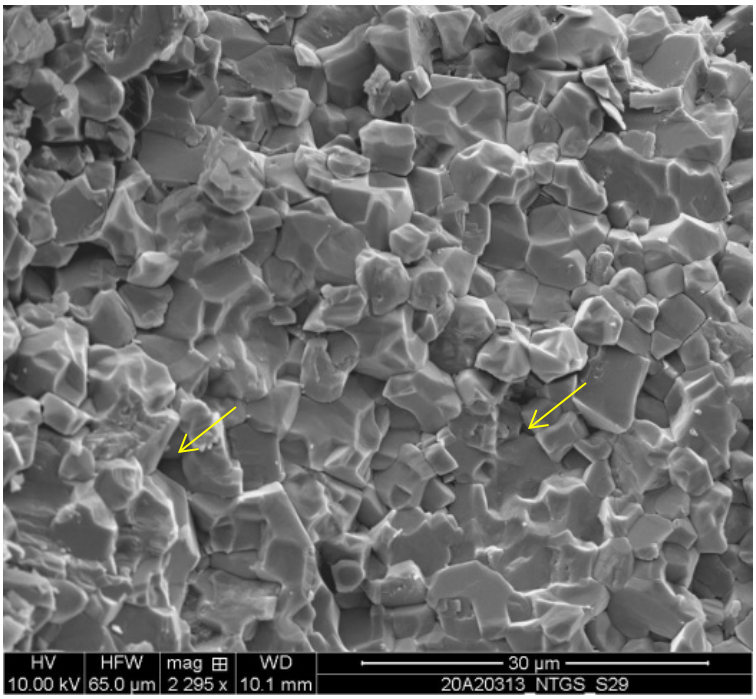


Figure 8.6. Sample S29, 7800.70ft/2377.65m. Moderate magnification Scanning Electron Microscope (SEM) image showing details of the anhedral to subhedral micrite matrix. Trace scattered submicron micropores are denoted by yellow arrows. **x2295**

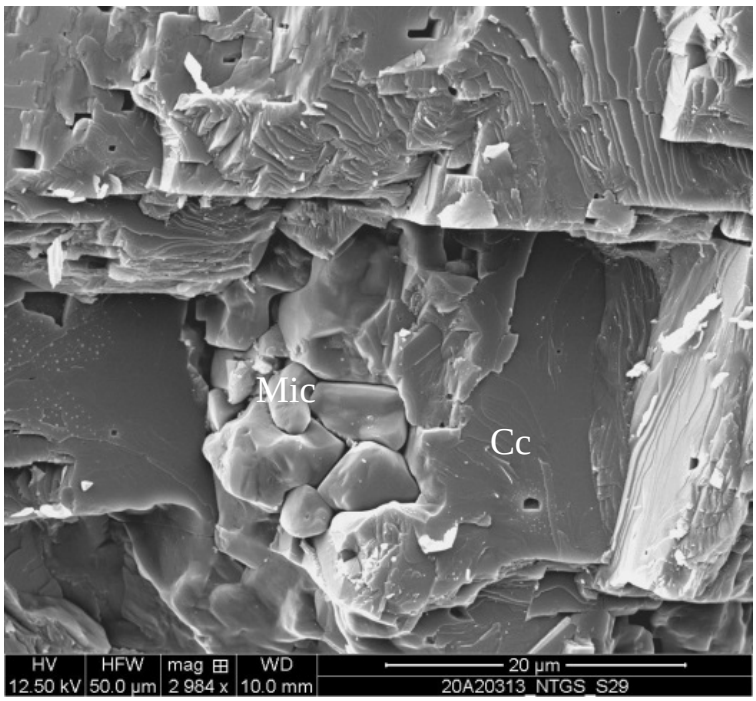


Figure 8.7. Sample S29, 7800.70ft/2377.65m. Scanning Electron Microscope (SEM) image showing anhedral micrite (Mic) and euhedral sparry calcite cement (Cc). **x2984**

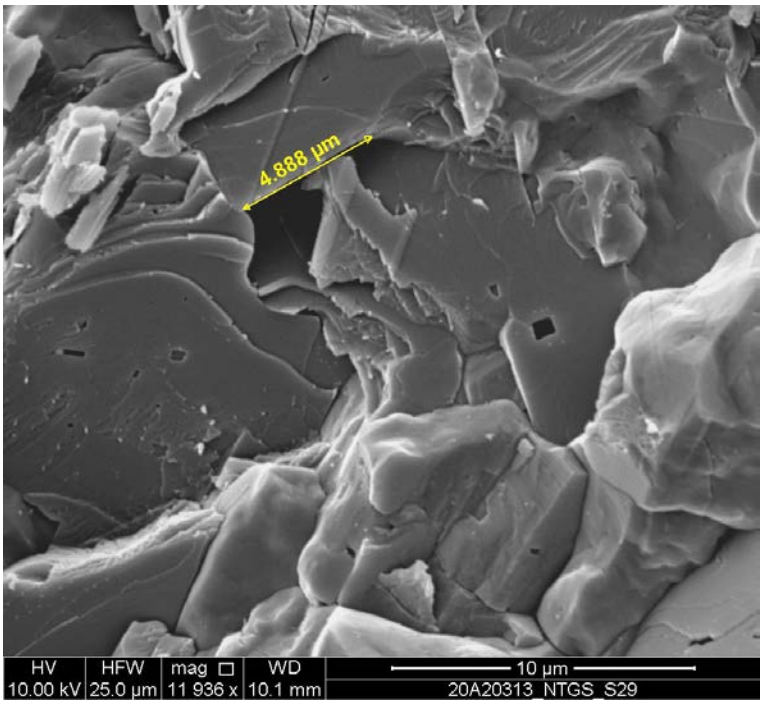


Figure 8.8. Sample S29, 7800.70ft/2377.65m. Scanning Electron Microscope (SEM) image of an isolated intercrystalline micropore (<5µm). **x11936**

Sample T28/ X44/ S28/ P18, 7803.00ft/2378.35m

Well Name	Imperial Sun Arrowhead Aurora M-47	**Location**	300/M-47-6040-12230/0
Sample Type	Thin section/SEM grain mount from a core sample	**Depth (m)**	7803.00ft/2378.35m
Stratigraphic Unit	Nahanni Formation	**Reservoir Quality**	Poor
Classification	Limestone (Grainstone)	**Stain type**	½ Dual carbonate stain

MINERALOGY

	Total bulk mineralogy					
Thin Section Point counting (%)	**Calcite**	**Dolomite**	**Anhydrite**	**Quartz**	**Pyrite**	**Clays & organics**
	100	-	-	-	TR	TR
	Framework, Matrix, Cement, and Replacement					
	Carbonate clasts	**Bioclasts**	**Detrital grains**	**Matrix**	**Pore filling cement**	**Replacement**
	-	89	-	1	10	TR

ADDITIONAL FEATURES and OTHER COMMENTS

Depositional	There are no preserved sedimentary structures in this sample. Stylolitized partings observed on the contacts between crinoid fragments are results of chemical compaction that occurred during burial diagenesis.
Textures	Mineralogy of this sample contains 100% of calcite, plus trace amounts of pyrite and clays & organics. Based on the abundance of framework grains (bioclasts - 89%) and very low amounts of micrite matrix (1%), the sample was classified as limestone-grainstone. The crystal texture of matrix is anhedral, while cement (10%) shows subhedral to euhedral crystal texture. The fabric of the grainstone often shows sutured contact between crinoid debris (chemical compaction) that are a dominant framework builder.
Framework (Carbonate clasts, Bioclasts)	The framework of this grainstone comprises primarily crinoids (85%) and minor amounts indistinct bioclasts fragments (4%).
Detrital Grains & Other Non-Carbonate Grains	There are no detrital grains in this sample.
Matrix	The matrix consists of calcite micrite (1%) and trace amounts of clays and organic matter.
Pore Filling Cements	Calcite spar that occurs in moderate amounts (10%) is the pore filling cement.
Replacement Minerals	Trace amounts of pyrite locally replace micrite within the matrix and micritized framework grains.
Porosity	There is no visible porosity in this sample.

The next pages show annotated microphotographs of the thin section and SEM sample with descriptions.

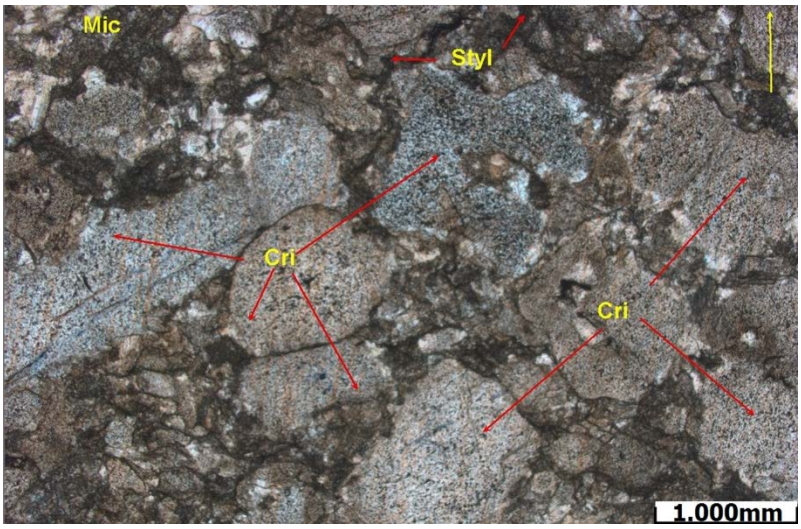


Figure 9.1. Sample T28, 7803.00ft/2378.35m. Low magnification overview of the crinoidal lime-grainstone that comprises plates, arm plate (upper-central), and stems (elongated fragment on the left). Note a sutured contact between adjacent grains defined by organic rich stylolitic laminae (Styl). Some of the primary interparticle pores are filled with dark brown (organic rich?) micrite (Mic) matrix. The internal pores within these crinoids are filled with micritic carbonates and/or organic material giving the grains a characteristic 'dusty' or speckled appearance. At high magnification, the regular arrangement of pores becomes more obvious. **x25ppl**

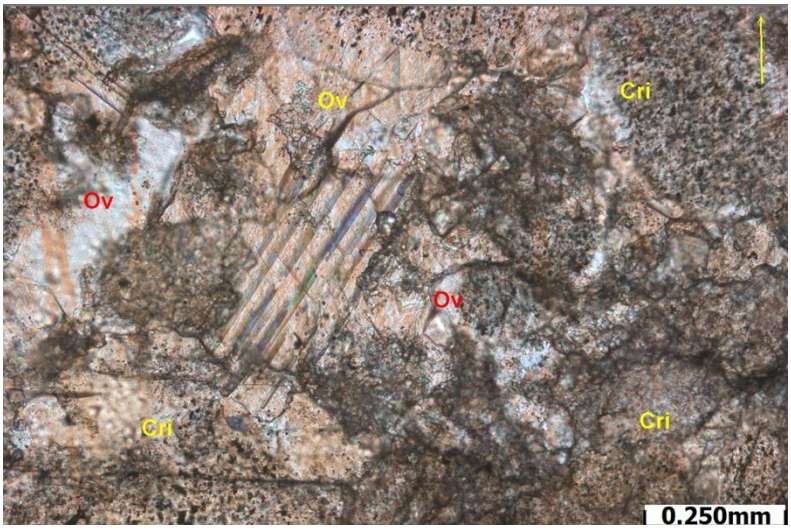


Figure 9.2. Sample T28, 7803.00ft/2378.35m. High magnification image of the sample shows in more details the allochems that are solely crinoid debris (Cri) that are fully cemented by syntaxial calcite overgrowths (Ov). The crinoids and their overgrowths show optical continuity (syntaxial cement), which is especially apparent when the twinning lamellae of the calcite crystal are continuous from grain to cement (middle-centre). This phenomena are common in crinoidal limestone deposits. Intense twinning usually is due to crystal dissolution and/or dislocation and it is typically a result of burial loading and tectonic deformation. **x100ppl**

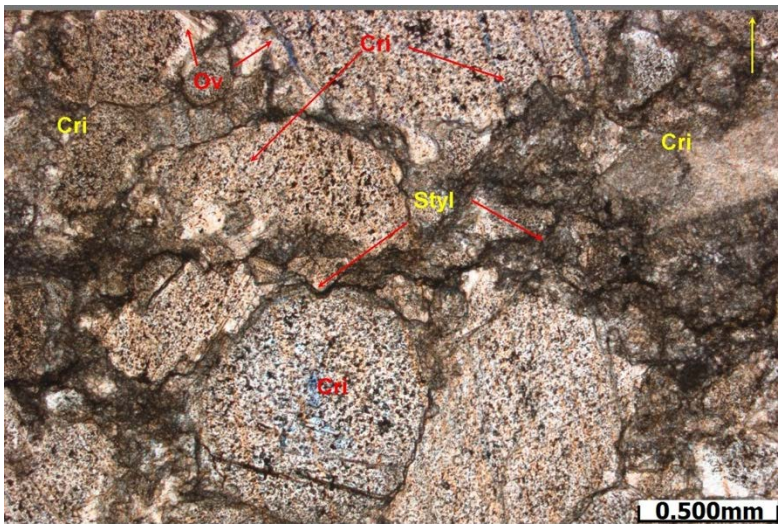


Figure 9.3. Sample T28, 7803.00ft/2378.35m. Moderate magnification image of the grainstone highlights the sutured grain contacts defined by organic-rich stylolitized partings (Styl).The allochems in this image are crinoids (Cri). The interparticle pores are filled with syntaxial overgrowths (Ov). **x200ppl**

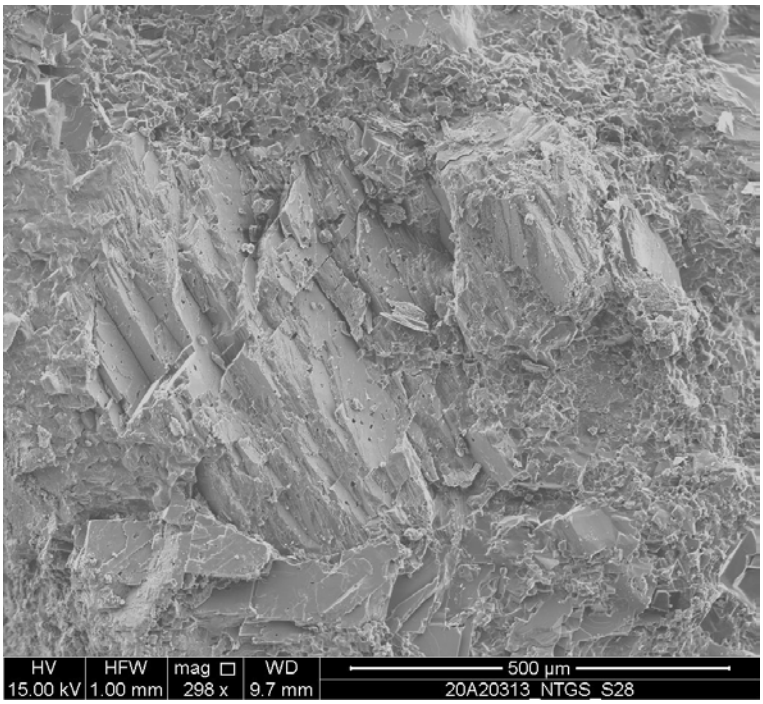


Figure 9.4. Sample S28, 7803.00ft/2378.35m. Low magnification Scanning Electron Microscope (SEM) image of euhedral calcite within the tight calcite micrite groundmass. **x298**.

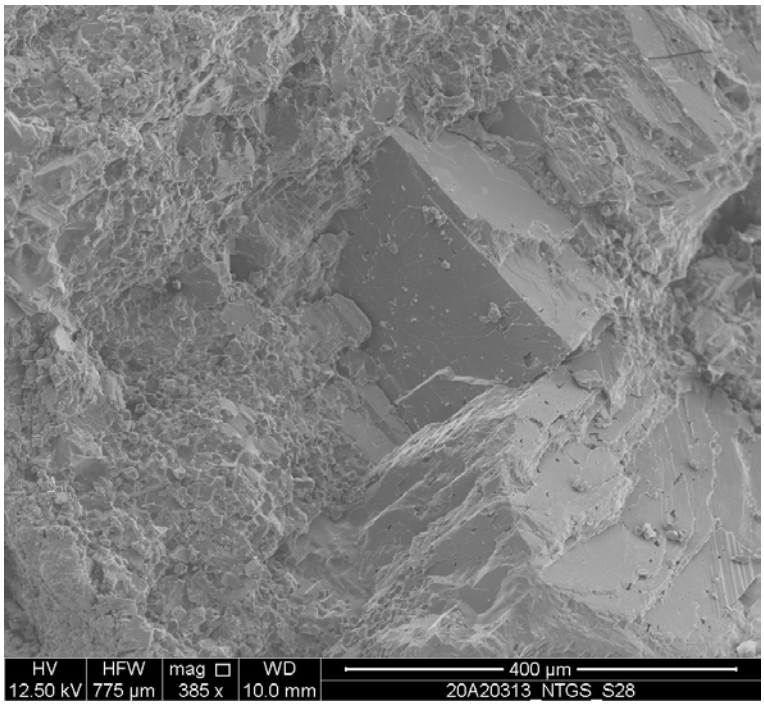


Figure 9.5. Sample T28, 7803.00ft/2378.35m. Alternate low magnification Scanning Electron Microscope (SEM) image showing similar features as shown in **Figure 9.4**. **x385**

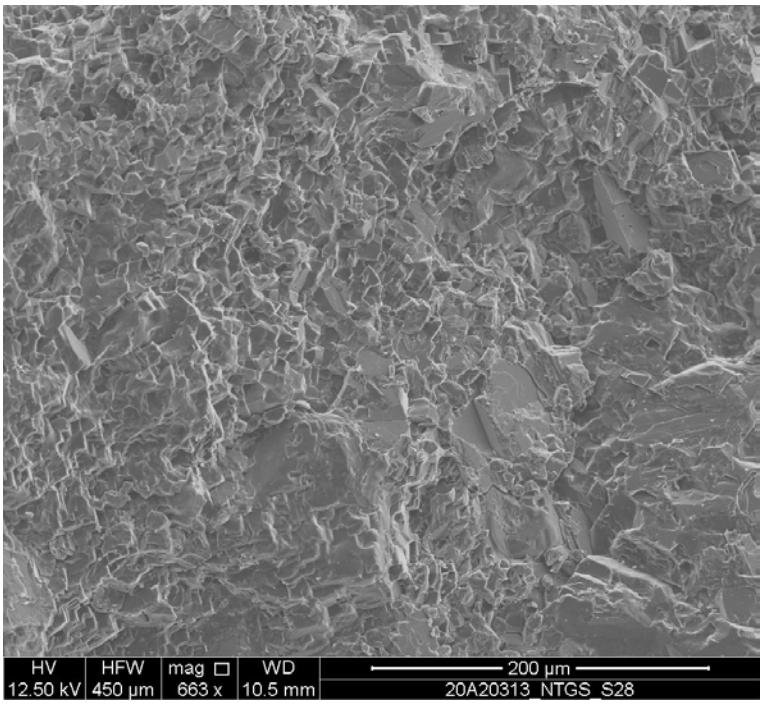


Figure 9.6. Sample T28, 7803.00ft/2378.35m. Slightly higher magnification Scanning Electron Microscope (SEM) image showing the micrite matrix. The sample lacks visible porosity. **x663**.

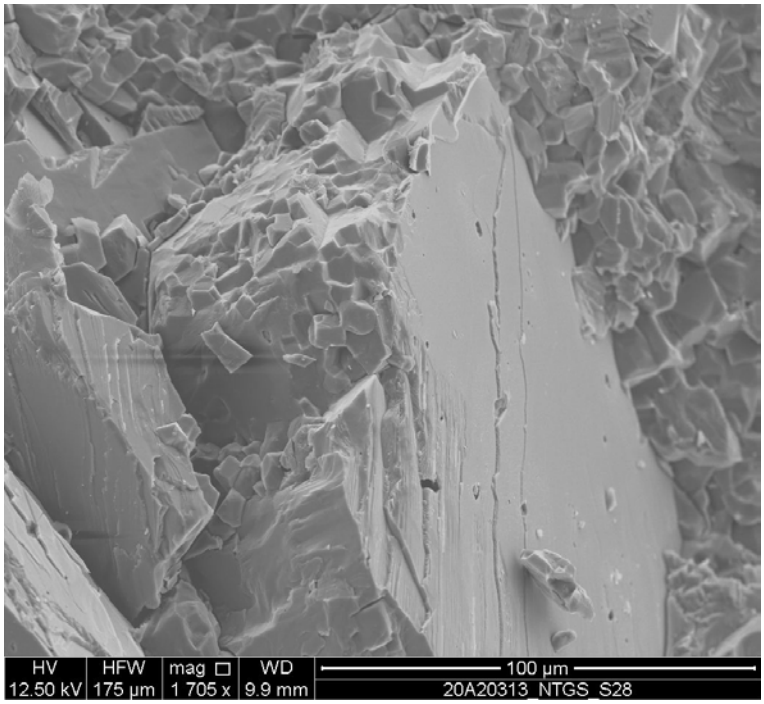


Figure 9.7. Sample T28, 7803.00ft/2378.35m. Scanning Electron Microscope (SEM) image showing calcite cement enveloped by the micritic matrix. Visible porosity in this sample is poor. **x1705**

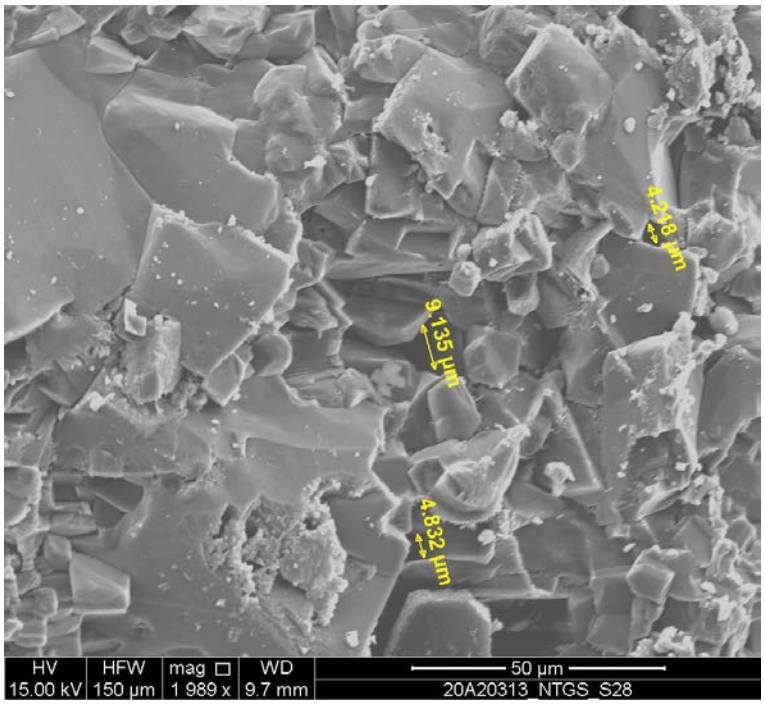


Figure 9.8. Sample T28, 7803.00ft/2378.35m. Scanning Electron Microscope (SEM) image showing trace micropores (<5µm). A rare macropore (~10µm) is suspected to reflect artefact porosity generated by grain-plucking. **x1989**

Sample T27/ S27/ P17, 7808.10ft/2379.91m

Well Name	Imperial Sun Arrowhead Aurora M-47	**Location**	300/M-47-6040-12230/0
Sample Type	Thin section /SEM grain mount from a core sample	**Depth (m)**	7808.10ft/2379.91m
Stratigraphic Unit	Nahanni Formation	**Reservoir Quality**	Poor
Classification	Limestone (Grainstone-Packstone)	**Stain type**	½ Dual carbonate stain

MINERALOGY

	Total bulk mineralogy					
Thin Section Point counting (%)	**Calcite**	**Dolomite**	**Anhydrite**	**Quartz**	**Pyrite**	**Clays & organics**
	99	TR	-	-	TR	1
	Framework, Matrix, Cement, and Replacement					
	Carbonate clasts	**Bioclasts**	**Detrital grains**	**Matrix**	**Pore filling cement**	**Replacement**
	-	86	-	5	9	TR

ADDITIONAL FEATURES and OTHER COMMENTS

Depositional	There are no preserved sedimentary structures in this sample. Stylolitized partings that outline sutured contacts between some of the allochems have developed during burial diagenesis (chemical compaction)
Textures	Mineralogy of this sample contains 99% of calcite, plus minor (1%) of clays and organic matter that is associated with stylolitized partings, plus trace amounts of pyrite. Based on the abundance of framework grains (bioclasts - 86%) and overall minor amounts of micrite matrix (4%), the sample was classified as grainstone to packstone. The crystal texture of matrix is anhedral, while cement (9%) shows subhedral to euhedral crystal texture. The fabric of the limestone often shows sutured contact especially between crinoid debris (chemical compaction).
Framework (Carbonate clasts, Bioclasts)	Allochems form 86% of the rock, and consist mainly of fragments of bryozoans (65%) with lesser crinoids (20%), minor (1%) of indistinct bioclast fragments, plus trace mollusks, and algae.
Detrital Grains & Other Non-Carbonate Grains	There are no detrital grains in this sample.
Matrix	The matrix consists of calcite micrite (4%) and minor (1%) of clays and organic matter.
Pore Filling Cements	Calcite spar (6%) and calcite druse (3%), plus trace ferroan dolomite are the pore filling cements.
Replacement Minerals	Trace amounts of pyrite locally replace micrite within the matrix and micritized framework grains.
Porosity	There is no visible porosity in this sample.

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

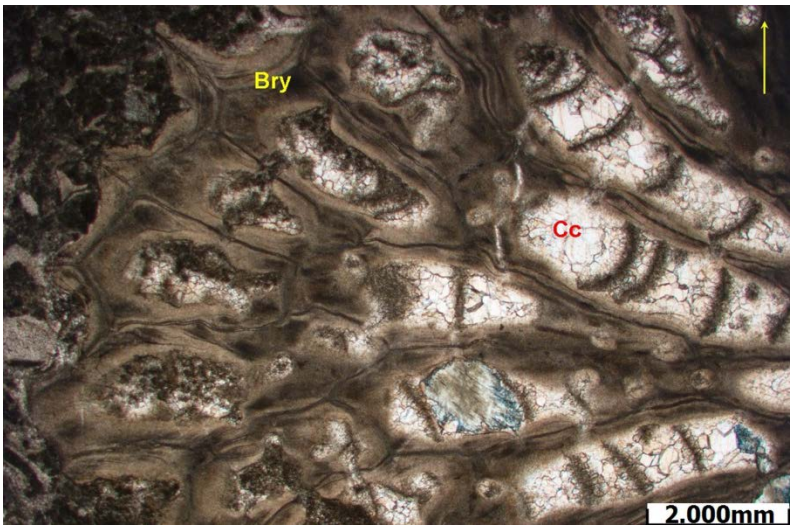


Figure 10.1. Sample T27, 7808.10ft/2379.91m. This low magnification image focuses on a large sized fenestrate bryozoans (Bry) that account for 65% of the total volume of the sample. Note the increasing thickness of the zooecia walls outward. The majority of zooecia are cemented with calcite druse and spar (Cc). **x12.5ppl**

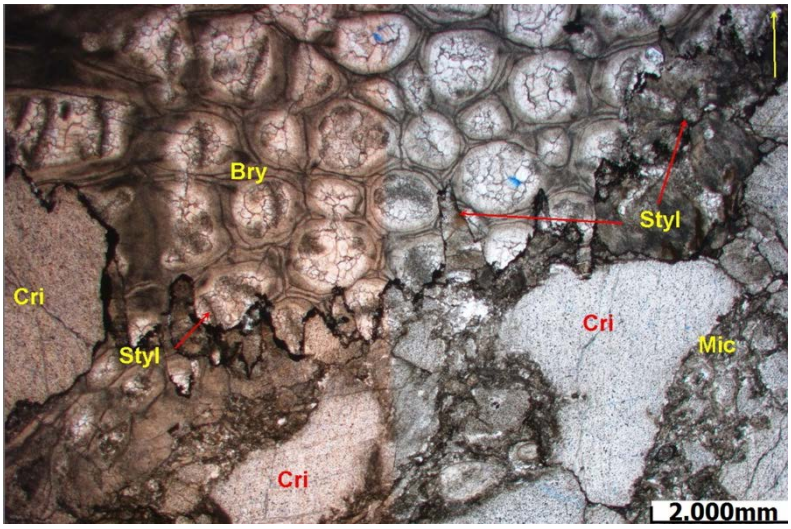


Figure 10.2. Sample T27, 7808.10ft/2379.91m. Another low magnification image of the sample shows both bryozoans (Bry) and crinoid (Cri) debris that are the main allochems in this sample. Note a low amplitude micro-stylolite (Styl) that mars the boundaries between some of the grains. Very minor amounts of micrite fills interparticle pores (Mic). Zooecia are totally plugged by the calcite druse cement. This image was taken on the border line between stained (left - red) and unstained portion of the thin section. **x12.5ppl**

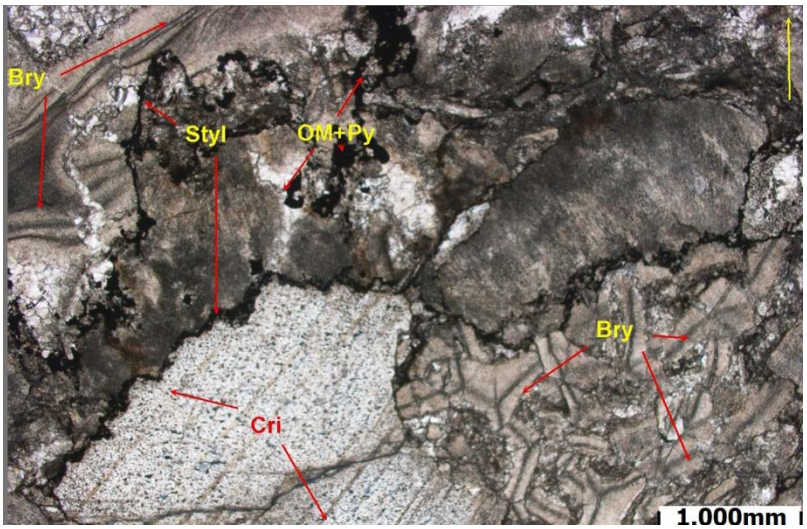


Figure 10.3. Sample T27, 7808.10ft/2379.91m. Another low magnification image of the sample was taken from the unstained portion of the thin section and presents bryozoans (Bry) and crinoid (Cri) plates. Note that the bryozoans in the lower right portion of the image has been highly fragmented and compacted The sutured contact between crinoids and bryozoans is defined by stylolitized laminae that contain organic material and pyrite (OM+Py). There is no visible porosity in this image. **x25ppl**

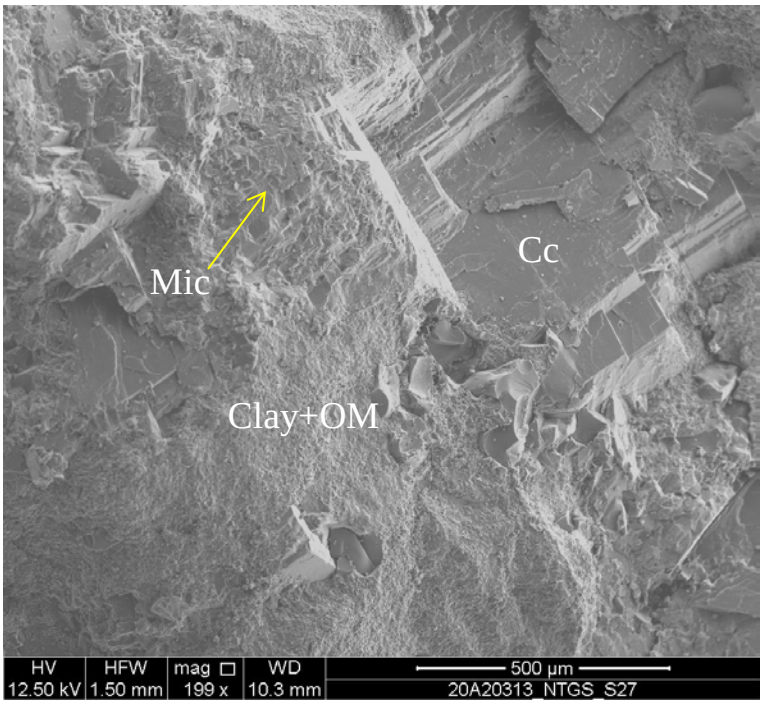


Figure 10.4. Sample S27, 7808.10ft/2379.91m. Scanning Electron Microscope (SEM) image showing euhedral calcite cement (Cc), micrite (Mic), plus clays and organics (Clay+OM) which are the main constituents which comprise this sample. The sample lacks visible porosity. **x199**

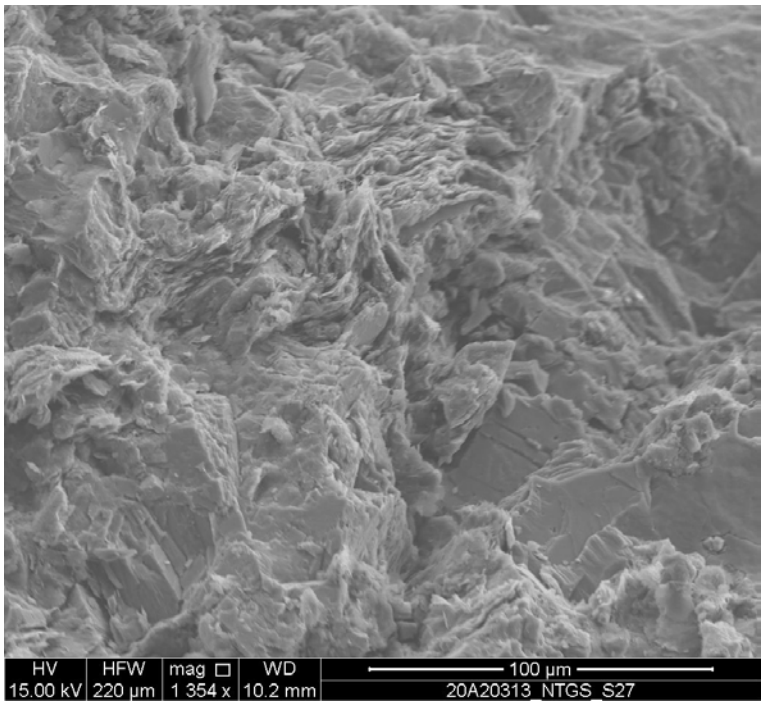


Figure 10.5. Sample S27, 7808.10ft/2379.91m. Scanning Electron Microscope (SEM) image showing the parallel alignment of platy clays or micas within the sample. **x1354**

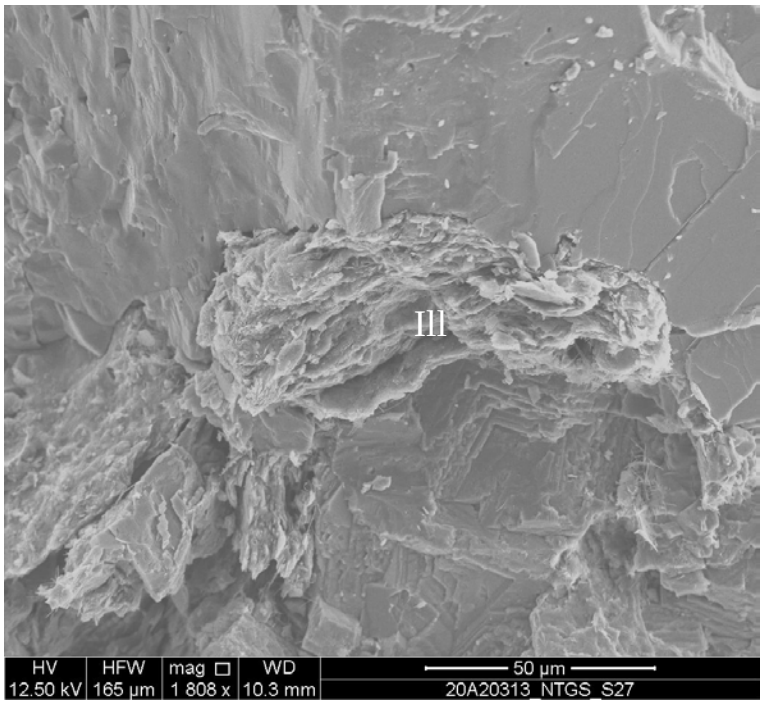


Figure 10.6. Sample S27, 7808.10ft/2379.91m. Scanning Electron Microscope (SEM) image of pore-occluding flaky illite (Ill). **x1808**

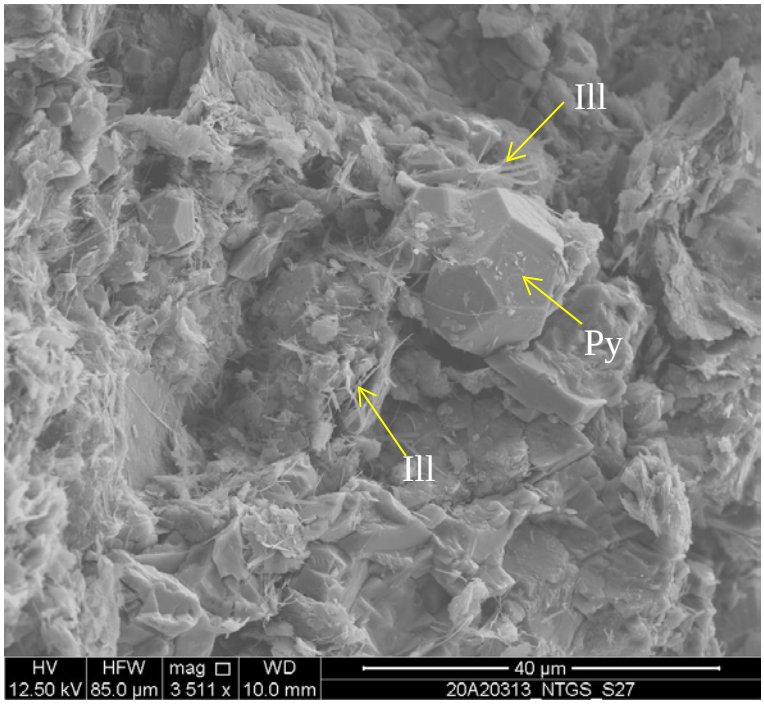


Figure 10.7. Sample S27, 7808.10ft/2379.91m. High magnification Scanning Electron Microscope (SEM) image showing euhedral secondary pyrite (Py), plus filamentous authigenic illite (Ill). This clay variety is highly prone to fluid induced migration. **x3511**

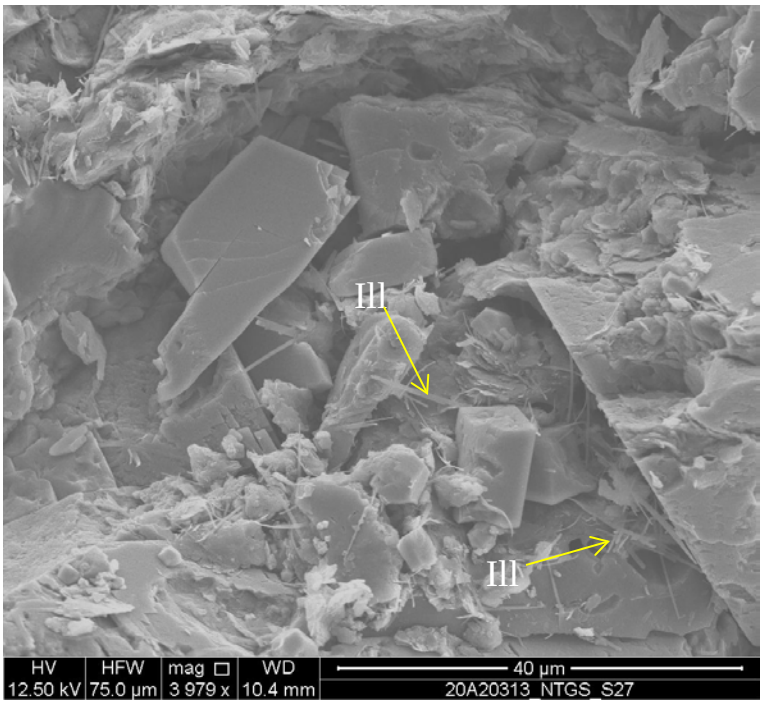


Figure 10.8. Sample S27, 7808.10ft/2379.91m. Alternate high magnification Scanning Electron Microscope (SEM) image displaying ribbon-like projections of authigenic illite (Ill). **x3979**

Sample T26/ S26/ P16, 7814.40ft/2381.83m

Well Name	Imperial Sun Arrowhead Aurora M-47	**Location**	300/M-47-6040-12230/0
Sample Type	Thin section/SEM grain mount from a core sample	**Depth (m)**	7814.40ft/2381.83m
Stratigraphic Unit	Nahanni Formation	**Reservoir Quality**	Poor
Classification	Limestone (Grainstone-Packstone)	**Stain type**	½ Dual carbonate stain

MINERALOGY

	Total bulk mineralogy					
Thin Section Point counting (%)	**Calcite**	**Dolomite**	**Anhydrite**	**Quartz**	**Pyrite**	**Clays & organics**
	98	-	-	-	TR	2
	Framework, Matrix, Cement, and Replacement					
	Carbonate clasts	**Bioclasts**	**Detrital grains**	**Matrix**	**Pore filling cement**	**Replacement**
	-	79	-	8	13	TR

ADDITIONAL FEATURES and OTHER COMMENTS

Depositional	There are no preserved sedimentary structures in this sample. Stylolitized partings that outline sutured contacts between some of the allochems have developed during burial diagenesis (chemical compaction). Some fracture are also present in the sample.
Textures	Mineralogically the sample comprises mainly calcite (98%), while clays and organic material and pyrite occur in minor (2%) and trace amounts respectively. The crystal texture of matrix is anhedral, while cement (13%) shows subhedral to euhedral crystal texture. The fabric of the limestone often shows sutured contact especially between crinoid debris (chemical compaction).
Framework (Carbonate clasts, Bioclasts)	Allochems were identified as corals (45%), crinoids (25), brachiopods (5%), and mollusks (2%). Some allochems could not be identified due to fragmentation and micritization and they were grouped together as unidentified bioclasts (see Petrographic Summary Table 1).
Detrital Grains & Other Non-Carbonate Grains	There are no detrital grains in this sample.
Matrix	The matrix consists of moderate amounts of calcite micrite (6%) and minor (2%) of clays and organic matter.
Pore Filling Cements	Calcite is the pore filling cement and it occurs as spar (10%) and druse (3%).
Replacement Minerals	Trace amounts of pyrite locally replace micrite within the matrix and micritized framework grains.
Porosity	There is a minor (1%) amount of micro-intercrystalline pores in this sample.

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

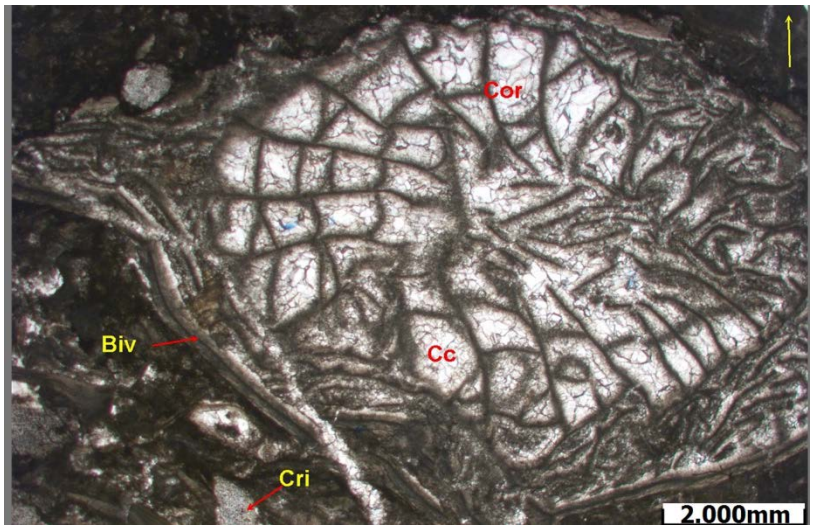


Figure 11.1. Sample T26, 7814.40ft/2381.83m. This low magnification image shows possible rugose coral fragment (Cor) with septa cemented with calcite druse and spar (Cc). Other allochems in this image include bivalve shell fragments and crinoid debris (Biv; Cri). Note that the matrix in this sample contain calcite micrite and fragmented indistinct bioclast fragments. **x12.5ppl**

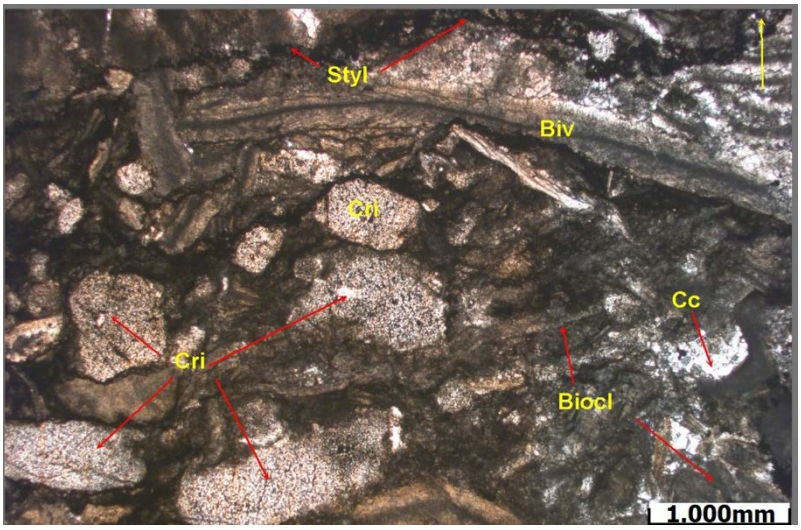


Figure 11.2. Sample T26, 7814.40ft/2381.83m. Another low magnification image of the sample shows mainly crinoid debris (Cri), plus occasional bivalve (Biv) and indistinct bioclast fragments (Biocl). Low amplitude micro-stylolite is observed close to the top of the image (Styl). Calcite cement (Cc) fills interparticle or intraparticle pore. There is no visible porosity in this image. **x25pl**

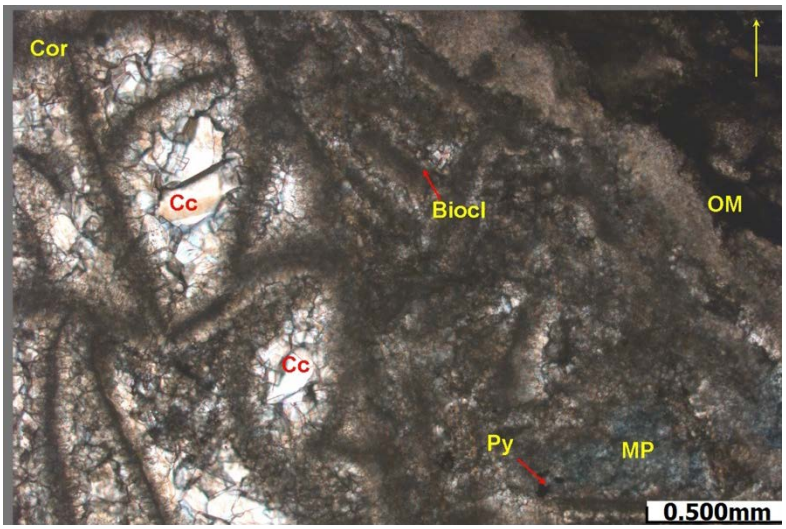


Figure 11.3. Sample T26, 7814.40ft/2381.83m. Moderate magnification image shows coral (Cor) and indistinct, highly micritic bioclast fragment (Biocl). Septa of the coral are filled with calcite cement (Cc). A small patch of microporosity (MP) is locally reduced by the precipitation of micropyrite (Py). Organic matter (OM) is a part of the matrix in this sample. **x50ppl**

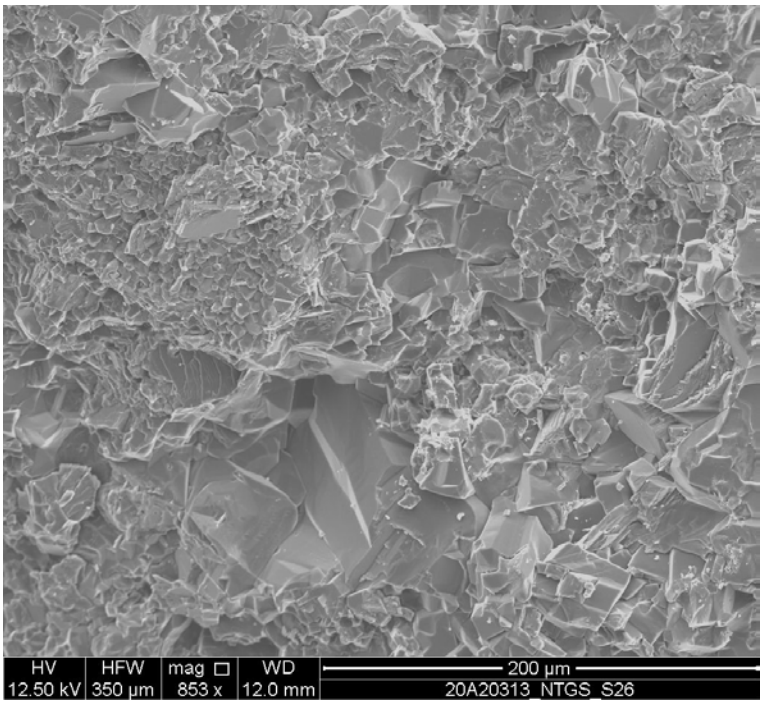


Figure 11.4. Sample S26, 7814.40ft/2381.83m. Low magnification Scanning Electron Microscope (SEM) image highlighting to overall crystal fabric of the sample. **x853**

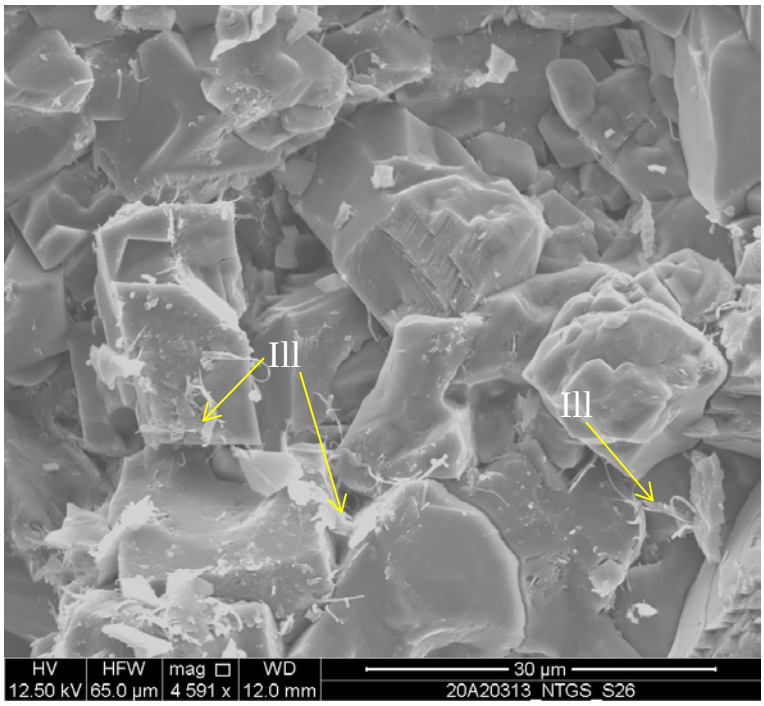


Figure 11.5. Sample S26, 7814.40ft/2381.83m. High magnification Scanning Electron Microscope (SEM) image showing sub- to euhedral calcite microspar (5-20µm) with scattered authigenic illite ribbons (Ill). This clay variety is highly prone to velocity induced migration. **x4591**

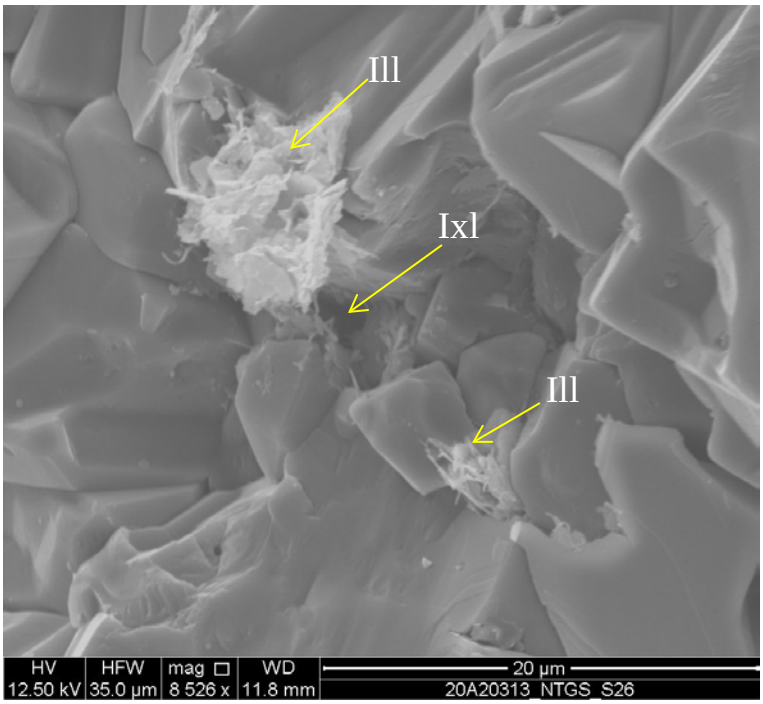


Figure 11.6. Sample S26, 7814.40ft/2381.83m. High magnification Scanning Electron Microscope (SEM) image showing an aggregate of illitic clay (Ill). Filimentous illite also appears to line the intercrystalline pore space (Ixl). This clay variety is highly prone to fluid induced migration. **x8526**

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, cementation of pores and pressure solution (stylolites).

Chemical compaction is evidenced through pressure solution features like micro-stylolites. Insoluble bituminous organic matter and possible clays are found along these micro-stylolites.

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

Porosity within the limestone samples includes micro-intercrystalline porosity (trace to 2% - T26, T29, T32, T33) and intercrystalline porosity (trace to 1% - T34 and T35). Trace fracture porosity occurs in samples T30 and T32-T33, in addition to trace micro-vuggy porosity in sample T35, plus trace interparticle in sample T34. The main porosity plugging factors observed at this location include cementation by calcite spar, plus the variable abundance of calcite micrite, which has locally recrystallized to tight mosaic microspar.

Reservoir quality for these eleven samples is mainly controlled by diagenesis (i.e. mineral diagenesis, recrystallization of micrite to microspar, compaction, and cementation) in addition to 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.). Reservoir quality is considered to be poor for all the study 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.

NAHANNI Formation

Sample ID	Depth (ft)	Total Micrite (%)	Total Cement (%)	Total Porosity (%)						Main Porosity controlling factors (*)	RQ(*)
				IP	Int.	Ixl	Mv	Fr	M		
Location: Imperial Sun Arrowhead Aurora M-47 300/M-47-6040-12230/0											
T36	7770.00	15	4	-	-	-	-	-	-	Mic; Cc; Com	P
T35	7775.00	5	19(*)	-	-	1	TR	-	-	Cc; Mic	P
T34	7779.30	2	5	TR	-	TR	-	-	-	Cc; Mic	P
T33	7784.30	1	6	-	-	-	-	TR	1	Cc	P
T32	7785.50	1	9	-	-	-	-	TR	2	Mic; Cc	P
T31	7793.10	10	10	-	-	-	-	-	-	Mic; Cc	P
T30	7796.10	1	5	-	-	-	-	TR	-	Cc; Com	P
T29	7800.70	8	10	-	-	-	-	-	TR	Cc; Mic	P
T28	7803.00	1	10	-	-	-	-	-	-	Cc	P
T27	7808.10	4	9	-	-	-	-	-	-	Cc; Mic	P
T26	7814.40	6	13	-	-	-	-	-	1	Cc: Mic	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; P**y** – 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 Imperial Sun Arrowhead Aurora M-47 300/M-47-6040-12230/0 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.

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DATA TABLES

Table 1
Petrographic Summary of Eleven Samples recovered from the Nahanni Formation at the Imperial Sun Arrowhead Aurora M-47 300/M-47-6040-12230/0 Location

Sample ID		T36	T35	T34	T33	T32	T31
Depth (ft)		7770.00	7775.00	7779.30	7784.30	7785.50	7793.10
Rock Type		LS	LS	LS	LS	LS	LS
Mineralogy	*Calcite*	94	90	99	99	100	96
	Dolomite	1	2	TR	TR	-	-
	Anhydrite	-	-	-	TR	-	-
	Quartz	TR	-	TR	-	-	-
	Chert	-	-	-	-	-	-
	Pyrite and Heavy Minerals	2	3	1	1	TR	TR
	Phosphate	-	-	-	-	-	-
	Clays & organics	3	5	TR	TR	TR	4
Total Rock Volume (%)		**100**	**100**	**100**	**100**	**100**	**100**
Carbonate Clasts	*Peloids*	15	60	-	-	TR	TR
	Ooids	-	1	-	-	-	-
	Intraclasts/Oncolintes	3	-	-	-	-	-
	Total:	**18**	**61**	**0**	**0**	**TR**	**TR**
Bioclasts/Fauna	*Mollusks*	5	TR	2	1	-	10
	Foraminifers	-	-	-	-	-	-
	Brachiopod (shell & spines)	18	-	-	1	-	20
	Bryozoa	TR	-	5	-	-	TR
	Corals	-	-	-	40	40	10
	Algae	TR	-	-	-	-	-
	Echinoderms/Crinoids	15	2	85	50	50	20
	Trilobites	-	-	-	-	-	5
	Ostracodes	-	-	-	-	-	1
	Stromatoporoid	-	-	-	-	-	-
	Unidentified	20	5	-	TR	TR	10
	Total:	**58**	**7**	**92**	**92**	**90**	**76**
Detrital Grains and Other Non-Carbonate Grains	*Quartz*	-	-	-	-	-	-
	Chert	-	-	-	-	-	-
	Heavy Mineral	-	-	-	-	-	-
	Total:	**0**	**0**	**0**	**0**	**0**	**0**
Matrix	*Micrite (calcite or dolomite)*	15	5	2	1	1	10
	Micro- and pseudospar	-	15	-	-	-	-
	Clays & organics	3	5	TR	TR	TR	4
	Sutured allochems	-	-	-	-	-	-
	Total:	**18**	**25**	**2**	**1**	**1**	**14**
Pore Filling Cement	*Calcite Spar*	3	2	5	5	9	10
	Calcite druse	TR	-	-	1	-	-
	Dolomite	1	1	-	TR	-	-
	Ferroan Dolomite	TR	1	TR	-	-	-
	Pyrite	-		-	-	-	-
	Anhydrite	-	-	-	TR	-	-
	Total:	**4**	**4**	**5**	**6**	**9**	**10**
Replacement	*Calcite*	-	-	-	-	-	-
	Dolomite	-	-	-	-	-	-
	Anhydrite	-	-	-	-	-	-
	Quartz/Chert	TR	-	TR	-	-	-
	Pyrite	2	3	1	1	TR	TR
	Total:	**2**	**3**	**1**	**1**	**TR**	**TR**
Total Rock Volume (%)		**100**	**100**	**100**	**100**	**100**	**100**
Crystal Texture (Matrix)		Anh	Anh	Anh	Anh	Anh	Anh
Crystal Texture (Cement)		Sub-Euh	Sub-Euh	Sub-Euh	Sub-Euh	Sub-Euh	Sub-Euh
Structure/Fabric		Styl; fracs/S	Styl; fracs	Styl; S	fracs; S	fracs	Lm
Ratio Matrix/Clasts (approximate)		1:4	1:3	1:45	1:90	1:90	1:5
Original Texture		WS-PS	PS-WS	GS	GS	GS	WS-PS
Porosity (%)	*Interparticle*	-	-	TR	-	-	-
	Intraparticle	-	-	-	-	-	-
	Intercrystalline	-	1	TR	-	-	-
	Fracture	-	-	-	TR	TR	-
	Micro-Vuggy	-	TR	-	-	-	-
	Micro- intercrystalline pores	-	-	-	1	2	-
	Total TS Porosity (%)	**0**	**1**	**TR**	**1**	**2**	**0**
Petrophysical Results	*Core Porosity (%)*	**0.5**	**1.6**	**1.5**	**2.7**	**4.3**	**0.7**
	Core Permeability (mD)	**0.01**	**0.08**	**0.05**	**8.06***	**52.1***	**0.03**
Reservoir Quality		**Poor**	**Poor**	**Poor**	**Poor**	**Poor**	**Poor**

Table 1 (continued)
Petrographic Summary of Eleven Samples recovered from the Nahanni Formation at the Imperial Sun Arrowhead Aurora M-47 300/M-47-6040-12230/0 Location

Sample ID		T30	T29	T28	T27	T26	
Depth (ft)		7796.10	7800.70	7803.00	7808.10	7814.40	
Rock Type		LS	LS	LS	LS	LS	
Mineralogy	*Calcite*	100	100	100	99	98	
	Dolomite	TR	-	-	TR	-	
	Anhydrite	-	-	-	-	-	
	Quartz	-	-	-	-	-	
	Chert	-	-	-	-	-	
	Pyrite and Heavy Minerals	TR	TR	TR	TR	TR	
	Phosphate	-	-	-	-	-	
	Clays & organics	TR	TR	TR	1	2	
Total Rock Volume (%)		**100**	**100**	**100**	**100**	**100**	
Carbonate Clasts	*Peloids*	2	5	-	-	-	
	Ooids	-	-	-	-	-	
	Intraclasts/Oncolintes	-	-	-	-	-	
	Total:	**2**	**5**	**0**	**0**	**0**	
Bioclasts/Fauna	*Mollusks*	-	5	-	TR	2	
	Foraminifers	-	-	-	-	-	
	Brachiopod (shell & spines)	TR	-	-	-	5	
	Bryozoa	-	-	-	65	TR	
	Corals	-	-	-	-	45	
	Algal	-	-	-	TR	-	
	Echinoderms/Crinoids	50	70	85	20	25	
	Trilobites	-	TR	-	-	-	
	Ostracodes	-	-	-	-	-	
	Stromatoporoid	40	-	-	-	-	
	Unidentified	2	2	4	1	2	
	Total:	**92**	**77**	**89**	**86**	**79**	
Detrital Grains	*Quartz*	-	-	-	-	-	
	Chert	-	-	-	-	-	
	Heavy Mineral	-	-	-	-	-	
	Total:	**0**	**0**	**0**	**0**	**0**	
Matrix	*Micrite (calcite or dolomite)*	1	8	1	4	6	
	Micro- and pseudospar	-	-	-	-	-	
	Clays & organics	-	TR	TR	1	2	
	Sutured allochems	-	-	-	-	-	
	Total:	**1**	**8**	**1**	**5**	**8**	
Pore Filling Cement	*Calcite Spar*	5	10	10	6	10	
	Calcite druse	-	-	-	3	3	
	Dolomite	TR	-	-	-	-	
	Ferroan Dolomite	-	-	-	TR	-	
	Pyrite	-	-	-	-	-	
	Anhydrite	-	-	-	-	-	
	Total:	**5**	**10**	**10**	**9**	**13**	
Replacement	*Calcite*	-	-	-	-	-	
	Dolomite	-	-	-	-	-	
	Anhydrite	-	-	-	-	-	
	Quartz/Chert	-	-	-	-	-	
	Pyrite	TR	TR	TR	TR	TR	
	Total:	**TR**	**TR**	**TR**	**TR**	**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		fracs	-	**Styl**	**Styl**	**Styl; fracs**	
Ratio Matrix/Clasts (approximate)		1:90	**1:10**	**1:90**	**1:20**	**1:10**	
Original Texture		GS	GS	GS	GS-PS	GS-PS	
Porosity	*Interparticle*	-	-	-	-	-	
	Intraparticle	-	-	-	-	-	
	Intercrystalline	-	-		-	-	
	Fracture	TR	-	-	-	-	
	Micro-Vuggy	-	-	-	-	-	
	Micro- intercrystalline pores	-	**TR**	-	-	**1**	
	Total TS Porosity (%)	**TR**	**TR**	**0**	**0**	**1**	
Petrophysical Results	*Core Porosity (%)*	**0.5**	**0.5**	**0.5**	**0.9**	**1.4**	
	Gas Permeability (mD)	**0.01**	**0.02**	**0.03**	**0.03**	**0.03**	
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

Northwest Territories Geological Survey **Work Order # 20A20313**

Bulk XRD Analysis using Rietveld Method **March, 2020**

Well Name: Imperial Sun Arrowhead Aurora M-47
Well ID: 300/M-47-6040-12230/0
NT WID # N204

Table 1: Results of quantitative mineral analysis (relative weight %) of X-ray diffraction data for 6 (six) samples using Rietveld method

Geology ID	Depth (ft)	Depth (m)	Core & Box #	NTGS Sample Type & #	**Calcite**	**Dolomite**	**Quartz**	**Pyrite**	**Total**
1	7770.00	2368.30	9 & 1 of 12 L	T36, X49, S36, P26	97.0	2.2	0.6	0.2	100.0
2	7775.00	2369.82	9 & 2 of 12 L	T35, X48, S35, P25	96.2	2.6	1.1	0.1	100.0
3	7779.30	2371.13	9 & 3 of 12 L	T34, X47, S34, P24	99.7		0.2	0.1	100.0
4	7784.30	2372.65	9 & 4 of 12 L	T33, X46, S33, P23	99.2	0.5	0.3		100.0
5	7793.10	2375.34	9 & 6 of 12 L	T31, X45, S31, P21	99.1	0.4	0.3	0.2	100.0
6	7803.00	2378.35	9 & 8 of 12 L	T28, X44, S28, P18	99.3	0.5	0.2		100.0

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