Petrographic and Reservoir Quality Analysis of Three Pre Test and Two Post Test McMurray Formation Samples: 06-05-095-06W4 and Two Pre Test McMurray Formation Samples: 102/11-08-095-06W4/00

Suncor Energy

GR 21175 2013; GR 21952 2014

GR Petrology Consultants Inc.
Suite 8, 1323 – 44th Avenue N.E.
Calgary, Alberta T2E 6L5
Tel: 403-291-3420 Fax: 403-250-7212
E-mail: mimi.reichenbach@grpetrology.com

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GR Petrology CONSULTANTS Inc.

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Executive Summary

Thin section analysis indicates the 102/11-08-095-06W4/00 samples are texturally and compositionally similar and classify as:

- Moderate - good reservoir quality, moderately sorted, mid fine grained subarkose: GR-001,
- Excellent reservoir quality, moderately sorted, mid fine grained subarkose: GR-002.

SEM analysis of 06-05-095-06W4 samples GR-001 to GR-003 suggest the 06-05-095-06W4 samples are texturally and compositionally similar to 102/11-08-095-06W4/00 thin section samples GR-001 and GR-002. Measured permeability on cleaned core suggest good reservoir quality for samples GR-001 to GR-004 and excellent reservoir quality for sample GR-005. Similar to the 102/11-08-095-06W4/00 samples, SEM analysis shows 06-05-095-06W4 samples are characterized by dominant intergranular porosity.

Both the 06-05-095-06W4 and 102/11-08-095-06W4 samples suites are considered capable of average good or better oil production.

Depositional processes exert the principal control on reservoir quality in the unconsolidated 06-05-095-06W4 and 102/11-08-095-06W4/00 McMurray Formation sandstones. Diagenetic factors slightly overprint the depositional controls on reservoir quality. Reservoir properties, early in the sandstone paragenesis, were strongly influenced by depositional parameters including mean grain size, the amount of detrital matrix, ductile grains and clasts and the ratio of competent grains (monocrystalline quartz, polycrystalline quartz, chert, feldspar) to less competent clasts. Diagenetic controls, in particular the degree of mechanical compaction and the total amount of emplaced cement, overprint the original depositional controls of reservoir quality. We expect that up to moderate porosity enhancement occurred after dissolution of carbonate cements and unstable lithic grains.

We consider McMurray Formation oil sand intervals, similar to the 06-05-095-06W4 and 102/11-08-095-06W4/00 samples, with permeability in excess of 600.0 mD should be capable of moderate or better commercial oil production; however, we suggest that the operator concentrate on sections with more than 1000 mD permeability. Zones with greater than 2500 mD permeability should be capable of good or better oil production. Zones with less than 400.00 mD permeability may contribute to production if in contact with more permeable zones.

Based on similar texture, composition, grain size, sorting, matrix content, volumes of porosity, porosity types and porosity distribution, we expect similar sensitivity concerns in the oil bearing 06-05-095-06W4 and 102/11-08-095-06W4/00 McMurray Formation intervals:

- Variable slight to moderate potential for permeability reduction related to fines migration.
- Significant potential for HCL acid - oil incompatibility.
- Significant potential for HCl - HF acid - oil incompatibility.
- At least moderate mineral sensitivity to untreated HCL acid and HCl - HF acid.
- Slight potential for clay expansion
- Slight to moderate sensitivity to water based fluids in terms of clay sloughing and migration.
- At least slight potential for scale formation with production of water.
- Slight to moderate potential for thermal conversion of minerals (silica dissolution and reprecipitation, possible formation of smectite and / or conversion of kaolinite to smectite).
- Potential for sand and fines migration and production.
- Slight gamma - log effects (feldspar).

Note: Fines migration tests conducted on native state 06-05-095-06W40 samples resulted in a 63% to 66% permeability reduction (personal communication of Weatherford Results). Moderate - good reservoir quality to excellent reservoir quality samples submitted for this study represent cleaned samples. We observed increased clay content (1.3% to 2.6%) in the Post Test Production Side bulk XRD fraction and local porosity blockage by migrated fines in the Post Test Production Side SEM sample (06-05-095-06W4 sample GR-003).

Introduction

General

This report contains the results of three projects:

GR 21175 2014: 06-05-095-04W4

- GR-001: Pre Test XRD and SEM Analysis; End Trim #4; 289.87 m.
- GR-002: Post Test (Fines Migration) XRD and SEM Analysis; Plug #4 Injection Side; 289.87 m.
- GR-003: Post Test (Fines Migration) XRD and SEM Analysis; Plug #4 Production Side; 289.87 m.
- GR-004: Pre Test XRD Analysis: SP3; 289.73 m.
- GR-005: Pre Test XRD Analysis: SP15; 293.79 m.

GR 21512 2014: 102/11-08-095-06W4/00

- GR-001A: Pre Test XRD Analysis: SP1; 274.25 m.

GR 21952 2014: 102/11-08-095-06W4/00

- GR-001: Pre Test Thin section and XRD Analysis: SP3; 274.47 m.
- GR-002: Pre Test Thin section and XRD Analysis: SP13; 279.34 m.

GR 21175 2014: 06-05-095-06W4

Three unconsolidated McMurray Formation core samples, recovered from the Suncor Firebag 06-05-095-06W4 well, were submitted for Scanning Electron Microscopy (SEM) and for Bulk and Glycolated Clay X-ray Diffraction Analysis (XRD). The sample suite includes Pre Test sample GR-001 (End Trim Plug #4), Fines Migration Post Test Injection Side sample GR-002 (Plug #4) and Fines Migration Post Test Production Side sample GR-003 (Plug #4). Pre Test sample GR-001 was recovered from 289.87 m. The same depth is used for samples GR-002 and GR-003.

In addition, two Pre Test samples GR-004 (SP3) and GR-005 (SP15) were submitted for Bulk and Glycolated Clay X-ray Diffraction Analysis (XRD). Samples GR-004 and GR-005 were respectively recovered from 289.73 m and 293.79 m.

Sample identification, estimated general lithology, estimated range in grain size, core analysis porosity and permeability values measured on equivalent clean core and analyses conducted are provided on Table 1. Tables 4A and 4B respectively present bulk X-ray diffraction (XRD) and glycolated clay XRD results. Plates 1 to 9 provide SEM images for the three samples.

Determination of lithology, mineralogy, matrix content, cement content, mean grain size, grain size ranges, paragenetic sequence and effective porosity is limited by SEM analysis. We recommend comprehensive thin section analysis to best characterize these samples; however, SEM and XRD results will be compared to thin section and XRD results for similar samples recovered from the 102/11-08-095-06W4/00 well.

SEM analysis of Pre Test and Post Test samples provides a general comparison of overall changes that may have occurred during testing and allows assessment of the presence or absence of formed clay minerals or other precipitates, the movement of fines material and potential dissolution or etching of grains, clays and cements.

GR 21952 2014: 102/11-08-095-06W4/00

Two McMurray Formation poorly consolidated to unconsolidated oil sand samples, selected at depths of 274.47 m (SP3) and 279.34 m (SP13) in the 102/11-08-095-06W4/00 well, form the basis of a comprehensive petrographic and reservoir quality assessment.

Reservoir characterization, assessment of reservoir quality and determination of reservoir sensitivity are the principal objectives of the petrographic study.

Objectives

The petrographic and reservoir quality analysis emphasizes:

1. The composition and distribution of rock components.
2. Textural and mineralogical composition versus reservoir quality.
3. Sandstone paragenesis and porosity evolution.
4. Synthesis of mechanisms that control reservoir quality.
5. Reservoir quality assessment.
6. Fluid sensitivity assessment.

Methods of Analysis

GR 21175 2014 samples GR-001 to GR-005, GR 21512 2014 sample GR-001A and GR 21952 2014 samples GR-001 and GR-002 were submitted for bulk and glycolated clay XRD analysis. Diffraction data was acquired using a Phillips XRG-3100 X-ray diffraction System. X-radiation was produced by a long fine focus Cu X-ray tube running at 40kV and 30mA. The Phillips goniometer was equipped with theta-compensation slit optics and a Cu Ka monochromator. The resulting diffraction data was then analyzed using the industry standard MDI Version Jade 2010 software package and the ICDD PDF-4+ powder diffraction database.

A sub-sample from each sample was lightly disaggregated. Two equivalent fractions of the disaggregated sample were selected for bulk analysis and for analysis of the less than 2-micron size fraction.

The fraction selected for bulk analysis was manually ground to a fine powder using an agate mortar and pestle. The resulting powder was carefully packed onto a glass sample holder to present a flat powder pack surface for powder diffraction analysis. Diffraction data on the bulk sample was acquired over a range of angles from 2 to 65 degrees with a step size of 0.05 degrees and a dwell time of 2 seconds/step.

Glycolated clay samples were prepared from a separate fraction of each disaggregated sample. The coarse powders were stirred into approximately 100 ml of distilled water with a small amount of Calgon to reduce surface tension and to aid clay dispersion. The resulting slurries were then stirred for about 2 minutes while immersed in an ultrasound bath. The water with suspended clay was poured into a 100 ml cylinder and allowed to settle for four hours leaving particles less than 2 microns in suspension. The clay suspensions were then siphoned into centrifuge tubes for high-speed centrifugal clay separation. Following centrifugal separation, the remaining water was decanted and the clay slurry was pipetted unto frosted glass slides and allowed to dry. Dried samples were placed in a chamber containing a glycol-saturated atmosphere for 24 hours. Diffraction data on the resulting clay slides was acquired over a range of angles from 2 to 40 degrees with a step size of 0.05 degrees and a dwell time of 2 seconds/step.

Data acquired from the bulk fraction was used to calculate the relative abundance of all rock components. The relative abundance of specific clay minerals within the clay fraction was determined using data obtained from the 2 micron size fraction.

Scanning electron microscopy (SEM) was conducted on GR 21175 2014 samples GR-001 to GR-003. The samples were mounted on aluminum stubs using carbon based, electrically conductive, double sided adhesive tape. These mounts were then sputter coated with gold, in order to dissipate electrostatic charges that would otherwise build up on non-conductive rock samples in the course of SEM examination, and thereby interfere with SEM imaging. SEM examination consisted of a careful evaluation of the samples, and included photo documentation of key features. SEM analysis provides a high magnification view of the pore system and the relationships between porosity, clay minerals, cements, and bitumen.

Thin section analysis was not conducted on any of the samples submitted from the 06-05-095-06W4 well (GR 21175 2014).

GR 21952 2014 samples GR-001 and GR-002 were submitted for comprehensive petrographic analysis that included a 300 point count modal analysis and a grain size analysis based on long-axis measurements of a minimum of 300 grains. Grain size and point count analyses were conducted perpendicular to bedding to avoid counting along clay laminae or measuring along coarse or fine laminae. In general, we note point count analysis of effective porosity in poorly consolidated sandstones tends to be somewhat conservative as oversized pores are typically counted as one pore to avoid over counting porosity in zones with disrupted fabric. We expect that counted effective porosity values, and therefore the calculated volume of intergranular porosity to total porosity, are somewhat low.

Thin section analysis provides compositional and textural information necessary to assess reservoir quality and allows interpretation of paragenesis, porosity evolution, reservoir quality and fluid sensitivity.

We used a custom designed algorithm to calculate mineralogy of samples GR-001 and GR-002 from the modal analysis data (Table 5).

Neither GR 21952 2014 samples were submitted for scanning electron microscopy (SEM).

SEM photomicrographs and descriptions of salient, textural and compositional features for 06-05-095-06W4 samples GR-001 to GR-003 (GR 21175 2014) are included on Plates 01 to 9. Thin section photomicrographs and descriptions of salient, textural and compositional features for 102/11-08-095-06W4/00 samples GR-001 and GR-002 (GR 21952 2014) are included on Plates 10 to 13.

Highlighted features are in red on the Plate Descriptions. Depending on which color is most easily visible, highlighted features are in either red or yellow on the petrographic Plates.

Documentation

The following tables document the SEM and XRD report:

- Table 1: Petrographic Sample Summary: GR 21175 2014 & GR 21952 2014.
- Table 2: Point Count Data and Lithologic Summary: GR 21952 2014.
- Table 3: Grain Size Data: GR 21952 2014.
- Table 4A: Bulk Fraction X-Ray Diffraction Data: GR 21175 2014, GR 21512 2014 & GR 21952 2014.
- Table 4B: Glycolated Clay Fraction X-Ray Diffraction Data: GR 21175 2014, GR 21512 2014 & GR 21952 2014.
- Table 5: Mineralogy Calculated from Thin Section Modal Analysis: GR 21952 2014.
- Table 6: Reservoir Quality Summary: GR 21952 2014.
- Figure 1: Ternary Sandstone Classification Diagram (QFR): GR 21952 2014.
- Figure 2: Ternary Porosity Distribution Diagram: GR 21952 2014.
- Figure H1: Grain Size Distribution Histograms: GR 21952 2014.
- X-ray Diffractograms.
- Plates 01 to 9: SEM photomicrographs and descriptions of salient sandstone features: GR 21175 2014.
- Plates 10 to 13: Thin Section Photomicrographs and Descriptions of salient sandstone features: GR 21952 2014.

COMPANY: Suncor Energy
WELLS: 06-05-095-06W4 & 102/11-08-095-06W4/00

FILES: GR 21175 & 21952 2014
FORMATION: McMurray

TABLE 1
PETROGRAPHIC SAMPLE SUMMARY

												Types of Analyses			
Sample #	**Sample ID**	**Well**	**Depth (m)**	**Sample Type**	**Lithology**	**Grain Size Range or Mean Grain Size (mm)**	**Sorting**	**GSPI**	**Total Por. (%)**	**Perm. (mD)**	**TS Por. (%)**	**TS**	**XRD**	**SEM**	**GS**
GR-001	Pre Test End Trim #4	06-05-095-06W4	289.87	OSC	Quartz Rich Sdst	Cs silt - cs sand	Moderate - Poor	n/a	29.9	5602	n/a		✓	✓	
GR-002	Post Test Plug #4 Injection Side	06-05-095-06W4	289.87	OSC	Quartz Rich Sdst	Cs silt - cs sand	Moderate - Poor	n/a	29.9	5602	n/a		✓	✓	
GR-003	Post Test Plug #4 Production Side	06-05-095-06W4	289.87	OSC	Quartz Rich Sdst	Cs silt - cs sand	Moderate - Poor	n/a	29.9	5602	n/a		✓	✓	
GR-004	SP3 (6-5) Pre Test	06-05-095-06W4	289.73	OSC	n/a	n/a	n/a	n/a	29.4	5600	n/a		✓		
GR-005	SP15 (6-5) Pre Test	06-05-095-06W4	293.79	OSC	n/a	n/a	n/a	n/a	34.0	8000	n/a		✓		
GR-001A	SP1 (102/11-08)	102/11-08-095-06W4/00	274.25	OSC	n/a	n/a	n/a	n/a	31.7	2078	n/a		✓		
GR-001	SP3 (102/11-08)	102/11-08-095-06W4/00	274.47	OSC	Subarkose	0.202 (m fine sand)	Moderate	5.353	32.8	1829	26.5	✓	✓		✓
GR-002	SP13 (102/11-08)	102/11-08-095-06W4/00	279.34	OSC	Subarkose	0.192 (m fine sand)	Moderate	5.889	35.9	6799	30.2	✓	✓		✓

TS - Thin Section Analysis	Sdst - Sandstone	GS - Grain Size	CS - Coarse	m-mid
XRD - X-ray Diffraction Analysis		* - estimated value		l - lower
SEM - Scanning Electron Microscopy		OSC - Oil Sand Core		u - upper

Note: Permeabilities represent air peremability measurements on cleaned core plugs or cleaned adjacent core plugs.

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FILE: GR 21952 2014
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TABLE 2
POINT COUNT DATA AND LITHOLOGIC SUMMARY

Sample #	Modal Analysis (%) - Porosity not included in 100% grain counts																															
	Total Por.	Siliciclastic and Carbonate Framework Grains											Other Framework Grains						Matrix	Authigenic Minerals											Porosity	
																				Clay		Cements									INT	MOL
	%	MQ	PQ	CT	FD	CRF	PRF	VRF	QRF	MRF	CBR	DD	GL	MI	PH	CD	HM	HC	MA	CR	KA	AQ	CA	FCA	DO	FDO	SD	PY	BA	PR	%	%
GR-001	26.5	74.0	1.0	1.7	4.0	tr	0.3	-	-	-	-	-	-	1.4	-	5.0	0.7	-	7.8	0.7	0.7	1.0	-	-	-	-	-	1.7	-	-	26.5	tr
GR-002	30.2	85.8	1.7	4.0	5.0	-	0.3	0.3	-	-	-	-	-	1.0	-	tr	0.3	-	tr	0.3	-	1.0	-	-	-	-	-	0.3	-	-	30.2	tr

MQ - MONOCRYSTALLINE QUARTZ
PQ - POLYCRYSTALLINE QUARTZ
CT - CHERT
FD - FELDSPAR
CRF - CLAY RICH ROCK FRAGMENT
PRF - PLUTONIC ROCK FRAGMENT
QRF - QUARTZOSE SEDIMENTARY R F
VRF - VOLCANIC ROCK FRAGMENTS
CBR - CARBONATE ROCK FRAGMENTS
DD - DETRITAL DOLOMITE
MRF - METAMORPHIC ROCK FRAGMENT

FOS - FOSSIL FRAGMENTS
GL - GLAUCONITE
MI - MICA
PH - PHOSPHATE
CD - PLANT DEBRIS
HM - HEAVY MINERALS
HC - BITUMEN
MA - MATRIX
CR - CLAY RIMS
KA - KAOLINITE
AQ - QUARTZ OVERGROWTHS

FD0 - FERROAN DOLOMITE
FCA - FERROAN CALCITE
SD - SIDERITE
PY - PYRITE
BA - BARITE
OTH - OTHER
tr - trace
INT - INTERGRANULAR
MOL - GRAIN MOLDIC
SLT - Slot
FR - Fracture

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FILE: GR 21952 2014
FORMATION: McMurray

TABLE 3
GRAIN SIZE DATA

GR Sample #	Depth (m)	Maximum (mm)	Quartile 3 (mm)	Mean (mm)	Median (mm)	Quartile 1 (mm)	Minimum (mm)	Standard Deviation
GR-001	274.47	0.471	0.254	0.206	0.202	0.145	0.059	0.075
GR-002	279.34	0.576	0.222	0.192	0.178	0.146	0.071	0.078

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WELLS: 06-05-095-06W4 &102/11-08-095-06W4/00

GR FILE #: GR 21175 2014 & GR 21953 2014
FORMATION: McMurray

TABLE 4A
BULK FRACTION X-RAY DIFFRACTION DATA

GR Sample #	Plug ID	Depth (m)	Qtz	KFd	Plag	Sid	Pyr	CaMg	Cal	Ank	Ana	Kaol	Ill	Chl	M-L	Smec	Total Clay
GR-001	Pre Test End Trim #4	289.87	95.4	1.5	0.5	0.3	0.4	-	0.3	0.3	-	0.9	0.4	trace	-	present	1.3
GR-002	Post Test Plug #4 Injection Side	289.87	95.9	1.3	0.6	0.3	0.2	-	0.2	0.2	-	0.9	0.4	trace	-	present	1.3
GR-003	Post Test Plug #4 Production Side	289.87	94.6	1.0	0.6	0.3	0.6	-	-	0.3	-	1.7	0.9	trace	-	present	2.6
GR-004	SP3 (6-5)	289.73	96.8	1.0	0.2	trace	0.2	-	0.2	trace	-	0.9	0.7	trace	-	present	1.6
GR-005	SP15 (6-5)	293.79	96.5	1.2	0.2	0.2	0.2	-	0.2	0.2	-	0.9	0.4	trace	-	present	1.3
GR-001A	SP1	274.25	94.0	4.0	0.3	-	0.4	-	-	-	-	0.9	0.4	trace	-	present	1.3
GR-001	SP3	274.47	95.7	0.5	0.3	0.2	0.4	0.2	-	0.2	0.3	1.3	0.9	trace	-	-	2.2
GR-002	SP13	279.34	95.9	1.1	0.3	-	0.6	0.2	-	0.2	-	1.3	0.4	trace	-	present	1.7

Qtz - Quartz - SiO_2
KFd - Potassium Feldspar - $KAlSi_3O_8$
Plag - Sodium Feldspar - $NaAlSi_3O_8$
Sid - Siderite - $FeCO_3$
Pyr - Pyrite - FeS_2
CaMg - Calcite, magnesian - $(Ca,Mg)CO_3$
Ank - Ankerite - $Ca(Fe,Mg)(CO_3)_2$
Ana - Anatase - TiO_2
Kaol - Kaolinite - $Al_2Si_2O_5(OH)_4$
Ill - Illite - $(K,H_3O)Al_2Si_3AlO_{10}(OH)_2$
Cal - Calcite - CaCO3
Chl - Chlorite - (Mg,Fe,Al)6(Si,Al)4O10(OH)8
M-L - Mixed Layer
Smec - Smectite - Na0.3Mg3(Si,Al)4O10(OH)2·6H2O
Total Clay - Kaol+Ill+Chl+M-L+Smec

All units are in percent unless otherwise noted.

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FORMATION: McMurray

TABLE 4B
LESSTHAN 2 MICRON GLYCOLATED CLAY FRACTION X-RAY DIFFRACTION DATA

GR Sample #	Plug ID	Depth (m)	Total clay in Bulk Sample	Total Smectite in Bulk Sample	Kaolinite	Illite	Chlorite	Mixed Layer	Smectite
GR-001	Pre Test End Trim #4	289.87	1.3	0.15	65.0	19.1	4.2	-	11.7
GR-002	Post Test Plug #4 Injection Side	289.87	1.3	0.06	58.5	26.2	10.9	-	4.4
GR-003	Post Test Plug #4 Production Side	289.87	2.6	0.05	71.6	22.8	3.8	-	1.8
GR-004	SP3 (6-5)	289.73	1.6	0.48	34.9	26.2	9.2	-	29.7
GR-005	SP15 (6-5)	293.79	1.3	0.15	56.7	19.5	12.2	-	11.6
GR-001A	SP1	274.25	1.3	0.02	72.5	21.7	4.1	-	1.7
GR-001	SP3	274.47	2.2	-	59.9	33.9	6.2	-	-
GR-002	SP13	279.34	1.7	0.04	79.1	14.1	4.3	-	2.5

All units are in percent unless otherwise noted.

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WELL:	102/11-08-095-06W4/00	**FORMATION:**	McMurray

TABLE 5
Mineralogy Calculated from Thin Section Modal Analysis

GR Sample #	Quartz (%)	Feldspar (%)	Dolomite (%)	Calcite (%)	Siderite (%)	Pyrite (%)	Clay (%)	Glauc (%)	Phos (%)	CD (%)	HM (%)	Grain Density Calculated (kg/m3)
GR-001	78.6	4.2	-	-	-	1.7	9.9	-	-	5.0	0.7	2663
GR-002	92.5	5.4	-	-	-	0.3	1.5	-	-	-	0.3	2661

Glauc (%) - Glauconite
Phos (%) - Phosphate
CD (%) - Carbonaceous Detritus
HM (%) - Heavy Minerals
tr - trace

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COMPANY:	Suncor Energy	FILE:	GR 21952 2014
WELL:	102/11-08-095-06W4/00	FORMATION:	McMurray

TABLE 6
RESERVOIR QUALITY SUMMARY

WELL	Spls (#)	CA Total Por (%) Avg.	Perm. (md) Avg.	TS Por. (%) Avg.	Int. Por. (%) Avg.	Mean Gr. Size (mm) Avg.	GSPI	Mtx (%) Avg.	Mtx & Pmtx (%) Avg.	Total Cmt. (%) Avg.	% Por. Infilled By Cmt. (%) Avg.	% Por. Infilled Qtz Cmt (%) Avg.	% Por. Infilled Pyr. (%) Avg.	Int Por. as % Tot Por. (%) avg.	Mpor. as % Tot Por. (%) avg.	RQA (oil bearing) Avg.
102/11-08-095-06W4/00	2	34.4	4314.00	28.4	28.4	0.199	5.621	3.9	7.8	2.9	9.2	3.2	3.3	82.4	17.6	Good

Por. - Porosity	TS - Thin Section	Cmt - Cement	Pyr. - Pyrite
Est. - Estimated	Int - Intergranular	Qtz - Quartz	Pmtx - Pseudomatrix
Avg. - Average	Gr - Grain	Sid - Siderite	Mtx - Matrix
Perm. - Permeability	GSPI - Grain Size Porosity Index	Mpor - Microporosity	RQA - Reservoir Quality Assessment

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Ternary Classification Diagram

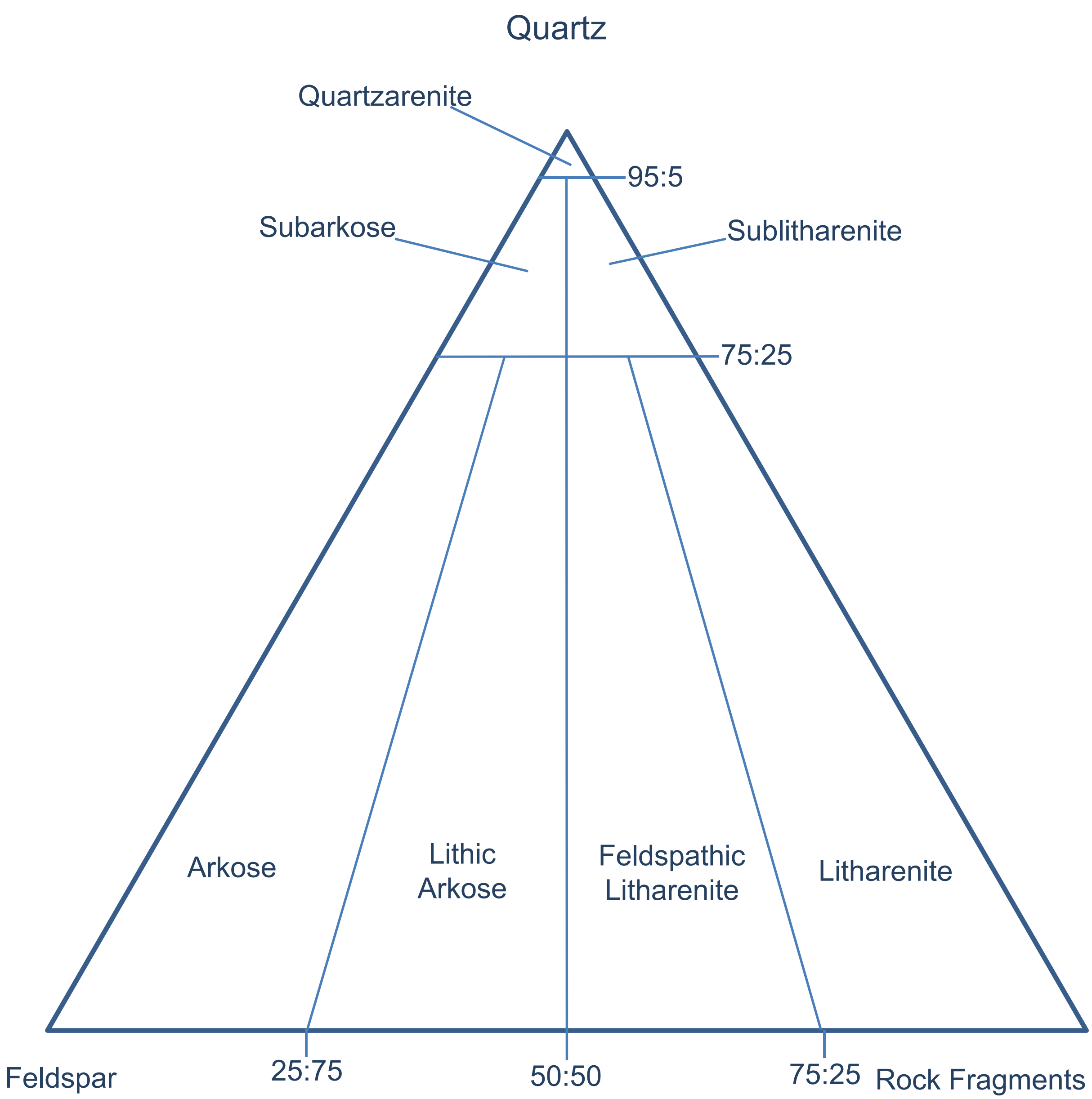

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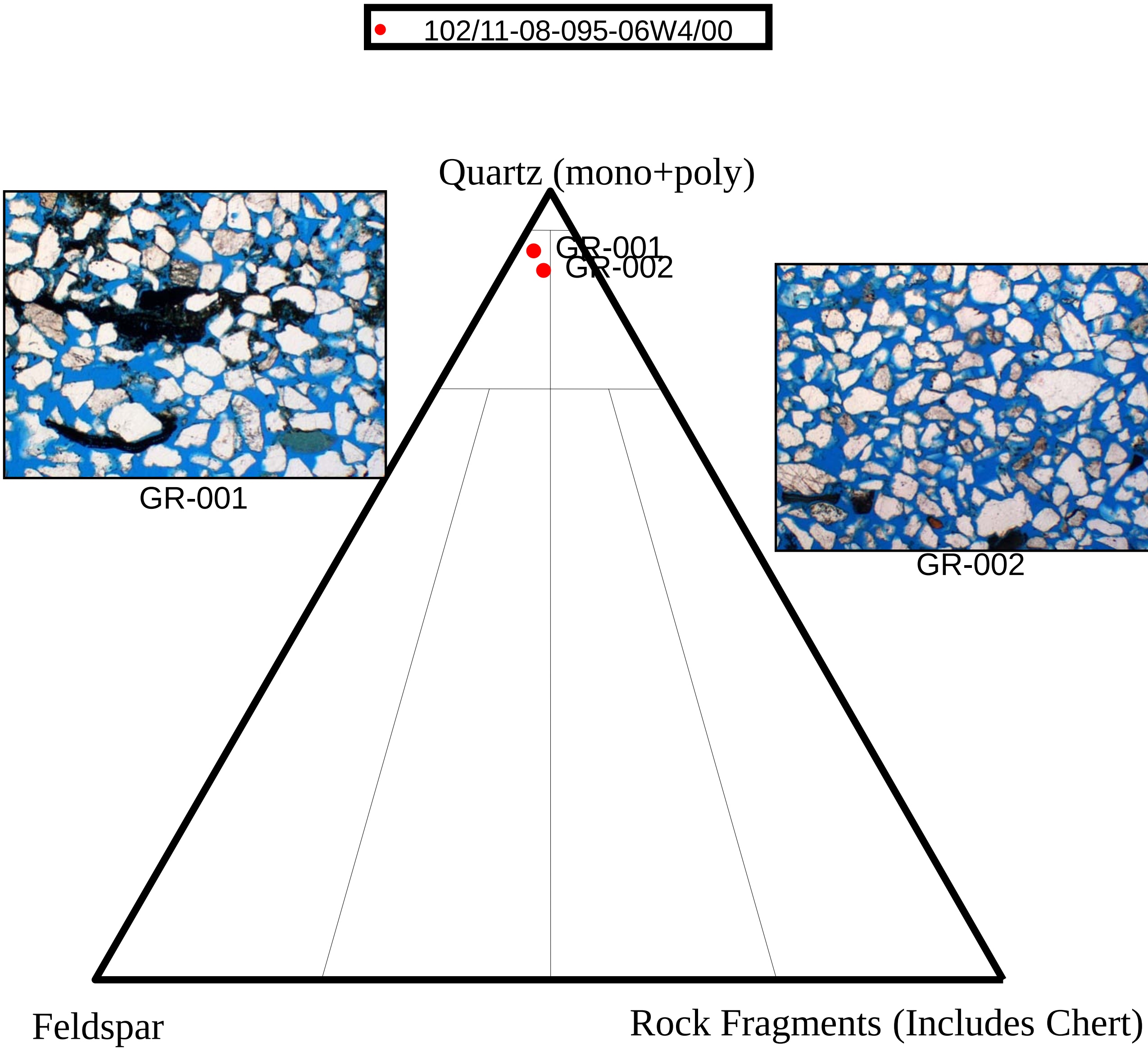
Figure 1
Ternary Classification Diagram (Q, F, R)
McMurray Formation



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Porosity Relationships

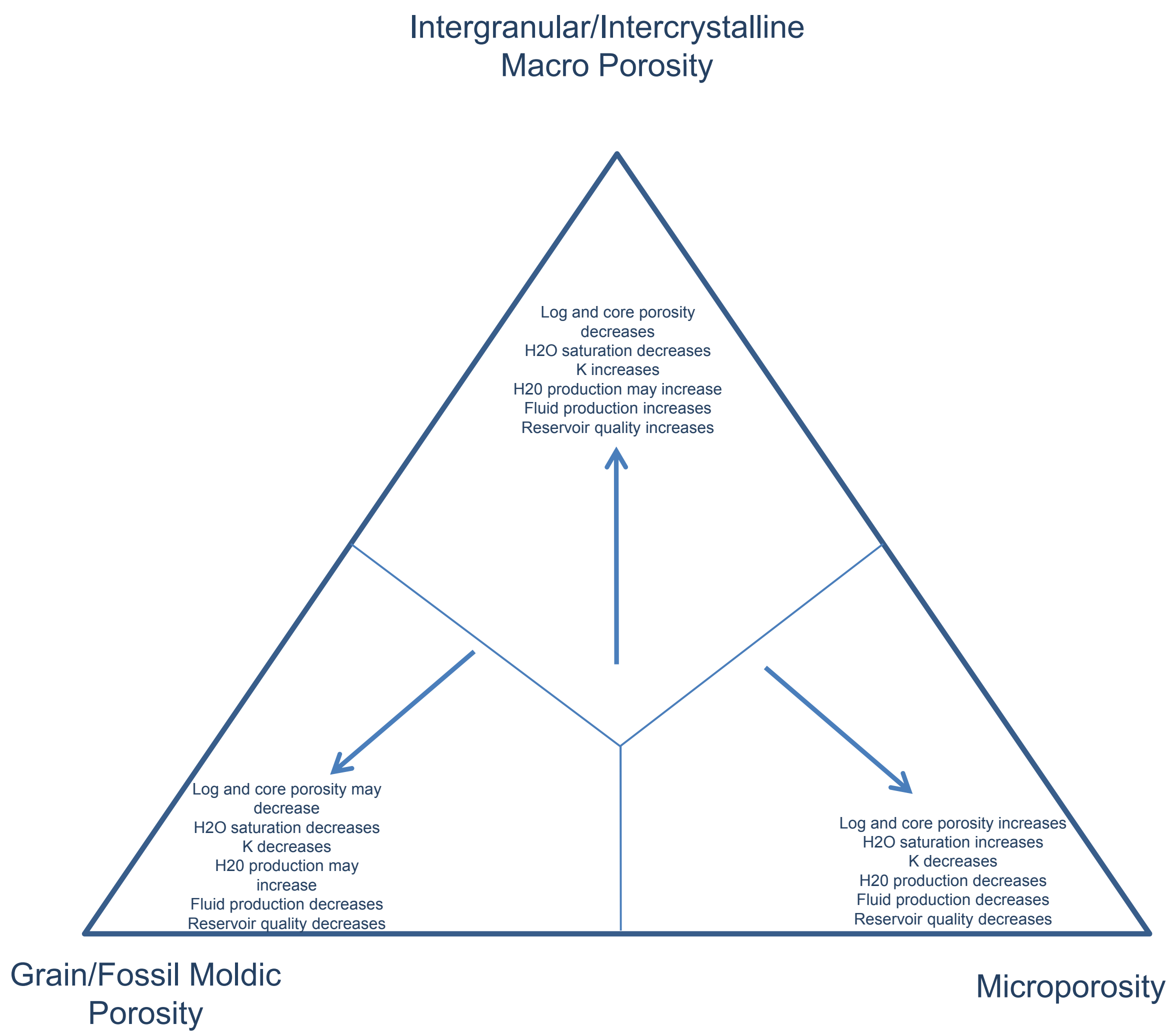

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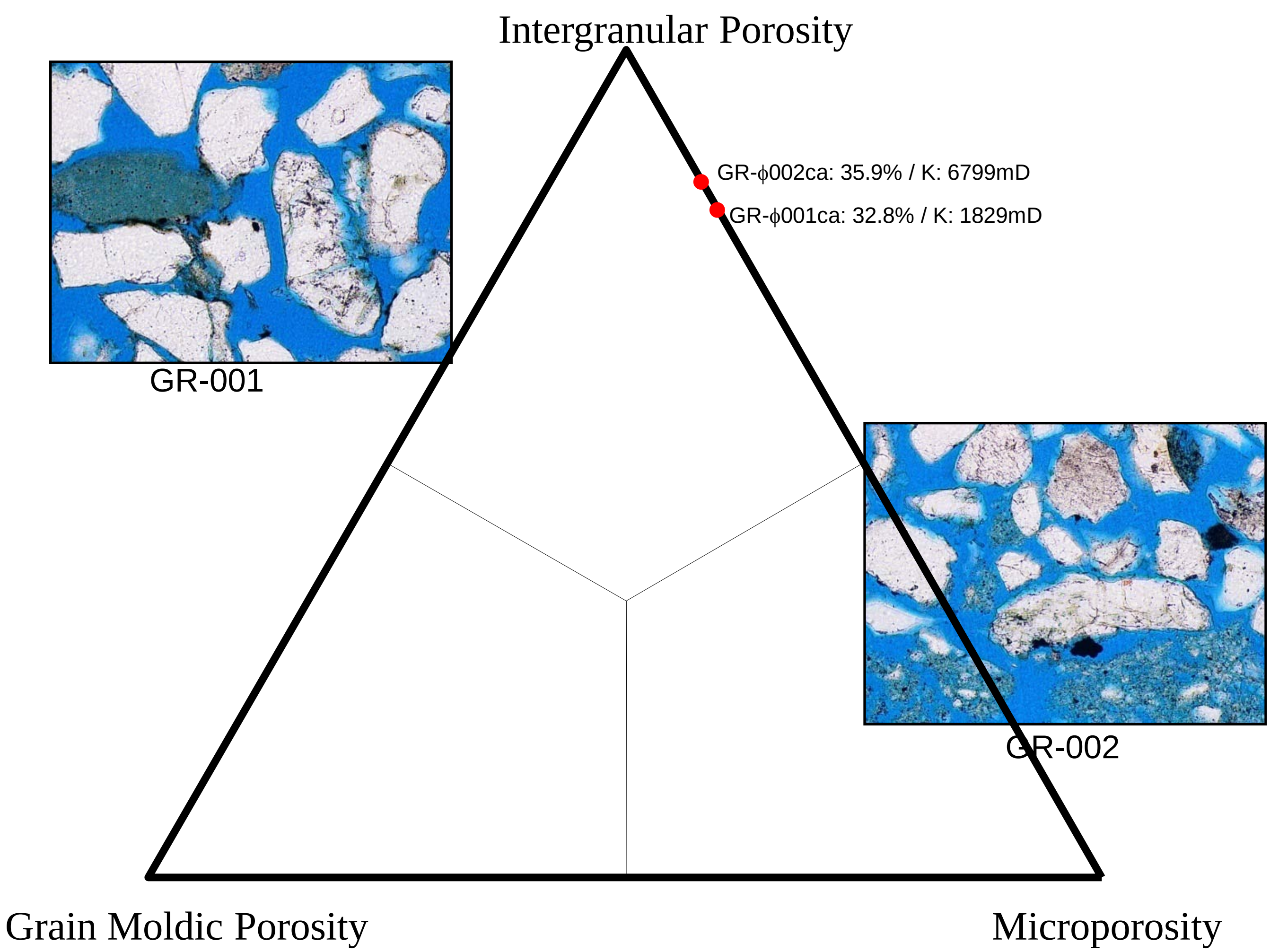
Figure 2
Porosity Sandstone Classification Diagram
McMurray Formation

• 102/11-08-095-06W4/00



ϕca : Total Analysis Porosity
K : Permeability

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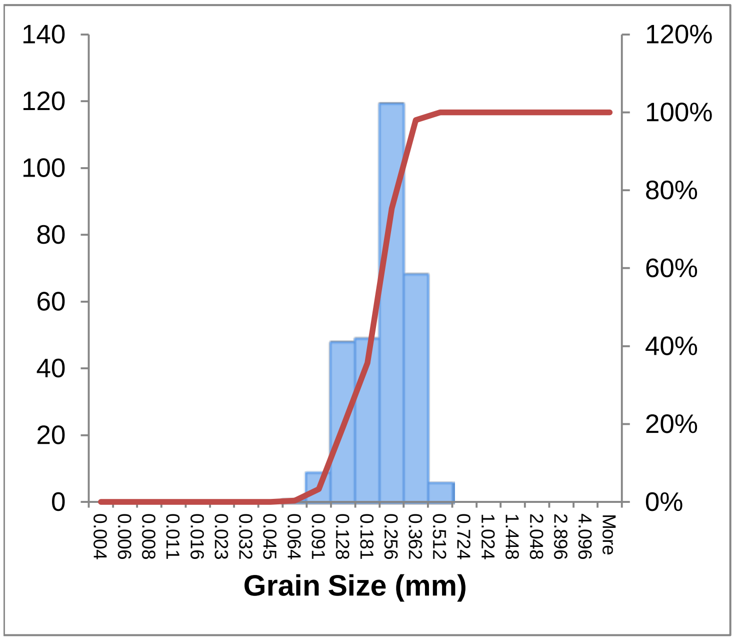
FIGURE H1: GRAIN SIZE HISTOGRAMS
McMurray Formation

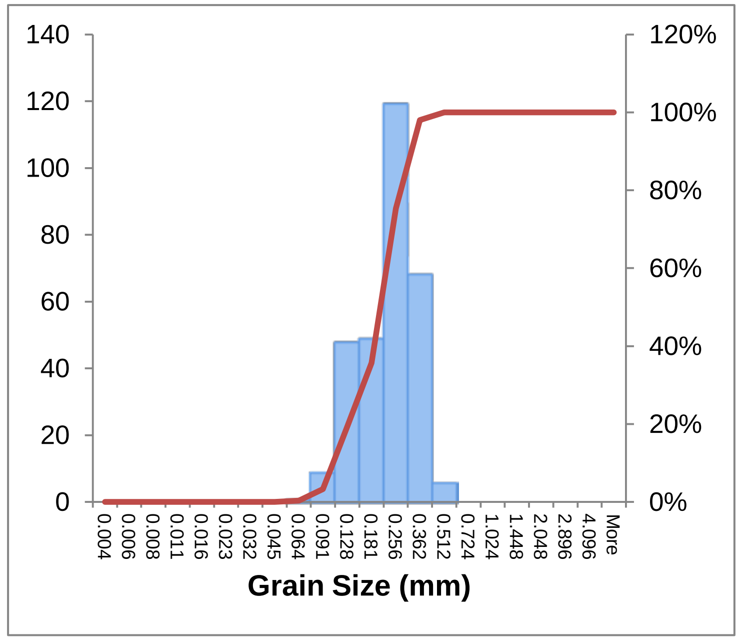
A

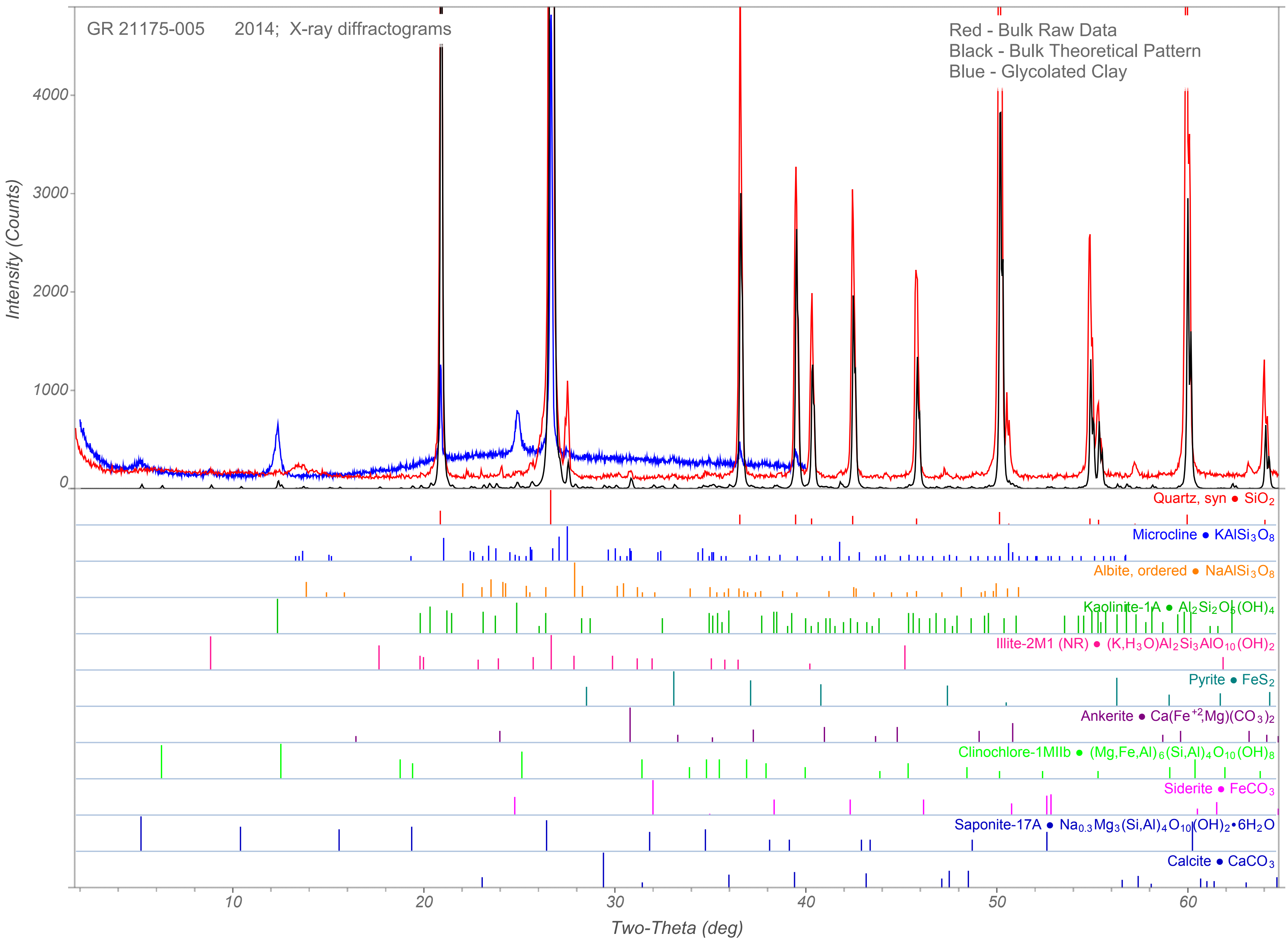
GR-001: 102/11-08-095-06W4/00



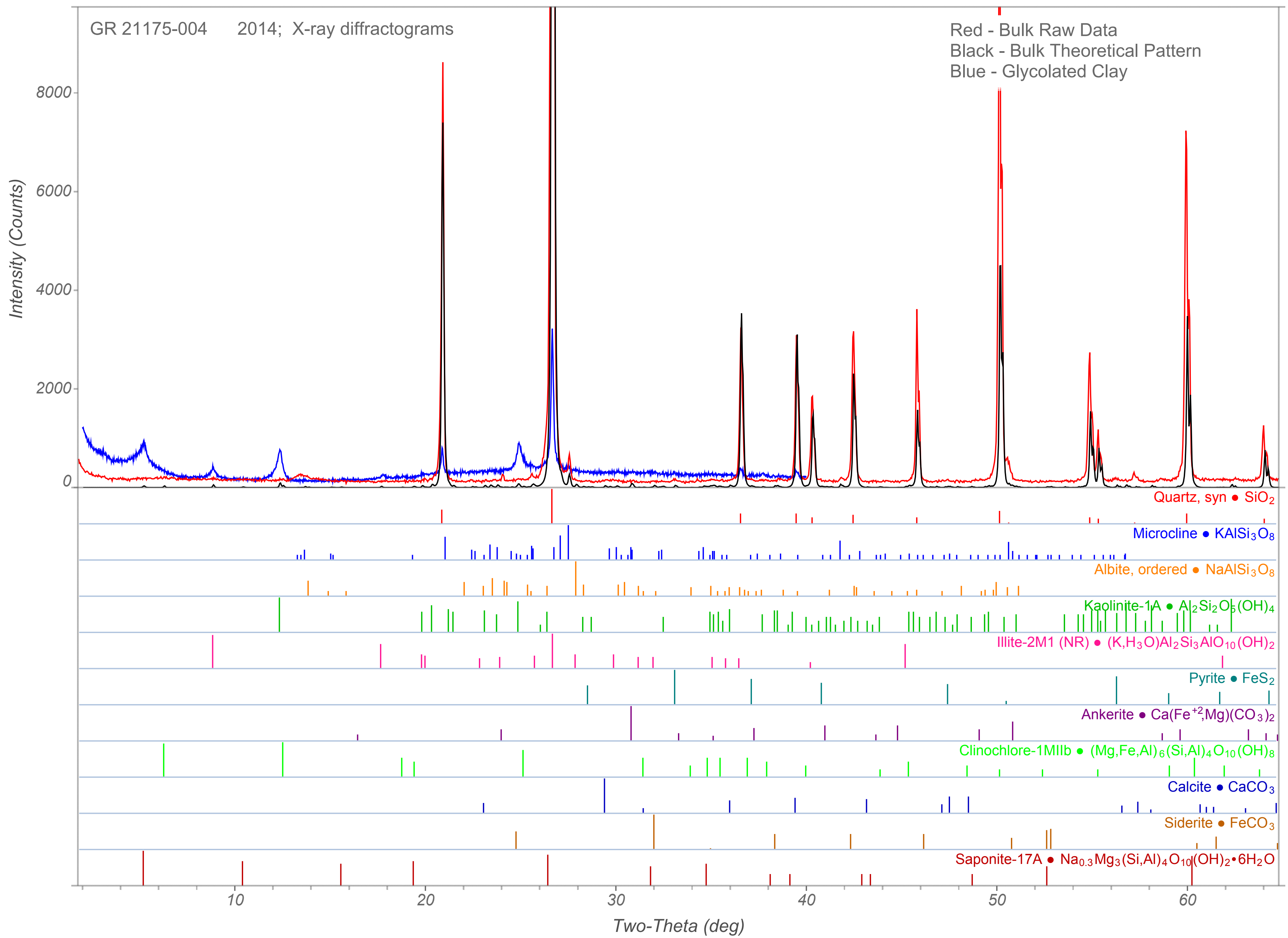
B

GR-002: 102/11-08-095-06W4/00

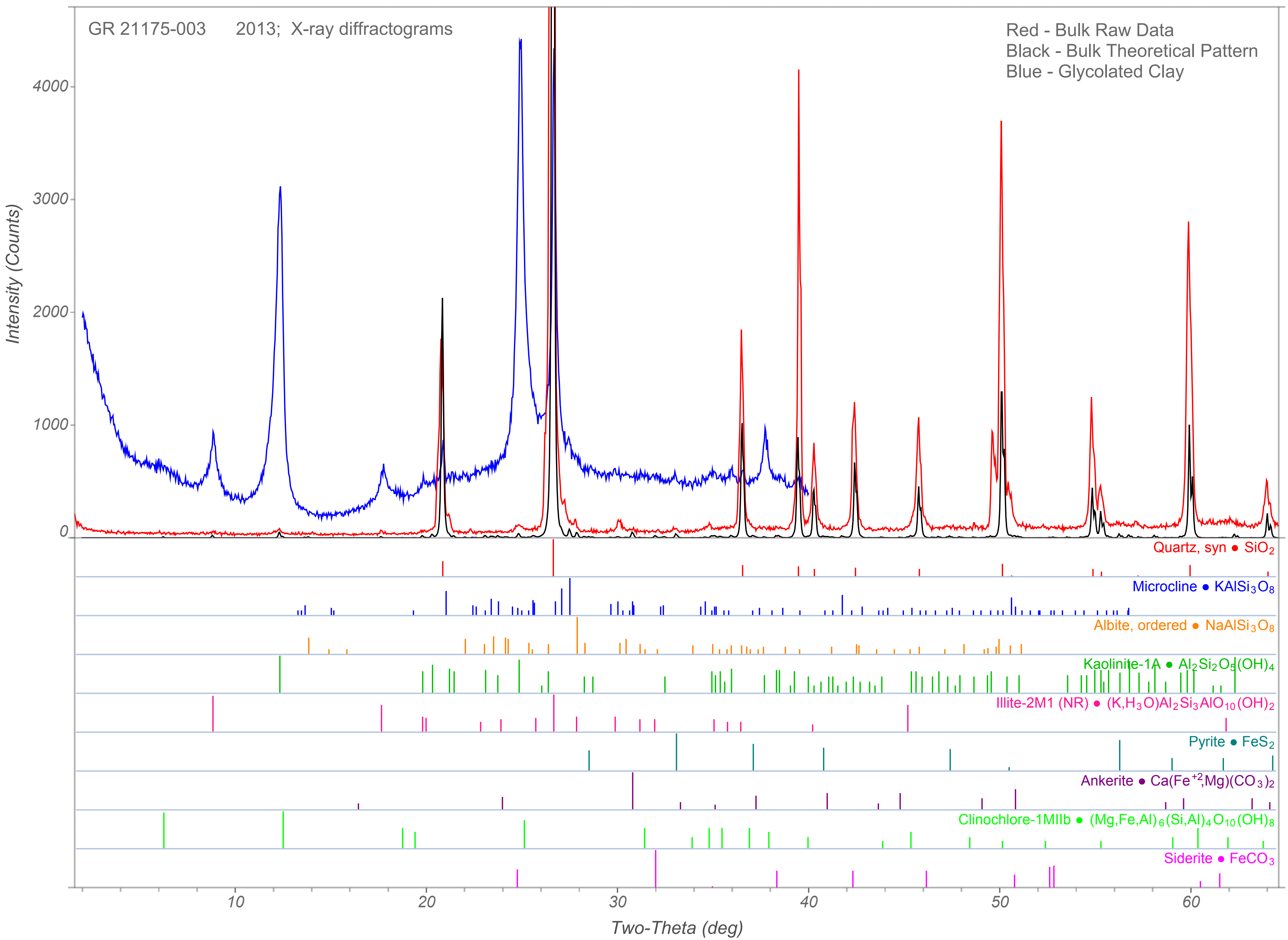


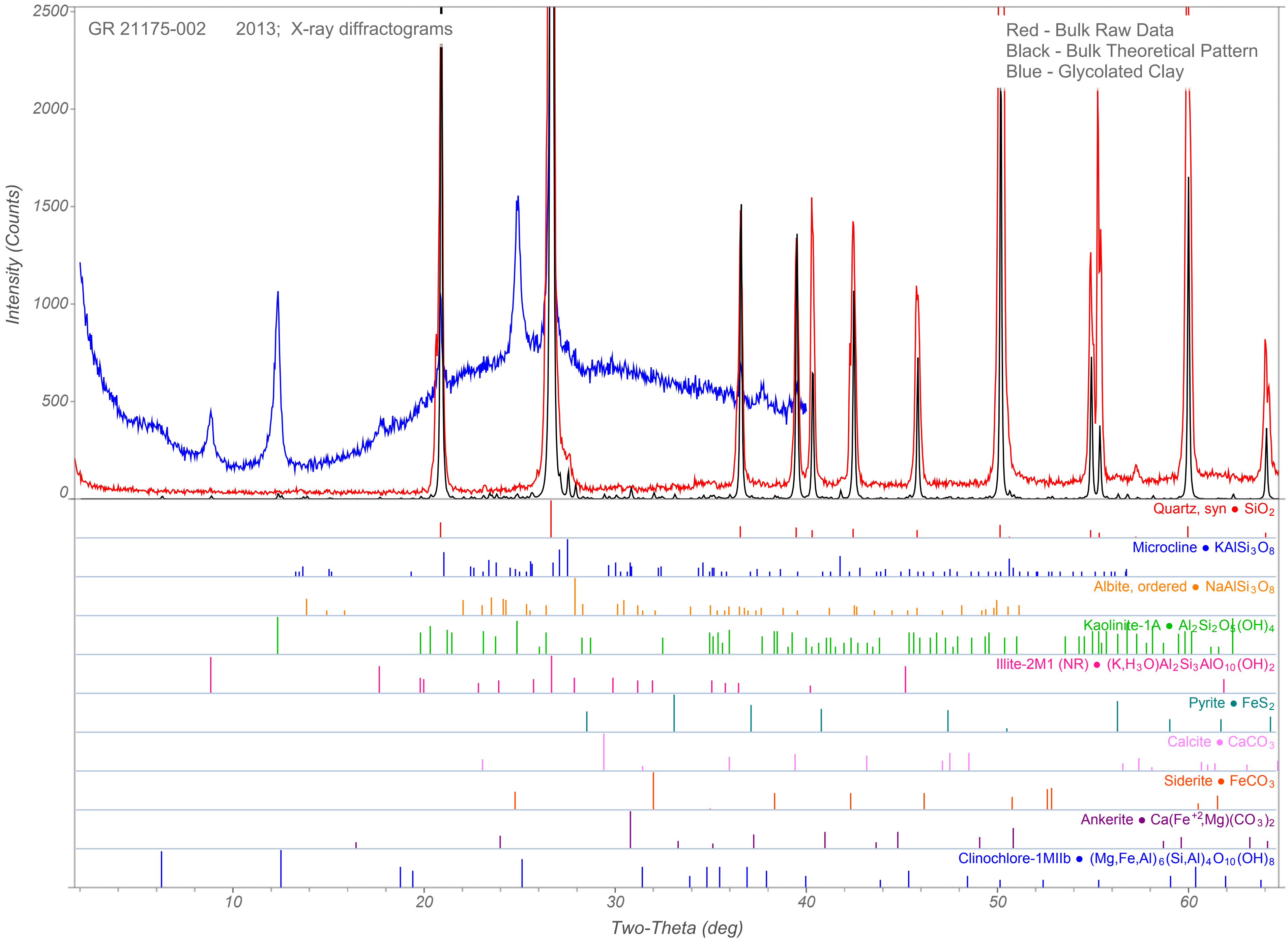


GR 21175-005 2014; X-ray diffractograms
Red - Bulk Raw Data
Black - Bulk Theoretical Pattern
Blue - Glycolated Clay
Intensity (Counts)
0
1000
2000
3000
4000
Quartz, syn • SiO_2
Microcline • $KAlSi_3O_8$
Albite, ordered • $NaAlSi_3O_8$
Kaolinite-1A • $Al_2Si_2O_5(OH)_4$
Illite-2M1 (NR) • $(K,H_3O)Al_2Si_3AlO_{10}(OH)_2$
Pyrite • FeS_2
Ankerite • $Ca(Fe^{+2},Mg)(CO_3)_2$
Clinochlore-1MIIb • $(Mg,Fe,Al)_6(Si,Al)_4O_{10}(OH)_8$
Siderite • $FeCO_3$
Saponite-17A • $Na_{0.3}Mg_3(Si,Al)_4O_{10}(OH)_2•6H_2O$
Calcite • $CaCO_3$
10
20
30
40
50
60
Two-Theta (deg)

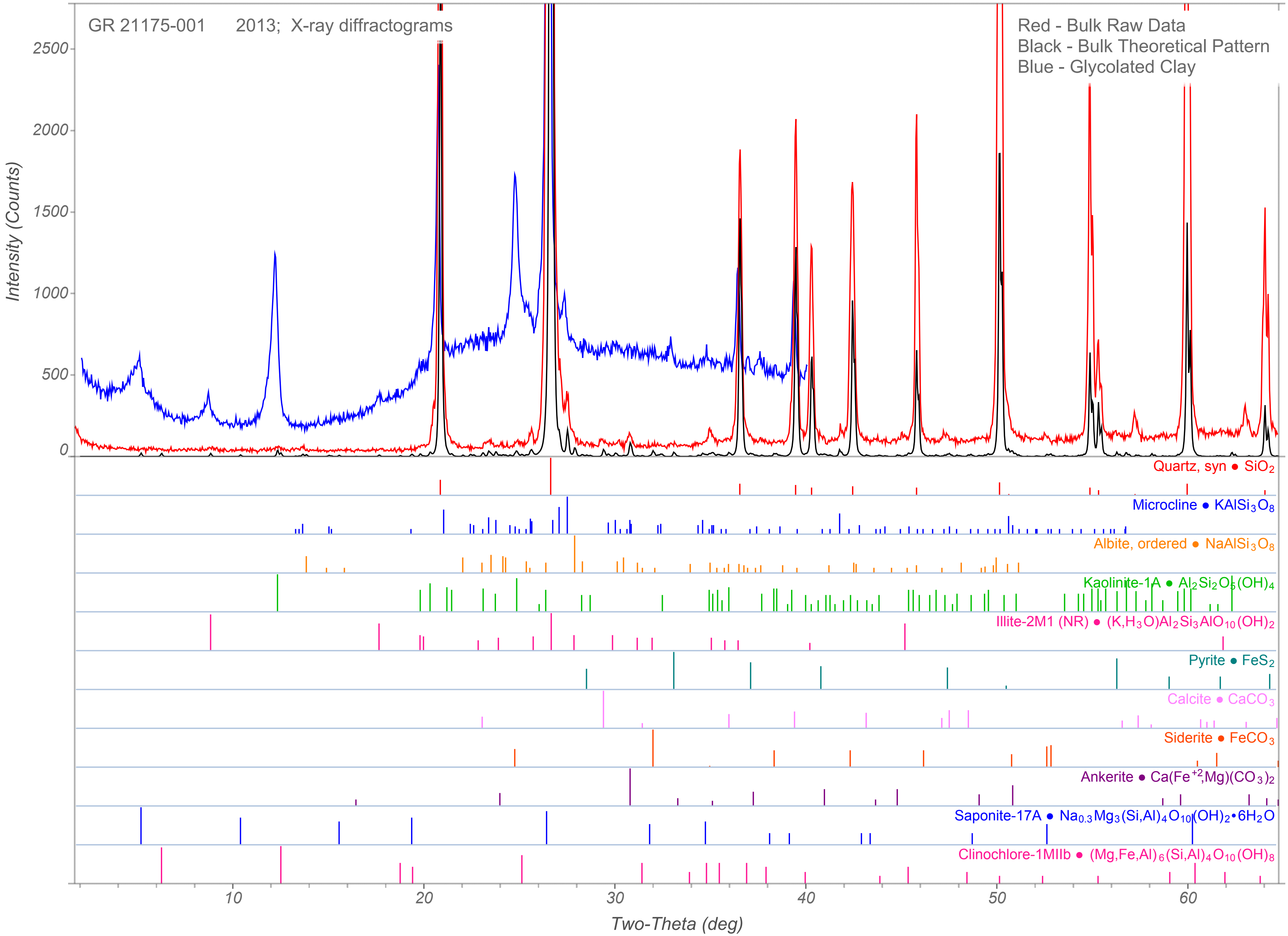


GR 21175-004 2014; X-ray diffractograms
Red - Bulk Raw Data
Black - Bulk Theoretical Pattern
Blue - Glycolated Clay
Intensity (Counts)
8000
6000
4000
2000
0
Quartz, syn • SiO_2
Microcline • $KAlSi_3O_8$
Albite, ordered • $NaAlSi_3O_8$
Kaolinite-1A • $Al_2Si_2O_5(OH)_4$
Illite-2M1 (NR) • $(K,H_3O)Al_2Si_3AlO_{10}(OH)_2$
Pyrite • FeS_2
Ankerite • $Ca(Fe^{+2},Mg)(CO_3)_2$
Clinochlore-1MIIb • $(Mg,Fe,Al)_6(Si,Al)_4O_{10}(OH)_8$
Calcite • $CaCO_3$
Siderite • $FeCO_3$
Saponite-17A • $Na_{0.3}Mg_3(Si,Al)_4O_{10}(OH)_2 \cdot 6H_2O$
10
20
30
40
50
60
Two-Theta (deg)

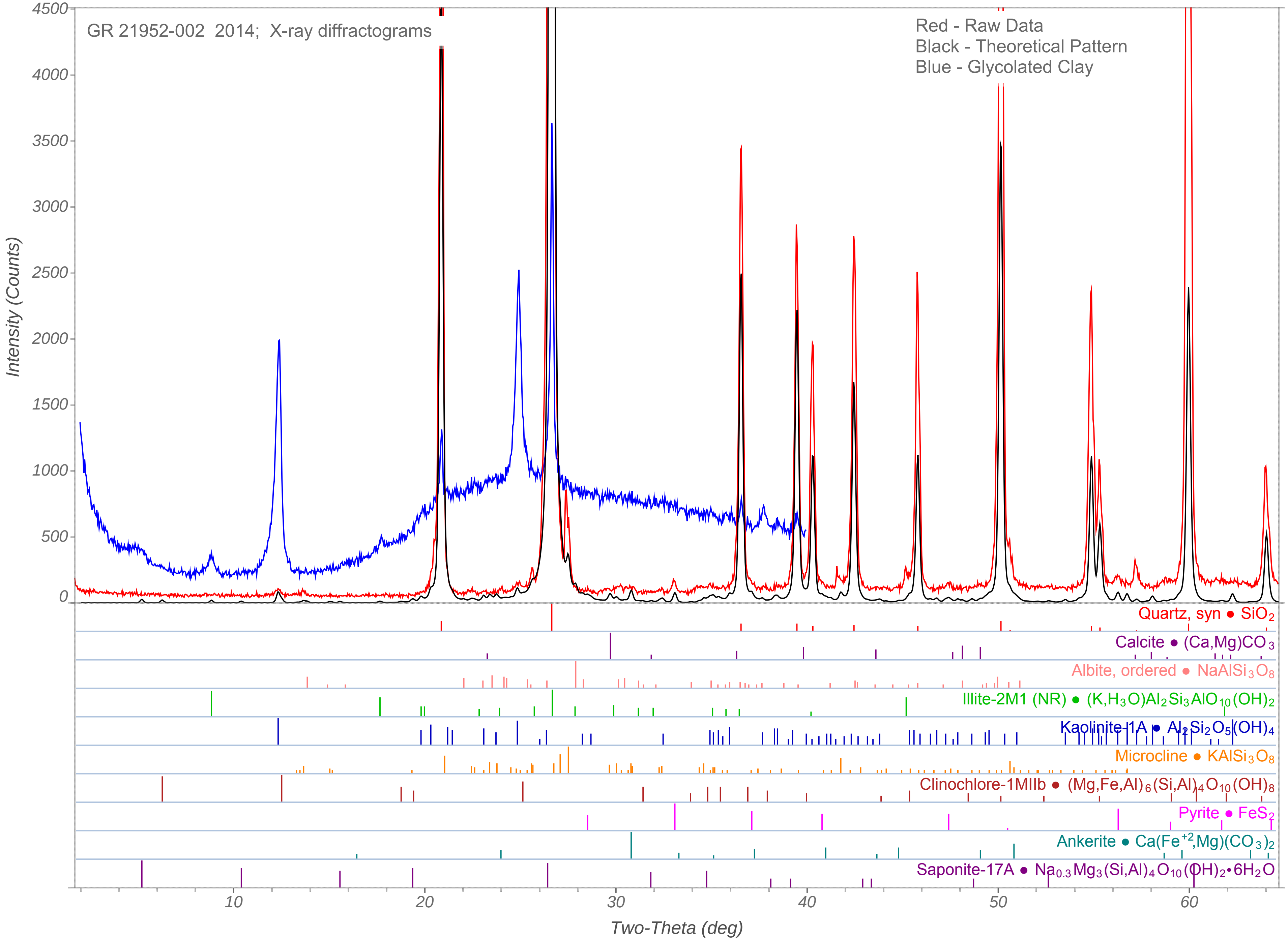

GR 21175-003 2013; X-ray diffractograms
Red - Bulk Raw Data
Black - Bulk Theoretical Pattern
Blue - Glycolated Clay
Intensity (Counts)
4000
3000
2000
1000
0
Quartz, syn ● SiO_2
Microcline ● $KAlSi_3O_8$
Albite, ordered ● $NaAlSi_3O_8$
Kaolinite-1A ● $Al_2Si_2O_5(OH)_4$
Illite-2M1 (NR) ● $(K,H_3O)Al_2Si_3AlO_{10}(OH)_2$
Pyrite ● FeS_2
Ankerite ● $Ca(Fe^{+2},Mg)(CO_3)_2$
Clinochlore-1MIIb ● $(Mg,Fe,Al)_6(Si,Al)_4O_{10}(OH)_8$
Siderite ● $FeCO_3$
10
20
30
40
50
60
Two-Theta (deg)

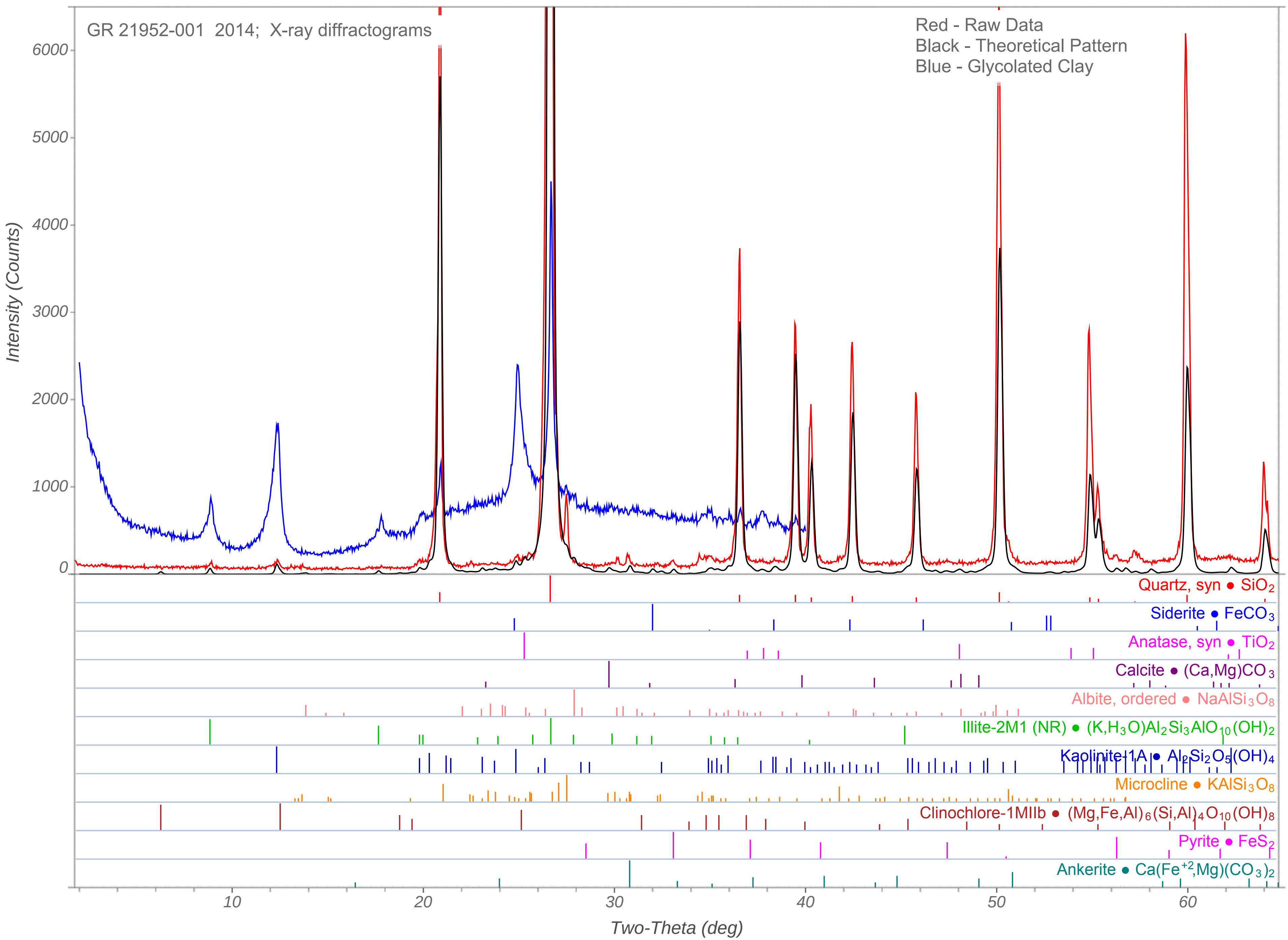


GR 21175-002 2013; X-ray diffractograms
Red - Bulk Raw Data
Black - Bulk Theoretical Pattern
Blue - Glycolated Clay
Intensity (Counts)
Two-Theta (deg)
Quartz, syn • SiO_2
Microcline • $KAlSi_3O_8$
Albite, ordered • $NaAlSi_3O_8$
Kaolinite-1A • $Al_2Si_2O_5(OH)_4$
Illite-2M1 (NR) • $(K,H_3O)Al_2Si_3AlO_{10}(OH)_2$
Pyrite • FeS_2
Calcite • $CaCO_3$
Siderite • $FeCO_3$
Ankerite • $Ca(Fe^{+2},Mg)(CO_3)_2$
Clinochlore-1MIIb • $(Mg,Fe,Al)_6(Si,Al)_4O_{10}(OH)_8$



GR 21175-001 2013; X-ray diffractograms
Red - Bulk Raw Data
Black - Bulk Theoretical Pattern
Blue - Glycolated Clay
Intensity (Counts)
2500
2000
1500
1000
500
0
Quartz, syn • SiO2
Microcline • KAlSi3O8
Albite, ordered • NaAlSi3O8
Kaolinite-1A • Al2Si2O5(OH)4
Illite-2M1 (NR) • (K,H3O)Al2Si3AlO10(OH)2
Pyrite • FeS2
Calcite • CaCO3
Siderite • FeCO3
Ankerite • Ca(Fe+2,Mg)(CO3)2
Saponite-17A • Na0.3Mg3(Si,Al)4O10(OH)2•6H2O
Clinochlore-1MIIb • (Mg,Fe,Al)6(Si,Al)4O10(OH)8
10
20
30
40
50
60
Two-Theta (deg)


GR 21952-002 2014; X-ray diffractograms
Red - Raw Data
Black - Theoretical Pattern
Blue - Glycolated Clay
Intensity (Counts)
Two-Theta (deg)
Quartz, syn • SiO_2
Calcite • $(Ca,Mg)CO_3$
Albite, ordered • $NaAlSi_3O_8$
Illite-2M1 (NR) • $(K,H_3O)Al_2Si_3AlO_{10}(OH)_2$
Kaolinite-1A • $Al_2Si_2O_5(OH)_4$
Microcline • $KAlSi_3O_8$
Clinochlore-1MIIb • $(Mg,Fe,Al)_6(Si,Al)_4O_{10}(OH)_8$
Pyrite • FeS_2
Ankerite • $Ca(Fe^{+2},Mg)(CO_3)_2$
Saponite-17A • $Na_{0.3}Mg_3(Si,Al)_4O_{10}(OH)_2 \cdot 6H_2O$



GR 21952-001 2014; X-ray diffractograms
Red - Raw Data
Black - Theoretical Pattern
Blue - Glycolated Clay
Intensity (Counts)
0
1000
2000
3000
4000
5000
6000
Quartz, syn • SiO2
Siderite • FeCO3
Anatase, syn • TiO2
Calcite • (Ca,Mg)CO3
Albite, ordered • NaAlSi3O8
Illite-2M1 (NR) • (K,H3O)Al2Si3AlO10(OH)2
Kaolinite-1A • Al2Si2O5(OH)4
Microcline • KAlSi3O8
Clinochlore-1MIIb • (Mg,Fe,Al)6(Si,Al)4O10(OH)8
Pyrite • FeS2
Ankerite • Ca(Fe+2,Mg)(CO3)2
10
20
30
40
50
60
Two-Theta (deg)

SEM and XRD Results: 06-05-095-06W4

X-ray diffraction analysis and SEM analysis show Pre Test sample GR-001 and Post Test samples GR-002 (Injection Side) and GR-003 (Production Side) contain a similar basic mineralogy and have similar grain size and sorting characteristics.

GR-001: Pre Test End Trim Plug #4; 289.87 m

SEM analysis suggest Pre Test sample GR-001 represents good or better reservoir quality, poorly consolidated, moderately to poorly sorted, quartz rich McMurray Formation sandstone. Observed grain size ranges from coarse silt to coarse sand size. Depending on the volume of chert and feldspar, we expect thin section petrology would classify this sample as a sublitharenite, subarkose or quartz rich chertarenite.

Framework grains appear to be dominantly composed of monocrystalline quartz. We note small volumes of leached chert, probable slightly leached polycrystalline quartz, preserved to leached feldspar and leached clay rich and silicate rich clasts (Plate 1D). We note minor disrupted mica (likely biotite) and rutile heavy minerals as shown on Plate 3C. In this sample suite, incipient quartz cement is very rarely developed and therefore cannot be used as a tool to differentiate monocrystalline quartz, polycrystalline quartz and chert in these SEM views.

Very minor volumes of probable detrital clays, identified as illite, chlorite and lesser smectite by EDS analysis, cling to grain surfaces and locally reduce porosity (Plates 1C; 2C,D; 3D). Smectite rich clays, with characteristic honeycomb morphology, locally rim grains as illustrated on Plates 1C and 3A. Minor volumes of well formed authigenic kaolinite and moderately formed probable recrystallized detrital kaolinite are loosely attached to pore walls and locally reduce porosity. Plates 1C, 2C and 3B illustrate kaolinite. Pyrite framboids and crystals also locally block porosity as shown on Plate 2A,B. Pore lining and flaky bitumen occurs in minor volumes (Plates 2D; 3D).

No carbonate minerals were observed; however, minor calcite, siderite and ankerite (ferroan dolomite) were detected in the bulk XRD fraction suggesting emplacement (and likely later dissolution) of at least minor volumes of patchy pore filling and replacive cements.

SEM analysis suggests this sample should have good to very good effective porosity, total porosity and permeability and low to low - moderate microporosity. Core analysis measured porosity and permeability values are respectively 29.9% and 5602 mD suggesting very good reservoir quality. Modified primary intergranular porosity is the dominant effective porosity type. We expect minor volumes of secondary intergranular porosity formed after carbonate dissolution and minor grain molds formed after dissolution of unstable grains.

Pre Test McMurray Formation sample GR-001 was submitted for bulk and glycolated clay XRD analysis. Identification of clay abundance and composition were the principal objectives of the XRD analysis. Tables 4A and 4B respectively present bulk XRD and glycolated clay XRD results.

98.7% non clay minerals were detected in Pre Test sample GR-001. Bulk XRD results indicate quartz is the dominant component forming 95.4% of the bulk sample. SEM analysis suggests quartz occurs as dominant monocrystalline quartz and lesser volumes of chert, polycrystalline quartz and quartz contained within rock fragments. Quartz cement is rare.

Both plagioclase and potassium feldspars were detected in minor volumes. Potassium feldspar is more common than plagioclase forming 1.5% of the bulk fraction. 0.5% plagioclase was detected. Identified feldspar primarily occurs as discrete feldspar grains.

Three phases of carbonate minerals were detected including 0.3% siderite, 0.3% calcite and 0.3% ankerite (ferroan dolomite). Carbonate minerals were not observed in the SEM sample. We expect calcite and ankerite occur as patchy remnant cement. Siderite likely occurs as a minor pore filling and replacive cement.

Pyrite was only other non clay mineral detected, forming 0.4% of the bulk fraction. Pyrite occurs as a precipitate in porosity and likely as a replacive phase. We do not expect pyrite – log effects in this zone characterized by less than 2% pyrite.

Total clay minerals comprise 1.3% of the bulk fraction of Pre Test sample GR-001. Clay minerals detected in the bulk fraction include clay present as detrital matrix, as a component of rock fragments, as detrital micas and as authigenic clay. Kaolinite is the most common clay detected, forming 0.9% of the bulk fraction. Illite comprises 0.4% of the bulk fraction. Trace chlorite and the presence of smectite were detected. Mixed layer clays were not detected.

Glycolated clay analysis shows a slightly different distribution of clay minerals. Glycolation fully expands smectite and smectite rich clays and allows the volume of smectite to be quantified. 65.0% kaolinite, 19.1% illite, 4.2% chlorite and 11.7% smectite were detected in the glycolated clay fraction. Smectite is calculated to comprise 0.15% of the bulk fraction suggesting potential for very slight clay expansion concerns. SEM analysis suggest illite and chlorite occur as detrital clay, smectite is present as a grain rimming phase and kaolinite occurs as minor volumes of authigenic kaolinite booklets and minor recrystallized detrital clays.

GR-002: Post Test Plug #4 Injection Side

SEM analysis suggest Post Test sample GR-002 (Injection Side) also represents good or better reservoir quality, poorly consolidated, moderately to poorly sorted, quartz rich McMurray Formation sandstone. Observed grain size ranges from coarse silt to coarse sand size. Depending on the volume of chert and feldspar, we expect thin section petrology would classify this sample as a sublitharenite, subarkose or quartz rich chertarenite.

Similar to Pre Test sample GR-001, we note dominant monocrystalline quartz, small volumes of leached chert (Plates 4C,D; 5B), probable slightly leached polycrystalline quartz (Plate 6B), preserved to leached feldspar (Plates 4C; 5C) and leached clay rich and silicate rich clasts. Incipient quartz cement is very rarely developed (Plate 6B). Plate 4C,D may indicate that chert grains show greater leaching compared to the Pre Test sample; however, the observed leached grains may result from irregular distribution of leached chert in the zone. Thin section analysis is recommended to better determine the distribution and preservation of chert in the section.

Very minor volumes of probable detrital clays, identified as illite, chlorite and lesser smectite by EDS analysis, cling to grain surfaces and locally reduce porosity (Plates 4C,D; 5B,C; 6). EDS analysis identified clay coated iron oxides (Plate 6B) that may have formed in the Post Test sample. Alternately, the iron oxides and clay may be present in the Pre Test interval and were simply not observed in the Pre Test sample. Small volumes of smectite rich clays are admixed with illite and chlorite (Plate 6D) and likely are present as a minor discontinuous grain rimming phase. Authigenic kaolinite was not observed; however, we expect that minor volumes of well formed authigenic kaolinite and moderately formed probable recrystallized detrital kaolinite are present. Similarly, we did not observe minor pyrite and expect that pyrite is present in small volumes. Pore lining and flaky bitumen occurs in minor volumes (Plate 5D).

No carbonate minerals were observed; however, minor calcite, siderite and ankerite (ferroan dolomite) were detected in the bulk XRD fraction suggesting emplacement (and likely later dissolution) of at least minor volumes of patchy pore filling and replacive cements.

SEM analysis suggests this sample should have good to very good effective porosity, total porosity and permeability and low to low - moderate microporosity. Modified primary intergranular porosity is the dominant effective porosity type. We expect minor volumes of secondary intergranular porosity formed after carbonate dissolution and minor grain molds formed after dissolution of unstable grains.

Post Test Injection Side McMurray Formation sample GR-002 was submitted for bulk and glycolated clay XRD analysis. Identification of clay abundance and composition were the principal objectives of the XRD analysis. Tables 4A and 4B respectively present bulk XRD and glycolated clay XRD results.

98.7% non clay minerals were detected in Post Test sample GR-002. Bulk XRD results indicate quartz is the dominant component forming 95.9% of the bulk sample. SEM analysis suggests quartz occurs as dominant monocrystalline quartz and lesser volumes of chert, polycrystalline quartz and quartz contained within rock fragments. Quartz cement is rare.

Both plagioclase and potassium feldspars were detected in minor volumes. Potassium feldspar is more common than plagioclase forming 1.3% of the bulk fraction. 0.6% plagioclase was detected. Identified feldspar primarily occurs as discrete feldspar grains.

Three phases of carbonate minerals were detected including 0.3% siderite, 0.2% calcite and 0.2% ankerite (ferroan dolomite). Carbonate minerals were not observed in the SEM sample. We expect calcite and ankerite occur as patchy remnant cement. Siderite likely occurs as a minor pore filling and replacive cement.

Pyrite was the only other non clay mineral detected, forming 0.2% of the bulk fraction. Pyrite occurs as a precipitate in porosity and likely as a replacive phase. We do not expect pyrite – log effects in this zone characterized by less than 2% pyrite.

Total clay minerals comprise 1.3% of the bulk fraction of Post Test Injection Side sample GR-002. Clay minerals detected in the bulk fraction include clay present as detrital matrix, as a component of rock fragments, as detrital micas and as authigenic clay. Kaolinite is the most common clay detected, forming 0.9% of the bulk fraction. Illite comprises 0.4% of the bulk fraction. Trace chlorite and the presence of smectite were detected. Mixed layer clays were not detected.

Glycolated clay analysis shows a slightly different distribution of clay minerals. Glycolation fully expands smectite and smectite rich clays and allows the volume of smectite to be quantified. 58.5% kaolinite, 26.2% illite, 10.9% chlorite and 4.4% smectite were detected in the glycolated clay fraction. Smectite is calculated to comprise 0.06% of the bulk fraction suggesting potential for very slight clay expansion concerns. We note slightly lower kaolinite, slightly greater illite, moderately greater chlorite and moderately lower smectite compared to the Pre Test glycolated clay fraction. As clay volumes are very small, these differences may simply reflect clay distribution. SEM analysis suggest illite and chlorite occur as detrital clay, smectite is present as a grain rimming phase and kaolinite occurs as minor volumes of authigenic kaolinite booklets and minor recrystallized detrital clays.

GR-003: Post Test Plug #4 Production Side

SEM analysis suggest Post Test sample GR-003 (Production Side) also represents good or better reservoir quality, poorly consolidated, moderately to poorly sorted, quartz rich McMurray Formation sandstone. Observed grain size ranges from coarse silt to coarse sand size. Depending on the volume of chert and feldspar, we expect thin section petrology would classify this sample as a sublitharenite, subarkose or quartz rich chertarenite.

Similar to Pre Test sample GR-001 and Post Test sample GR-002, we note dominant monocrystalline quartz, small volumes of leached chert (Plate 9C), probable slightly leached polycrystalline quartz, preserved to leached feldspar (Plate 8B) and leached clay rich and silicate rich clasts. Incipient quartz cement is very rarely developed.

Greater volumes of total clay minerals (2.6% compared to 1.3% in both samples GR-001 and GR-002) characterize Post Test sample GR-003. Plate 7 Views B and C, Plate 8 Views B,C,D and Plate 9A suggest greater volumes of porosity are blocked by clays and fines in this Post Test sample. These results may suggest that clays and fines material were transported from the Injection Side or may simply indicate irregular clay distribution in the core plug. We recommend thin section analysis to better assess clay distribution.

Minor volumes of probable detrital clays and possibly transported clays and fines locally block porosity and cling to grain surfaces. Pore blocking material consists of quartz fines and admixed kaolinite, illite and lesser chlorite.

EDS analysis of altered minerals, precipitate coated grains or precipitates (Plate 9B-D) that were not observed in samples GR-001 and GR-002 shows these grains consist of about 36% iron, 34% oxygen, 22% silica, 5.0% carbon and less than 1% each sodium, copper, aluminum, sulphur and potassium. These grains or coated grains may have formed in the Post Test sample or alternately are present in the Pre Test interval and were simply not observed in the Pre Test sample.

One area with thickly smectite coated grains and thickly smectite lined pores was observed in Post Test Production Side sample GR-003 as shown on Plate 7C,D. As the samples were subjected to fines migration tests, we assume that these clay rims did not form in the Post Test sample. Moderately formed kaolinite and admixed fines locally block pores and cling to grain surfaces (Plates 8; 9A,C). We did not observe minor pyrite and expect that pyrite is present in small volumes. Pore lining and flaky bitumen occurs in minor volumes (Plate 5D).

No carbonate minerals were observed; however, minor siderite and ankerite (ferroan dolomite) were detected in the bulk XRD fraction suggesting emplacement (and likely later dissolution) of at least minor volumes of patchy pore filling and replacive cements. Calcite that occurs in minor volumes in Pre Test sample GR-001 and Post Test Injection Side sample GR-002 was not detected in Post Test Production Side sample GR-003. This may indicate that calcite was dissolved or may simply reflect the patchy distribution of very minor calcite cement.

SEM analysis suggests this sample should have good to very good effective porosity, total porosity and permeability and low to low - moderate microporosity. Permeability may be somewhat reduced compared to samples GR-001 and GR-002. Modified primary intergranular porosity is the dominant effective porosity type. We expect minor volumes of secondary intergranular porosity formed after carbonate dissolution and minor grain molds formed after dissolution of unstable grains.

Post Test Production Side McMurray Formation sample GR-003 was submitted for bulk and glycolated clay XRD analysis. Identification of clay abundance and composition were the principal objectives of the XRD analysis. Tables 4A and 4B respectively present bulk XRD and glycolated clay XRD results.

97.4% non clay minerals were detected in Post Test sample GR-002. Bulk XRD results indicate quartz is the dominant component forming 94.6% of the bulk sample. SEM analysis suggests quartz occurs as dominant monocrystalline quartz and lesser volumes of chert, polycrystalline quartz and quartz contained within rock fragments. Quartz cement is rare.

Both plagioclase and potassium feldspars were detected in minor volumes. Potassium feldspar is more common than plagioclase forming 1.0% of the bulk fraction. 0.6% plagioclase was detected. Identified feldspar primarily occurs as discrete feldspar grains. Potassium feldspar values slightly decline in the Post Test samples; however, this slight difference may simply reflect irregular feldspar distribution.

Two phases of carbonate minerals were detected including 0.3% siderite and 0.3% ankerite (ferroan dolomite). Calcite was not detected indicating either dissolution of calcite or irregular calcite distribution. Carbonate minerals were not observed in the SEM sample. We expect calcite and ankerite occur as patchy remnant cement. Siderite likely occurs as a minor pore filling and replacive cement.

Pyrite was the only other non clay mineral detected, forming 0.6% of the bulk fraction. Pyrite occurs as a precipitate in porosity and likely as a replacive phase. We do not expect pyrite – log effects in this zone characterized by less than 2% pyrite.

Total clay minerals comprise 2.6% of the bulk fraction of Post Test Production Side sample GR-003. Clay minerals detected in the bulk fraction include clay present as a detrital matrix, as a component of rock fragments, as detrital micas and as authigenic clay. Kaolinite is the most common clay detected, forming 1.7% of the bulk fraction. Illite comprises 0.9% of the bulk fraction. Trace chlorite and the presence of smectite were detected. Mixed layer clays were not detected.

Glycolated clay analysis shows a very slightly different distribution of clay minerals. Glycolation fully expands smectite and smectite rich clays and allows the volume of smectite to be quantified; however, only very minor smectite was present. 71.6% kaolinite, 22.8% illite, 3.8% chlorite and 1.8% smectite were detected in the glycolated clay fraction. Smectite is calculated to comprise 0.05% of the bulk fraction suggesting potential for very slight clay expansion concerns. We note moderately greater kaolinite, slightly greater illite, similar chlorite and significantly lower smectite compared to the Pre Test glycolated clay fraction. As clay volumes are very small, these differences may simply reflect clay distribution. SEM analysis suggest illite and chlorite occur as detrital clay, smectite is present as a grain rimming phase and kaolinite occurs as minor volumes of authigenic kaolinite booklets and minor recrystallized detrital clays.

Comparison of Samples

Comparison of Pre Test sample GR-001, Post Test Injection Side sample GR-002 and Post Test Production Side sample GR-003 suggests:

- Greater total clay in Post Test Production Side sample GR-003.
- Possible transported silica, silicate and kaolinite fines and increased pore blockage in Post Test Production Side sample GR-003.
- Possible formation of iron bearing precipitates in Post Test samples GR-002 and GR-003.

XRD Results: Pre Test SP3 (GR-004) and SP15 (GR-005)

Pre Test McMurray Formation samples GR-004 (SP3) and GR-005 (SP15) were submitted for bulk and glycolated clay XRD analysis only. Identification of clay abundance and composition were the principal objectives of the XRD analysis. Tables 4A and 4B respectively present bulk XRD and glycolated clay XRD results.

98.4% and 98.7% non clay minerals were respectively detected in Pre Test samples GR-004 and GR-005. Bulk XRD results indicate quartz is the dominant component respectively forming 96.8% and 96.5% of the bulk samples. We expect quartz occurs as dominant monocrystalline quartz and lesser volumes of chert, polycrystalline quartz, quartz contained within rock fragments and quartz cement.

Both plagioclase and potassium feldspars were detected in minor volumes. Potassium feldspar is more common than plagioclase forming 1.0% (GR-004) and 1.2% (GR-005) of the bulk fractions. 0.2% plagioclase was detected in both samples GR-004 and GR-005. We expect that identified feldspar primarily occurs as discrete feldspar grains.

Three phases of carbonate minerals were detected including 0.2% calcite (GR-004, GR-005), trace (GR-004) and 0.2% (GR-005) siderite and trace (GR-004) and 0.2% (GR-005) ankerite (ferroan dolomite). We expect calcite and ankerite occur as patchy remnant cement. Siderite likely occurs as a minor pore filling and replacive cement.

Pyrite was the only other non clay mineral detected, forming 0.2% of the bulk fractions of both samples GR-004 and GR-005. Pyrite occurs as a precipitate in porosity and likely as a replacive phase. We do not expect pyrite – log effects in this zone characterized by less than 2% pyrite.

Total clay minerals comprise 1.6% of the bulk fraction of Pre Test sample GR-004 and 1.3% of Pre Test sample GR-005. Clay minerals detected in the bulk fraction include clay present as a detrital matrix, as a component of rock fragments, as detrital micas and as authigenic clay. Kaolinite is the most common clay detected, forming 0.9% of the bulk fractions of both samples GR-004 and GR-005. Illite respectively comprises 0.7% and 0.4% of the bulk fractions of samples GR-004 and GR-005. Trace chlorite and the presence of smectite were detected in both samples. Mixed layer clays were not detected.

Glycolated clay analysis shows a slightly different distribution of clay minerals. Glycolation fully expands smectite and smectite rich clays and allows the volume of smectite to be quantified. 34.9% kaolinite, 26.2% illite, 9.2% chlorite and 29.7% smectite were detected in the glycolated clay fraction of sample GR-004. Smectite is calculated to comprise 0.48% of the bulk fraction suggesting potential for at least slight clay expansion concerns. 56.7% kaolinite, 19.5% illite, 12.2% chlorite and 11.6% smectite were detected in the glycolated clay fraction of sample GR-005. Smectite is calculated to comprise 0.15% of the bulk fraction suggesting potential for slight clay expansion concerns.

Petrographic Results: 102/11-08-095-06W4/00

General

McMurray Formation sandstones, recovered from 274.47 m (SP3) and 279.34 m (SP13) in the 102/11-08-095-06W4/00 well (Project GR 21952 2014), represent poorly consolidated to unconsolidated:

- Moderate - good reservoir quality, moderately sorted, mid fine grained subarkose: GR-001,
- Excellent reservoir quality, moderately sorted, mid fine grained subarkose: GR-002.

Excellent reservoir quality sample GR-002 appears massive to vaguely laminated. Alignment of coarser grained clasts shown on Plate 12A suggest vague laminae. Probable laminae disrupted by bioturbation characterize moderate - good reservoir quality sample GR-001.

The 102/11-08-095-06W4/00 McMurray samples are characterized by very good core analysis total porosity, respectively 32.8% in moderate - good reservoir quality sample GR-001 and 35.9% in excellent reservoir quality sample GR-002. Good to very good effective porosity typifies the sample suite, respectively 26.5% in sample GR-001 to 30.2% in sample GR-002. Depending on the volume of matrix and pseudomatrix components, the mean grain size, the degree of compaction and the volume of emplaced cements, the 102/11-08-095-06W4/00 McMurray sandstones show moderate - good permeability (1829 mD: GR-001) and excellent permeability (6799 mD: GR-001).

Measured mean grain sizes are respectively 0.206 mm (mid fine sand) in sample GR-001 and 0.192 mm (mid fine sand) in sample GR-002. No logs were provided and it is uncertain if the samples were recovered from the same sand body; therefore, no definitive comments on grain size trends could be made. Coarse silt size clasts (GR-001) and lower very fine sand size clasts (GR-002) were the smallest measured grains. Maximum measured grain size ranges from upper medium sand (GR-001) to lower coarse sand (GR-002). Average mean grain size for the two 102/11-08-095-06W4/00 samples is 0.199 (mid fine sand).

Framework Grains

Basic framework composition is similar for the two submitted 102/11-08-095-06W4/00 McMurray Formation sandstone samples; however, the abundance of individual components show moderate variation between samples.

Competent framework components present in both samples include monocrystalline quartz, polycrystalline quartz, chert, feldspar, plutonic rock fragments and heavy minerals. In both 102/11-08-095-06W4/00 samples, total competent grains are significantly more common than total ductile grains. Total competent grains form 81.7% (GR-001) and 97.1% (GR-002) of the samples. Total ductile grains, consisting of clay clasts, volcanic rock fragments, micas and plant debris, comprise 6.4% (GR-001) and 1.3% (GR-002) of the samples. Average competent grain and ductile grain values for the two samples are respectively 89.4% and 3.9%. Matrix plus pseudomatrix averages 7.8%.

Subrounded to subangular monocrystalline quartz is the single most common framework grain in both samples, comprising 74.0% (GR-001) and 85.8% (GR-002) of the samples. Average monocrystalline quartz value for the two 102/11-08-095-06W4/00 sample suite is 79.9%. Cross polarized Plates for each sample show the distribution of monocrystalline quartz.

Feldspars range from well preserved to leached and microporous in these subarkose intervals. Feldspar comprises 4.0% (GR-001) and 5.0% (GR-002) of the samples with an average value of 4.5%. Dissolution of feldspar created microporous grains and released silicate fines to the pore system. Extensive dissolution of feldspar also likely created minor volumes of grain moldic porosity that supplement the intergranular pore system. Thin section photomicrograph Plates 10C, 11B,C, 12C and 13C illustrate variably well preserved to leached feldspar.

Chert occurs in minor to moderate volumes comprising 1.7 % (GR-001) and 4.0% (GR-002) of the samples. Average chert value is 2.9%. Chert ranges from well preserved to leached and microporous. Chert dissolution released minor volumes of silica fines to the pore system. Examples of leached chert are shown on Plates 10B, 11D, 12B and 13A,B,D.

Other competent grains present in minor to moderate volumes include 1.0% (GR-001) and 1.7% (GR-002) polycrystalline quartz, 0.3% (GR-001, GR-002) plutonic rock fragments and 0.3% (GR-002) and 0.7% (GR-001) heavy minerals. Zircon, pyroxene and opaques are the most common heavy minerals. Average polycrystalline quartz, plutonic rock fragment and heavy mineral values for the two 102/11-08-095-06W4/00 sample suite are respectively 1.4%, 0.3% and 0.5%. Plate 13B shows detrital zircon.

Preserved to leached clay rich rock fragments and volcanic rock fragments occur in trace to very minor volumes. Clay clasts form trace volumes of sample GR-001, whereas 0.3% volcanic rock fragments were encountered in sample GR-002. Dissolution of clay clasts and volcanic rock fragments created very minor volumes of intragranular microporosity as shown on Plates 11A and 13B.

Other ductile grain types include 1.4% (GR-001) and 1.0% (GR-002) micas and 5.0% (GR-001) and trace (GR-002) plant fragments. Compacted plant fragments are associated with disrupted compacted clay laminae and burrows in sample GR-001 as shown on Plates 10 and 11. Minor plant debris in sample GR-002 is shown on Plate 13A,C. Average plant fragment value is 2.5%. Slightly compacted muscovite and biotite micas are illustrated on Plates 11B and 13B. Micas average 1.2%.

Figure 1 is Folk's standard sandstone ternary classification diagram that shows the 102/11-08-095-06W4/00 McMurray Formation intervals plot as subarkose.

Matrix Clays and XRD Results

Trace to moderate (7.8% in GR-001) volumes of clay matrix typify the 102/11-08-095-06W4/00 McMurray Formation intervals. Matrix clay alone slightly lowers reservoir quality in the interval represented by sample GR-001 and negligibly lowers reservoir quality in the interval represented by sample GR-002. Pseudomatrix (ductile grains) forms 6.4% (GR-001) and 1.3% (GR-002) of the samples; however, ductile grains are only locally compacted between more competent grains. Most grains show expanded, straight, tangential to slightly indented grain boundaries indicating overall slight compaction effects. Compaction of matrix plus pseudomatrix has a slight - moderate adverse effect on reservoir quality in the interval represented by sample GR-001.

Both 102/11-08-095-06W4/00 McMurray Formation samples chosen for thin section analysis were submitted for bulk and glycolated clay x-ray diffraction analyses (XRD). Bulk and glycolated clay XRD analysis was also conducted on 102/11-08-095-06W4/00 sample GR-001A (SP1: 274.25 m: GR 21512 2014). Identification of clay abundance and composition were the principal objectives of the XRD analysis. Tables 4A and 4B respectively present bulk XRD and glycolated clay XRD results.

Non clay minerals form 98.7% (GR-001A), 97.8% (GR-001) and 98.3% (GR-002) of the samples. Bulk XRD results indicate quartz is the principal mineral in all samples, forming 94.0% (GR-001A), 95.7% (GR-001) and 95.9% (GR-002) of the samples. Petrographic analysis shows quartz occurs as dominant monocrystalline quartz, minor to moderate volumes of chert and lesser volumes of polycrystalline quartz, quartz cement and quartz contained within rock fragments.

Both potassium feldspar and plagioclase feldspar were detected in all samples. All samples contain greater volumes of potassium feldspar compared to plagioclase. Potassium feldspar comprises 4.0% (GR-001A), 0.5% (GR-001) and 1.1% (GR-002) of the samples. 0.3% plagioclase feldspar was detected in all samples. Identified feldspar primarily occurs as discrete feldspar grains and as minor components of volcanic rock fragments and plutonic rock fragments.

Three phases of carbonate minerals were detected in samples GR-001 and GR-002 including siderite, magnesian calcite and ankerite (ferroan dolomite). Magnesian calcite and ankerite occur in both samples, each comprising 0.2% of both samples. 0.2% siderite was detected in sample GR-001. Carbonate minerals were not observed in the thin sections nor were they detected in the bulk XRD fraction of sample GR-001A (SP1: 274.25 m). We assume that magnesian calcite and ankerite may represent very minor volumes of remnant patchy pore filling cement. Siderite may occur as a pore filling or replacive phase.

Pyrite was detected in all bulk fractions, forming 0.4% (GR-001A, GR-001) and 0.6% (GR-002) of the samples. All samples contain less than 2%; therefore, we do not anticipate pyrite - log effects.

Other detected non clay minerals include 0.3% anatase in sample GR-001.

Total clay minerals comprise 1.3% (GR-001A), 2.2% (GR-001) and 1.7% (GR-002) of the bulk fractions. Clay minerals detected in the bulk fraction include clay present as detrital matrix, as a component of rock fragments, as detrital micas and as authigenic clay. Kaolinite is the most common clay detected in all samples, forming 0.9% (GR-001A) and 1.3% (GR-001, GR-002) of the bulk fractions. Illite comprises 0.9% (GR-001) and 0.4% (GR-001A, GR-002) of the bulk fractions. Chlorite comprises trace volumes of all bulk fractions. The presence of smectite is indicated in samples GR-001A and GR-002.

Glycolated clay analysis shows a similar (GR-001) to slightly different (GR-001A, GR-002) distribution of clay minerals as glycolation fully expands the lattice of expandable smectite clays and therefore allows the volume of smectite to be quantified. Kaolinite forms 72.5% (GR-001A), 59.9% (GR-001) and 79.1% (GR-002) of the glycolated clay fractions. Illite comprises 21.7% (GR-001A), 33.9% (GR-001) and 14.1% (GR-002) of the glycolated clay fractions. 4.1% (GR-001A), 6.2% (GR-001) and 4.3% (GR-002) chlorite occurs in the glycolated clay fractions. Smectite comprises 1.7% of the glycolated clay fraction of sample GR-001A and 2.5% of the glycolated clay fraction in sample GR-002. Mixed layer clays were not detected in the sample suite and smectite was not detected in sample GR-001. Thin section suggests most clay minerals primarily occur as components of detrital clay. Minor volumes of authigenic kaolinite booklets were observed in sample GR-001. Small volumes of kaolinite may occur as a component of clay clasts. Illite likely occurs as a component of clay matrix, micas, clay clasts and possibly as minor clay rims. Chlorite may represent clay matrix and chlorite micas. Expandable smectite clays likely occur as a component of detrital matrix. SEM analysis is required to determine the composition of locally formed grain rims.

The presence of very minor volumes of smectite in sample GR-001A (smectite is calculated to form 0.02% of the bulk sample) and sample GR-002 (smectite is calculated to form 0.04% of the bulk sample) suggests very minor potential for clay expansion and resultant permeability reduction.

Very minor to minor formation of smectite and thermal conversion of kaolinite to smectite may occur under the elevated temperatures and pressures of a thermal EOR project.

All of the analyzed 102/11-08-095-06W4/00 zones lie well above 2000 m, the approximate depth at which expandable clays convert to non expandable illite.

Cements

The 102/11-08-095-06W4/00 McMurray Formation intervals experienced very slight to possibly moderate cementation.

Minor early grain rimming clays are discontinuously present on some grain surfaces. We encountered 0.7% (GR-001) and 0.3% (GR-002) distinctive clay rims. SEM analysis is recommended to determine if grain rimming contain expandable smectite clays similar to the 06-05-095-06W4 samples. Clay rims predate formation of incipient quartz cement and initially inhibited quartz cementation.

Incipient authigenic quartz occurs in minor volumes. We suggest that the variable matrix content, the early and irregular emplacement of carbonate cements (assumed) and migration of oil inhibited precipitation of authigenic quartz as syntaxial overgrowths on monocrystalline quartz grains. Where present, quartz cement minimally reduces porosity. We encountered 1.0% incipient quartz cement in both samples. Examples of discontinuous quartz overgrowths are shown on Plate 12B.

Pyrite occurs as scattered pore filling and replacive crystals and framboids. Minor volumes of pyrite were encountered during point count analysis, forming 1.7% (GR-001) and 0.3% (GR-002) of the samples. We do not expect pyrite - log effects in these zones characterized by less than 2% pyrite. Plates 12B and 13A show examples of pyrite cement.

Pore filling authigenic kaolinite was rarely observed in the sample suite. We detected 0.7% distinctive kaolinite in sample GR-001. Most kaolinite is loosely attached to pore walls and would be available for velocity induced migration; however, simple kaolinite fines migration alone is not expected to impact reservoir quality.

Very minor volumes of siderite, magnesian calcite and ankerite (ferroan dolomite), detected during XRD analysis, were not observed in the thin section intervals.

Mineralogy Calculated from Thin Section Modal Analysis

Algorithms designed by GR Petrology calculated the mineralogy of each sample submitted for comprehensive petrographic assessment. Based on the density of each mineral we calculated a theoretical grain density for each sample. Table 5 presents the mineralogy of the samples as calculated from the thin section modal analysis.

Quartz, occurring as dominant monocrystalline quartz, minor to moderate volumes of chert, polycrystalline quartz and quartz cement and minor volumes of silica contained in rock fragments and silica occurring as micron-sized components of detrital matrix clay, dominates the mineralogy of the 102/11-08-095-06W4/00 McMurray Formation sandstones. Based on point count results, quartz forms 78.6% (GR-001) and 92.5% (GR-002) of the mineralogy. Average quartz value for the two analyzed 102/11-08-095-06W4/00 McMurray Formation samples is 85.6%.

Feldspar mainly occurs as moderate volumes of detrital grains and as a component of minor volumes of volcanic rock fragments and plutonic rock fragments. Minor feldspar occurs as silt size grains released from leached grains. Detected feldspar comprises 4.2% of the mineralogy of sample GR-001 and 5.4% of sample GR-002. Average feldspar value for the analyzed 102/11-08-095-06W4/00 McMurray Formation samples is 4.8%.

Pyrite forms 1.7% of sample GR-001 and 0.3% of sample GR-002 with an average value of 1.0%. Both zones are characterized by less than 2% pyrite suggesting these intervals will not experience pyrite - log effects.

Clay minerals assessed for mineralogy include clay principally contained within clay matrix, lesser clay rich rock fragments and probable minor authigenic clay. Our algorithm also assigns a percentage of the counted clay matrix to quartz to represent the fine silt associated with matrix clays and a percentage of the clay rich rock fragments to quartz; therefore, clay volumes on the mineralogy Table are not directly the sum of the clay rich components on the point count Table. We note rare distinctive authigenic kaolinite booklets in sample GR-001. Clay minerals are calculated to comprise 9.9% (GR-001) and 1.5% (GR-002) of the analyzed 102/11-08-095-06W4/00 McMurray Formation samples. Average calculated clay value is 5.7%.

5.0% plant debris occurs in sample GR-001. 0.7% (GR-001) and 0.3% (GR-002) heavy minerals are present.

Grain density values calculated from the thin section point count mineralogical data for the two analyzed 102/11-08-095-06W4/00 samples are similar, respectively 2663kg/m^3 (GR-001) and 2661kg/m^3 (GR-002). Average calculated grain density is 2662kg/m^3. Grain density increases as the volume of dolomite, phosphate, siderite and pyrite increase and decreases as the volume of plant fragments increases.

<u>Paragenesis and Reservoir Evolution</u>

Moderate - good reservoir quality (GR-001) and excellent (GR-002) reservoir quality, unconsolidated to poorly consolidated McMurray Formation sandstones, recovered from the 102/11-08-095-06W4/00 well, developed and modified through the following paragenesis:

1. Deposition of a submature to mature mixture of dominant monocrystalline quartz, minor to moderate volumes of feldspar and minor to moderate volumes of lithic grains (polycrystalline quartz, chert, volcanic rock fragments, plutonic rock fragments, clay clasts, micas, plant debris, heavy minerals) and very minor (GR-002) to moderate (GR-001) volumes of detrital clay under moderate - high to high energy conditions.
2. Slight to moderate mechanical compaction, grain reorientation and ductile deformation of soft grains and clays resulted in moderate loss of intergranular porosity.
3. Minor emplacement of grain rimming clays. Minimal porosity reduction.
4. Early emplacement of minor amounts of pyrite very slightly lowered effective porosity.

5. Probable local emplacement of very minor pore filling and / or replacive siderite minimally lowered reservoir quality.
6. Dewatering of matrix clays, and underlying and overlying shales. Precipitation of minor amounts of authigenic kaolinite into open pores as aggregates of pseudohexagonal crystals. Minimal reduction of effective intergranular porosity and increase in non effective microporosity.
7. Continued compaction and very minor pressure solution at grain contacts. Incipient precipitation of authigenic quartz cement as overgrowths on a few monocrystalline quartz grains. Minor porosity reduction.
8. Assumed emplacement of patchy carbonate cements (calcite, ankerite) slightly to moderately reduced porosity.
9. Assumed dissolution of carbonate cements slightly to moderately enhanced porosity.
10. Dissolution of feldspars, chert and rock fragments at least slightly enhanced porosity.
11. Hydrocarbon migration.

Reservoir Quality Assessment

General

Measured permeability values suggest the 102/11-08-095-06W4/00 McMurray Formation sandstones submitted for thin section analysis represent moderate - good reservoir quality (GR-001) and excellent reservoir quality (GR-002), poorly consolidated to unconsolidated, moderately sorted, mid very fine grained subarkose.

Good (GR-001) and very good (GR-002) effective porosity characterizes the 102/11-08-095-06W4/00 samples. Effective porosity, determined by point count analysis, is respectively 26.5% in moderate - good reservoir quality sample GR-001 and 30.2% in excellent reservoir quality sample GR-002. Average effective porosity for the two 102/11-08-095-06W4/00 McMurray Formation samples is 28.4%.

Core analysis measured total porosity values for samples GR-001 and GR-002 are respectively 32.8% in moderate - good reservoir quality sample GR-001 and 35.9% in excellent reservoir quality sample GR-002. Average core analysis porosity for the two samples is 34.4%. Core analysis permeability values are respectively 1829 mD in moderate - good reservoir quality sample GR-001 and 6799 mD in excellent reservoir quality sample GR-002.

Average measured permeability for the two 102/11-08-095-06W4/00 McMurray Formation samples is 4314 mD (average good reservoir quality). Microporosity forms about 19% (GR-001) and 16% (GR-002) of total porosity based on core analysis total porosity values.

In these poorly consolidated to unconsolidated sandstones, total porosity consists of modified intergranular porosity, lesser secondary cement moldic intergranular porosity (assumed), grain moldic porosity and microporosity that exists in authigenic clays, in leached lithic grains and feldspar and in detrital clay matrix. Effective porosity in both samples (Figure 2) consists of dominant modified primary intergranular porosity and lesser secondary cement moldic intergranular pores. At least minor volumes of grain molds supplement the intergranular pore system. We expect that grain molds are somewhat more common than observed (grain moldic porosity was not encountered during point count analysis) as grain molds in unconsolidated to poorly consolidated samples may be included in oversized intergranular pores. Petrographic examination shows the presence of highly leached feldspar and chert and lesser leached rock fragments in both samples. Variable volumes of clay matrix preserved low volumes of microporosity. Modified primary intergranular and probable lesser secondary intergranular porosity form about 81% of total porosity in sample GR-001 and 84% of total porosity in sample GR-002. Figure 2 demonstrates as the volume of microporosity rises relative to total porosity, reservoir quality tends to decline.

Moderate - good reservoir quality sample GR-001 and excellent reservoir quality sample GR-002 plot in the intergranular porosity region of Figure 2.

Primary intergranular porosity slightly to moderately declined with mechanical compaction and the ductile deformation of soft clays and grains. Porosity declined further with the emplacement of minor volumes of authigenic kaolinite, with the emplacement of minor amounts of syntaxial quartz overgrowths, with the emplacement of minor volumes of pyrite and with the assumed emplacement of minor to moderate volumes of calcite, siderite and ankerite cements. As carbonate occluded pores and replaced earlier cements, grains and clays, effective porosity and reservoir quality declined. Most of the calcite and ankerite were removed; however, very minor volumes of magnesian calcite and ankerite were identified in the bulk XRD fractions of both samples. Very minor siderite was also detected in sample GR-001. We expect that little dissolution of siderite has occurred. Grain moldic porosity, formed after the dissolution of unstable feldspar, chert and other unstable lithics, slightly to possibly moderately enhanced porosity and reservoir quality.

The 102/11-08-095-06W4/00 McMurray Formation interval shows, on average, 3.9% matrix, 7.8% matrix plus pseudomatrix, 2.9% total authigenic cement, 9.2% of the available porosity is occluded by total cement, 3.2% of the available porosity is occluded by quartz cement and 3.3% of the available porosity occluded by pyrite.

This report classifies McMurray Formation intervals recovered from the 102/11-08-095-06W4/00 well as follows:

- Very low reservoir quality sandstone: Less than 200 mD.

- Low reservoir quality sandstone: 200 mD - 400 mD.
- Low – moderate reservoir quality sandstone: 400 mD – 600 mD.
- Moderate reservoir quality sandstone: 600 mD – 1500 mD.
- Moderate - good reservoir quality sandstone: 1500 mD – 2500 mD.
- Good reservoir quality sandstone: 2500 mD – 4000 mD.
- Very good reservoir quality sandstone: 4000 mD – 6000 mD.
- Excellent reservoir quality: Greater than 6000 mD.

Factors Controlling Reservoir Quality

Depositional processes exert the principal control on reservoir quality in the 102/11-08-095-06W4/00 McMurray Formation sandstones. Diagenetic factors slightly overprint the depositional controls on reservoir quality. Reservoir properties, early in the sandstone paragenesis, were strongly influenced by depositional parameters including mean grain size, the amount of detrital matrix, ductile grains and clasts and the ratio of competent grains (monocrystalline quartz, polycrystalline quartz, chert, feldspar) to less competent clasts.

Diagenetic controls, in particular the degree of mechanical compaction and the total amount of emplaced cement, slightly overprint the original depositional controls of reservoir quality.

In general, coarser grained sediment should be more permeable that otherwise similar, finer grained sediment. Well sorted sand should have higher porosity than more poorly sorted sediment. Grain size may also influence later reservoir evolution, as finer grained silt and sand may be more readily susceptible to compaction induced loss of porosity than coarser grained sediment. Sediment framework composition plays a key role in the evolution of reservoir quality, as more lithic rich sand tend to be highly susceptible to compaction, while highly quartzose sediment is susceptible to severe quartz cementation. Chert rich and feldspar rich zones are susceptible to grain leaching.

Thin section petrology shows that similar mechanisms and processes were active in generating the McMurray Formation sandstone reservoirs intersected by the 102/11-08-095-06W4/00 well. We consider the analyzed and similar McMurray Formation oil sand intervals with permeability in excess of 600.0 mD should be capable of moderate or better commercial oil production; however, we suggest that the operator concentrate on sections with more than 1000 mD permeability. Zones with greater than 2500 mD permeability should be capable of good or better oil production. Zones with less than 400.00 mD permeability may contribute to production if in contact with more permeable zones.

Table 6 summarizes average values for key factors for this sample suite.

Comparison of the 06-05-095-06W4 and 102/11-08-095-06W4/00 Sample Suites

Comparison of the 06-05-095-06W4 McMurray Formation samples, submitted for SEM and XRD analysis, and the 102/11-08-095-06W4/00 McMurray Formation samples, submitted for thin section and XRD analysis, suggests:

- Thin section analysis indicates the 102/11-08-095-06W4/00 samples are texturally and compositionally similar and classify as moderately sorted, mid fine grained subarkose.
- Monocrystalline quartz grains dominate the 102/11-08-095-06W4/00 samples. Chert and polycrystalline quartz occur in minor to moderate volumes. Feldspar occurs in moderate volumes in both samples. Rock fragments, micas and heavy minerals are less common. Plant fragments are present in minor (GR-002) to moderate (GR-001) volumes.
- Matrix clays, detected during point count analysis, form moderate (GR-001) to trace (GR-002) volumes of the 102/11-08-095-06W4/00 samples.
- 102/11-08-095-06W4/00 sample GR-002 (279.34 m) has the greatest measured permeability and reservoir quality (6799 mD and excellent reservoir quality), the greatest measured core analysis total porosity (35.9%), the greatest counted effective porosity and intergranular porosity (30.2%), the greatest intergranular porosity to total porosity value (92.1%), the lowest volume of porosity infilled by total cement (5.0%) and the greatest GSPI (5.889).
- 102/11-08-095-06W4/00 sample GR-001 (274.47 m) has the lowest measured permeability and reservoir quality (1829 mD and moderate - good reservoir quality), measured core analysis total porosity of 32.8%, counted effective porosity and intergranular porosity of 26.5%, intergranular porosity to total porosity value of 80.8%, 13.4% of porosity is infilled

by total cement and GSPI of 5.353. Mean grain size of 0.206 mm is greater than measured mean grain size for sample GR-002 (0.192 mm).

- SEM analysis of 06-05-095-06W4 samples GR-001 to GR-003 suggest the 06-05-095-06W4 samples are texturally and compositionally similar to 102/11-08-095-06W4/00 thin section samples GR-001 and GR-002. Scattered large grains were observed during SEM analysis (Plates 1A; 4A; 7A) suggesting moderate - poor sorting; however, comparison with thin section Plate 12A shows scattered larger clasts in the overall moderately sorted 102/11-08-095-06W4/00 sample GR-002.
- Grain size analysis of 102/11-08-095-06W4/00 samples GR-001 and GR-002 shows grains range in size from coarse silt size to lower coarse sand size. We observed coarse silt size to coarse sand size clasts during SEM examination of 06-05-095-06W4 samples GR-001 to GR-003.
- SEM analysis also suggests monocrystalline quartz grains dominate the 06-05-095-06W4 samples and that chert and feldspar occur in minor to moderate volumes. Rock fragments are less common.
- Core analysis total porosity values for 06-05-095-06W4 samples GR-001 to GR-003, GR-004 and GR-005 are respectively 29.9%, 29.4% and 34.0% whereas permeability values are respectively 5602 mD, 5600 mD and 8000 mD suggesting reservoir quality similar to 102/11-08-095-06W4/00 sample GR-002. Similar to the 102/11-08-095-06W4/00 samples, SEM analysis shows 06-05-095-06W4 samples are characterized by dominant intergranular porosity.
- SEM analysis also suggests minor to locally moderate volumes of detrital clays similar to 102/11-08-095-06W4/00 sample GR-002.
- XRD analysis indicates a similar distribution of minerals in all analyzed samples. Quartz is the dominant component forming 94.6% (GR-003) to 96.8% (GR-004) of the 06-05-095-06W4 samples and 94.0% (GR-001A) to 95.9% (GR-002) of the 102/11-08-095-06W4/00 samples. Thin section analysis indicated quartz occurs as dominant monocrystalline quartz, minor to moderate volumes of chert and polycrystalline quartz and minor volumes of quartz cement, quartz occurring as a component of rock fragments and silica fines.
- All samples contain both potassium feldspar and plagioclase feldspar. Potassium feldspar is

more common than plagioclase in all samples, comprising 1.0% (GR-003, GR-004) to 1.5% (GR-001) of the 06-05-095-06W4 samples and 0.5% (GR-001) to 4.0% (GR-001A) of the 102/11-08-095-06W4/00 samples. Plagioclase feldspar forms 0.2% (GR-004, GR-005) to 0.6% (GR-002, GR-003) of the 06-05-095-06W4 samples and 0.3% (GR-001A, GR-001, GR-002) of the 102/11-08-095-06W4/00 samples. Thin section analysis indicates feldspar primarily occurs as detrital grains. Lesser feldspar is present as silicate fines and as a component of plutonic and volcanic rock fragments.

- With the exception of 102/11-08-095-06W4/00 sample GR-001A, minor volumes of carbonate minerals were detected in all bulk XRD fractions. Siderite forms trace (GR-004) to 0.3% (GR-001 to GR-003) of the 06-05-095-06W4 samples and 0.2% of 102/11-08-095-06W4/00 sample GR-001. 0.2% (GR-002, GR-004, GR-005) and 0.3% (GR-001) calcite was detected in the 06-05-095-06W4 samples, whereas 0.2% magnesian calcite was detected in 102/11-08-095-06W4/00 samples GR-001 and GR-002. Ankerite forms trace (GR-004) to 0.3% (GR-001) of the 06-05-095-06W4 samples and 0.2% of 102/11-08-095-06W4/00 samples GR-001 and GR-002.
- All samples contain very minor pyrite in the bulk XRD fractions; therefore, we do not expect pyrite - log effects.
- Bulk XRD analysis detected minor to moderate volumes of total clay minerals in both the 06-05-095-06W4 and 102/11-08-095-06W4/00 sample suites. Total clay minerals comprise 1.3% (GR-00, GR-002, GR-005) to 2.6% (GR-003) of the 06-05-095-06W4 samples and 1.3% (GR-001A) to 2.2% (GR-001) of the 102/11-08-095-06W4/00 samples.
- Kaolinite is the most common clay detected in all bulk fractions. Illite occurs in lesser volumes. Trace chlorite was detected in all samples. With the exception of 102/11-08-095-06W4/00 sample GR-001, the presence of smectite is indicated in all bulk fractions.
- Kaolinite is also the most common clay mineral in the glycolated clay fraction forming 34.9% (GR-004) to 71.6% (GR-003) of the 06-05-095-06W4 glycolated clay fractions and 59.9% (GR-001) to 79.1% (GR-002) of the 102/11-08-095-06W4/00 glycolated clay fractions. Illite occurs in moderate volumes ranging from 19.1% (GR-001) to 26.2% (GR-004) of the 06-05-095-06W4 glycolated clay fractions and 14.1% (GR-002) to 33.9% (GR-001) of the 102/11-08-095-06W4/00 glycolated clay fractions. Chlorite forms 3.8% (GR-003) to 12.2% (GR-005) of the 06-05-095-06W4 glycolated clay fractions and 4.1% (GR-

001A) to 6.2% (GR-001) of the 102/11-08-095-06W4/00 glycolated clay fractions. Smectite, detected in all samples with the exception of 102/11-08-095-06W4/00 sample GR-001, comprises 1.8% (GR-003) to 29.7% (GR-004) of the 06-05-095-06W4 glycolated clay fractions and 1.7% (GR-001A) to 2.5% (GR-002) of the 102/11-08-095-06W4/00 glycolated clay fractions. Smectite is calculated to comprise 0.05% (GR-003) to 0.48% (GR-004) of the 06-05-095-06W4 bulk samples and 0.02% (GR-001A) to 0.04% (GR-002) of the 102/11-08-095-06W4/00 bulk fractions indicating very slight to at least slight (102/11-08-095-06W4/00 sample GR-004) potential for clay expansion concerns.

- SEM analysis shows the presence of minor well formed loosely attached authigenic kaolinite booklets, lesser moderately formed probable recrystallized detrital kaolinite booklets, wispy loosely attached illite and chlorite clays and locally developed grain rimming smectite.
- Based on similar texture, composition, grain size, sorting, matrix content, volumes of porosity, porosity types and porosity distribution, we expect similar sensitivity concerns in the oil bearing 06-05-095-06W4 and 102/11-08-095-06W4/00 McMurray Formation intervals:
    - Variable slight to moderate potential for permeability reduction related to fines migration.
    - Significant potential for HCL acid - oil incompatibility.
    - Significant potential for HCl - HF acid - oil incompatibility.
    - At least moderate mineral sensitivity to untreated HCL acid and HCl - HF acid.
    - Slight potential for clay expansion
    - Slight to moderate sensitivity to water based fluids in terms of clay sloughing and migration.
    - At least slight potential for scale formation with production of water.
    - Slight to moderate potential for thermal conversion of minerals (silica dissolution and reprecipitation, possible formation of smectite and / or conversion of kaolinite to smectite).
    - Potential for sand and fines migration and production.
    - Slight gamma - log effects (feldspar).

Reservoir Sensitivity

Petrographic analysis shows the poorly consolidated to unconsolidated 06-05-095-06W4 and 102/11-08-095-06W4/00 McMurray Formation sandstones consist of dominant quartz, minor to moderate feldspar, minor amounts of pyrite, minor volumes of carbonate minerals and minor to moderate volumes of clay minerals. Thin section and SEM analysis shows minor to moderate amounts of authigenic kaolinite. Minor volumes of illite and chlorite clays may occur as authigenic phases. Authigenic smectite occurs as a grain rimming phase. Thin section petrology, SEM analysis and X-ray diffraction analysis suggests the following reservoir sensitivity conditions:

Reduction in Porosity and Permeability: Primary intergranular porosity was moderately reduced and modified by the effects of mechanical compaction and by precipitation of minor to possibly moderate volumes of cement. Minor volumes of incipient authigenic quartz characterize these oil sand intervals. Authigenic quartz cement is poorly developed and was likely inhibited by:

- High lithic content.
- In some samples by the emplacement of calcite and dolomite cement.
- The migration of oil into the section.

We consider the dissolution of precursor carbonate cements had at least a slight enhancing effect on reservoir quality. Precipitation of minor amounts of authigenic pyrite, trace to minor amounts of siderite, up to moderate volumes of calcite and ankerite cements (assumed) and at least minor amounts of pore filling kaolinite had a slight to moderate negative effect on effective porosity and permeability. Smectite rich clay rims minimally reduce porosity; however, may slightly to moderately affect permeability. Minor to probable moderate secondary macroporosity, formed by the dissolution of unstable clasts and feldspars, slightly to moderately enhanced reservoir permeability.

Microporosity Effects: Microporosity in these rocks occurs in detrital clays, in highly scattered authigenic kaolinite clays, in loosely packed silicate and other fines, and within the fabrics of variably leached chert, feldspar, volcanic rock fragments, and other lithic grains. These moderate -

good reservoir quality to excellent reservoir quality oil sand sandstones have a low microporosity component (about 16%: GR-002 to 19%: GR-001 in 102/11-08-095-06W4/00 samples GR-001 and GR-002).

Consider the volume of microporosity when evaluating reservoir quality and reserves by logs alone in clay rich zones identified by sample evaluation. Expect sections with high microporosity to show fair to good total porosity, significant neutron-density log separation, and low permeability. The microporosity component generally can be expected to be partly to completely saturated with water. If the water saturation values exceed the approximate microporosity component, expect some water production with hydrocarbon. If the microporosity component is undersaturated in water expect the sandstones to be somewhat susceptible to aqueous phase trapping. Severity of aqueous phase trapping is controlled by four major parameters:

- Difference between initial water saturation and the irreducible water saturation.
- Configuration of the oil or gas phase relative permeability curves.
- Physical depth of invasion.
- Available reservoir pressure to mobilize the entrapped reservoir fluids.

Aqueous phase loading, a transient and non-permanent variant of aqueous phase trapping, can also cause substantial short to medium term reductions in oil or gas production rates.

In general, in systems containing large open pores such as the analyzed 06-05-095-06W4 and 102/11-08-095-06W4/00 McMurray Formation intervals, the physical diameter of the pores is sufficient that very low capillary pressures are obtained, and permanent aqueous phase trapping is not a significant concern.

Consider the following to remove an existing phase trap:

- Increase capillary pressure, by increasing drawdown pressure for example, to reduce residual water or oil saturation.

- Reduce apparent interfacial tension between water and oil or water and gas phases, by using additives such as chemical surfactants, mutual solvents, or liquid carbon dioxide, to reduce resulting capillary pressure and hence generate lower irreducible water saturation at given reservoir pressure drawdown.

- Change the physical geometry of the pore system, by using an acid treatment for example, to increase the radius of curvature of phases present in porous media and thereby reduce the capillary pressure and allow production of trapped phases.

- Physically remove the trapped water saturation through evaporation or heat treatment techniques.

Sections characterized by high volumes of microporosity could also be susceptible to deep filtrate invasion and possible water block.

Migration of fines: Poorly consolidated to unconsolidated reservoir quality 06-05-095-06W4 and 102/11-08-095-06W4/00 sandstone samples represent heavy oil sand reservoirs that contain moderate volumes of potentially mobile combined kaolinite clay and silicate fines. Kaolinite clay crystals and silicate fines (including silt grains and fragments of chert and feldspar) that are poorly attached to pore walls and loosely packed into pores are considered susceptible to velocity induced migration.

Minor (0.7% by modal analysis) volumes of kaolinite were identified in 102/11-08-095-06W4/00 samples GR-001 and GR-002. Although the kaolinite clay crystals and aggregates are considered susceptible to velocity induced migration, it is highly unlikely that simple kaolinite fines migration alone would have an important impact on productivity in the better reservoir quality intervals.

We expect a slight to moderate permeability reduction caused by migration of all forms of silicate fines in the mid fine grained, clay poor, moderate - good to excellent reservoir quality sandstones with enlarged pores and pore throats.

Expect a moderate permeability reduction caused by migration of all forms of silicate fines in more clay rich, low to moderate reservoir quality sandstones characterized by smaller pores and pore throats (if present).

The potential for problems involving the release and migration of fines is dependent upon:

- Wettability of the fines.
- Type, viscosity, and velocity of the fluid moving through the pore system.
- Pore geometry and pore throat diameters.
- Reservoir permeability.

Fines could be induced to migrate by physical or chemical means. Fines migration in these intervals may be induced by high fluid flow velocities or by changes in pore fluid chemistry. Avoid sudden pH or salinity shocks to the pore fluid chemistry. The potential for permeability loss caused by simple fines migration would depend on:

- The fabric, texture and pore distribution of the sandstone. Higher permeability clastics with open oversized pores and many internal flow passages, similar to the analyzed McMurray Formation intervals, are less susceptible to permeability loss caused by fines migration than lower reservoir quality sandstones with fewer open pores. In lower permeability rocks permeability can decline rapidly as pores and pore throats become occluded with transported fines.

- Type, viscosity and velocity of fluid moving through the sandstone pore system. Kaolinite clays and other silicate fines usually are encased in a water layer and most susceptible to movement in an aqueous phase. The potential for fines migration is greatest immediately after a drill stem test or after initial completion when filtrates and other aqueous fluids are expelled on initial production. The potential for fines migration increases with breakthrough of a water front at production wells. Fines migration can also occur under high hydrocarbon flow rates when the water layer is disrupted by turbulent hydrocarbon flow in pores.

- Immediately after drill stem tests when mud is allowed to crash against an unprotected formation sand.

Kaolinite clay and other silicate fines migration may be prevented by carefully controlling filtrate production rates after well completion and by controlling subsequent hydrocarbon and water production rates. Fines migration may be expected after a steam flood or passage of water through the reservoir. Assuming that the fines are in a water wet state, fines migration may occur at steam or water injection wells and subsequently be transported away from the well-bore into the bulk volume of the reservoir. There should be little reduction of permeability in injection wells caused by simple fines migration. However, at production wells, fines material is transported from the reservoir into the area around the well-bore and, in the lower reservoir quality sandstones, may cause variable slight to moderate permeability reduction and slight to moderate reduction in productivity. Fines migration would probably be initiated with breakthrough of a water front and should be manifest as a drop in total fluid production.

Clay stabilizing agents are generally not effective in preventing fines release and migration; therefore, injection and withdrawal rates of water based completion fluids will be required to minimize the potential for problems involving fines release and migration. If fines migration is noted in wells producing only heavy oil, oil production rates may have to be regulated. The critical velocity at which fines will migrate may be determined by dynamic core displacement tests.

Note: Fines migration tests conducted on native state 06-05-095-06W40 samples resulted in a 63% to 66% permeability reduction (personal communication of Weatherford Results). Moderate - good reservoir quality to excellent reservoir quality samples submitted for this study represent cleaned samples. We observed increased clay content (1.3% to 2.6%) in the Post Test Production Side bulk XRD fraction and local porosity blockage by migrated fines in the Post Test Production Side SEM sample (06-05-095-06W4 sample GR-003).

Water sensitivity: X-ray diffraction analysis, conducted on all samples, shows clays consist of dominant to common kaolinite, moderate illite and minor to moderate volumes of chlorite and smectite. SEM analysis, conducted on 06-05-095-06W4 samples GR-001 to GR-003, show smectite occurs as a grain rimming phase. Distinct authigenic pore filling kaolinite, identified during point count and SEM analysis, was shown to be loosely attached to pore walls. Grain rimming clays observed during thin section analysis consist of smectite rendering this zone at least slightly sensitive to clay expansion concerns. Local formation of illite and / or chlorite clay rims may also occur. Wispy illite and chlorite clay was observed in the SEM samples. The sandstones are slightly to moderately sensitive to clay sloughing and migration in water of different chemistry than formation brine.

Log Effects: Pyrite occurs in trace to minor volumes in the analyzed McMurray Formation sandstone intervals. In all analyzed samples, pyrite forms less than 2% of the intervals as detected by bulk XRD analysis or point count analysis. We do not expect pyrite - log effects in these zones.

Zones that contain greater than 2% pyrite may experience pyrite – log effects. In general, pyrite lowers resistivity log readings. Pyrite also increases the density and lowers the apparent porosity as calculated by density logs. As the volume of pyrite in a sandstone increases, logs may show prospective rock as dense and wet. Logs that show porosity and somewhat lower resistivity than required for gas production could be reflecting pyrite and not water.

Trace to minor amounts of siderite, calcite and / or magnesian calcite and ankerite characterize the analyzed McMurray intervals suggesting porosity logs will not be affected by mineralogy. If greater volumes of siderite and ankerite are present in the zone, density and resistivity logs may be slightly affected. Dolomite and siderite increase density log readings and lower apparent porosity on sandstone scale porosity logs.

This zone contains minor to moderate feldspar; therefore, we expect variable slight feldspar - log effects.

HCl Acid Sensitivity: These zones contain small amounts of carbonate cements and minor chlorite. Consider these heavy oil reservoir sandstones highly sensitive to HCl acid in terms of potential to form sludge or emulsion caused by adverse reaction between the acid and the oil. Petrology shows that HCl acid would have no beneficial effect on the formation components themselves. HCl would not, in normal situations, be used in oil bearing sections. Siderite and chlorite can react adversely with untreated HCL acid to precipitate gelatinous ferric hydroxide that may reduce near-well-bore permeability. We consider the 06-05-095-06W4 and 102/11-08-095-06W4/00 intervals to have very slight potential to form iron hydroxide gels.

HCl-HF Acid Sensitivity: The sandstones contain minor to moderate amounts of combined potassium and sodium feldspars and up to minor volumes of calcite, siderite and ankerite. The occurrence of these minerals suggests that HCl-HF acid should not be used as a damage removal chemical. The HF acid phase can react with iron or calcium released by the dissolution of carbonates to form insoluble fluoride precipitates and with potassium and sodium released by the dissolution of feldspars to form permeability reducing fluosilicates.

Again, the presence of siderite and very minor volumes of chlorite suggest very slight potential for the formation of gelatinous ferric hydroxide upon contact HCl and / or HCL-HF acid.

Only a trace volume of distinctive residual bitumen or hydrocarbon, that stains microporous clays and grains and occurs as flakes on grain surfaces, was observed in the analyzed 06-05-095-06W4 and 102/11-08-095-06W4/00 McMurray Formation samples. However, these rocks are oil sand intervals and are therefore considered extremely sensitive to HCl and HCl-HF acid and alcoholic fluids in terms of the potential to form sludge or emulsion, caused by the adverse reaction between acid/alcoholic fluids and bitumen/oil.

If acid is required as a perforation wash or to remove down hole scale, ensure the acid system has enhanced fluid loss control properties, offers superior fines removal, and is compatible with the formation, bitumen, and formation fluids. The potential for adverse reaction increases significantly if there is free iron in the system. The acid service company should conduct stringent compatibility tests to design the proper mixture of demulsifier, iron sequestrant, oxygen scavenger, corrosion inhibitor, and acid. An acid compatibility test should incorporate the following:

- Sample of proposed acid mixture, including all additives.

- Sample of formation oil.
- Formation rock samples (core or cuttings).
- Iron filings to simulate iron in tubular equipment.

The acid-rock-oil mixture should be blended at formation temperature. The test should be run to acid neutralization. At the conclusion of the acid compatibility test no sludge can be tolerated, and any emulsion that forms must break within 30 minutes.

Sand Production: The reservoir quality core samples recovered from the 06-05-095-06W4 and 102/11-08-095-06W4/00 wells represent unconsolidated to poorly consolidated, mid fine grained heavy oil sandstone. In friable oil sands there is high potential for problems involving sand migration and production.

In poorly consolidated sediment, the potential for sand production into the well-bore depends upon:

- The degree of induration, grain size and sorting of the sediment.
- Type and amount of fines,
- Completion and production procedures.

One of the main causes of sand production into a well-bore is the drag forces between sand grains and moving hydrocarbons. Drag forces are increased by an increase in flow rate and by an increase in fluid viscosity. A reduction in the drag forces will significantly reduce the potential for problems involving sand migration and production.

Drag forces can be reduced by decreasing production rates (not usually the optimum solution) or by increasing overall flow area. Overall flow area may be increased by:

- Providing clean, large perforations through the producing section.
- Increasing perforation density.
- Increasing length of perforated section.
- Creating a conductive path some distance into the reservoir by means of packed fracture.

Good completion practices, use of clean fluids and careful selection of perforating charges and conditions may reduce the potential for sand migration and production.

Wettability may also affect the potential for release and migration of sand into the well-bore. If sand grains and other fines move preferentially in a water phase, problems involving sand production may be expected at production wells with a passage of a steam front or hot water phase.

We expect sand and fines migration and production, particularly in the higher permeability, less consolidated sand sections. In more argillaceous sections, if present in the area, we expect some clay and fines migration along with the sand.

Screens, gravel packs or slotted liners may be required to control sand production in wells drilled to these horizons. Alternatively, the operator may elect to pump both sand and oil and use surface facilities to remove sand.

Scale Formation: Precipitation of solid materials, which may form scales, occurs if there is a change in physical conditions (pressure and/or temperature), or if the water becomes supersaturated with respect to the scale-forming material. Solid precipitates may either remain in suspension in the water or may form a scale on a surface such as a pipe wall. Formation plugging may result from filtration of suspended particles from the water, and solid scale may block pore throats. Generally, with production of water, the presence of carbonate minerals (ferroan and non-ferroan carbonates) suggests potential for carbonate scale formation at perforations, in tubing, and in surface equipment.

These sandstones contain minor amounts of iron rich siderite cement, minor calcite and minor volumes of ankerite. Petrology suggests that formation of carbonate, iron carbonate and / or iron scales may be encountered if water is produced from the reservoir. Steam or water passing through these intervals may become enriched in iron and carbonate ions and the formation of carbonate, iron carbonate and / or iron scales may occur at production wells with water breakthrough. Comprehensive water analysis is required to determine scaling potential and suitable scale inhibitor treatment.

Thermal Conversion of Minerals: There is at least moderate potential for problems involving thermal conversion of minerals if McMurray Formation intervals, characterized by common quartz, minor to moderate feldspar, at least minor volumes of kaolinite, minor smectite and at least minor volumes of carbonate, undergo a thermal EOR recovery project. Some of the expected or possible mineralogical reactions that may occur under the elevated temperatures of a steam flood are:

- Dissolution and precipitation of silica resulting in a reduction of formation porosity and permeability. The rate of these processes is controlled in part by pH, temperature and the presence or absence of bitumen, with nucleation and reprecipitation of silica enhanced at elevated temperatures. Chert rich zones are expected to have greater potential for silica dissolution and reprecipitation compared to chert poor zones. The analyzed sandstones contain minor to moderate volumes of chert.

- The formation of smectite (montmorillonite) where various mineralogic mixtures of clays (kaolinite), quartz, feldspar and/or carbonates are reacted with water at temperatures above 200^{o}C. The minerals necessary for the thermal conversion of kaolinite to smectite occur in sufficient abundance in the analyzed McMurray Formation intervals to suggest potential for at least minor smectite formation and possible moderate resultant permeability reduction.

Other mineralogic changes that may occur at relatively low to high temperatures include:

- Decomposition of siderite at 400^{o}C to 550^{o}C (not expected to cause problems).
- Decomposition of pyrite at 350^{o}C to 450^{o}C (not expected to cause problems).
- Irreversible collapse at smectite at 300^{o}C to 700^{o}C (not expected to cause problems).
- Dehydroxilation of smectite at 500^{o}C to 750^{o}C (not expected to cause problems).
- Irreversible collapse of degraded illite at 250^{o}C to 300^{o}C (unlikely to cause production problems).

GR Petrology has conducted petrographic analyses on a number of samples recovered from oil sand cores subjected to experimental steam displacement tests. In addition to the above mineralogic transformations, other physical transformations that would appear to occur in steam displaced cores include:

- Mobilization of bitumen, and movement of a mixture of clay, hydrocarbon and fines through the rock pore system. We expect at least moderate fines mobilization in similar poorly consolidated heavy oil sand reservoir sections.
- Fracturing of quartz grains.
- Reduction of porosity caused by blockage of pores by transported clay. Not expected to cause significant production decline in the better reservoir quality sands. May cause moderate reduction in production lower permeability zones or in in clay rich zones (if present).
- Incipient transformation of kaolinite to smectite (at least slight potential in these sands).
- Formation of acicular silica precipitates (probably will occur but should not cause noticeable production loss.

Field Operations

The analyzed McMurray Formation intervals represent moderate - good reservoir quality to excellent reservoir quality oil bearing zones considered capable of average good or better oil production. Fracture stimulation may be employed to optimize productivity in lower reservoir quality zones (if present).

In general, when designing perforations be sure to compliment the appropriate type of completion (such as natural, stimulated, or sand control completion). A key consideration in perforation design of natural completions is the selection of overbalance versus underbalance perforating. The success of stimulated completions depends largely on how well the perforation allows delivery of treatment fluids and frac pressures into the reservoir. In perforating, care should also be taken to incorporate appropriate specifications for important geometrical factors such as shot density, perforation diameter, perforation phasing, and perforation length. Perforate underbalanced through clean, filtered reservoir oil.

Avoid the use of acid unless an acid perforation wash is necessary to establish good communication with the formation prior to fracture stimulation. These intervals would not benefit substantially from acid stimulation. **HCl-HF acid is not recommended.** HCl-HF acid exposure will result in the formation of insoluble fluoride precipitates and fluosilicate formation and possibly in the formation of gelatinous ferric hydroxide. This zone must be considered acid sensitive in terms of acid - oil incompatibility, acid - bitumen incompatibility and in terms of the potential to increase problems with fines migration. Any proposed acid blend must be tested to ensure compatibility between it, reservoir rock, reservoir oil and any other reservoir fluids. Acid should be injected at sufficient pressure to clean and break down perforations, but should not be squeezed deep into the formation. Complete the required acid perforation wash and then remove the acid prior to fracture stimulation.

In general, fracture fluid systems should be designed based on key parameters of fluid type, viscosity requirements, fluid rheology, economics of the fluid, experience with local formations, laboratory data on the formation, material availability, and fracture face damage. Ensure various fracture fluid additives and the fracture fluid base are compatible with the formation and various other fluids and additives, and that they enhance fluid loss recovery and reduce formation and formation face damage. Among other things, a successful proppant system should reduce or eliminate proppant flowback and unwanted water production, provide cohesion between the proppant grains without damaging permeability or conductivity of the proppant pack, help maintain highly conductive fractures and long term production, eliminate incompatibility issues, reduce/eliminate fines migration, and improve permeability of the proppant pack.

In low to moderate reservoir quality zones (if present in significant volumes), fracture stimulation may be required to optimize productivity. Emplacement of a packed fracture to increase effective flow radius is one of the most effective methods of preventing fines migration. Consider high grade compatible oil or clean filtered reservoir oil as the proppant carrying fluid. Oil based fluids must be tested to ensure compatibility with reservoir oil. Treated water based fluids should be an acceptable frac proppant carrying fluid if clay expansion concerns are known to be minimal.

Conventional strength proppant should be used at these depths (about 274 m to 294 m).

Thin Section Photomicrographs and
Scanning Electron Micrographs
and
Descriptions

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Scanning Electron Photomicrographs and Descriptions - Plate 1
06-05-095-06W4
McMurray Formation
Quartz Rich Sandstone
C.A. Porosity: 29.9% Permeability: 5602 mD
TS Effective Porosity: n/a

Sample No. GR-001: Pre Test End Trim #4; 289.87 m

A-D Overview A shows good relief suggesting good effective porosity, good total porosity and good permeability in this poorly consolidated, moderately to poorly sorted, coarse silt size to coarse sand size quartz rich sandstone. Core analysis total porosity and permeability values are respectively 29.9% and 5602 mD. We expect dominant monocrystalline quartz typifies the framework. View B shows assumed monocrystalline quartz: MQ grains lack quartz overgrowth cement, well connected intergranular porosity: ϕin and loosely attached silica and silicate fines: SF in the pore system. Images C and D provide a closer view of pores that are locally clay blocked: MTX and loosely attached fines that likely represent a leached grain: LG. Bulk XRD analysis detected 95.4% quartz, 1.5% potassium feldspar, 0.5% plagioclase feldspar, 0.4% pyrite, 0.3% calcite, 0.3% siderite, 0.3% ankerite and 1.3% total clay minerals consisting of 0.9% kaolinite, 0.4% illite, trace chlorite and the presence of smectite in pre test sample GR-001.

Photo A x50; Photo B x150; Photo C x350; Photo D x500

06-05-095-06W4 GR-001: Pre Test 289.87m

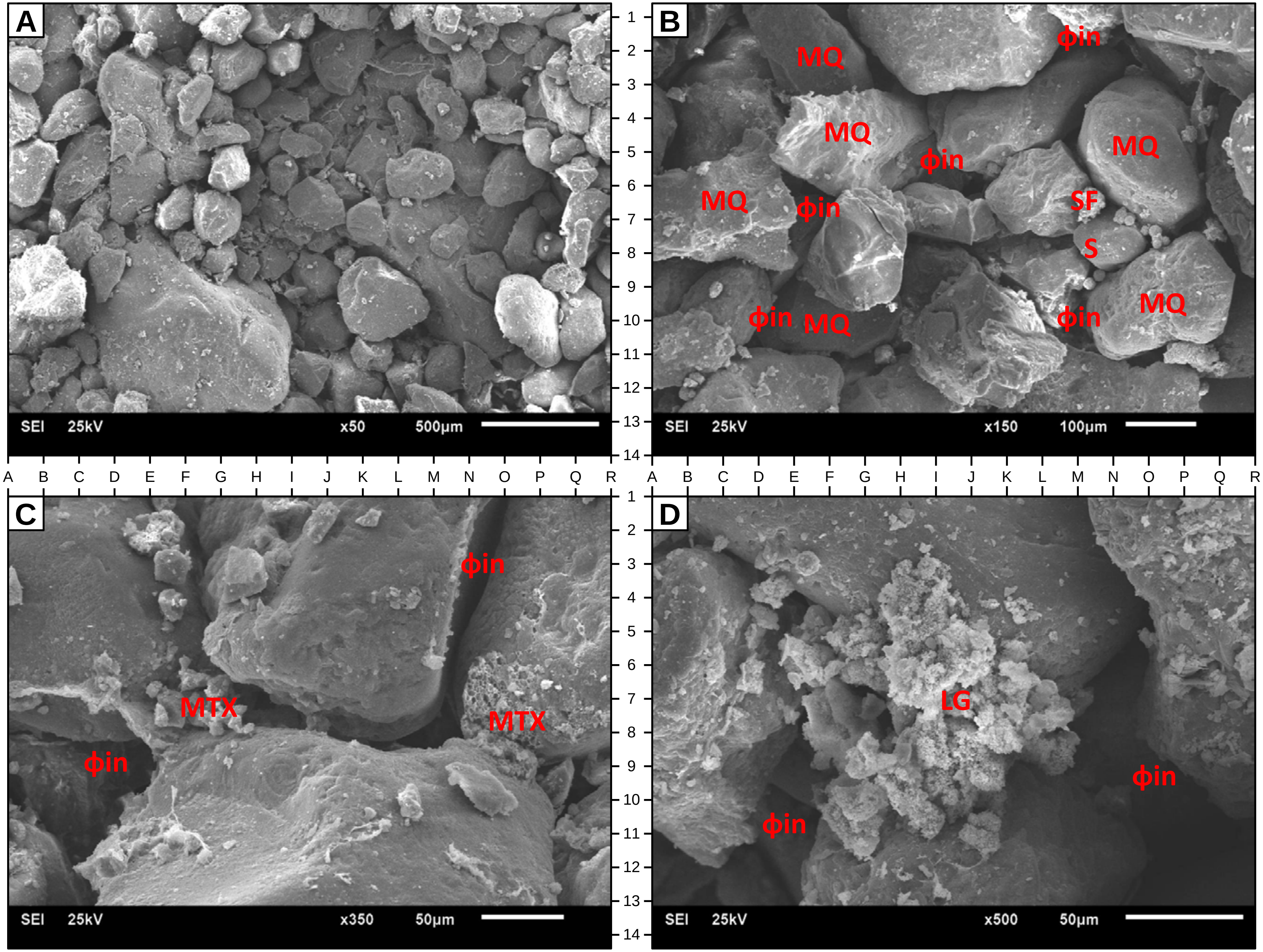

Plate 01
GR 21175 2014

McMurray Formation

GR Petrology CONSULTANTS Inc.

Scanning Electron Photomicrographs and Descriptions - Plate 2
06-05-095-06W4
McMurray Formation
Quartz Rich Sandstone
C.A. Porosity: 29.9% Permeability: 5602 mD
TS Effective Porosity: n/a

Sample No. GR-001: Pre Test End Trim #4; 289.87 m

A-D Views A and B illustrate pore filling and replacive pyrite: PY and well formed pyrite framboids and crystals that loosely infill porosity: ϕin. Pyrite is irregularly emplaced in porosity as indicated by very minor volumes of pyrite detected in the XRD bulk fraction. Other features shown on these SEM views include:

- Moderately well formed authigenic kaolinite emplaced in porosity: KA,
- Slightly less well formed kaolinite that may represent recrystallized detrital clays: RKA,
- Silicate fines: SF,
- Wispy illite and chlorite clays: IL-CH,
- Grain coating and flaky bitumen: BIT,
- Preserved intergranular porosity: ϕin.

Glycolated clay X-ray diffraction analysis shows the clay suite consists of 65.0% kaolinite, 19.1% illite, 4.2% chlorite and 11.7% smectite. Smectite is calculated to comprise 0.15% of the bulk sample.

Photo A x500; Photo B x750; Photos C - D x1000

06-05-095-06W4 **GR-001: Pre Test** **289.87m**

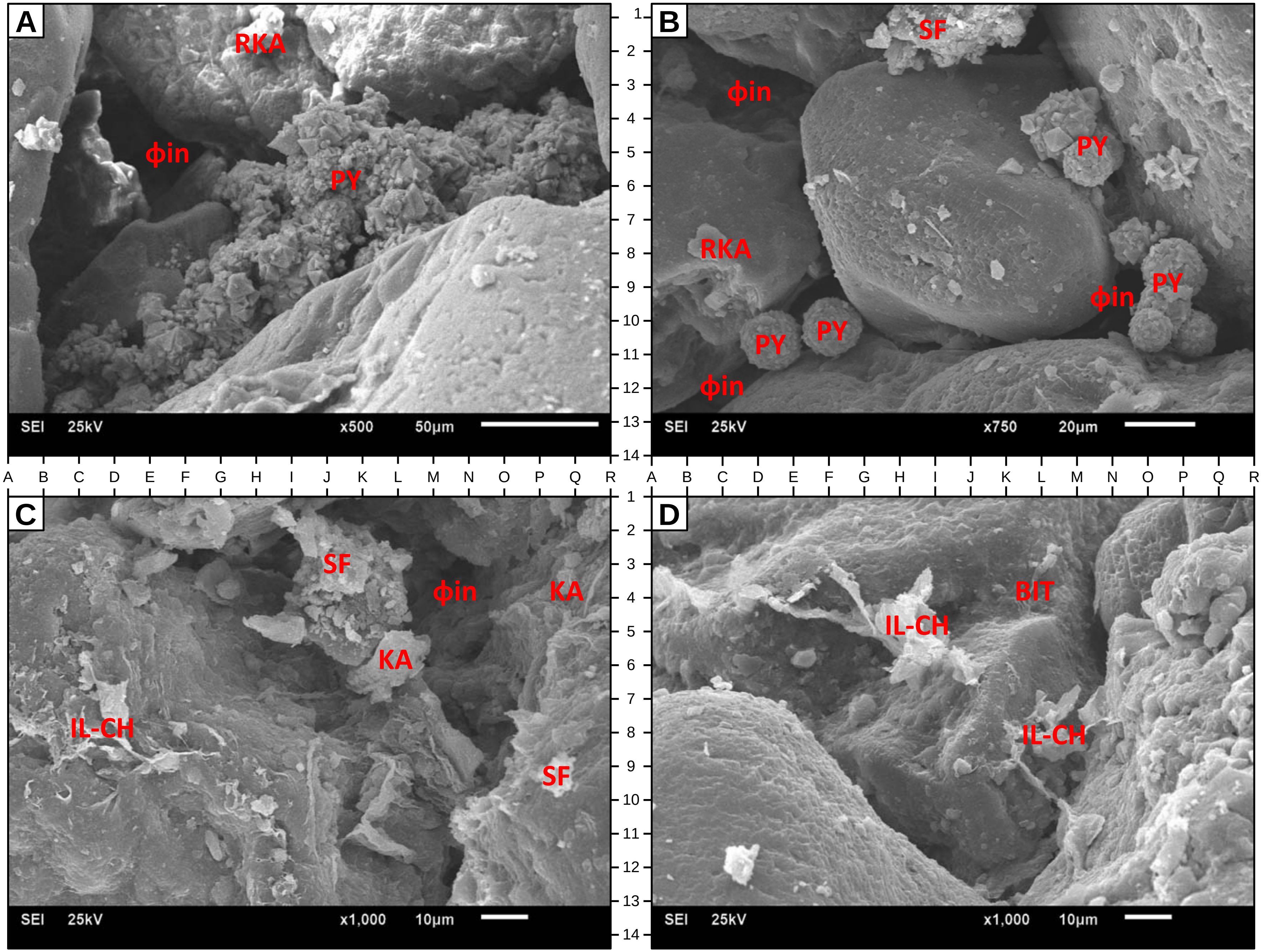

Plate 02
GR 21175 2014

McMurray Formation

GR Petrology Consultants Inc.

Scanning Electron Photomicrographs and Descriptions - Plate 3
06-05-095-06W4
McMurray Formation
Quartz Rich Sandstone
C.A. Porosity: 29.9% Permeability: 5602 mD
TS Effective Porosity: n/a

Sample No. GR-001: Pre Test End Trim #4; 289.87 m

A-D Features detailed on these SEM views include:

- Well formed authigenic kaolinite emplaced in porosity: KA,
- Moderately formed probable recrystallized detrital kaolinite: RKA,
- Mat of illite and chlorite: IL-CH, View D,
- Grain coating smectite rich clays with honeycomb texture: SM,
- Grain coating and clay coating bitumen: BIT,
- Probable mixed micas and titanium oxide: MI-TO,
- Well connected and expanded intergranular porosity: ϕin.

Note microporosity preserved within clay fabrics and within leached grains.

Photos A - B x1200; Photo C x1500; Photo D x2500

06-05-095-06W4 **GR-001: Pre Test** **289.87m**

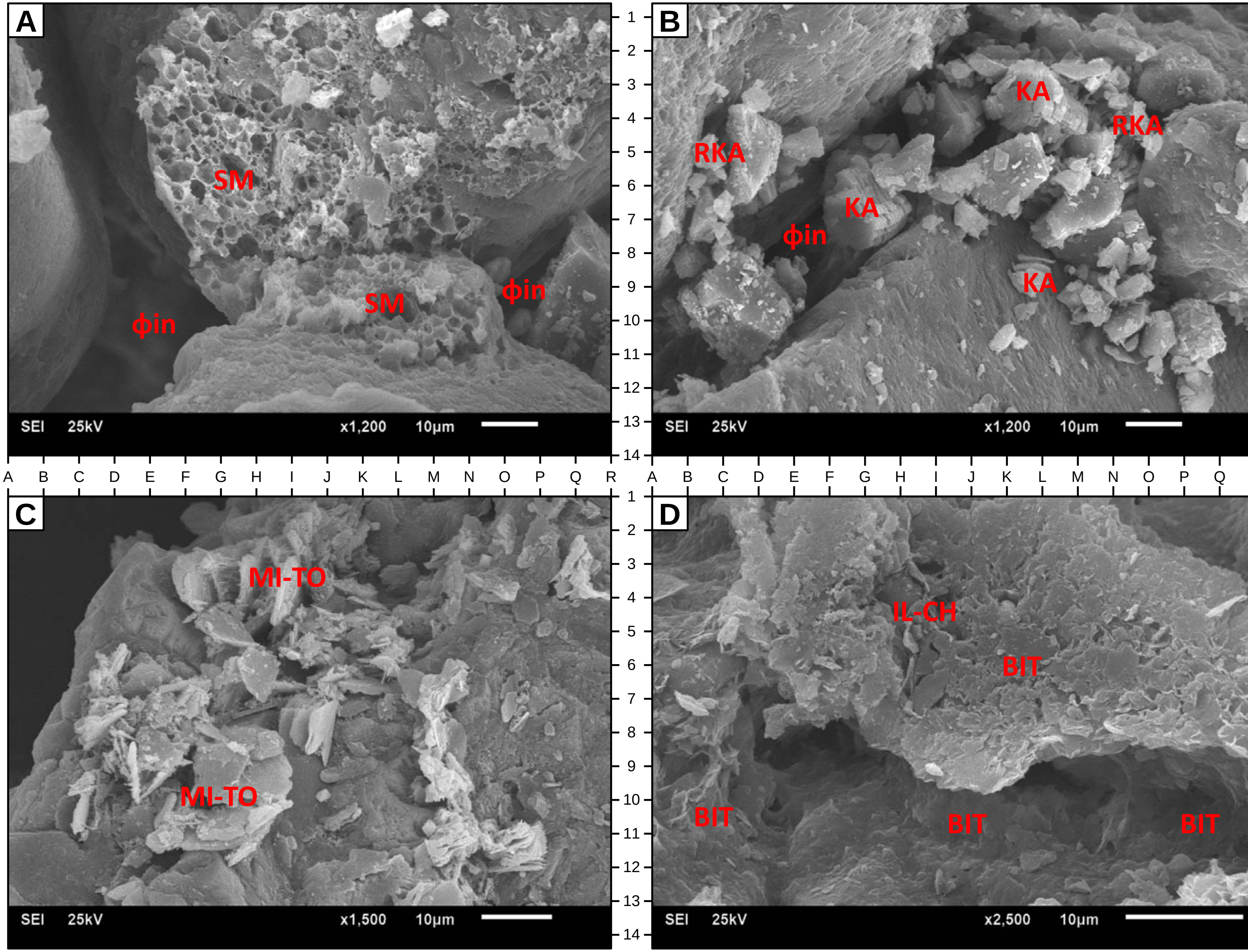

Plate 03 **McMurray Formation**

GR 21175 2014

GR Petrology CONSULTANTS Inc.

Scanning Electron Photomicrographs and Descriptions - Plate 4
06-05-095-06W4
McMurray Formation
Quartz Rich Sandstone
C.A. Porosity: 29.9% Permeability: 5602 mD
TS Effective Porosity: n/a

Sample No. GR-002: Post Test Plug #4 Injection Side

A-D Views A and B show very good relief suggesting good effective porosity, well connected intergranular porosity: ϕin, Views C-D, good total porosity and good permeability in this unconsolidated, moderately to poorly sorted, coarse silt size to coarse sand size quartz rich sandstone. Views C and D illustrate leached grains including chert: CT and possibly clay clasts. Note View D provides a close up of the grain shown at N-10 in View C. EDS analysis of these grains indicates the presence of silica and clays including illite and chlorite. A probable leached feldspar or feldspathic rock fragment: FD is shown in View C. Thin section analysis is required to definitively determine grain types. 95.9% quartz, 1.3% potassium feldspar, 0.6% plagioclase feldspar, 0.2% pyrite, 0.2% calcite, 0.3% siderite, 0.3% ankerite and 1.3% total clay minerals consisting of 0.9% kaolinite, 0.4% illite, trace chlorite and the presence of smectite in post test sample GR-002. Reported core analysis porosity and permeability values represent the clean pre test plug.

Photo A x50; Photo B x150; Photo C x350; Photo D x1200

06-05-095-06W4 **GR-002: Post Test Injection Side** **289.87m**

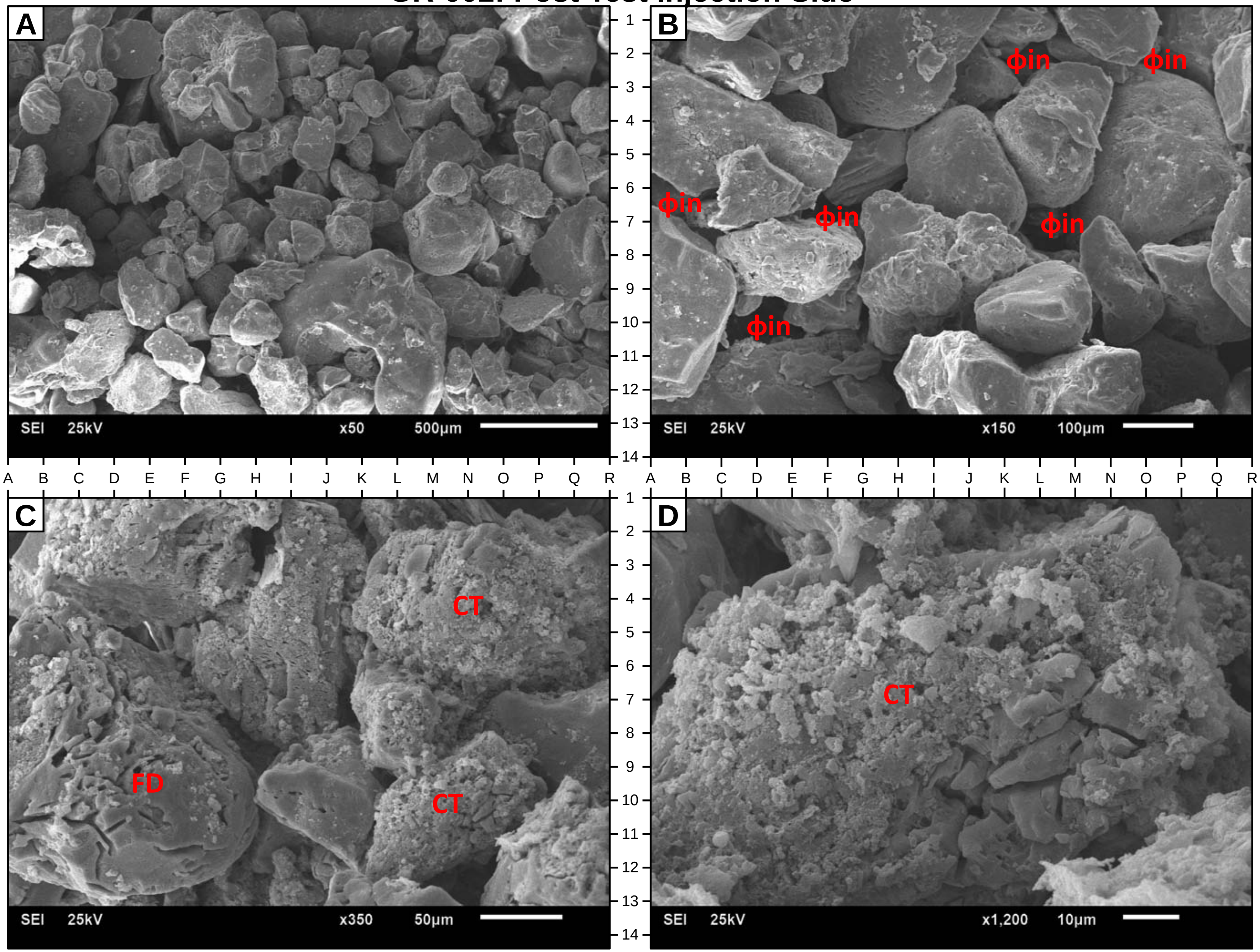

Plate 04 **McMurray Formation**

GR 21175 2014

GR Petrology CONSULTANTS Inc.

Scanning Electron Photomicrographs and Descriptions - Plate 5
06-05-095-06W4
McMurray Formation
Quartz Rich Sandstone
C.A. Porosity: 29.9% Permeability: 5602 mD
TS Effective Porosity: n/a

Sample No. GR-002: Post Test Plug #4 Injection Side

A-D This higher magnification SEM Plate illustrates:

- Well connected effective intergranular porosity: ϕin,
- Probable leached chert: CT,
- Silica and silicate fines: SF,
- Patchy grain rimming clay: GRC,
- Leached potassium feldspar: FD, View C,
- Bitumen flake: BIT, View D.

58.5% kaolinite, 26.2% illite, 10.9% chlorite and 4.4% smectite were detected in the glycolated clay fraction of post test sample GR-002. Smectite is calculated to comprise 0.06% of the bulk sample.

Photo A x350; Photo B x750; Photo C x1000; Photo D x1500

GR Petrology CONSULTANTS Inc.

06-05-095-06W4 **GR-002: Post Test Injection Side** **289.87m**

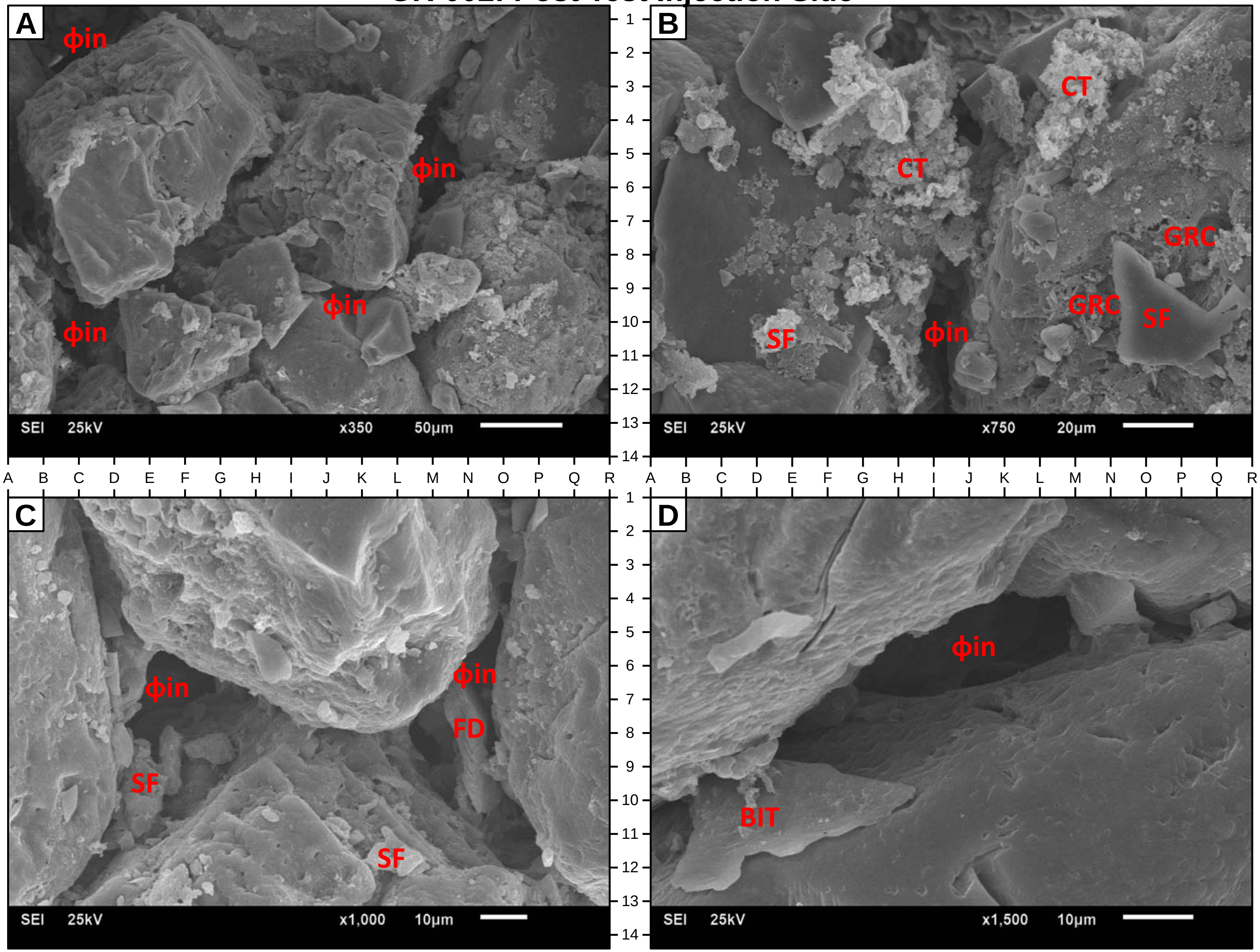

Plate 05
GR 21175 2014

McMurray Formation

GR Petrology CONSULTANTS Inc.

Scanning Electron Photomicrographs and Descriptions - Plate 6
06-05-095-06W4
McMurray Formation
Quartz Rich Sandstone
C.A. Porosity: 29.9% Permeability: 5602 mD
TS Effective Porosity: n/a

Sample No. GR-002: Post Test Plug #4 Injection Side

A-D Further SEM views that show:

- Pore blocked mixed illite, chlorite and bitumen: IL-CH & BIT,
- Iron oxide and admixed clay: IO, View B,
- Mixture of illite, chlorite and smectite clays that locally block pores: MTX,
- Leached quartz rich grain: LG, View B,
- Loosely attached silicate fines: SF,
- Incipient quartz overgrowths: AQ,
- Intergranular porosity: ϕin.

Note microporosity preserved within clay fabrics and within leached grains.

Photo A x1500; Photo B x2000; Photo C x3500; Photo D x5000

06-05-095-06W4 **GR-002: Post Test Injection Side** **289.87m**

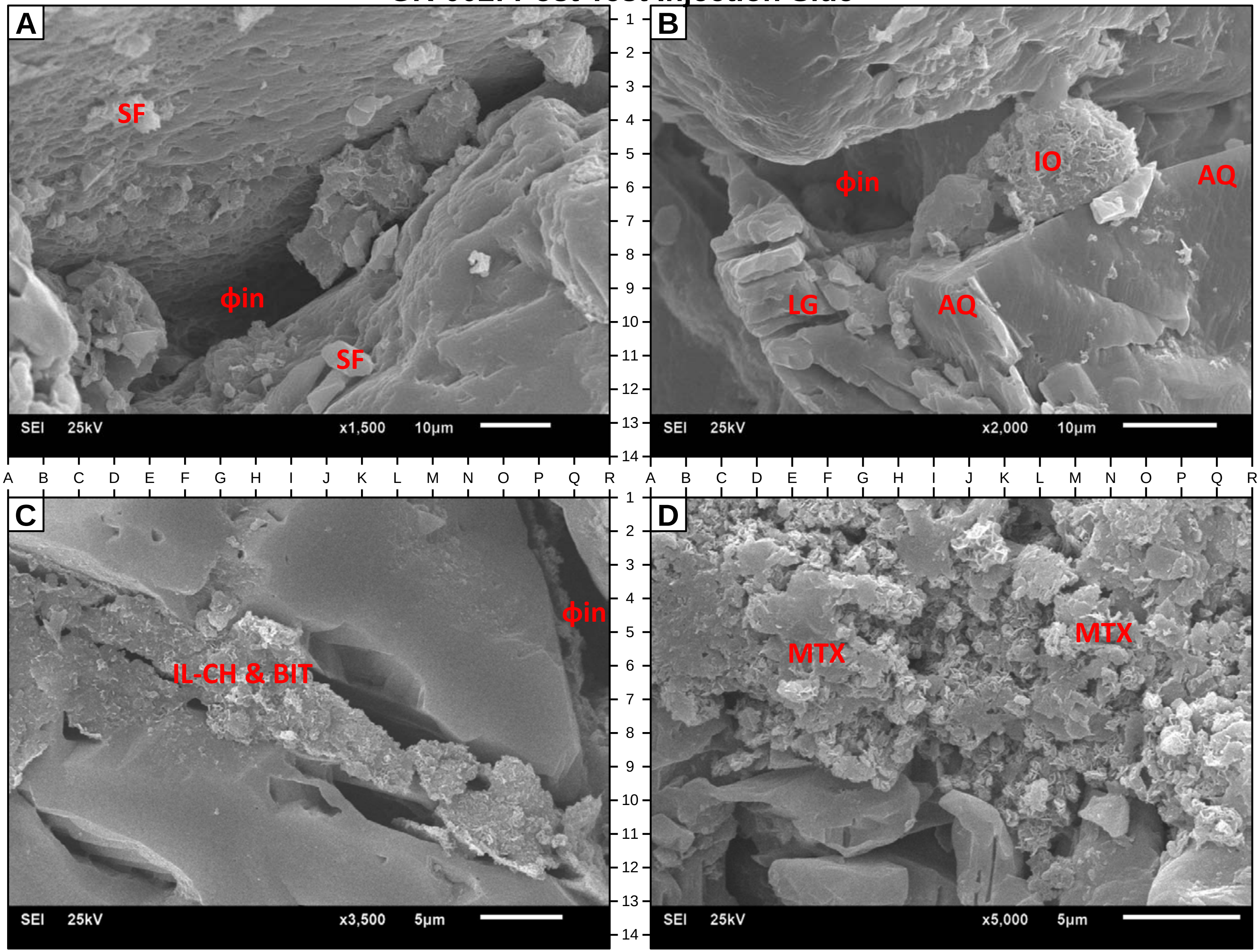

Plate 06 **McMurray Formation**

GR 21175 2014

GR Petrology CONSULTANTS Inc.

Scanning Electron Photomicrographs and Descriptions - Plate 7
06-05-095-06W4
McMurray Formation
Quartz Rich Sandstone
C.A. Porosity: 29.9% Permeability: 5602 mD
TS Effective Porosity: n/a

Sample No. GR-003: Post Test Plug #4 Production Side

A-D Very good relief indicates good effective porosity and probable good total porosity and permeability in this unconsolidated, moderately to poorly sorted, coarse silt size to coarse sand size quartz rich sandstone. Views B and C show clays: MTX locally block intergranular porosity: ϕin in the post test production sample. Thickly developed authigenic smectite rims: SM are also locally formed. The presence of smectite and locally blockage of pores in the production end may result in lower permeability compared to the pre test sample and the post test injection end sample; however, porosity and permeability values were not measured. XRD analysis suggests lower smectite volumes in the post test production end compared to the pre test and post test injection end samples. XRD analysis detected 94.6% quartz, 1.0% potassium feldspar, 0.6% plagioclase feldspar, 0.6% pyrite, 0.3% siderite, 0.3% ankerite and 2.6% total clay minerals consisting of 1.7% kaolinite, 0.9% illite, trace chlorite and the presence of smectite in post test sample GR-003. Reported core analysis porosity and permeability values represent the clean pre test plug.

Photo A x50; Photo B x150; Photo C x350; Photo D x2500

06-05-095-06W4 GR-003: Post Test Production Side 289.87m

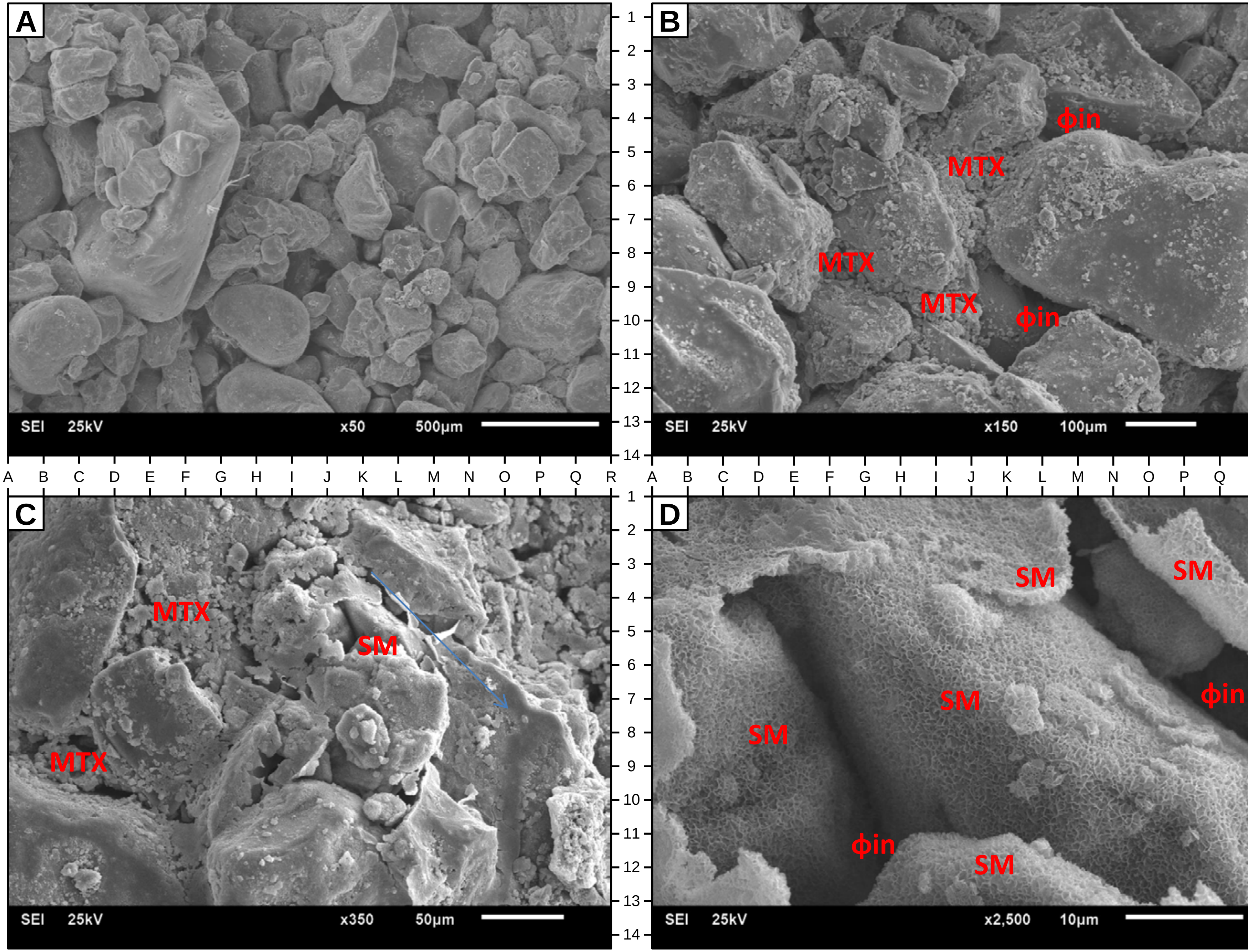

Plate 07
GR 21175 2014

McMurray Formation

GR Petrology CONSULTANTS Inc.

Scanning Electron Photomicrographs and Descriptions - Plate 8
06-05-095-06W4
McMurray Formation
Quartz Rich Sandstone
C.A. Porosity: 29.9% Permeability: 5602 mD
TS Effective Porosity: n/a

Sample No. GR-003: Post Test Plug #4 Production Side

A-D Silica fines and likely disaggregated kaolinite: SF & KA locally line pores and block pores: ϕin in the production end. View C shows partially blocked pores and a pyrite framboid: PY. Silica fines: SF, an iron rich mineral: I and a feldspar fine: FD are illustrated in View B. Note also the leached chert fragment: CT in View B. SEM analysis suggests increased fines in the post test production end. Clay volumes detected by bulk XRD analysis increased from 1.3% in both the pre test sample and post test injection end sample to 2.6% in the post test production end. Both kaolinite and illite show increasing volumes. The detected increase could suggest slightly irregular clay distribution in the areas sampled for XRD analysis and / or that some loosely attached kaolinite and illite bearing clay fines were moved to the production end of the core plug. Glycolated clay X-ray diffraction analysis shows the clay suite consists of 71.6% kaolinite, 22.8% illite, 3.8% chlorite and 1.8% smectite in post test sample GR-003. Smectite is calculated to comprise 0.05% of the bulk sample.

Photo A x350; Photos B - C x500; Photo D x1200

06-05-095-06W4 **GR-003: Post Test Production Side** **289.87m**

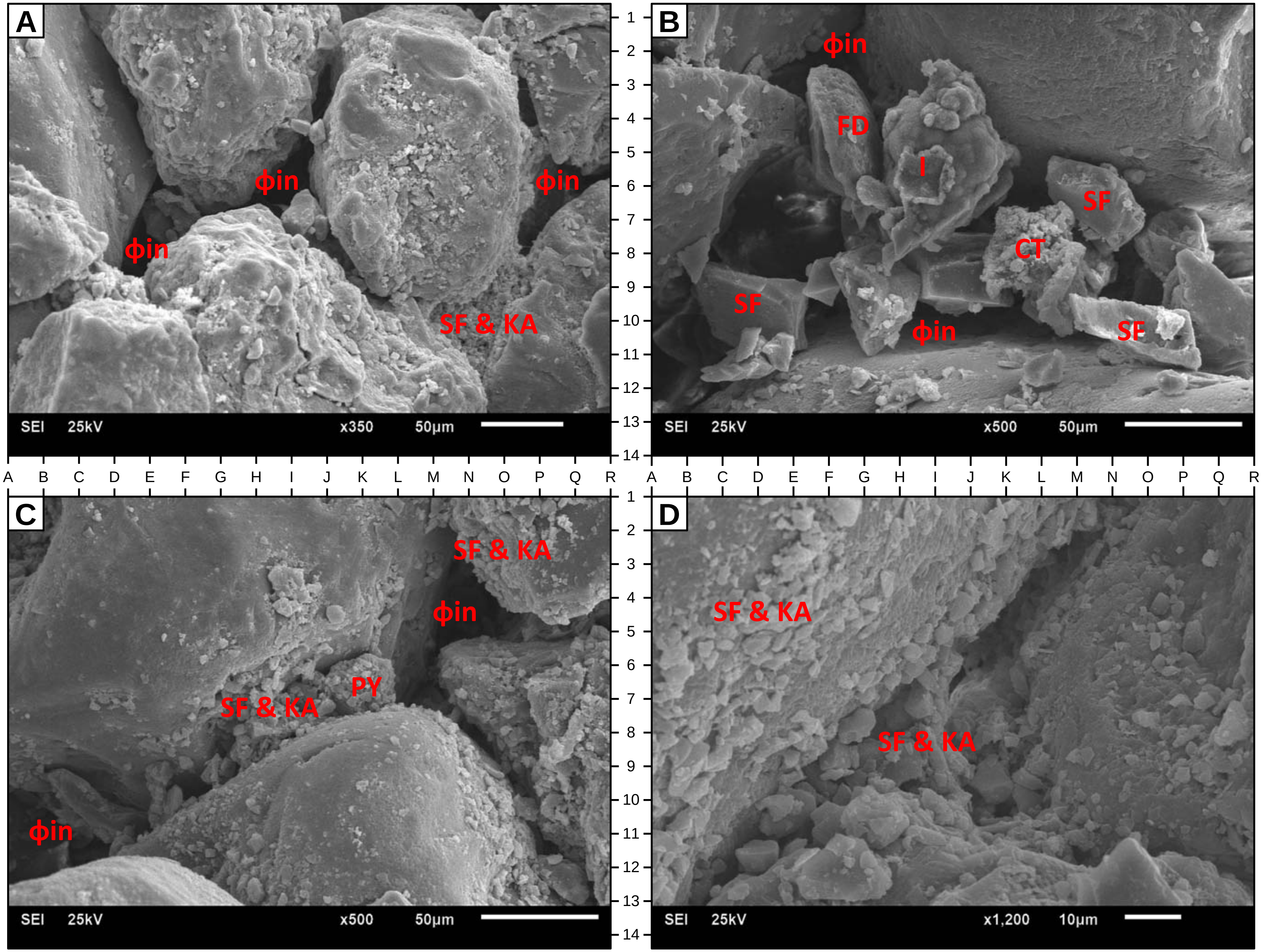

Plate 08 **McMurray Formation**

GR 21175 2014

GR Petrology CONSULTANTS Inc.

Scanning Electron Photomicrographs and Descriptions - Plate 9
06-05-095-06W4
McMurray Formation
Quartz Rich Sandstone
C.A. Porosity: 29.9% Permeability: 5602 mD
TS Effective Porosity: n/a

Sample No. GR-003: Post Test Plug #4 Production Side

A-D Additional SEM images that illustrate:

- Silica and kaolinite fines that cling to grain surfaces and locally block pores: SF & KA,
- Leached chert fragments: CT,
- Loosely attached kaolinite booklet: KA,
- Precipitate or altered mineral consisting of about 36% iron, 34% oxygen, 22% silica, 5% carbon and less than 1% each sodium, copper, aluminum, sulphur and potassium: PPT or GR.

Photo A x1500; Photos B - C x2000; Photo D x2500

06-05-095-06W4 **GR-003: Post Test Production Side** **289.87m**

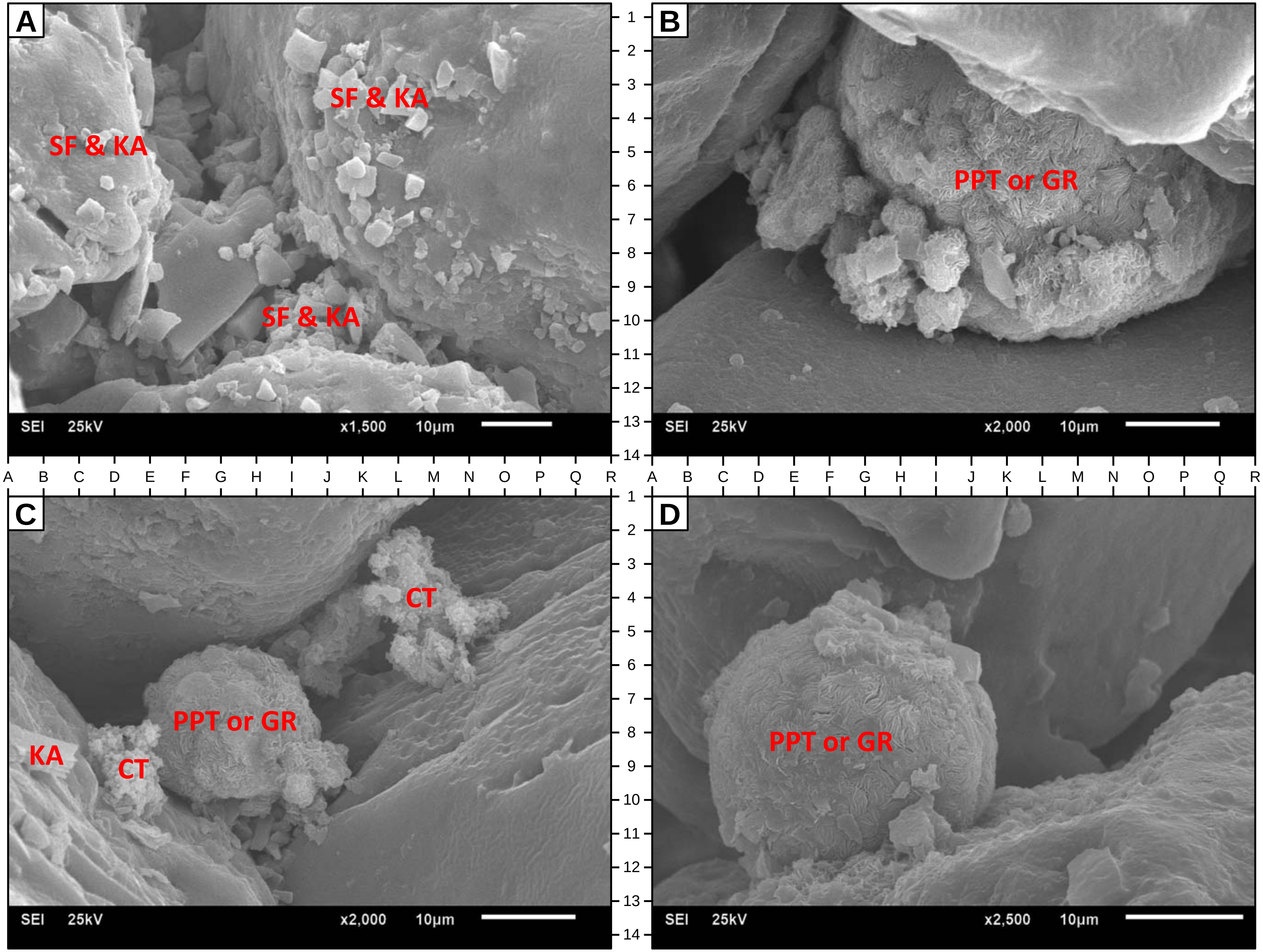

Plate 09 **McMurray Formation**

GR 21175 2014

GR Petrology CONSULTANTS Inc.

Thin Section Photomicrographs and Descriptions - Plate 10
102/11-08-095-06W4/00
McMurray Formation
Subarkose
C.A. Porosity: 32.8% Permeability: 1829 mD
TS Effective Porosity: 26.5%

Sample No. GR-001 (GR 21952 2014): SP3: 274.47 m

A-D Good effective porosity (blue, Views A-C), counted at 26.5%, typifies this laminated and / or burrowed, unconsolidated, moderately sorted, mid fine grained subarkose with 32.8% core analysis total porosity and 1829 mD permeability. All Views show well connected modified primary and lesser secondary intergranular porosity (blue) preserved between clay laminae and pods. Compacted clasts and 7.8% matrix that form discontinuous laminae: LAM and irregular pods as shown in View C. Clay matrix: MTX is locally compacted between grains as illustrated in View B. Framework components include about:

- 74% monocrystalline quartz: solid grey and white, View D; MQ,
- 4% preserved to leached feldspar: FD,
- 2% preserved to leached chert: CT,
- 5% plant debris: CD,
- Lesser polycrystalline quartz, clay clasts, plutonic rock fragments, micas and heavy minerals.

Bulk XRD analysis detected 95.7% quartz, 0.5% potassium feldspar, 0.3% plagioclase feldspar, 0.4% pyrite, 0.2% each siderite, magnesian calcite and ankerite, 0.3% anatase and 2.2% total clay minerals consisting of 1.3% kaolinite, 0.9% illite and trace chlorite.

Photo A PPL x12.5; Photo B PPL x100; Photos C+D PPL,XPL x32

102/11-08-095-06W4/00 **GR-001: SP 3** **274.47 m**

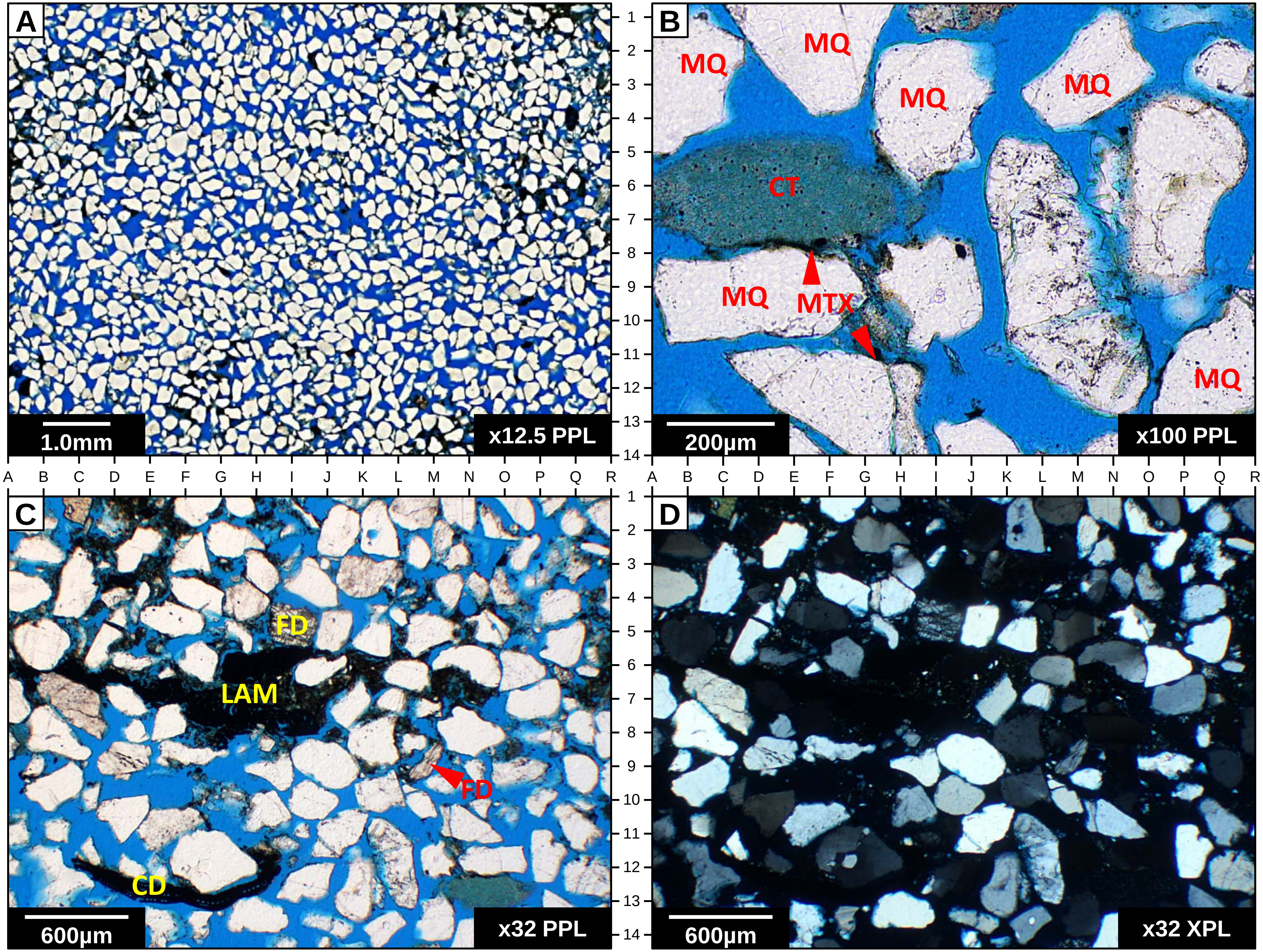

Plate 10 **McMurray Formation**

GR 21952 2014

GR Petrology CONSULTANTS Inc.

Thin Section Photomicrographs and Descriptions - Plate 11
102/11-08-095-06W4/00
McMurray Formation
Subarkose
C.A. Porosity: 32.8% Permeability: 1829 mD
TS Effective Porosity: 26.5%

Sample No. GR-001 (GR 21952 2014): SP3: 274.47 m

A-D These higher magnification Views show:

- Patchy to well connected modified primary and secondary intergranular porosity: blue,
- Range in grain size from coarse silt to upper medium sand,
- Dominant monocrystalline quartz: MQ,
- Variably well preserved to leached chert: CT,
- Preserved to leached feldspar: FD,
- Leached clay clasts: CRF,
- Slightly deformed mica: MI,
- Compacted plant fragments: CD,
- Compacted clay matrix and silt size grains that locally occlude porosity: MTX.

Glycolated clay X-ray diffraction analysis shows the clay suite consists of 59.9% kaolinite, 33.9% illite and 6.2% chlorite.

Photos A-B PPL x100; Photos C-D PPL x200

102/11-08-095-06W4/00 **GR-001: SP 3** **274.47 m**

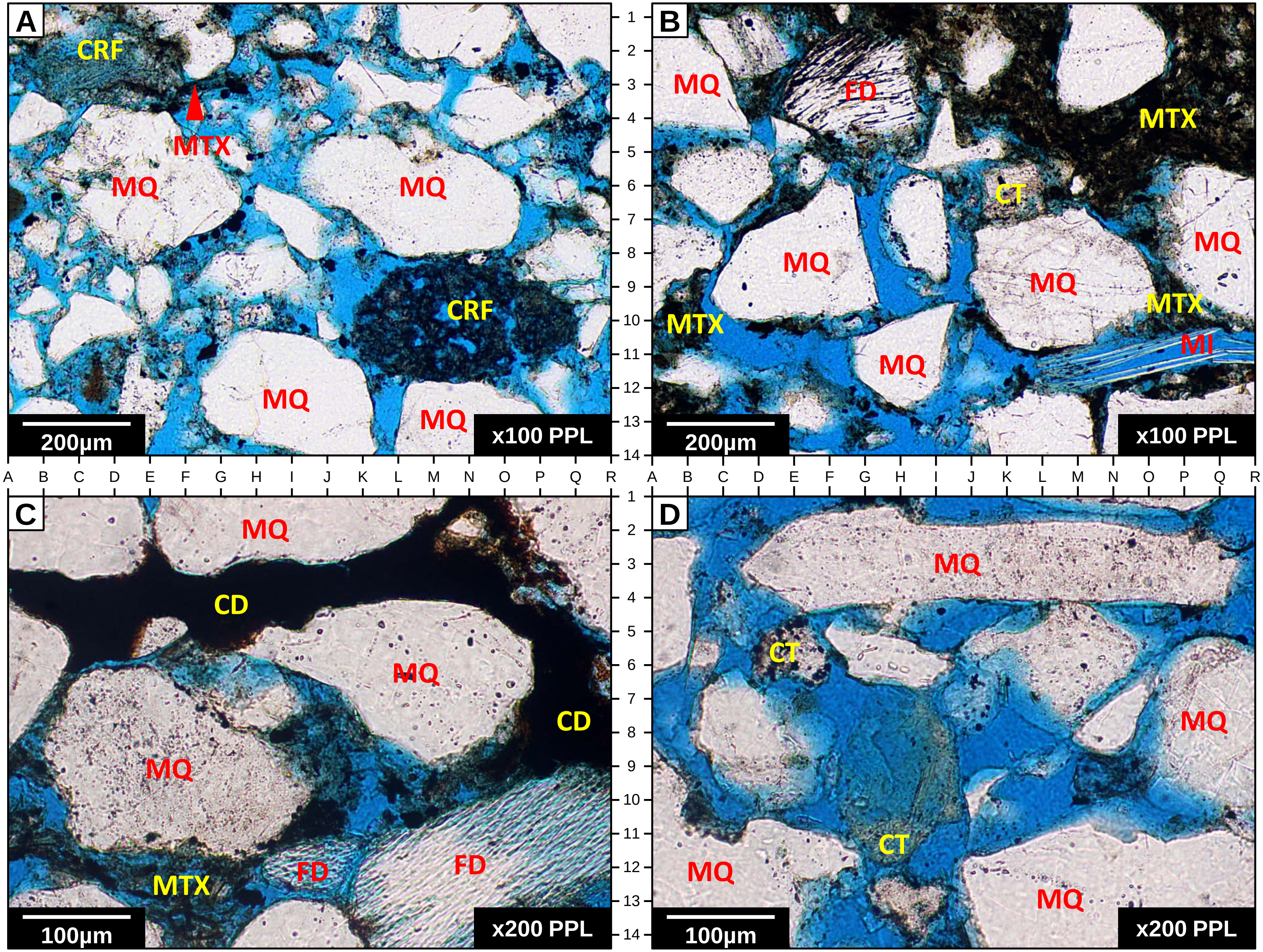

Plate 11 **McMurray Formation**

GR 21952 2014

GR Petrology CONSULTANTS Inc.

Thin Section Photomicrographs and Descriptions - Plate 12
102/11-08-095-06W4/00
McMurray Formation
Subarkose
C.A. Porosity: 35.9% Permeability: 6799 mD
TS Effective Porosity: 30.2%

Sample No. GR-002 (GR 21952 2014): SP13: 279.34 m

A-D 30.2% well connected effective intergranular porosity (blue) generates 35.9% core analysis total porosity and 6799 mD permeability in this massive to vaguely laminated, unconsolidated, moderately sorted, mid fine grained subarkose. Compaction effects, trace volumes of clay matrix and minor volumes of cement (1.0% incipient quartz overgrowths: AQ, 0.3% pyrite: PY and 0.3% clay rims) slightly reduced porosity. Framework grains include about:

- 86% monocrystalline quartz: solid grey and white, View D; MQ,
- 5% preserved to leached feldspar: FD,
- 4% preserved to leached chert: CT,
- 2% polycrystalline quartz,
- Lesser volumes of plutonic rock fragments, volcanic rock fragments, micas, plant debris and heavy minerals.

Bulk XRD analysis detected 95.9% quartz, 1.1% potassium feldspar, 0.3% plagioclase feldspar, 0.6% pyrite, 0.2% magnesian calcite, 0.2% ankerite and 1.7% total clay minerals consisting of 1.3% kaolinite, 0.4% illite, trace chlorite and the presence of smectite.

Photo A PPL x12.5; Photo B PPL x100; Photos C+D PPL,XPL x32

102/11-08-095-06W4/00 **GR-002: SP 13** **279.34 m**

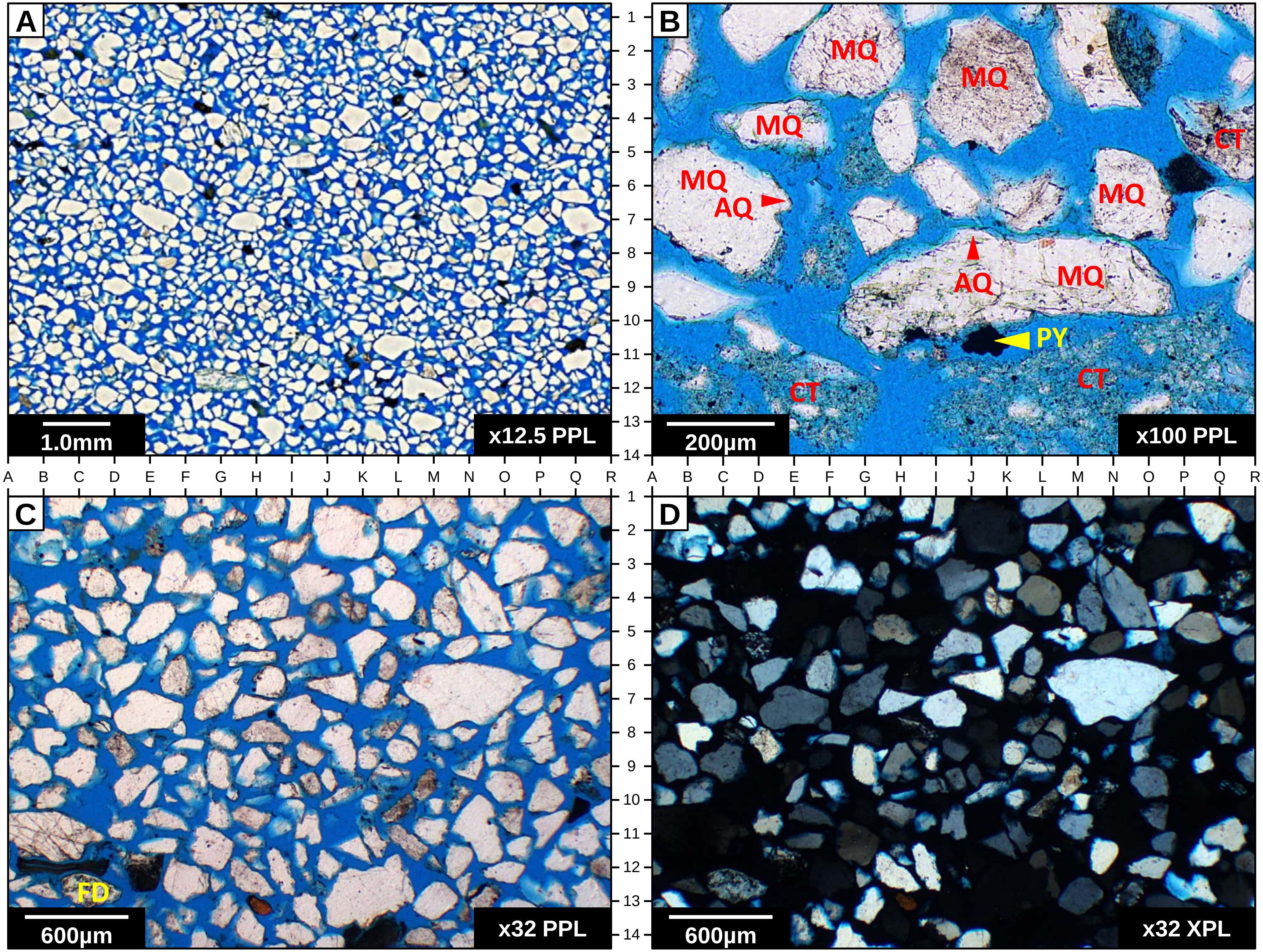

Plate 12 **McMurray Formation**

GR 21952 2014

GR Petrology CONSULTANTS Inc.

Thin Section Photomicrographs and Descriptions - Plate 13
102/11-08-095-06W4/00
McMurray Formation
Subarkose
C.A. Porosity: 35.9% Permeability: 6799 mD
TS Effective Porosity: 30.2%

Sample No. GR-002 (GR 21952 2014): SP13: 279.34 m

A-D Views A and C illustrate minor compacted clay matrix: MTX and plant fragments: CD that negligibly lower reservoir quality in this interval. Other illustrated features include:

- Well connected intergranular porosity: blue,
- Variably leached feldspar: FD,
- Well preserved to highly leached chert: CT,
- Zircon heavy mineral: HM,
- Probable leached clay clast: CRF,
- Minimally deformed muscovite mica: MI,
- Pyrite framboids precipitated in porosity: PY,
- Monocrystalline quartz grains that typically lack overgrowth cement: MQ.

Glycolated clay X-ray diffraction analysis shows the clay suite consists of 79.1% kaolinite, 14.1% illite, 4.3% chlorite and 2.5% smectite. Smectite is calculated to comprise 0.04% of the bulk sample.

Photos A-B PPL x100; Photos C-D PPL x200

102/11-08-095-06W4/00 **GR-002: SP 13** **279.34 m**

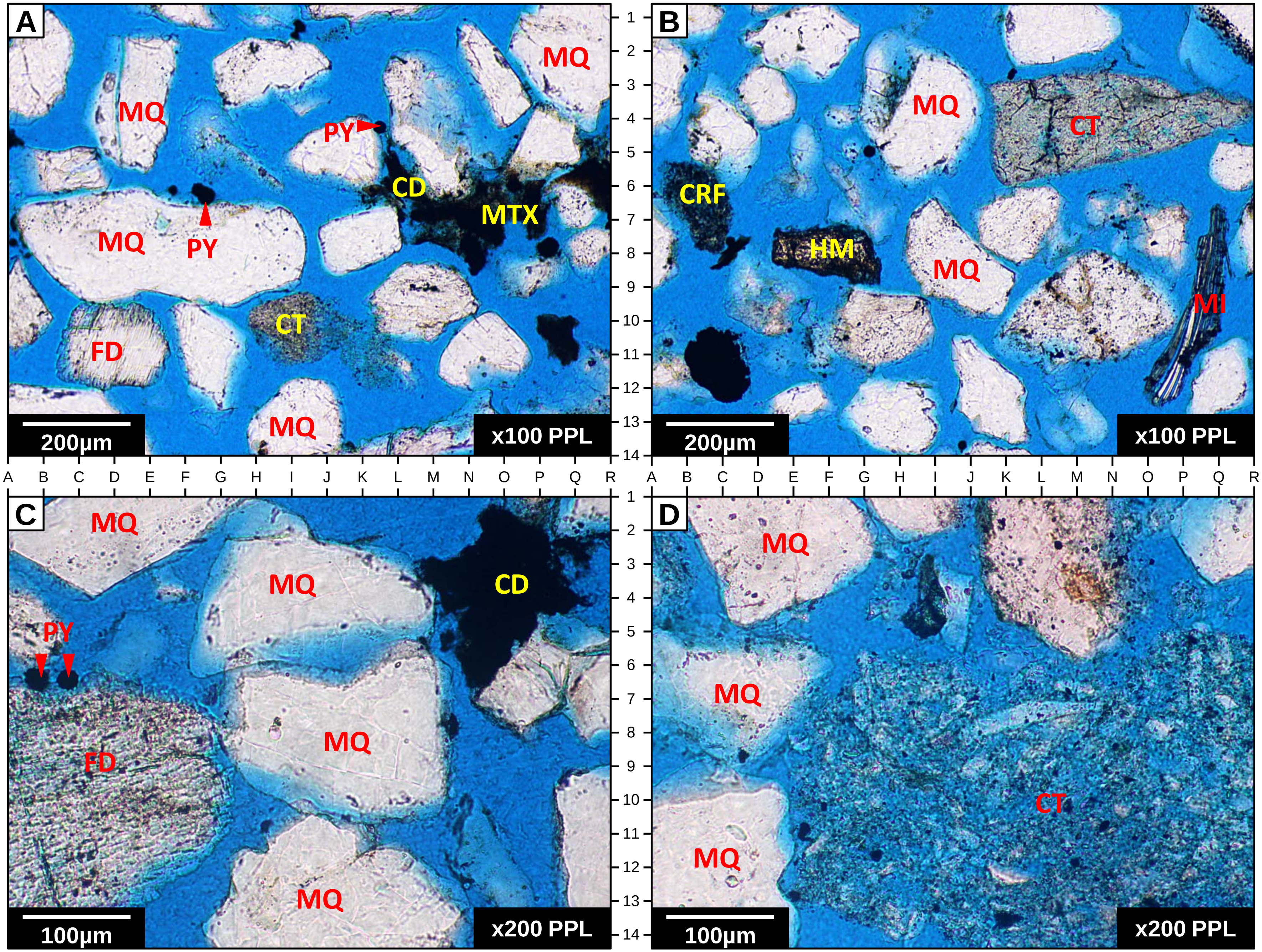

Plate 13 **McMurray Formation**

GR 21952 2014

GR Petrology CONSULTANTS Inc.