A PETROGRAPHIC STUDY OF NINE CORE SAMPLES RECOVERED FROM THE GRAND RAPIDS FORMATION AT WELL LOCATION: SUNCOR ET AL HANGTN 7-13-084-10 100/07-13-084-10W4M/00 License # 0492672

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SERVICE BEYOND ANALYSIS

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EXECUTIVE SUMMARY

The purpose of this study is to describe the observed lithological characteristics, associated reservoir quality and fluid sensitivity of nine thin section samples (see table in introduction for depths, etc.) collected from the Grand Rapids Formation at well location Suncor et al Hangstn 7-13-084-10 100/07-13-084-10W4/00 (Lic. #0492672). Eight of these samples were also analyzed using combined X-ray diffraction (XRD). Petrographic analyses and interpretations are based on the observation of thin sections, X-ray diffraction (XRD) analysis and permeability values based at SAPD (Suncor Agat Permeability Device). Particle size distribution and SAPD analyses where conducted on twelve samples which include the nine thin sections ran but were reported separately.

According to the Folk (1974) classification for sandstones the observed samples are determined to be feldspathic litharenite (samples 1, 3, 5 to 8, 10 and 12) and litharenite (sample 4). The Grand Rapids Formation has been divided into two units based on mineralogy and grain size differences. The upper unit is defined by samples 1 (269.58m) to 5 (276.31m) while the lower unit is defined by samples 6 (278.66m) to 12 (297.16m). Samples 2, 9 and 11 were not analyzed by thin section or XRD.

Primary mineralogy of the **upper unit** consists of chert (14% to 45%), with equal to lesser amounts of monocrystalline quartz (8% to 18%), rock fragments (volcanic – 7% to 12%, sedimentary – 6% to 13%, plutonic – 6% to 13%, and metamorphic – 1% to 3%), plagioclase feldspar (11% to 15%), potassium feldspar (3% to 10%), plus polycrystalline quartz (1% to 5%) and trace detrital dolomite in samples 4 and 5. Accessory minerals include mica (trace to 2% [sample 1 only]), heavy minerals (trace to 1%), carbonaceous debris (trace to 1%), plus trace glauconite (sample 1 and 5 only). The grain sizes for the upper unit are variable and have following averages and size ranges: sample 1: fine upper (very fine upper to medium upper, sample 3: medium upper (very fine lower to very coarse lower), sample 4: coarse upper (very fine lower to granule) and sample 5: medium lower (very fine lower to medium upper with rare very coarse upper). Sample 3 and 4 are poorly sorted and have angular/subangular to round grains, sample 5 is moderately to poorly sorted and has subangular to rounded grains and sample 1 is moderately sorted and has angular to subrounded grains.

The intergranular matrix of the upper unit consists mostly of pseudo-matrix (1% to 2%) with trace detrital matrix. The authigenic clays consist of kaolinite (1% to 2%), chlorite (trace to 1%), plus trace illite and unidentified clay. The non-clay diagenetic minerals are quartz (trace to 1%) and feldspar (trace) overgrowths, siderite (trace to 1% with none in sample 3), plus trace pyrite (samples 3 and 5 only) and dolomite (samples 3 and 4 only).

The grain composition of these five **lower unit** samples consists of rock fragments (volcanic – 8% to 18%, sedimentary – 6% to 1%; plutonic – 4% to 11%, and metamorphic – 3% in all samples), monocrystalline quartz (13% to 26%), detrital dolomite (6% to 15%), plagioclase (7% to 12%) and potassium (3% to 4%) feldspar, plus chert (1% to 6%). Accessory minerals include carbonaceous debris (trace increasing with depth to 5%), mica (1% to 3%), heavy minerals (trace to 1%), and glauconite (trace to 1%). The grain sizes for the lower unit samples 6 to 8 and 10 have average grain size of fine lower and range between very fine lower/coarse silt to medium lower. The basal sample 12 has average grain size of very fine upper and range between coarse silt to fine lower with average of very fine upper. All five samples are moderately sorted and angular to subrounded/subangular (sample 12).

The intergranular matrix for the lower unit sand consists mostly of pseudo-matrix (1% to 2% in samples 6 to 8 and 10, and 7% in sample 12) and detrital matrix (4% in sample 12 and 1% in the other four samples). The authigenic clays consist of kaolinite (1% to 2%), chlorite (trace to 2%), illite (trace to 1%) and trace unidentified clay (except sample 12). The non-clay diagenetic minerals are siderite (1% to 2% with trace only in sample 12), quartz overgrowths (1% to 2%), dolomite (1% to 2%), pyrite (1% to 2% in samples 8, 10 & 12 and trace in samples 6 and 7) and trace feldspar overgrowths (except samples 8 and 10).

The combined bulk and clay XRD analysis (Table 2) results for eight samples (only sample 6 was not analyzed) indicates that the samples consist mainly of quartz (48% to 84%) [silicon dioxide, SiO_2] with lesser to minor amounts of plagioclase feldspar (7% to 17%) [calcium sodium aluminum silicate, $(Ca,Na)(Si,Al)_4O_8$], dolomite (trace to 1% for samples 1 and 5, plus 14% to 26% for samples 7, 8, 10 and 12) [magnesium calcium carbonate, $CaMg(CO_3)_2$], illite (1% to 14%) [potassium aluminum silicate hydroxide, $KAl_2(OH)_2(AlSi_3(O,OH)_{10})$], kaolinite (3% to 8%) [aluminum silicate hydroxide, $Al_4Si_4O_{10}(OH)_8)$] and potassium feldspar (3% to 7%) [potassium aluminum silicate, $K(SiAl_3O_8)$]. In addition, moderate to trace amounts of chlorite (trace to 4%) [iron, magnesium aluminum silicate, $(Mg,Fe)_5Al(AlSi_3)O_{10}(OH)_9$], pyrite (trace and 1% for samples 3 and 4 only) [iron sulfide, FeS_2], muscovite (1% for samples 7 and 10 only) [potassium aluminum silicate hydroxide, $KAl_2(AlSi_3O_{10})(OH)_2$], siderite (1% for samples 8, 10 & 12 only) [iron carbonate, $FeCO_3$], plus trace smectite (none in sample 4) [$(1/2\ Ca,Na)_{0.7}(Al,Mg,Fe)_4\ (Si,Al)_8O_{20}(OH)_4 \cdot nH_2O$] are also detected. XRD analyses generally indicate higher quartz content then that observed in thin section. This is the result of quartz within the samples being represented by mono- to polycrystalline quartz grains, chert and quartz rich rock fragments (volcanic, plutonic and silty shale). See the Discussion of Results section for more details on XRD interpretations.

Porosity types observed within the Grand Rapids Formation include intergranular porosity (13% to 27%) and minor/moderate to significant (sample 12 only) microporosity within detrital and authigenic clays and from partial grain dissolution (for example tripolitic chert) and highly weathered volcanic rock fragments. Where grains are more extensively dissolved, secondary dissolution pores (trace to 3%) are also visible. Most the grain dissolution pores are in leached chert or feldspar. Ineffective microporosity may also be associated with authigenic and detrital clays, plus pseudo-matrix and altered argillaceous rock fragments.

Potential reservoir problems which may be associated with the Grand Rapid Formation at well location 100/07-13-084-10WM/00: 1) Fines migration (detrital and authigenic clays, pseudo-matrix and dissolution fines) may lead to significant reductions in permeability if mobilized when in contact with injection or production fluids. High flow rates should be avoided in order to reduce the occurrence of fines migration, 2) Plugging of slot liners may decrease production rates and create pressure build-up near the wellbore, 3) The presence of minor swelling clays (smectite) may result in moderate reductions in permeability and possible formation damage. Injection water must be compatible with formation water and mineralogy, 4) Clays, silt and very fine sand grains, may also cause production issues if they are produced along with hydrocarbons. The determination of grain size distribution can aid in sand production modeling, 5) Well logs should be reviewed and corrected by a petrophysicist according to the mineralogy that is present within the samples (for example potassium within illite, potassium feldspar, feldspathic lithoclasts and muscovite would increase gamma ray readings on logs) and 6) fluid production or injection may also cause formation collapse or compaction of framework grains contributing to an overall reduction in porosity.

INTRODUCTION

The purpose of this study is to describe the observed lithological characteristics, associated reservoir quality and fluid sensitivity of nine thin section samples collected from the Grand Rapids Formation at well location Suncor et al Hangstn 7-13-084-10 100/07-13-084-10W4/00, License no. 0492672. Petrographic analyses and interpretations are based on the observation of thin section samples generated from core. X-ray diffraction analysis (XRD) analyses were also completed on eight of these samples to confirm mineralogy and clay types. “Coulter LS” Laser Diffraction particle size analysis was also conducted on the twelve samples (including the nine thin sections) selected samples in order to determine particle size distribution. An overview of general sample information can be found below within **Table A:**

Sample No.	Depth (m)	Formation	Rock Type*	Analyses*
1	269.58-269.68	Grand Rapids	FL	TS, XRD, PSD, SAPD
2	271.79-271.89	Grand Rapids	N/A	PSD, SAPD
3	273.5-273.6	Grand Rapids	FL	TS, XRD, PSD, SAPD
4	274.53-274.63	Grand Rapids	LR	TS, XRD, PSD, SAPD
5	276.31-276.41	Grand Rapids	FL	TS, XRD, PSD, SAPD
6	278.66-278.76	Grand Rapids	FL	TS, PSD, SAPD
7	280.82-280.92	Grand Rapids	FL	TS, XRD, PSD, SAPD
8	283.87-283.97	Grand Rapids	FL	TS, XRD, PSD, SAPD
9	286.7-286.8	Grand Rapids	N/A	PSD, SAPD
10	289.74-289.84	Grand Rapids	FL	TS, XRD, PSD, SAPD
11	294.26-294.36	Grand Rapids	N/A	PSD, SAPD
12	297.16-297.26	Grand Rapids	FL	TS, XRD, PSD, SAPD

Table A: General sample information. * TS – thin section analysis, XRD – combined bulk and clay XRD analysis, PSD – particle size distribution, SAPD – Suncor Agat Permeability Device, FL – feldspathic litharenite, LR - litharenite.

METHODS OF ANALYSIS

Thin Section Analysis

In order for pore spaces to be visible in thin section, the samples were mounted in Teflon sleeves, cleaned of any residual hydrocarbons in a toluene bath and then impregnated with blue epoxy to highlight porosity. Next, samples were polished and mounted onto a glass slide where they were ground down to a total thickness of 30 µm. Half of each thin section was then stained with a combination of Alizarin Red and potassium ferricyanide to highlight carbonate mineralogy, and the alternate half with sodium cobaltinitrite in order to highlight potassium feldspars. Finally, a second glass slide was glued on to the samples to protect the polished surface. The prepared thin sections were then examined petrographically and point counted (300 points). The petrographic data summary is provided in the Tables and Figures section of this report (**Table 1**). The thin section photomicrographs and descriptions illustrating the features of the samples are also provided in the Appendix section of this report (**Plates 1 to 9)**.

X-ray Diffraction Analysis

Small portion of eight samples were analyzed by X-Ray Diffraction (XRD) techniques. Clay fraction (less than 3µm size) of the samples has been separated from the bulk sample by the centrifuging method. In order to fractionate, sample has been treated in an ultrasonic bath using sodium hexametaphosphate as a deflocculating agent that facilitate complete disintegration of the matrix from the grains. The samples were then centrifuged in two phases. In the first phase, the sample was centrifuged at 600 rpm for 5 minutes that enable coarser particle to settle down at the bottom of the tube. The clay size particles remain in the fluid in suspension, which has been decanted to another tube, and the clay size particles have been collected from this fluid after the second phase of centrifuging at 3000 rpm for 20 minutes. The clay fraction is mounted on a glass slide, dried and placed in a glycol vapor bath for 24 hours in order to identify expandable clays. Weight fractions are measured for both bulk and clay portions of the sample.

It should be noted that XRD sample was taken from the same depth that was used for thin section. The XRD results are listed in **Table 2**[1].

PETROGRAPHIC DESCRIPTION AND INTERPRETATION

The Grand Rapids Formation at the Suncor Hangstn 100/07-13-084-10W4M/00 location has been divided into two units based on mineralogy and grain size differences. The upper unit is defined by samples 1 (269.58m) to 5 (276.31m) while the lower unit is defined by samples 6 (278.66m) to 12 (297.16m).

Grain sizes observed in thin section are reported according to the Wentworth scale, which has the following divisions: very fine silt (3.9 – 7.8μm), fine silt (7.8 – 15.6μm), medium silt (15.6 – 31μm), coarse silt (31 – 63μm), very fine sand (63 – 125μm), fine sand (125 – 250μm), medium sand (250 - 500μm), coarse sand (500 - 1000μm), very coarse sand (1000 -2000μm), as well as granule (2000 - 4000μm) and pebble (>4000μm) sized clasts. The prefix "lower" means that the grain size is toward the lower end of the size range, while the prefix "upper" denotes that the grain size is toward the upper end of a specific size range.

<u>The Upper Unit</u>

These four samples are moderately to highly chert rich with moderate amounts of feldspar, and other types of rock fragments (volcanic, plutonic, sedimentary and minor metamorphic). Sample 3 is a litharenite, while the other three samples with higher amounts of feldspar are classified as feldspathic litharenite. The samples are mineralogically immature (high content of chert and other rock fragments and feldspar and only moderate amounts of quartz). Texturally submature due to low amounts of detrital clay, moderate to poor sorting in regards to the framework grain size. The samples are generally massive with no sedimentary structures present. The chert rich sample 3 has horizontally orientated grains or clasts. Samples 1 and 2

[1] Note: Bulk and clay XRD analysis does not differentiate between detrital clays, authigenic clays and clays derived from framework grains. The silica in XRD can be quartz, chert, siliceous shale and very fine silts.

have framework grains that are angular to subrounded (sample 1) or round (sample 2) while samples 3 and 4 have grains that subrounded to round. The grain size range and averages are highly variable and are summarized in the following table.

Sample No.	Depth (m)	Sorting	Grain Size Average	Grain Size Range
1	269.58-269.68	Moderate	fU	vfU - mU
3	273.5-273.6	Poor	mU	vfL - vcL
4	274.53-274.63	Poor	cU	vfL - Granule
5	276.31-276.41	Poor to Moderate	mL	vfL – mU with rare vcU

vfL: very fine lower, vfU: very upper, fU: fine upper, mL: medium lower, mU: medium lower, cU: coarse upper, vcL: very coarse lower, vcU: very coarse upper

A descriptive summary of framework grains, plus accessory and diagenetic minerals is provided in the following. Percentages in brackets refer to the rock volume.

Primary mineralogy[2] consists of chert (14% to 45%), with equal to lesser amounts of monocrystalline quartz (8% to 18%), rock fragments (volcanic – 7% to 12%, sedimentary – 6% to 13%, plutonic – 6% to 13%, and metamorphic – 1% to 3%), plagioclase feldspar (11% to 15%), potassium feldspar (3% to 10%), plus polycrystalline quartz (1% to 5%) and trace detrital dolomite in samples 4 and 5. Accessory minerals include mica (trace to 2% [sample 1 only]), heavy minerals (trace to 1%), carbonaceous debris (trace to 1%), plus trace glauconite (sample 1 and 5 only). The intergranular matrix consists mostly of pseudo-matrix (1% to 2%) with trace detrital matrix. The authigenic clays consist of kaolinite (1% to 2%), chlorite (trace to 1%), plus trace illite and unidentified clay. The non-clay diagenetic minerals are quartz (trace to 1%) and feldspar (trace) overgrowths, siderite (trace to 1% with none in sample 3), plus trace pyrite (samples 3 and 5 only) and dolomite (samples 3 and 4 only).

[2] For compositional proportions see Table 1 in the Appendix

The Lower Unit

The lower unit of the Grand Rapids Formation defined by samples 6 (278.66m) to 12 (297.16m). Based on the mineralogy and mineralogical proportions all five of these samples are feldspathic litharenites (after Folks, 1974). Sample 12 has higher volumes of matrix and authigenic clays than the other four samples thus plots closer to being a litharenite then the other four samples. When compared to upper unit these samples contain significant amounts of detrital dolomite, plus lesser amounts of chert, but greater amounts of other types of rock fragments, siderite, pyrite (samples 8, 10 and 12) and in sample 12 higher amounts of pseudo- and detrital matrix. These five samples are mineralogically immature (high content rock fragments and feldspar, plus moderate amounts of quartz). Texturally submature due to low amounts of detrital clay (except sample 12), moderate sorted regards to the framework grain size. The samples 6 to 8 are generally massive with no sedimentary structures present while samples 10 and 12 have a horizontal orientated or laminated fabric. Samples 6 to 8 and 10 have angular to subrounded framework grains while basal sample 12 has angular to subangular grains. The average grain size for samples 6 to 8 and sample 10 is fine lower with grain size range of very fine lower/coarse silt to medium lower. The basal sample 12 has average grain size of very fine upper with a range between coarse silt to fine lower.

The grain composition of these five samples consists rock fragments (volcanic – 8% to 18%, sedimentary – 6% to 13%; plutonic – 4% to 11%, and metamorphic – 3% in all samples), monocrystalline quartz (13% to 26%), detrital dolomite (6% to 15%), plagioclase (7% to 12%) and potassium (3% to 4%) feldspar and chert (1% to 6%). Accessory minerals include carbonaceous debris (trace increasing with depth to 5%), mica (1% to 3%), heavy minerals (trace to 1%), and glauconite (trace to 1%). The intergranular matrix consists mostly of pseudo-matrix (1% to 2% in samples 6 to 8 and 10, plus 7% in sample 12) and detrital matrix (4% in sample 12 and 1% in the other for samples). The authigenic clays consist of kaolinite (1% to 2%), chlorite (trace to 2%), illite (trace to 1%) and trace unidentified clay (except sample 12). The non-clay diagenetic minerals are siderite (1% to 2% with trace only in sample 12), quartz overgrowths (1% to 2%), dolomite (1% to 2%), pyrite (1% to 2% in samples 8, 10 & 12 and trace in samples 6 and 7) and trace feldspar overgrowths (except samples 8 and 10).

Detailed Mineralogy

These two informal units will be described together, but any significant differences between samples within the unit will also be mentioned.

The majority of the quartz visible within the samples is monocrystalline and appears colourless under plane polarized light and displays first-order white to grey interference colors under cross polarized light, shows mainly straight extinction. Minor amounts of polycrystalline quartz are composed of a mosaic of several sutured quartz crystals. XRD results generally suggest elevated amounts of quartz in comparison to thin section point counts of individual quartz grains. This is probably due to the presence of quartz that comprises volcanic, plutonic and sedimentary rock fragments, plus chert grains. Trace quartz grains were noted to contain heavy mineral inclusions, such as zircon, tourmaline or rutile. Trace to minor amounts of quartz overgrowths has also been detected. However, these overgrowths most likely do not pose significant issues in regard to reductions in porosity and subsequent permeability values.

Both plagioclase and potassium feldspars are observed in thin section as single clasts, as well as within plutonic and volcanic rock fragments. For the proportion between potassium and plagioclase feldspar within the sample look at the Petrographic Summary (Table 1). Most of the feldspar grains are altered to various degrees due to weathering, sericitization (precipitation of minute muscovite shards during hydrothermal alteration of silicates) and chloritization. Note that some of the alteration of feldspar and other labile framework components may have occurred in the source areas or during transportation to the sedimentary basin. Feldspars are colourless under plane polarized light and display low order interference colours under plane polarized light. These grains display a variety of twinning patterns which aid in deciphering feldspar composition. In some cases, it is difficult to segregate each type due to fragmentation in which case grains are small, hence difficult to interpret twinning. Plagioclase feldspars typically display albite twinning, where simple and Carlsbad twins are displayed on many of these grains. A solution of sodium cobaltinitrite was applied to half of each thin section for ease in identification of potassium feldspars. Therefore, potassium feldspar grains in these portions of the samples appear yellow in plane polarized light due to the applied stain. Many of these grains also appear dark brown to black along grain boundaries and fractures which is considered to be a reaction product of the staining process. Under cross polarized light, the applied stain typically masks interference colours or twinning patterns. In most cases, twinning was not visible in association with unstained potassium feldspar, but a few grains appear to have tartan twinning. Where twinning is absent, two cleavage planes which intersect at 90˚ identify grains as potassium feldspar. The presence of feldspars, specifically potassium bearing varieties, may result in an increased gamma ray reading. Therefore, log based lithological interpretations should be made with caution. Selective leaching of feldspars grains creates secondary dissolution micropores that could develop to larger size secondary porosity that contributes to the overall visible porosity of the sediment (Plates 1.3 & 5.4:GD). The aluminum (Al) and silicon (Si) ions released during feldspars dissolution are potential source for the creation of authigenic kaolinite. Some feldspar grains or feldspathic rock fragments display secondary feldspar overgrowths.

A variety of lithic grains including chert, plus volcanic, sedimentary, plutonic and minor metamorphic rock fragments occur in all the samples collected from the Grand Rapids Formation. Chert (most abundant in upper unit samples 1, 3 to 5) appears colorless to light brown under cross polarized light and is composed mostly of microcrystalline quartz that displays low order interference colours under cross polarized light. Minor chert grains are composed of cryptocrystalline quartz, where crystals are very difficult to see with the petrographic microscope. Argillaceous chert, which contains an appreciable amount of clay, is also noted throughout the collected samples. In the upper unit of the Grand Rapids Fm. isolated dissolution pores (Plates 3.1 and 3.2:GD) occur in the large chert grains or granules. Spongy micro-porous tripolitic chert (Plate 3.3:TCht) and relict carbonate textures are found in the chert of the upper unit of the Grand Rapids Formation.

Volcanic rock fragments appear colourless to light brown in plane polarized light. Some of these grains also contain micas and therefore have low to intermediate interference colours under cross polarized light. Volcanic clasts generally have a felty texture and are comprised of small laths of plagioclase and/or potassium feldspar, or sometimes are comprised predominately of microcrystalline quartz. Many of volcanic rock fragments have a highly altered to brown illite or chlorite groundmass and are thus clay rich. Selective leaching of the volcanic rock fragments has formed secondary dissolution micro-pores (Plate 9.4:VRFC11) that are too small size to be effective porosity. Sedimentary rock fragments are represented by dark brown organic matter-rich shale or mudstone clasts and occasionally by silty to sandy shale grains (Plate 2.2: SRF). Some of the shale grains are rich in illitic clays and appears brown to yellow-brown in plane polarized light (Plate 3.2:SRF) and in the lower unit of Grand Rapids are partly replaced by fusiform very fine crystalline siderite (Plate 6.3:Sid). Illitization of the mud clasts can be seen under cross polarized light, where there is apparent that the clasts are composed of fine clay sized particles with high order interference colors. Other shale fragments have a high organic content as indicated by their dark brown-black appearance in both plane and polarized light. In the more consolidated sample 12, some of the mud clasts are compacted and squeezed between harder framework components creating more pseudo-matrix (Plate 9.2:Pmtx and SRF) that obstructs intergranular pores. Plutonic rock fragments show granitic (more potassium feldspar rich) or diorite (plagioclase feldspar rich) texture and comprise relatively large euhedral plagioclase or potassium feldspar and quartz crystals. The plutonic rock fragments are partly weathered to clay minerals. The grain dissolution pores after the leaching feldspar crystals were noted in some of these plutonic rock fragments (Plate 1.4: GD and PRF). Metamorphic clasts appear brown to colourless under plane polarized light conditions, while they display low to intermediate interference colours under cross polarized light. Metamorphic grains consist of micaeous schist or argillaceous phyllites or quartzose grains in which individual crystals (mica, quartz, etc.) have become stretched or elongated indicating the host rock was subjected to conditions with elevated stress and strain. Metamorphosed shale clasts (phyllites) display schistosity defined by the alignment of platy minerals, such as micas. Many volcanic and metamorphic rock fragments also appear to be altered to clays and/or compacted or leached. In this case, these fragments have been counted as pseudo-matrix within the ‘Matrix’ section of the Petrographic Summary (Table 1). Some chert grains, in addition to volcanic, plutonic and metamorphic rock fragments, have also been partially dissolved resulting in microporosity or secondary dissolution pores. The significant amounts of detrital dolomite in the lower unit of the Grand Rapids Formation consists as abraded grains are colourless to translucent yellow-brown under plane polarized light and display extreme interference colours under cross polarized light. Some of detrital dolomite grains have diagenetic overgrowths.

Mica flakes display well developed parallel cleavage and middle order interference colors and occurs as biotite (Plates 5.4, 7.3 & 8.4: Biot), muscovite (Plate 7.2: Musc), and chlorite (Plates 2.3 & 9.2:Chl). Overall mica is more common in the five finer grain sized lower unit sandstones of the Grand Rapids Formation. Mica (generally chlorite) is observed in trace to minor (1%) amounts in the more chert grain rich portion of the upper unit of Grand Rapids (samples 1 to 5). Note that micas are common components in metamorphic rock fragments (micaceous phyllites and mica rich schists). Additionally, the weathered feldspathic lithoclasts shows the abundance of sericite, which is actual micro-muscovite. Muscovite appears colorless in plane polarized light, while chlorite displays pale greenish brown pleochroism. Biotite mica appears brown in plane polarized light, shows moderate to strong pleochroism, plus high birefringence in cross polarized light that is masked by deep color of this mineral. Chlorite shows either low (up to gray) or anomalous blue birefringence. Carbonaceous debris are present in all analyzed samples in trace (samples 3 to 5 and 7), minor (1% or 2% - samples 1, 6, 8 and 10) and common amounts in sample 12 (5%). The coaly grains (Plates 9.1:CD) of sample 12 are aligned parallel to the bedding plane. When observed under reflected light it is apparent that some of the macropores within carbonaceous debris has often been plugged with micropyrite. The minor to trace amounts of heavy minerals were identified as zircon (all samples), chloritoid (most samples), garnet (samples 4, 5 and 10), tourmaline (samples 4 and 8), epidote (sample 7), sphene (sample 7) and rutile (sample 7). Zircon is colorless in thin section, has very high relief and high (up to 3rd order) birefringence. Tourmaline and epidote have similar optical properties with the color range from yellow-green (epidote) and brown-green (tourmaline). Both minerals are pleochroic, show high relief and moderate birefringence. Chloritoid is olive-green with strong pleochroism and high relief. Sphene is colourless to pale grey but show varying shades of brown and yellow with stage rotation. Garnet is light to medium brown, subangular to rounded, plus has high relief and is isotropic in cross polarized light. Rutile occurs in several shades of orange ranging to red and amber and is often pleochroic. Rutile also occurs as inclusions in quartz grains in nearly all the samples. Glauconite was detected in trace (samples 1, 5, 6, 8, 10 & 12), and moderate (sample 7) amounts. Glauconite (Plates 4.3, 5.3, 6.2 & 9.4:G) was found mainly as brownish-green (oxidation of iron or altered to smectite?), somewhat weathered oval shaped pellets[3] that are locally plastically deformed and squeezed into the intergranular pore space. Glauconite show speckled microcrystalline texture under cross polarized light conditions. It was noted that most of the glauconite pellets are similar in size like the other framework components. Dark brown phosphate grains which are isotropic under cross polarized light grains are possible fish skeletal fragments (sample 6 only). Rare prismatic zeolites (sample 7 only) are clear in plane polarized light and show no birefringence in cross polarized light. The zeolites are slightly smaller than most framework grains and generally

[3] Although in this study glauconite is grouped with "Framework Grains" it should be noted that this marine clay likely forms on the sediment surface during very early diagenesis.

occur in argillaceous pseudo-matrix or argillaceous lithoclasts and may have diagenetic origin and thus are not true accessory grains.

Matrix content (1% to 3% in sample 1, 3 to 8 and 10, plus 11% in sample 12) is variable within the collected samples and is more frequently observed within the sample at the base of the Grand Rapids Formation. The majority of the matrix is the result of compaction of ductile constituents including shale clasts, volcanic, peloidal glauconite, plus highly altered or micaceous grains result in the generation of a 'pseudomatrix'. It is also important to note that due to the unconsolidated nature of the samples it was sometimes difficult to delineate patchy interstitial clays (matrix) from shaly intraclasts, which are classified as sedimentary rock fragments within the petrographic summary (Table 1). The dissolution of volcanic rock fragments also make pseudo-matrix (Plate 5.3: Pmtx) and the leaching of feldspathic grains (plutonic rock fragments and feldspar) produces dissolution fines (Plates 1.3, 2.3 4.3, 7.4 & 9.3:DF) that float in the interstitial space and are also considered to be a component of the pseudo-matrix. The less common "true" detrital matrix is considered to be intermixed detrital clays, micas, clay and silt sized quartz and feldspar grains, plus fine organic matter. The detrital matrix occurs mostly as brown material coating framework grains and locally filling (especially in sample 12) intergranular space. The matrix (pseudo- and detrital) clays are locally replaced by very fine crystalline siderite rhombs (Plate 6.3:Sid). Clay composition, as confirmed by XRD, includes varying amounts of kaolinite and illite, plus lesser chlorite and trace smectite. Clay content reported by XRD encompasses both detrital and authigenic clays and argillaceous lithoclasts.

Authigenic clays are also noted within the Grand Rapid Formation are dominated by patchy distributed intergranular pore filling authigenic kaolinite (1% to 2% - Plates 1.4, 3.4, 6.3 & 8.2:K). The authigenic kaolinite occurs as patches of tightly packed vermiforms composed of very fine to fine crystalline booklets that fill and/or float within modified intergranular pores Typically kaolinite appears colorless in plane polarized light, while under cross polarized light displays low order white and gray interference colors. The ions for kaolinite precipitation are largely derived from the alteration of labile detrital minerals, in particular feldspars (TUCKER, 1998). The kaolinite booklets comprise significant amounts of micro-porosity. Both authigenic and detrital kaolinite are highly prone to fines migration and plugs intergranular and secondary pore throats. Authigenic illite (trace to 1%) occurs as minor grain coatings and pore bridges (Plates 1.4 & 4.4:ill) that has first order bright birefringence in cross polarized light. Some of glauconite peloids are altered to illite. Iron-bearing authigenic clays (chlorite and possibly the smectite) occur as grain-coating cements or as precipitates within intergranular pores (trace to 1%) within many of the collected samples. Chlorite platelets coat framework grain, plus also form inclusions within rock fragments. The groundmass of weathered volcanic rock fragments is often chloritized. Chlorite appears green in plane polarized light and displays indistinct interference colors. Under extremely high magnification the bladed crystal habit of the clay could be observed. Rare authigenic chlorite (Plate 6.4:Chl) bridges intergranular pores and could be the product of leached or altered chloritic volcanic rock fragments. Due to crystal size and the presence of grain coating possible smectite clays (Plates 2.4 and 6.4:AC) is often difficult to resolve with the petrographic microscope, and is therefore classified as 'unidentified' within the petrographic summary (Table 1). Based on XRD results, chlorite is the most abundant iron-bearing clay within the collected sandstones, with lesser amounts of smectite clays. Authigenic clays also appear to be generated by the alteration of unstable framework grains and are often a component of the interstitial pseudo-matrix and show a remnant of a grain shape. Clays and leached framework grains are source of non-effective micro-porosity in this sand. Please refer to the Fluid Sensitivity and Recommendations section for reservoir complications associated with these clay minerals.

Non-clay diagenetic minerals include siderite (trace to 2% - with none in sample 2), quartz (trace to 2%) to feldspar (trace in all samples but 8 and 10), pyrite (1% to 2% in samples 8, 10 and 12, plus trace in samples 3, 5 to 7) and possible dolomite (1% to 2% in lower unit sample, plus trace in sample 3 and 4).

Siderite consists of aggregates (spherules) of labile, microcrystalline to fine crystalline flattened rhombs. The formation of this iron carbonate typically originates within the micropores of clays in the detrital matrix or argillaceous framework grains. In the study samples the siderite usually fills modified intergranular pores (Plates 6.2:Sid) and occasional occludes dissolution pores with feldspathic framework grains. Siderite is pale yellow to brown in color under plane polarized light. Under cross polarized light, this mineral displays extreme interference colors. Siderite may form where there is a low sulfide concentration, low pH and oxidizing conditions. Therefore, this mineral commonly precipitates at the surface. However, siderite can also form in shallow marine conditions suggesting that the occurrence of this mineral is not an indicator of depositional environment. Siderite crystals have a fusiform botryoidal shape and appear to have replaced clays or fine-grained detrital clasts, such as shale fragments. In some cases, patches of aphanocrystalline to very finely crystalline siderite partially occlude intergranular pore spaces where the secondary cement continues to nucleate from the replaced grain. Well-formed, very finely to finely crystalline siderite was also observed as aggregates of lozenge-shaped crystals, or flattened rhombs situated within pore throats. Pyrite is opaque in both plane and cross polarized light; therefore it was identified using a reflected light. Pyrite forms microlitic inclusions within labile lithoclasts (i.e. carbonaceous detritus is often encrusted/replaced with micro-pyrite framboids), but patches of pyrite framboid cements (Plates 4.4 & 9.4:Py) were also encountered during the thin section examination (Plate 2.2:G8). Black pyrite that is present within the samples is formed under reducing conditions during the early stages of diagenesis. This mineral is isotropic under cross polarized light due to possessing a cubic habit and was therefore identified under reflected light. Pyrite appears to replace some unstable grains and shale clasts, or has precipitated within intergranular pore spaces, where a framboidal habit is observed. Minor euhedral dolomite rhombs (especially in the lower unit sample) occur floating in the intergranular pores is possible diagenetic cement (Plate 5.2:Dol? & Plate 8.2:Dol). In addition the some detrital dolomite grains have euhedral crystal termination and thus are diagenetic dolomite overgrowths. Monocrystalline quartz (Plates 6.3, 7.4 & 8.3:Ov) and lesser amounts of feldspar have euhedral overgrowths.

DISCUSSION OF OTHER RESULTS

SAPD Results

The SAPD (Suncor Agat Permeability Device) analysis gives porosity and permeability results for these nine samples. These porosity and permeability results can be found at base the Petrographic Summary Table 1 in the Tables and Figures section of the report, plus in the Appendix in the header of Plates 1 to 9. From the SAPD results the permeabilities quoted as Nitrogen (N_2) Permeability results while porosity used the results labelled for Helium Pore Volume. The information regarding these porosity and permeability numbers make it possible to compare the same properties (in this case porosity) of the rock samples that were taken from the same intervals but were measured using different techniques. The thin section visible porosity determined by point counting techniques ranges from a high of 30% (sample 5) to low of 14% in sample 12. The helium pore volumes numbers of 31% to 37% are the results from the SAPD results that are compared to the nine samples with petrographic analysis (XRD and thin section). The main reason for the difference between SAPD and thin section porosity is that helium pore volume measures both visible (effective) porosity and non-visible (non-effective) microporosity, which is present within detrital matrix, authigenic clays, and leached lithoclasts. It is believed that abundance of microporosity reflects the difference in the porosity values of the core samples and porosity determined by the point counting technique.

XRD Analysis

The combined bulk and clay XRD analysis (Table 2) results for eight samples (only sample 6 was not analyzed) indicates that they consist mainly of quartz (48% to 84%) [silicon dioxide, SiO_2] with lesser to minor amounts of plagioclase feldspar (7% to 17%) [calcium sodium aluminum silicate, $(Ca,Na)(Si,Al)_4O_8$], dolomite (trace to 1% for samples 1 and 5, plus 14% 26% for samples 7, 8, 10 and 12) [magnesium calcium carbonate, $CaMg(CO_3)_2$], illite (1% to 14%) [potassium aluminum silicate hydroxide, $KAl_2(OH)_2(AlSi_3(O,OH)_{10})$], kaolinite (3% to 8%) [aluminum silicate hydroxide, $Al_4Si_4O_{10}(OH)_8)$] and potassium feldspar (3% to 7%) [potassium aluminum silicate, $K(SiAl_3O_8)$]. In addition, moderate to trace amounts of chlorite (trace to 4%) [iron, magnesium aluminum silicate, $(Mg,Fe)_5Al(AlSi_3)O_{10}(OH)_9$], pyrite (trace and 1% for samples 3 and 4 only) [iron sulfide, FeS_2], muscovite (1% for both samples 7 and 10 only) [potassium aluminum silicate hydroxide, $KAl_2(AlSi_3O_{10})(OH)_2$], siderite (1% for samples 8, 10 & 12 only) [iron carbonate, $FeCO_3$], plus trace smectite (none in sample 4) [(1/2 $Ca,Na)_{0.7}(Al,Mg,Fe)_4 (Si,Al)_8O_{20}(OH)_4 \cdot nH_2O$] are also detected.

The clay fraction ranges from 1.74% to 5.44% of the total sample weight. The clay XRD analysis (Table 1) indicates that the clay fraction consists mostly of kaolinite (30% to 70%) and illite (14% to 40%) with lesser amounts of chlorite (6% to 17%), quartz (1% to 12%), smectite (3% to 11%, except sample 4), siderite (2% to 5% for samples 8, 10 and 12 only), dolomite (1% to 4% for samples 7, 8, 10 and 12 only), potassium feldspar (1% to 4%), plus minor plagioclase feldspar (1% to 2%).

Overall, XRD results (see Table 2 – Summary of XRD Analysis) appear to reflect trends visible in thin section (see Table 1 – Petrographic Summary). XRD analyses generally indicate higher quartz content then that observed in thin section. This is the result of quartz within the samples being represented by monocrystalline quartz grains, chert and lesser amounts of polycrystalline quartz. Quartz is also a constituent of volcanic, metamorphic and plutonic grains within the Grand Rapids Formation. Quartz content is notably higher in XRD for the upper unit of the Grand Rapids which is a reflection of the abundant chert content. Plagioclase feldspar that is detected by XRD analysis has very good correlation in amounts to what is observed in thin section, suggesting that the additional feldspar within lithoclasts (plutonic and volcanic) would be overall insignificant. Potassium feldspar in thin section tend to be greater in value that the amount potassium feldspar detected in XRD which suggest that this type of feldspar has been partially altered clays/mica like illite, sericite (micro-muscovite) and possible kaolinite. Overall the amounts of feldspar content appears to vary locally, however mineral percentages are generally within the acceptable range of error for this type of analysis. Variation in quartz and feldspar content is also the result of grain size. Optical properties such as twinning and cleavage which aid in deciphering this mineral from quartz or other varieties of feldspar may not be visible in thin section if grains are too small to resolve; whereas, XRD is capable of detecting silt and clay sized particles of these minerals. Therefore, XRD results allow for higher resolution of quartz and to lesser extent at this location with feldspar content in comparison with the petrographic microscope.

In regard to clay minerals, XRD analysis also allows for higher resolution of clay content in comparison with the petrographic microscope. XRD results indicate that samples collected from the Grand Rapids Formation at location 100/07-13-084-10W4M/00 contain kaolinite, illite, plus minor chlorite and trace smectite clays in varying proportions. In general, clay content is dominated by pore-filling detrital and authigenic kaolinite, and illite mostly has a detrital origin (i.e. pseudo-matrix and argillaceous lithoclasts). The amounts of clays in samples 1 to 10 are relatively similar (significantly lower in the more chert rich samples 3 and 4) with the clay content in order of abundance as stated above, with except of the absence of smectite in sample 4. The lower sample 12 has significantly higher amounts of clay minerals (21% compared to 5% to 17% in the other seven samples) which correspond with the increase clay minerals seen in thin section. In addition the clay types in sample 12 are dominated by illite, with lesser amounts kaolinite, chlorite and trace smectite which does correlate to the larger amounts argillaceous lithoclasts (sedimentary and altered clay rich volcanic) and matrix (pseudo- and detrital, plus authigenic clays). XRD data indicates that minor to moderate amounts of kaolinite are present within these collected samples. Well-formed authigenic pore-filling kaolinite was identified in thin section of all samples (1% to 2%). The rest of the kaolinite detected by XRD are associated with sedimentary clasts and altered feldspar grains.

XRD analyses also confirm the presence of illite which reflects mudstone intraclasts, sedimentary rock fragments (shale clasts and trace sandstone fragments), matrix content, plus rare illitic grain-coatings. Micas and glauconite are also generally difficult to differentiate from illite within XRD results due to having similar peak positions within X-ray diffractograms.

Some of chlorite and smectite are also sometimes noted in association with altered lithic grains or have precipitated as grain coatings. These clays are listed in the petrographic summary (Table 1) as unclassified authigenic clays due to having an indistinct morphology under the petrographic microscope. Chlorite is present within both the bulk and clay fractions of the XRD in samples 8 and 12 only. Bulk chlorite is most likely a reflection of micaceous chlorite which is present as detrital flakes, as a constituent of volcanic and metamorphic grains, or chemically altered clasts. Where present, detrital matrix content consists of detrital clays which are often intermixed with clay and silt sized particles of quartz, feldspars, lithic grains, micas, and carbonaceous debris. Clay composition varies throughout the well with the majority of detrital clays consisting of kaolinite and illite. However, based on XRD results chlorite may also be constituents of the detrital matrix. Trace smectite probably found as grain coating and is component of altered glauconite grains.

It is also important to note that since thin sections and XRD samples are taken from slightly different core localities, results can vary between sample sets. Similarly, non-clay minerals which occur having a heterogeneous distribution including siderite, pyrite and dolomite, plus micas, zeolites, heavy minerals and phosphate, may or may not be represented within the given sample. The significant increase of dolomite and presence of moderate amounts of siderite in the lower unit of Grand Rapids is reflected well in the XRD results. The minerals that occur in trace amounts in thin sections like individual heavy mineral, phosphate (sample 6) and zeolites (sample 7) are too low in amounts to be detected by XRD. The carbonaceous debris detected in thin section are amorphous (non-crystalline) and thus not detected by XRD.

DIAGENESIS

The Cretaceous Grand Rapids has been interpreted as fluvial or estuarine channels cutting though shoreface deposits. Channel fill consists of progradational estuarine sediments and fluvial sequences. Due to sample size, it is difficult to interpret depositional environment from thin section. However, depositional energy can be inferred from grain sorting and rounding. The majority of the samples is moderately to poorly sorted and is comprised of angular to subrounded grains indicating moderate energy deposition. Poor sorting and the presence of very coarse to granular sized chert in samples 3 and 4 may indicate erosional contacts or storm events. Additional features visible in thin section, such as the presence of glauconite indicate probable marine influences.

Pyrite may have formed very early in the post-depositional history, or syndepositionally at the sediment-water interface under anoxic conditions. Pyrite typically precipitates under reducing conditions in shallow water and is sourced by the bacterial decomposition of organic matter and the reduction of dissolved sulphate in pore water (Tucker, 1998). Siderite also often forms during early stage diagenesis at relatively shallow burial depths, but can also form during later burial. The precipitation of siderite commonly occurs in non-marine reducing environments during the early stages of diagenesis. However, siderite may also form from marine pore fluids when in association with the decomposition of organic matter (Scholle and Ulmer-Scholle, 2006). The aphanocrystalline to fine crystal size may suggest it has replaced relatively fine precursor sediments, such as clays or shale clasts. The minor amounts of dolomite cements primary in the lower sand unit suggests that meteoric reflux through sand caused dissolution detrital dolomite and then re-precipitation as intergranular cement or possible overgrowths Glauconite is a secondary mineral typically formed penecontemporaneously upon deposition and is associated with the replacement of fecal pellets. This mineral is typical of near or shore sands in marine settings and is also associated with reducing conditions.

Good to very good amounts of porosity have been preserved within the observed samples collected from the Grand Rapids Formation as the result of minor reduced by compaction. However, the apparent effects of mechanical compaction are increased in basal sample 12 due to the increased amounts of ductile grains (carbonaceous debris, shale clasts, altered volcanic rock fragments and interstitial matrix). The localized compaction of sedimentary rock fragments, micas, highly altered grains and glauconite was also observed in other samples from this well location, but is not considered to have a significant impact on porosity and permeability trends.

The majority of the samples contain trace to minor grain-coating clays (illite, chlorite and smectite) that were likely precipitated from solution during the early stages of diagenesis, while some clay content also appears to have been generated by the degradation of volcanic, plutonic and metamorphic clasts. It is possible that early smectite was later converted to illite through burial diagenesis and changes in pore fluid chemistry. Smectite will often convert to illitic clays, with depth and increased temperature. Some smectite content may also be an alteration product of glauconite. The minor illite grain coatings may be associated with the illitization of kaolinite, or may also have originated as smectite or illite-smectite coatings which transformed to illite with increasing depth and temperature.

With continued burial, grain dissolution will also often initiate during the early stages of diagenesis as pore fluids are introduced or modified. The partial dissolution of volcanic or plutonic rock fragments, metamorphic rock fragments, in addition to feldspar and chert grains, was noted within the collected sandstones. The minor to trace quartz and feldspar overgrowths occurs after compaction which released silicon, aluminum, potassium, etc. into the pore system of this sand and thus partially source for these overgrowths. Petrographic observation suggests that some grain-rimming clay precipitated prior to grain dissolution.

The timing of kaolinite precipitation is not clear, however, the precipitation of kaolinite within the Grand Rapids Fm. likely represents a period when relatively freshwater was entering the system. The localization of pore-filling kaolinite may be related to local sources of solutes needed to precipitate kaolinite, such as the in situ dissolution of feldspar the leaching of feldspathic constituents within volcanic rock fragments. Kaolinite authigenesis typically occurs at relatively shallow depths and low temperatures as silica and aluminum are released from dissolved grains in humid environments.

The following table (**Table D**) outlines the diagenetic features visible within the samples and relates these features to effective (intergranular, secondary grain dissolution) porosity:

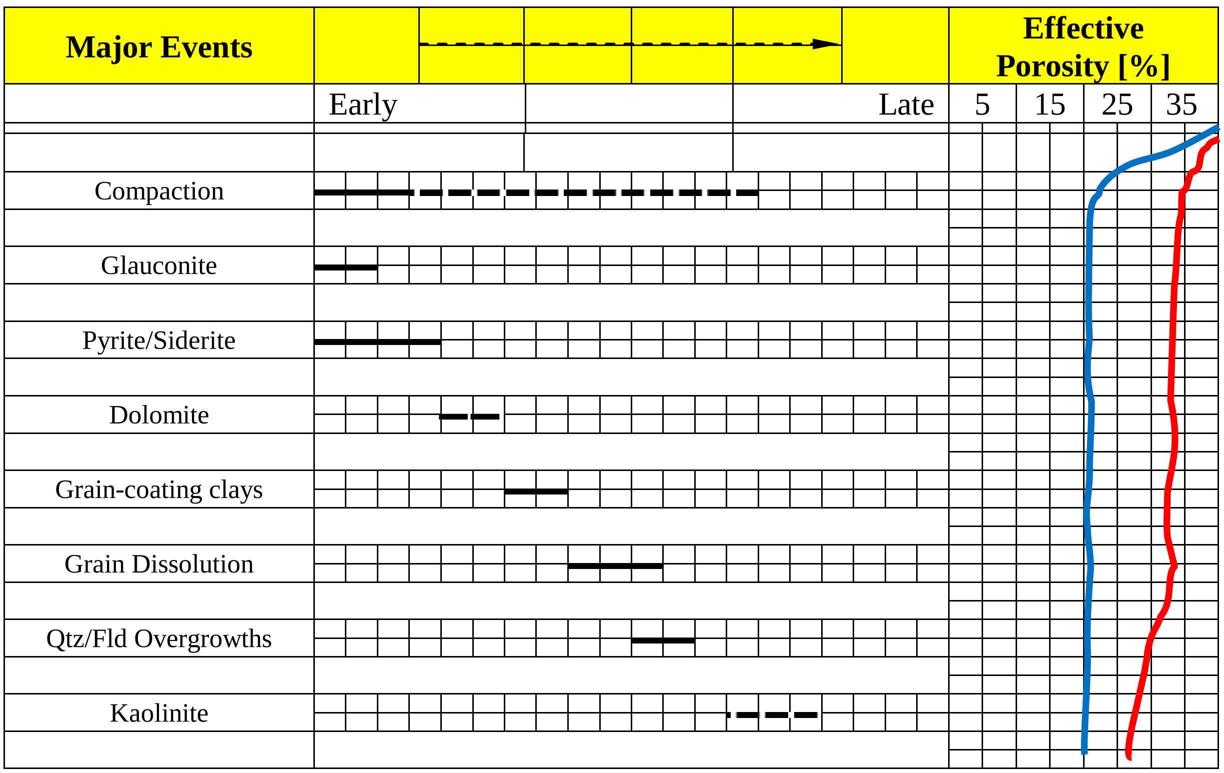

Table D Diagenetic features of the Grand Rapids Formation and effects on porosity. – known,--- not well understood. Samples 1, 3 to 8 & 10 (red line); Sample 12 (blue line)

POROSITY, PERMEABILITY AND RESERVOIR QUALITY

Porosity types observed within the Grand Rapids Formation include intergranular porosity (13% to 27%) and minor/moderate to significant microporosity (sample 12) with in detrital and authigenic clays and from partial grain dissolution (for example tripolitic chert [Plate 3.3:TCht] and highly weathered volcanic rock fragments [Plate 3:2:VRF{C11}]. Where grains are more extensively dissolved, secondary dissolution pores (trace to 3%) are also visible. Most the grain dissolution pores are in leached chert (Plate 3.1:GD) or feldspar (Plate 1.3:GD). Ineffective microporosity may also be associated with authigenic and detrital clays, plus pseudo-matrix and altered argillaceous rock fragments. It is important to note that due to the unconsolidated nature of the sandstones and also to cleaning, intergranular porosity may be highly variable and is not considered to be truly representative of in situ reservoir conditions. Reservoir quality has been based on the following table (**Table E**):

Porosity (%)	Reservoir Quality
30+	Excellent
26 - 30	Very Good
20 - 25	Good
15 - 19	Moderate - Good
5 - 14	Poor – Moderate

Table E Reservoir quality interpretations based on porosity.

Below is a representative table of samples and corresponding reservoir quality (**Table F**):

Sample ID	Thin Section Porosity (%)			Reservoir Quality
	IP	GD	MP	
1	27	2	Minor	Very Good
3	25	3	Minor	Very Good
4	23	2	Minor	Very Good
5	27	3	Minor	Very Good
6	23	1	Moderate	Good
7	24	1	Minor	Good
8	20	TR	Minor	Good
10	24	1	Moderate	Good
12	13	1	Abundant	Moderate

Table F: Reservoir quality of the samples and corresponding porosity values.

Overall reservoir quality is based on the abundance of effective porosity (intergranular and secondary dissolution porosity) present within the samples. However, fluid sensitivity issues and fines migration associated with the various types of detrital and authigenic clays within the Grand Rapids also need to be considered. Please see the Fluid Sensitivity and Recommendations section for details.

In general, preferential reservoir quality (samples which have good to very good porosity) at well location 100/07-13-084-10W4/00 is associated with sandstones which contain <10% clay (detrital and authigenic), but have variable average grain size of fine lower to coarse upper, and are moderately to poorly sorted. Samples with relatively decreased or localized clay content appear to have well-connected porosity suggesting preferential permeability values and reservoir quality. As previously stated, due to the unconsolidated nature of the samples, the original grain fabric has been disturbed. Therefore, these are noted as general trends. Samples with moderate clays (>10%) are estimated to have moderate permeability. Detrital clays, pseudo-matrix and pore-filling authigenic kaolinite result in ineffective microporosity and the occlusion of intergranular pores, while grain-coating clays reduce pore volumes and connectivity between the primary pore system. Fluid sensitivity, due to fines migration and to minor extent swelling clays, may also be of concern within this reservoir.

Aside from clay content, additional factors which may influence reservoir quality include grain dissolution and the presence of secondary mineralogy such as siderite cement, quartz and feldspar overgrowths, dolomite, and framboidal pyrite. Microporosity and secondary porosity generated by grain dissolution may locally enlarge primary pores and increase connectivity of the primary pore system, however likely has a negligible effect on overall reservoir quality within the Grand Rapids Formation. Siderite was observed in trace to minor amounts in most of the collected samples. Siderite is often observed to replace clays and detrital grains. Sometimes, aphanocrystalline siderite will nucleate from the replaced grain to partially occlude the adjacent pore space. Euhedral quartz and feldspar overgrowths, are localized and likely do not have a significant effect on overall reservoir quality.

Grain size and sorting may also have an effect on porosity trends. The chert rich samples 3 and 4 are poorly sorted but due to coarser grain size and lower amounts of total matrix material (4% and 3%) have very good reservoir quality (see SAPD calculated at 11309.38mD and 14803.65mD). The other two samples (#1 and #5) from the upper unit of the Grand Rapids Formation are also have very good reservoir quality because of the high amounts of total porosity (29% or 30%) and the minor to moderate amounts of matrix material (2% and 5%) and the fine upper or medium lower average framework grain size. The first four samples from the lower unit of the Grand Rapids have good reservoir quality because of the fine lower average grain size, lower amounts of visible porosity (20% to 25%) and minor to moderate matrix material (4% to 7%). The basal sample 12 has only moderate reservoir quality because of lower amounts of visible porosity (14%), significant amounts of detrital and pseudo-matrix, plus authigenic clays (total of 15% for the three components filling intergranular space) and a higher degree of compaction due greater amounts of labile argillaceous lithoclasts and matrix material. The laminated structures (bedding and aligned carbonaceous debris) of sample 12 may represent micro-scale permeability barriers depending on the lateral extent of the laminations.

FLUID SENSITIVITY AND RECOMMENDATIONS

Potential reservoir problems which may be associated with the Grand Rapids Formation at well location Suncor Hangstn 7-13-084-10 100/07-13-084-10W4M/00 may include the following:

1) *Blocking of pore throats due to the migration of fines.*

   Fines migration (kaolinite, illite, detrital matrix, pseudo-matrix and dissolution fines) may lead to significant reductions in permeability if mobilized when in contact with fluids (wastes or waters). Samples with increased amounts of kaolinite in both thin section and XRD are typically highly prone to velocity induced migration. High flow rates should be avoided in order to reduce the occurrence of fines migration.

2) *Plugging of slot liners due to clays.*

Plugging of slot liners may decrease injection or production rates and create pressure build-up near the wellbore. Factors which may increase the probability of sediment build-up in the slot liners include clay content, and the presence of partially dissolved grains.

3) *Sand production associated with unconsolidated sandstones.*

The samples predominantly consist of unconsolidated sand sized grains. Various methods, such as the placement of screens, can be used to minimize sand migration. The grain size distribution calculated can aid in sand production modeling.

4) *Swelling Clays.*

Smectite is considered to be a swelling variety of clay. However, the degree of swelling depends on clay composition. Smectite was detected by XRD in trace amounts in all samples but #4. This smectite occurs in too small of amounts to confirm its type (i.e., if it was montmorillonite). Fresh water systems (changes in in-situ formation water to fresher water) will cause smectite to swell and may result in reductions in permeability and possible formation damage. The small amounts of smectite detected suggest the potential for swelling clays is insignificant.

5) *Formation Collapse.*

Fluid production or injections may also cause formation collapse or compaction of framework grains contributing to an overall reduction in porosity.

6) *Correction of well logs.*

Well logs should be reviewed and corrected by a petrophysicist according to the mineralogy that is present within the samples collected from the Grand Rapids

Formation. For example, potassium-bearing mineralogy (potassium feldspar, portion of plutonic rock fragments illite, and kaolinite) present within the collected samples will cause increased gamma ray responses. Overall these clays minerals increase in amounts with depth. Similarly, iron-bearing mineralogy (chlorite, pyrite, siderite, and smectite) may increase readings on bulk density logs and decrease readings on resistivity and neutron logs.

In order to reduce and avoid fines migration in relation to these Grand Rapids Formation samples, the fluid injection and or production rate needs to be held at, or below a "critical velocity." If production and injection rates are held below the critical velocity, fines migration and the subsequent blockage of pore throats is not expected. Clays which are most susceptible to velocity induced migration include kaolinite, illite, plus loose generally feldspathic dissolution fines. Transport of kaolinite fines is dependent on colloidal forces between the clay particles or other framework grains, in addition to hydrodynamic forces from pore fluids. Colloidal forces dominate except near the wellbore where fluid velocities are highest (Gunther et al, 1994). Factors which may influence the mobilization of kaolinite fines include water chemistry, where high pH and low salt concentration favor the deflocculation of kaolinite particles. Therefore, clay migration is most severe when lithologies are "shocked" by flowing significantly fresher water than that of formation water through the pore system. The salinity of injected fluids may effect permeability reduction caused by migrating clays. Temperature is also factor which may influence fines migration. At lower temperatures, the transport of fines such as kaolinite is probable, whereas at higher temperatures mineral transformation processes may dominate.

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TABLES AND FIGURES

TABLE 1
Petrographic Summary of nine Sandstone Samples from the Grand Rapids Formation at the Suncor Hangstn 100/07-13-084-10W4M/00 Location, Lic.#0492672

Sample ID		**1**	**3**	**4**	**5**	**6**	**7**
Depth (m)		**269.58**	**273.50**	**274.53**	**276.31**	**278.66**	**280.82**
Rock Type		**FL**	**FL**	**LR**	**FL**	**FL**	**FL**
Quartz	*Monocrystalline*	18	12	8	18	21	21
	Polycrystalline	5	1	2	4	3	4
	Total	**23**	**13**	**10**	**22**	**24**	**25**
Feldspar	*Potassium Feldspar*	9	10	3	7	4	4
	Plagioclase	14	14	11	15	12	11
	Total (or Fld not classified)	**23**	**24**	**14**	**22**	**16**	**15**
Rock Fragments	*Chert*	14	27	45	18	5	6
	Sedimentary Rock Fragments	7	6	13	8	9	8
	Volcanic Rock Fragments	12	10	7	10	14	10
	Metamorphic Rock Fragments	2	3	1	2	3	3
	Plutonic Rock Fragments	11	12	6	13	11	8
	Detrital Calcite	-	-	-	-	-	-
	Detrital Dolomite	-	-	TR	TR	6	12
	Total	**46**	**58**	**72**	**51**	**48**	**47**
Accessories	*Mica*	1	TR	TR	TR	1	2
	Heavy Minerals	TR	1	TR	1	TR	1
	Glauconite	TR	-	-	TR	TR	1
	Carbonaceous Debris	1	TR	TR	TR	1	TR
	Phosphate	-	-	-	-	TR	-
	Zeolites	-	-	-	-	-	TR
	Total	**2**	**1**	**TR**	**1**	**2**	**4**
Matrix	*Pseudo-Matrix*	2	2	2	1	3	1
	Detriital Matrix	TR	TR	TR	TR	1	1
	Total	**2**	**2**	**2**	**1**	**4**	**2**
Authigenic Clays	*Kaolinite*	2	1	1	1	1	1
	Illite	TR	TR	TR	TR	TR	1
	Chlorite	1	1	TR	TR	1	TR
	Smectite	-	-	-	-	-	-
	Unidentified	TR	TR	TR	TR	TR	TR
	Total	**3**	**2**	**1**	**1**	**2**	**2**
Cements/ Replacement	*Quartz Overgrowths*	1	TR	1	1	1	2
	Feldspar Overgrowths	TR	TR	TR	TR	TR	TR
	Calcite	-	-	-	-	-	-
	Ferroan Calcite	-	-	-	-	-	-
	Dolomite	-	TR	TR	-	2	1
	Ferroan Dolomite	-	-	-	-	-	-
	Anhydrite	-	-	-	-	-	-
	Siderite	TR	-	TR	1	1	2
	Pyrite	-	TR	-	TR	TR	TR
	Residual Hydrocarbon	-	-	-	-	-	-
	Total	**1**	**0**	**1**	**2**	**4**	**5**
Total Rock Volume (%)		**100**	**100**	**100**	**100**	**100**	**100**
Structures		Mss	Mss, Bimodal	Bimodal	Mss	Mss	Mss
Textures	*Grain Size Average*	fU	mU	cU	mL	fL	fL
	Grain Size Range	vfU - mU	vfL - vcL	vfL - Granule	vfL-mU, rr vcU	vfU - mL	vfL - mL
	Sorting	M	P	P	P & M	M	M
	Roundness	A - SR	A - R	SA - R	SA - R	A - SR	A - SR
Diagenesis	*Compaction*	X	X	X	X	X	X
	Grain Fabric	G, P, rrF	G, P, rrCC	G, P, rrF	G, P, rrF	G, P, rrF & CC	G, P, ffF & CC
	Cementation	NCem	NCem	NCem	NCem	NCem	NCem
	Dissolution	GD	GD	GD	GD	GD	GD
Visible Porosity	*Intergranular*	27	25	23	27	23	24
	Dissolution (unclassified)	-	-	-	-	-	-
	Grain Dissolution	2	3	2	3	1	2
	Cement Dissolution	-	-	-	-	-	-
	Total Visible Porosity (%)	**29**	**28**	**25**	**30**	**24**	**26**
Petrophysical Results	*Calculated Porosity (%)*	**3.0**	**37.0**	**36.0**	**37.0**	**36.0**	**36.0**
	Gas Permeability (mD)	**5751.00**	**11309.38**	**14803.65**	**6539.72**	**6864.55**	**6748.93**
Reservoir Quality		**VG**	**VG**	**VG**	**VG**	**G**	**G**

Structures:	**Mss**-massive, **Lm**-laminae; **Xlm**-cross laminae; **Xb**-cross bedded; **Bd**-bedded; **Bt**-bioturbated
Compaction:	**X**-slightly; **XX**-moderately; **XXX**-highly
Grain Fabric:	**G**-grain supported; **M**-matrix supported; **C**-cement supported; **P**-point contacts; **F**-flat contacts; **CC**-concavo-convex contacts; **S**-sutured contacts
Cementation:	**Cem**-completely cemented; **NCem**-non-cemented; **PCem**-partly cemented
Dissolution:	**Cor**-corroded surfaces; **GD**-grain dissolution; **GR**-grain replacement; **CCD**-complete cement dissolution; **SCD**-selective cement dissolution

TABLE 1 (continued)
Petrographic Summary of nine Sandstone Samples from the
Grand Rapids Formation at the Suncor Hangstn 100/07-13-084-10W4M/00 Location, Lic.#0492672

Sample ID Depth (m) Rock Type		8 283.87 FL	10 289.74 FL	12 297.16 FL			
Quartz	*Monocrystalline*	22	26	13			
	Polycrystalline	2	2	2			
	Total	**24**	**28**	**15**			
Feldspar	*Potassium Feldspar*	4	3	4			
	Plagioclase	11	7	9			
	Total (or Fld not classified)	**15**	**10**	**13**			
Rock Fragments	*Chert*	5	6	1			
	Sedimentary Rock Fragments	9	6	13			
	Volcanic Rock Fragments	8	12	18			
	Metamorphic Rock Fragments	3	3	3			
	Plutonic Rock Fragments	7	7	4			
	Detrital Calcite	-	-	-			
	Detrital Dolomite	15	11	7			
	Total	**47**	**45**	**46**			
Accessories	*Mica*	2	3	2			
	Heavy Minerals	1	TR	1			
	Glauconite	TR	TR	TR			
	Carbonaceous Debris	2	2	5			
	Phosphate	-	-	-			
	Zeolites	-	-	-			
	Total	**5**	**5**	**8**			
Matrix	*Pseudo-Matrix*	2	2	7			
	Detriital Matrix	1	1	4			
	Total	**3**	**3**	**11**			
Authigenic Clays	*Kaolinite*	1	1	2			
	Illite	TR	1	1			
	Chlorite	TR	2	1			
	Smectite	-	-	-			
	Unidentified	TR	TR	-			
	Total	**1**	**4**	**4**			
Cements/ Replacement	*Quartz Overgrowths*	1	1	1			
	Feldspar Overgrowths	-	-	TR			
	Calcite	-	-	-			
	Ferroan Calcite	-	-	-			
	Dolomite	1	1	1			
	Ferroan Dolomite	-	-	-			
	Anhydrite	-	-	-			
	Siderite	2	1	TR			
	Pyrite	1	2	1			
	Residual Hydrocarbon	-	-	-			
	Total	**5**	**5**	**3**			
Total Rock Volume (%)		**100**	**100**	**100**			
Structures		Mss	Hrtl Orientated	Hrtl Lm			
Textures	*Grain Size Average*	fL	fL	vfU			
	Grain Size Range	cSlt - mL	cSlt - mL	cSlt - fL			
	Sorting	M	M	M			
	Roundness	A - SR	A - SR	A - SA			
Diagenesis	*Compaction*	X	X	XX			
	Grain Fabric	G, P, F	G, P, rrF	G, P, M, rrF			
	Cementation	NCem	NCem	NCem			
	Dissolution	GD	GD	GD			
Visible Porosity	*Intergranular*	20	24	13			
	Dissolution (unclassified)	-	-	-			
	Grain Dissolution	TR	1	1			
	Cement Dissolution	-	-	-			
	Total Visible Porosity (%)	**20**	**25**	**14**			
Petrophysical Results	*Core Porosity (%)*	**36.0**	**35.0**	**34.0**			
	Gas Permeability (mD)	**6201.20**	**6072.46**	**1077.37**			
Reservoir Quality		**G**	**G**	**M**			

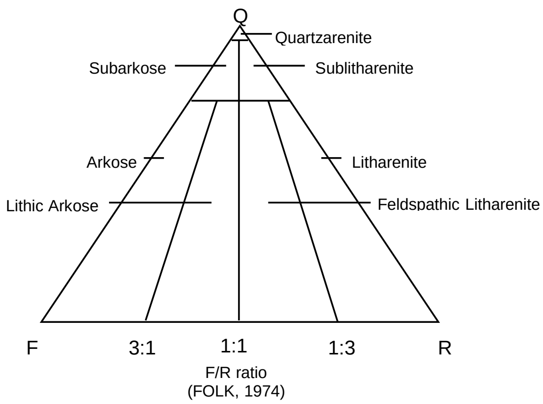
Structures: **Mss**-massive, **Lm**-laminae; **Xlm**-cross laminae; **Xb**-cross bedded; **Bd**-bedded; **Bt**-bioturbated
Compaction: **X**-slightly; **XX**-moderately; **XXX**-highly
Grain Fabric: **G**-grain supported; **M**-matrix supported; **C**-cement supported; **P**-point contacts; **F**-flat contacts; **CC**-concavo-convex contacts; **S**-sutured contacts
Cementation: **Cem**-completely cemented; **NCem**-non-cemented; **PCem**-partly cemented
Dissolution: **Cor**-corroded surfaces; **GD**-grain dissolution; **GR**-grain replacement; **CCD**-complete cement dissolution; **SCD**-selective cement dissolution

FIGURE 1

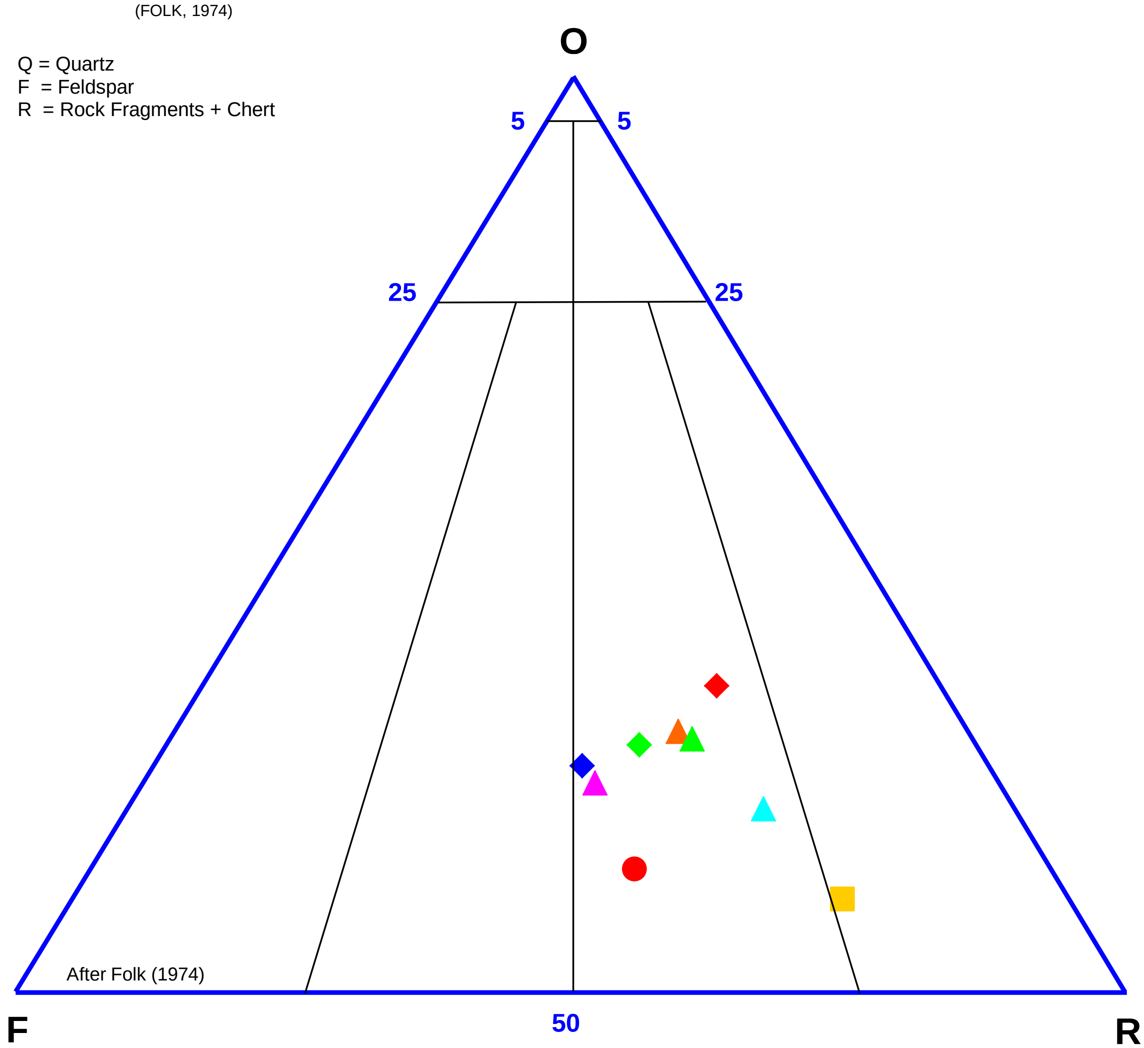
Sandstone Classification of twelve Sandstone Samples from the Grand Rapids Formation at the Suncor Hangstn 100/07-13-084-10W4M/00 Location

Legend

Sample	Depth
1	269.58 m
3	273.50 m
4	274.53 m
5	276.31 m
6	278.66 m
7	280.82 m
8	283.87 m
10	289.74 m
12	297.16 m



Q = Quartz
F = Feldspar
R = Rock Fragments + Chert



LIST OF ABBREVIATIONS (SANDSTONES)

ROCK TYPE

QA – QUARTZARENITE

SA – SUBARKOSE

SL – SUBLITHARENITE

AR – ARKOSE

LA – LITHIC ARKOSE

FL – FELDSPATHIC LITHARENITE

LR – LITHARENITE

SORTING

VW – VERY WELL SORTED

W – WELL SORTED

M – MODERATELY SORTED

P – POORLY SORTED

GRAIN SIZE

P – PEBBLE

GR – GRANULE

vcU – UPPER VERY COARSE

vcL – LOWER VERY COARSE

cU – UPPER COARSE

cL – LOWER COARSE

mU – UPPER MEDIUM

mL – LOWER MEDIUM

fU- UPPER FINE

fL – LOWER FINE

vfU – UPPER VERY FINE

vfL – LOWER VERY FINE

slt – SILT

RESERVOIR QUALITY

VG – VERY GOOD

G – GOOD

M – MODERATE

F - FAIR

P – POOR

ROUNDNESS

WR – WELL ROUNDED

R – ROUNDED

SR – SUBROUNDED

SA – SUBANGULAR

A - ANGULAR

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Table 2 - Summary of XRD Analysis

Company: SUNCOR ENERGY INCORPORATION (SUNCOR MEADOW PROJECT) — Work Order No. 19A19459 (RC29648)

Location: SUNCOR ET AL WWB HANGSTN 7-13-84-10; 100-07-13-084-10W4-00; Grand Rapids Fm; LIC # 0492672 — March, 2019

SAMPLE ID.	TYPE OF ANALYSIS	WEIGHT %	Qtz	Plag	K-Feld	Cal	Dol	Anhy	Pyr	Musc	Bar	Sider	← CLAYS Kaol	Chl	Ill	ML	CLAYS → Smec	Total Clay
	BULK FRACTION:	96.06	66	18	7	0	TR	0	0	0	0	0	5	0	4	0	0	9
1	CLAY FRACTION:	3.94	1	1	1	0	0	0	0	0	0	0	70	6	14	0	7	97
269.58-269.68m	BULK & CLAY	100	63	17	7	0	TR	0	0	0	0	0	8	TR	5	0	TR	13
	BULK FRACTION:	98.26	85	8	3	0	0	0	TR	0	0	0	3	0	1	0	0	4
3	CLAY FRACTION:	1.74	6	2	3	0	0	0	0	0	0	0	58	8	17	0	6	89
273.5-273.6m	BULK & CLAY	100	84	8	3	0	0	0	TR	0	0	0	4	TR	1	0	TR	5
	BULK FRACTION:	97.34	84	7	3	0	0	0	1	0	0	0	2	0	3	0	0	5
4	CLAY FRACTION:	2.66	12	2	2	0	0	0	0	0	0	0	44	17	23	0	0	84
274.53-274.63m	BULK & CLAY	100	82	7	3	0	0	0	1	0	0	0	3	TR	4	0	0	7
	BULK FRACTION:	95.73	67	14	7	0	1	0	0	0	0	0	5	1	5	0	0	11
5	CLAY FRACTION:	4.27	6	2	4	0	0	0	0	0	0	0	39	14	24	0	11	88
276.31-276.41m	BULK & CLAY	100	66	13	7	0	1	0	0	0	0	0	6	1	6	0	TR	13
	BULK FRACTION:	94.62	63	9	3	0	15	0	0	1	0	0	6	0	3	0	0	9
7	CLAY FRACTION:	5.38	6	2	1	0	4	0	0	0	0	0	30	13	40	0	5	88
280.82-280.92m	BULK & CLAY	100	60	9	3	0	14	0	0	1	0	0	7	1	5	0	TR	13
	BULK FRACTION:	96.53	52	11	4	0	19	0	0	0	0	1	3	4	7	0	0	14
8	CLAY FRACTION:	3.47	3	1	1	0	1	0	0	0	0	2	35	16	38	0	3	92
283.87-283.97m	BULK & CLAY	100	50	11	4	0	18	0	0	0	0	1	4	4	9	0	TR	17
	BULK FRACTION:	94.56	51	9	3	0	27	0	0	1	0	1	6	0	2	0	0	8
10	CLAY FRACTION:	5.44	4	1	1	0	2	0	0	0	0	5	30	12	37	0	8	87
289.74-289.84m	BULK & CLAY	100	48	9	3	0	26	0	0	1	0	1	7	1	4	0	TR	12
	BULK FRACTION:	94.70	47	9	4	1	21	0	0	0	0	1	4	1	12	0	0	17
12	CLAY FRACTION:	5.30	6	1	1	0	1	0	0	0	0	3	32	12	39	0	5	88
297.16-297.26m	BULK & CLAY	100	45	8	4	1	20	0	0	0	0	1	5	2	14	0	TR	21

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XRD LEGEND

- XRD Analysis is semi-quantitative (approx. 10% at best) and identifies only crystalline substances; amorphous (non-crystalline) substances will not be detected.
- Bulk Fraction – greater than 3 micron size fraction.
- Clay Fraction – less than 3 micron size fraction.
- Bulk and Clay – mathematical recalculation including the bulk and clay fraction representing the whole sample.
- Total Clay – sum of the clay minerals (may include authigenic and matrix clays plus clays in rock fragments).

ABBREVIATIONS

Amp - Amphiboles	Dol - Dolomite	Marc - Marcasite	Pr - Pure (95 – 100%)
Ana - Analcime	Gyp - Gypsum	ML* - Illite-Smectite	NPr - Near Pure (90 – 95%)
Anhy- Anhydrite	Hal - Halite	ML** - Corrensite (chlorite-smectite)	Abnt - Abundant (60 – 90%)
Ank - Ankerite	Hem - Hematite	Plag - Plagioclase Feldspar	Com - Common (30 – 60%)
Apa - Apatite	Ill - Illite	Pyr - Pyrite	Mnr - Minor (10 – 30%)
Bar - Barite	Kaol - Kaolinite	Qtz - Quartz	Rre - Rare (1 – 10%)
Cal - Calcite	K-feld- Potassic Feldspar	Sider - Siderite	Tr - Trace; detectable,
Chl - Chlorite	Mack - Mackinawite	Smec - Smectite (montmorillonite)	but not measurable (0 – 1%)
Phos – Phosphate	Musc - Muscovite	Wues - Wuestite	Unk - Unknown

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<u>BULK & CLAY PROCEDURES</u>

1. Crush dry rock sample until grains disintegrate completely.

2. Weigh empty beaker and put sample in it. Weigh again "total weight". (≈3g of sample).

3. Add 50 mL of distilled water, plus a few drops of Sodium Metaphosphate.

4. Put in ultrasonic bath for 2 (two) hours.

5. Stir sample and pour out top portion into test tube.

6. Centrifuge for 5 minutes at 600 rpm.

7. Pour out top portion into another test tube for the clay fraction (<3µm) sample.

8. Recombine the coarser residue in the first test tube with the residue in the beaker and weight this "bulk sample" (after drying completely). Subtract this weight from the "total weight" to get the clay fraction weight.

9. Centrifuge the "clay fines" in the second test tube for 20 minutes at maximum rpms.

10. Pour out most of the water then shake test tube using Vortex Mixer.

11. Pipette onto a glass slide.

12. Put the slide on the hot plate (low) until dry then run sample in XRD.

13. Then put slide in a glycol vapour bath overnight (glycolated clay); Smectite will swell and be recognized.

14. If chlorite suspected, then treat the remaining sample in the test tube with diluted HCl and leave overnight (acidized clay). If chlorite was present in the sample this test causes it to disappear.

15. Run the "clay fraction" slide from 2-38 degrees.

16. Grind the "bulk sample" and spread the powder on an aluminum holder then run from 4-58 degrees.

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APPENDIX

Thin Section Photomicrographs and Descriptions (Plates 1 to 9)

THIN SECTION PHOTOMICROGRAPH DESCRIPTION: PLATE 1
LOCATION: SUNCOR ET AL HANGSTN 7-13-084-10 100/07-13-084-10W4M/00
FORMATION: GRAND RAPIDS
ROCK TYPE: FELDSPATHIC LITHARENITE

SAMPLE 1, 269.58m Thin Section Porosity: 29% SAPD Porosity: 37% SAPD Permeability: 5751.00mD

1 Low magnification views of a massive and moderately sorted feldspathic litharenite. Detrital grains range in size from very fine upper to medium upper, while average grain size is determined to be fine upper. The primary framework is comprised of rock fragments (volcanic [VRF], plutonic [PRF], sedimentary [SRF] and minor metamorphic), quartz (mono- [MQ] and lesser polycrystalline), feldspar (plagioclase [Plag] and potassium [Kfsp]) and chert (Cht). Accessory grains include moderate amounts of mica (muscovite, chlorite and biotite), carbonaceous debris, plus trace heavy minerals (zircon and chloritoid) and glauconite. Minor amounts of pseudo-matrix (2% - Pmtx) derived from compaction or alteration of feldspathic or argillaceous lithoclast and trace detrital matrix slightly fill primary porosity. Minor amounts of authigenic kaolinite (K – 2%), chlorite (1%) and trace grain coating illite and unidentified clays were also detected. Minor quartz overgrowths (1%), plus trace siderite and feldspar overgrowths were also observed. The visible pore system consists of intergranular (27%) and minor grain dissolution (2%) porosity. Overall reservoir quality is considered to be very good due to lack of compaction, matrix content and diagenetic cements which only slightly reduce or occlude primary pore volumes. **x25 ppl**

2 High magnification view in feldspar stained portion of the thin section showing that interstitial detrital matrix (Mtx) and muscovite mica (Musc) are compacted between framework grains consisting of chert (Cht), silty shale (SRF), altered plagioclase feldspar (Plag), plutonic rock fragments (PRF), weathered volcanic rock fragments (VRF), monocrystalline quartz (MQ) and yellow stained potassium feldspar (Kfsp). Blue epoxy shows intergranular porosity. **x100 ppl**

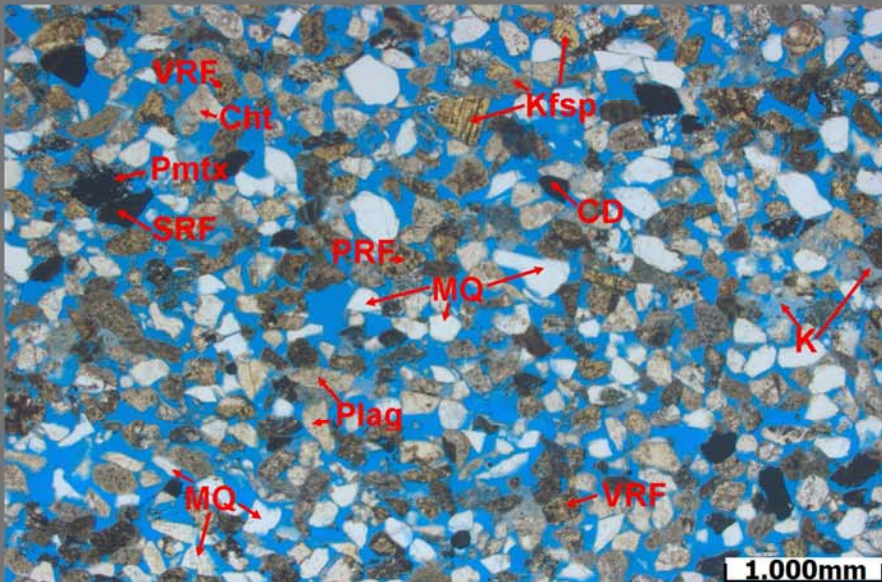
3 High magnification view showing that feldspar dissolution has created secondary pores in feldspathic grains, plus dissolution fines (DF) and micro-porous pseudo-matrix (PMtx). The coal debris grains are rich in pyrite inclusions (CD&Py). The framework grains in this image are mono- (MQ) to polycrystalline (PQ) quartz, silty shale (SRF), chlorite groundmass volcanic rock fragments (VRF), micaceous schist (MRF), plus plagioclase (Plag) and potassium feldspar (Kfsp). **x100 ppl**

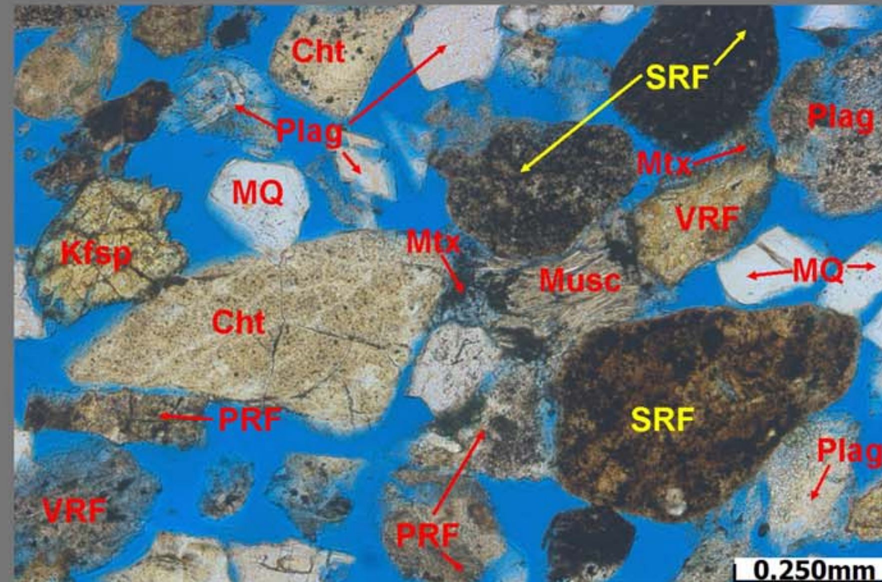
4 Very high magnification view of authigenic kaolinite (K), very fine crystalline siderite, grain coating authigenic illite (ill) and indistinct clays (AC). Leached feldspar lathes (GD) are common in plutonic rock fragments (PRF). Mono- (MQ) to polycrystalline (PQ) quartz, chert (Cht), plagioclase feldspar (Plag) and sedimentary rock fragments (SRF) are the other framework grains. **x200 ppl**

1	**2**
3	**4**

SUNCOR ENERGY CORPORATION
SUNCOR ET AL HANGSTN 7-13-084-10 100/07-13-084-10W4M/0
GRAND RAPIDS

APRIL, 2019
A19459





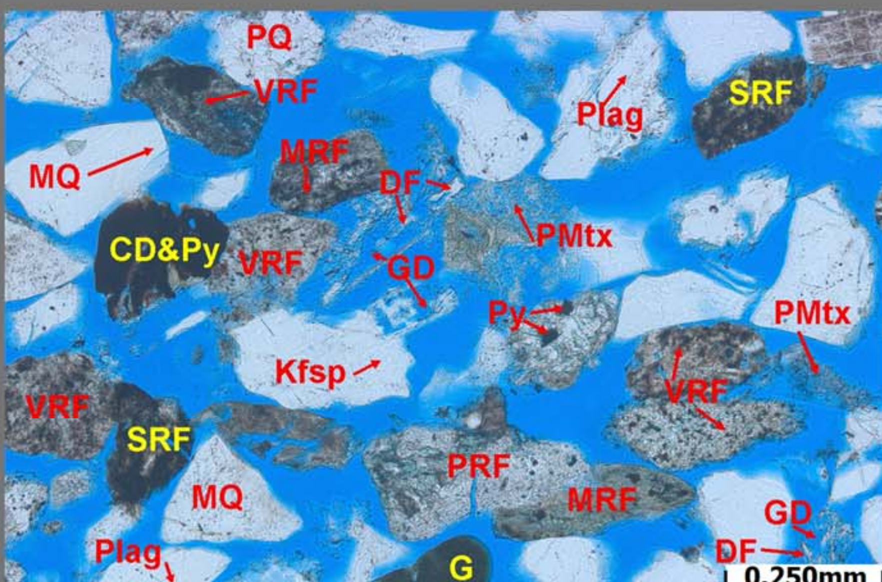
1 2 3 4 5 6 7 8 9 10 11 12 13 14

A B C D E F G H I J K L M N O P Q

1|2
3|4

A B C D E F G H I J K L M N O P Q

1 2 3 4 5 6 7 8 9 10 11 12 13 14



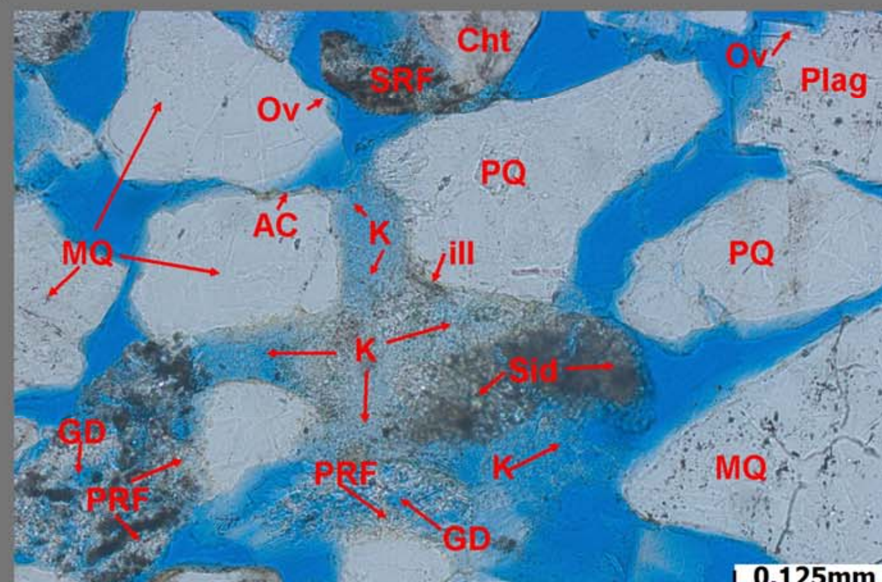


PLATE #1

Sample 1: 269.58m

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THIN SECTION PHOTOMICROGRAPH DESCRIPTION: PLATE 2
LOCATION: SUNCOR ET AL HANGSTN 7-13-084-10 100/07-13-084-10W4M/00
FORMATION: GRAND RAPIDS
ROCK TYPE: FELDSPATHIC LITHARENITE

SAMPLE 3, 273.50m   Thin Section Porosity: 28%   SAPD Porosity: 37%   SAPD Permeability: 11,309.38mD

1 Low magnification views of a massive and poorly sorted almost bimodal feldspathic litharenite. Detrital grains range in size from very fine upper to very coarse lower, while average grain size is determined to be medium upper. The primary framework is comprised of rock fragments (volcanic [VRF], plutonic, sedimentary [SRF] and lesser metamorphic), chert (Cht), quartz (mono- [MQ] and minor polycrystalline) and feldspar (plagioclase [Plag] and potassium [Kfsp]). Accessory grains include minor amounts of heavy minerals (zircon, sphene and chloritoid [Chld]), plus trace mica (chlorite) and carbonaceous debris. Minor amounts of pseudo-matrix (2%) derived from compaction or alteration of feldspathic or argillaceous lithoclasts and trace detrital matrix slightly fill primary porosity. Minor amounts of authigenic kaolinite (K – 1%), plus trace chlorite, grain coating illite and unidentified clays were also detected. Trace quartz and feldspar overgrowths, dolomite and pyrite were also observed. The pore system consists of intergranular (25%) and lesser grain dissolution (3%) porosity. Reservoir quality is considered to be very good due to lack of compaction, plus low amounts matrix material and diagenetic cements. **x25 ppl**

2 High magnification view in feldspar stained portion of the thin section showing grain dissolution pores (GD) with volcanic rock fragments (VRF) that locally results in dissolution fines rich pseudo-matrix (Pmtx) that is highly migratable in any flow regime. Interstitial authigenic kaolinite (K) is also prone to fines migration. The other framework grains consisting of chert (Cht), silty, sandy or organic-rich shale (SRF), potassium feldspar (Kfsp), micaceous schist (MRF) and monocrystalline quartz (MQ). Blue epoxy shows intergranular porosity. **x100 ppl**

3 High magnification view in finer grained zone of this sample showing that the intergranular pores (blue epoxy) are partially filled with chlorite (Chl), dissolution fines (DF), feldspar and quartz overgrowths (Ov), detrital matrix (Mtx) and authigenic kaolinite (K). Secondary pores (GD) occur in partially leached chert and feldspar grains. The framework grains are mono- (MQ) to polycrystalline (PQ) quartz, silty shale (SRF), volcanic rock fragments (VRF), plutonic rock fragments (PRF), chert (Cht) and plagioclase feldspar (Plag). **x100 ppl**

4 Very high magnification view of migratable authigenic kaolinite (K) and dissolution fines (FL) and grain coating authigenic clays (AC) reducing intergranular pores (IP). Sericite (Ser) inclusions along cleavage in plagioclase feldspar and plutonic rock fragments (PRF). Silty shale (SRF), chert (Cht) and monocrystalline quartz (MQ) are the other framework grains. **x200 ppl**

1	**2**
3	**4**

SUNCOR ENERGY CORPORATION | APRIL, 2019
SUNCOR ET AL HANGSTN 7-13-084-10 | 100/07-13-084-10W4M/0 | A19459
GRAND RAPIDS

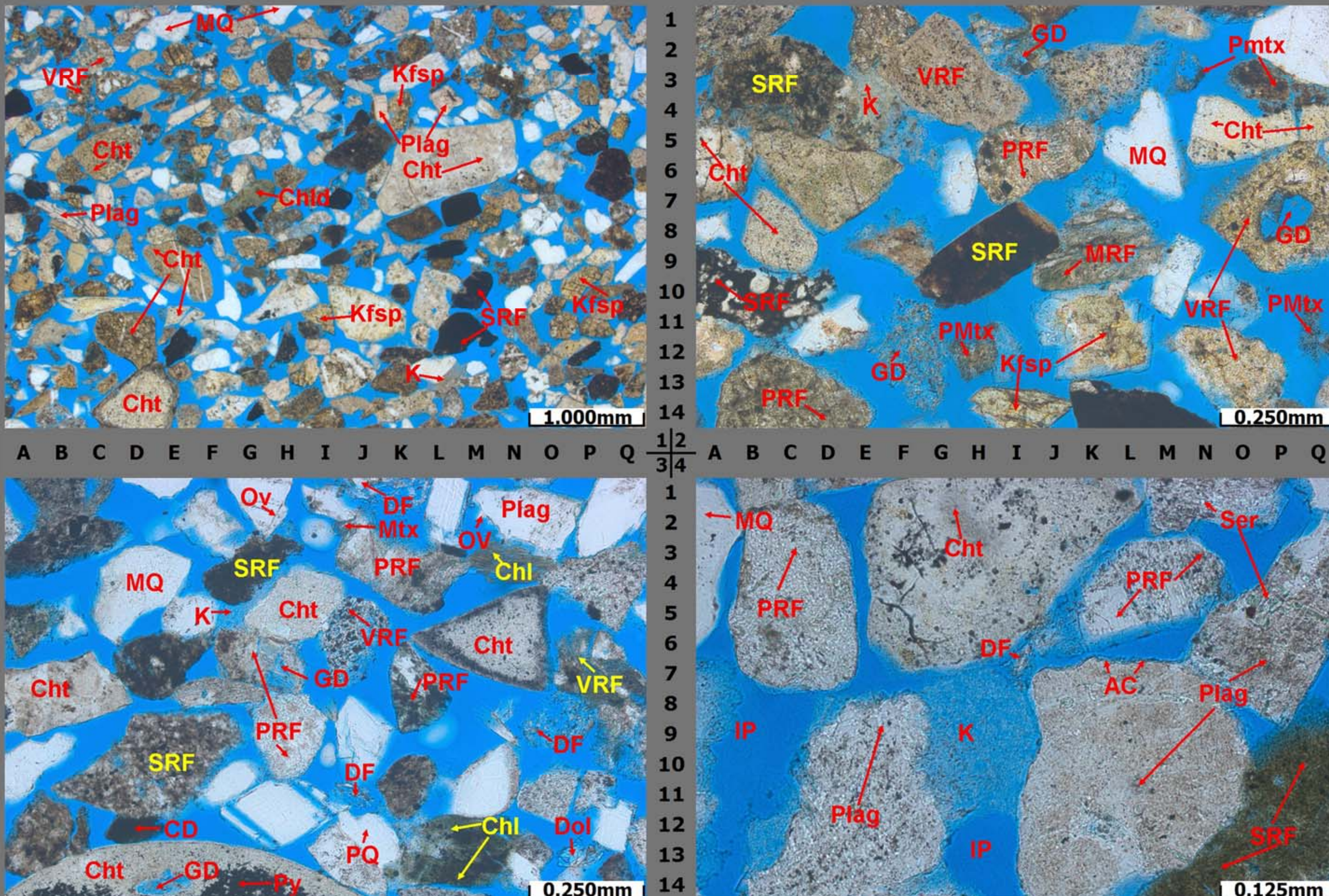

PLATE #2

Sample 3: 273.50m

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THIN SECTION PHOTOMICROGRAPH DESCRIPTION: PLATE 3
LOCATION: SUNCOR ET AL HANGSTN 7-13-084-10 100/07-13-084-10W4M/00
FORMATION: GRAND RAPIDS
ROCK TYPE: LITHARENITE

SAMPLE 4, 274.53m Thin Section Porosity: 25% SAPD Porosity: 36% SAPD Permeability: 14,803.52mD

1 Low magnification views of a horizontally orientated, bimodal textured and poorly sorted chert rich litharenite. Detrital grains range in size from very fine lower to granule (2 to 4µm) sized, while average grain size is determined to be coarse upper. The primary framework is comprised of chert (Cht), rock fragments (shale [SRF], volcanic [VRF], plutonic, siliceous sandstone [SS] and lesser metamorphic), feldspar (plagioclase [Plag] and lesser potassium [Kfsp]), lesser amounts of quartz (mono- [MQ] and minor polycrystalline) and trace detrital dolomite. Accessory grains include trace amounts of heavy minerals (zircon, chloritoid and tourmaline), plus trace mica (chlorite) and carbonaceous debris. Minor amounts of pseudo-matrix (2%) derived from compaction or alteration of feldspathic or argillaceous lithoclasts and trace detrital matrix slightly fill primary porosity. Minor amounts of authigenic kaolinite (K – 1%), plus trace chlorite, grain coating illite and unidentified clays were also detected. Minor (1%) quartz and trace feldspar overgrowths, siderite (1%) and trace dolomite were also detected. The pore system consists of intergranular (23%) and lesser grain dissolution (GD - 2%) porosity. Reservoir quality is considered to be very good due to lack of compaction, plus low amounts matrix material and diagenetic cements. **x25 ppl**

2 High magnification view in feldspar stained portion of the thin section showing grain dissolution pores (GD) within chert (Cht) and highly leached volcanic rock fragments (VRF). Siderite (Sid) cement occludes secondary pores within a chert grain. Pseudo-matrix (Pmtx) derived from loose dissolution fines and possible detrital dolomite (DTD?) occurs within interstitial space. Plagioclase feldspar (Plag) and silty shale (SRF) are other framework grains in this image. **x100 ppl**

3 High magnification view show the intergranular pores slightly filled with migratable pseudo-matrix (Pmtx), detrital matrix (Mtx) and dissolution fines (DF). Micro-porous tripolitic chert (TCht), dense non-porous chert (Cht), plagioclase feldspar (Plag), schist (MRF), shale (SRF), volcanic rock fragments (VRF), plus mono- (MQ) to polycrystalline (PQ) quartz are the framework grains in this image. **x100 ppl**

4 Very high magnification view of intergranular pores (blue epoxy) locally occluded by authigenic kaolinite booklets (K). Indistinct grain-coating and pore bridging authigenic clays (AC) are most likely illitic in composition. The framework and accessory grains are chert (Cht), volcanic rock fragments (VRF), plagioclase feldspar (Plag), silty shale (SRF), polycrystalline quartz (PQ) and coal debris (CD). **x200 ppl**

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GRAND RAPIDS

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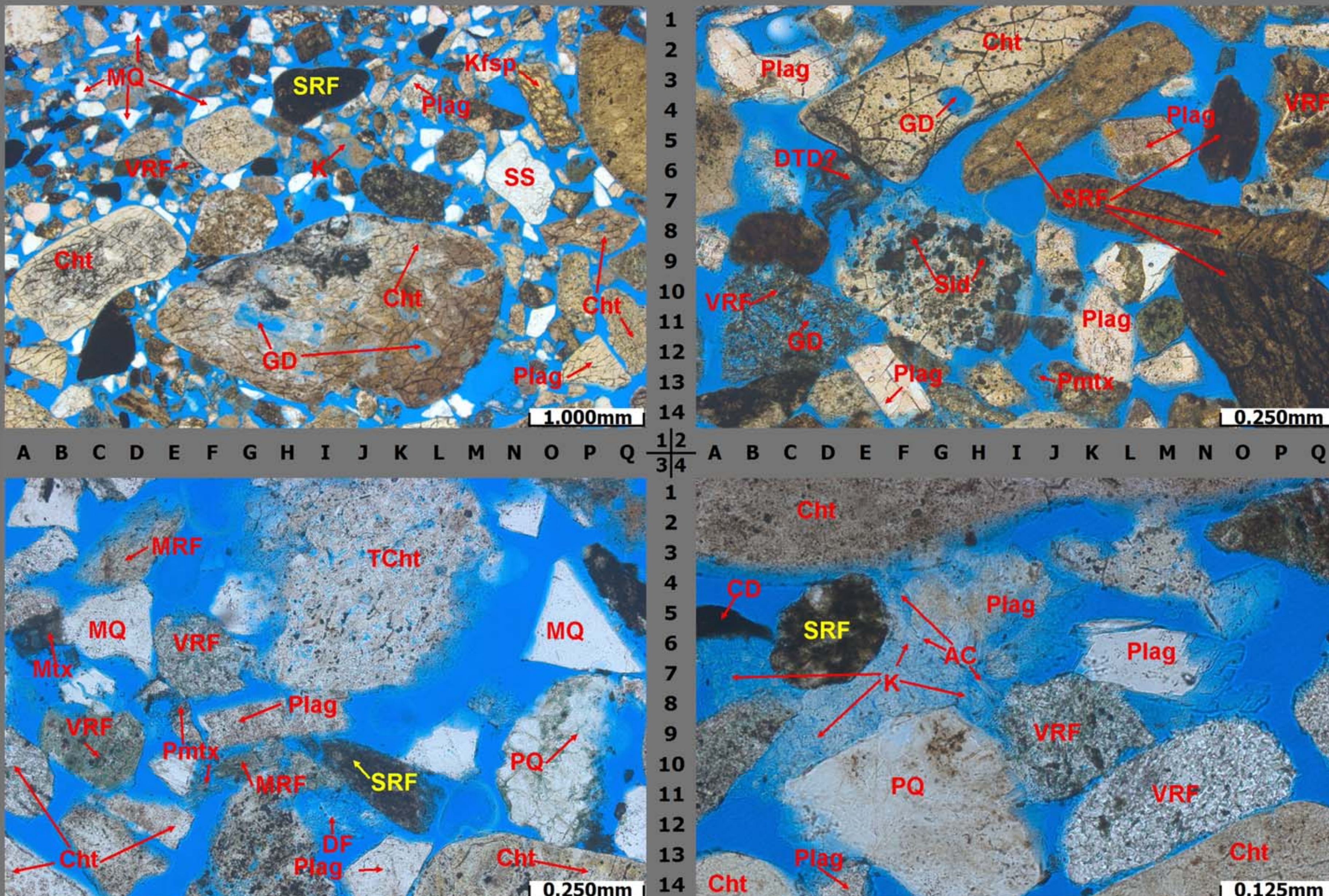

PLATE #3

Sample 4: 274.53m

AGAT Laboratories

THIN SECTION PHOTOMICROGRAPH DESCRIPTION: PLATE 4
LOCATION: SUNCOR ET AL HANGSTN 7-13-084-10 100/07-13-084-10W4M/00
FORMATION: GRAND RAPIDS
ROCK TYPE: FELDSPATHIC LITHARENITE

SAMPLE 5, 276.31m Thin Section Porosity: 30% SAPD Porosity: 37% SAPD Permeability: 6539.52mD

1 Low magnification views of a massive and moderately to poorly sorted feldspathic litharenite. Detrital grains range in size from very fine lower to medium upper (with rare very coarse upper), while average grain size is determined to be medium lower. The primary framework is comprised of rock fragments (plutonic [PRF], volcanic [VRF], sedimentary [SRF] and minor metamorphic), quartz (mono- [MQ] and lesser polycrystalline), feldspar (plagioclase [Plag] and potassium [Kfsp]), chert (Cht) and trace detrital dolomite (DTD). Accessory grains include minor heavy minerals (zircon, chloritoid [Chld] and garnet), plus trace mica (muscovite and chlorite), glauconite and carbonaceous debris. Minor amounts of pseudo-matrix (1% - Pmtx) derived from compaction or alteration of feldspathic or argillaceous lithoclast and trace detrital matrix slightly fill primary porosity. Minor amounts of authigenic kaolinite (K – 1%), plus trace chlorite, illite and unidentified clays were also detected. Minor quartz overgrowths (1%) and siderite (1%), plus trace overgrowths were also detected. The visible pore system consist intergranular (27%) and grain dissolution (3%) porosity. Overall reservoir quality is considered to be very good due to lack of compaction, matrix content and diagenetic cements which could reduce primary pore volumes. **x25 ppl**

2 High magnification view in feldspar stained portion of the thin section showing that interstitial pseudo-matrix (Pmtx) derived from altered leached probable volcanic rock fragments. Trace illite (ill) coats grains The following framework and accessory grains are visible in this image: monocrystalline quartz (MQ), potassium feldspar (Kfsp), volcanic rock fragments (VRF), chert (Cht), organic rich shale (SRF), and granitic plutonic rock fragments (PRF), micaceous phyllite (MRF), plagioclase feldspar and altered round glauconite peloids (G). **x100 ppl**

3 This high magnification view shows minor amounts of feldspathic dissolution fines (DF) floating the intergranular pore system (blue epoxy). Possible authigenic chlorite (yellow Chl) coats porosity while chlorite mica (red Chl) occurs within a schist grain (MRF). The other grains in this image are monocrystalline quartz (MQ), clay rich (brown) to dense chert (Cht), plutonic rock fragments (PRF), shale (SRF), plagioclase feldspar (Plag), biotite (Biot) and glauconite (G). **x100 ppl**

4 Heavy minerals (HM) inclusions occur in plagioclase feldspar (Plag) and plutonic rock fragments (PRF). Monocrystalline quartz (MQ), volcanic rock fragments (VRF), shale (SRF), chert (Cht) and garnet (G) are sand grains. The intergranular pores (IP) are enhanced by grain dissolution (GD), or are limited by pyrite (Py), authigenic kaolinite and pseudo-matrix. **x200 ppl**

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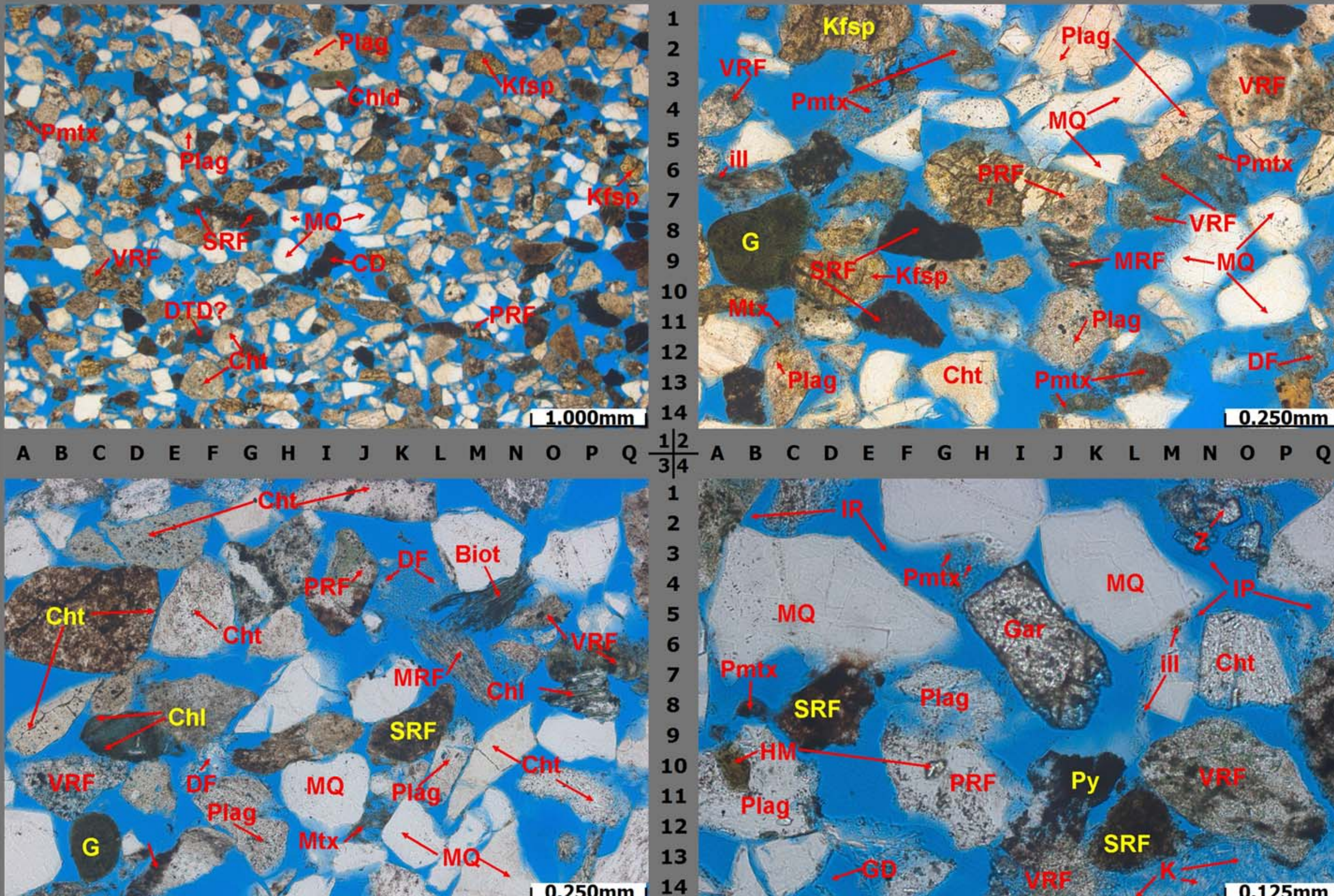

PLATE #4

Sample 5: 276.31m

AGAT Laboratories

THIN SECTION PHOTOMICROGRAPH DESCRIPTION: PLATE 5
LOCATION: SUNCOR ET AL HANGSTN 7-13-084-10 100/07-13-084-10W4M/00
FORMATION: GRAND RAPIDS
ROCK TYPE: FELDSPATHIC LITHARENITE

SAMPLE 6, 278.66m **Thin Section Porosity: 24%** **SAPD Porosity: 36%** **SAPD Permeability: 6864.55mD**

1 Low magnification views of a massive and moderately sorted feldspathic litharenite. Detrital grains range in size from very fine upper to medium lower, while average grain size is determined to be fine lower. The primary framework is comprised of rock fragments (volcanic [VRF], plutonic [PRF], sedimentary [SRF] and minor metamorphic), quartz (mono- [MQ] and minor polycrystalline), feldspar (plagioclase [Plag] and potassium [Kfsp]), with lesser amounts of detrital dolomite and chert (Cht). Accessory grains include minor mica (muscovite, biotite and chlorite), carbonaceous debris, trace heavy minerals (zircon, chloritoid and garnet), glauconite and phosphate. Pseudo-matrix (3% - Pmtx) derived from compaction or alteration of feldspathic or argillaceous lithoclast and detrital matrix (1%) locally fill the primary porosity. Minor amounts of authigenic kaolinite (K - 1%) and chlorite (Chl – 1%), plus trace illite and unidentified clays were also detected. Minor possible dolomite (2%), quartz overgrowths (1%), siderite (1%), plus trace feldspar overgrowths and pyrite were also detected. The visible pore system consist of intergranular (23%) and minor grain dissolution (1%) porosity. Overall reservoir quality is considered to be good due mostly to matrix content and diagenetic cements that reduce the interconnectiveness of the pore system. **x25 ppl**

2 High magnification view in feldspar stained portion of the thin section showing that interstitial pseudo-matrix (Pmtx) derived from altered leached probable volcanic rock fragments. The pore system is occluded by pore bridging authigenic chlorite (Chl) and possible subhedral dolomite cement (Dol?) that has a probably source related to detrital dolomite grains (DTD). The following framework and accessory grains are visible in this image: monocrystalline quartz (MQ), potassium feldspar (Kfsp), volcanic rock fragments (VRF), chert (Cht), silty shale (SRF), and plutonic rock fragments (PRF), plagioclase feldspar, detrital dolomite (DTD) and altered elongated glauconite peloids (G). **x100 ppl**

3 Pseudo-matrix (Pmtx) derived from altered and leached argillaceous lithoclasts and trace authigenic illite (ill) fill minor amounts of primary porosity (blue epoxy). It is difficult to distinguish detrital (DTD) dolomite from possible secondary cement (Dol). The other sand grains are monocrystalline quartz (MQ), plagioclase feldspar (Plag), biotite (Biot), volcanic (VRF) and plutonic (PRF) rock fragments, silty shale (SRF), zircon (Z), glauconite (G) and chloritoid (Chld). **x100 ppl**

4 Grain coating chlorite (Chl), detrital clays (Mtx) and dolomite (Dol) cement slightly reduced porosity (IP). Grain dissolution pore (GD) occurs in plagioclase feldspar (Plag). Mono- (MQ) to polycrystalline quartz (PQ), volcanic rock fragments (VRF), shale (SRF), schist or phyllite (MRF), detrital dolomite (DTD), biotite (Biot) and coal debris (CD) are the grains. **x200 ppl**

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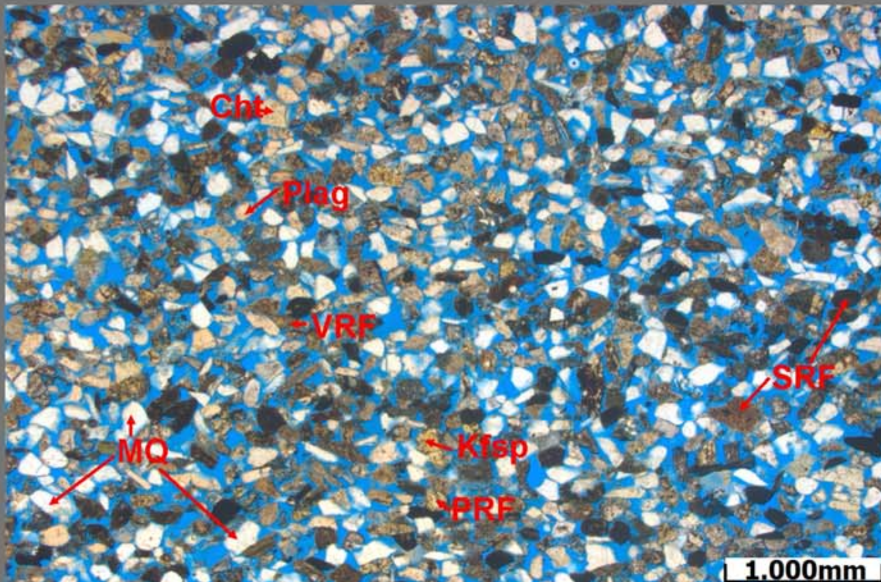

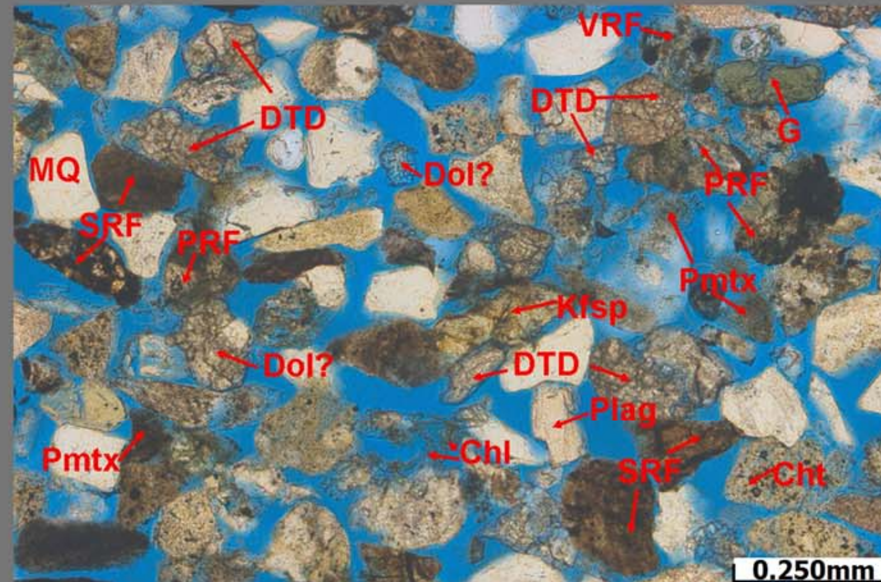

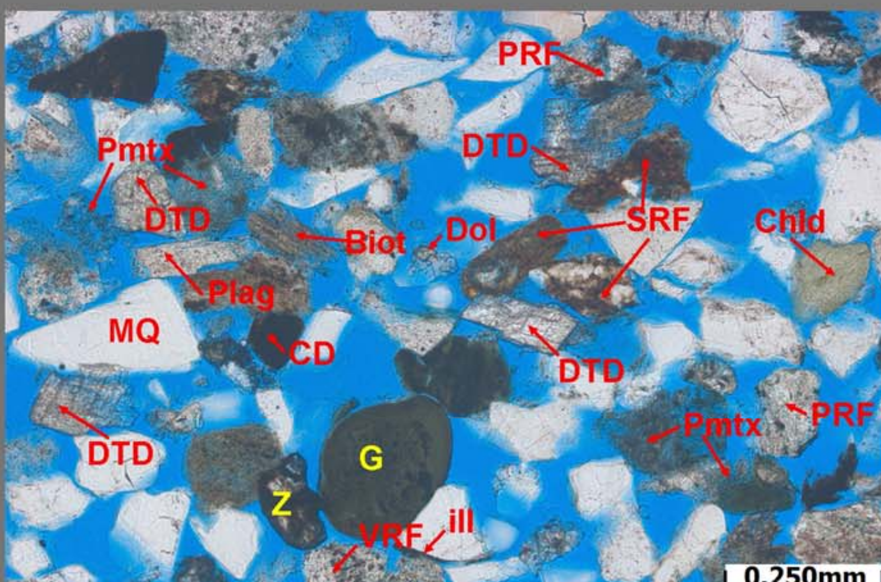

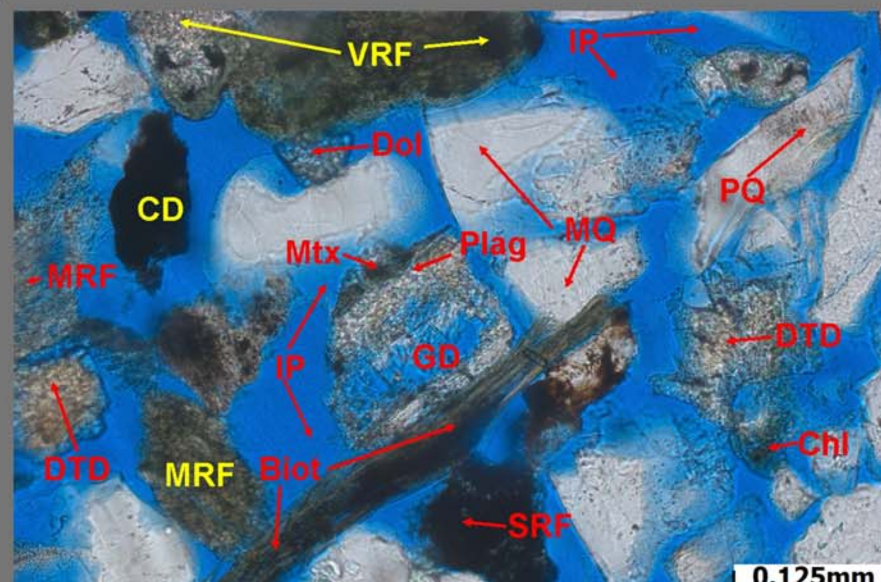

PLATE #5

Sample 6: 278.66m

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THIN SECTION PHOTOMICROGRAPH DESCRIPTION: PLATE 6
LOCATION: SUNCOR ET AL HANGSTN 7-13-084-10 100/07-13-084-10W4M/00
FORMATION: GRAND RAPIDS
ROCK TYPE: FELDSPATHIC LITHARENITE

SAMPLE 7, 280.82m Thin Section Porosity: 26% SAPD Porosity: 36% SAPD Permeability: 6748.93mD

1 Low magnification views of a massive and moderately sorted feldspathic litharenite. Detrital grains range in size from very fine upper to medium lower (average of fine lower). The framework is comprised of rock fragments (volcanic [VRF], plutonic, sedimentary and minor metamorphic), quartz (mono- and lesser polycrystalline), feldspar (plagioclase [Plag] and potassium [Kfsp]), detrital dolomite (DTD) and lesser amounts of chert (Cht). Accessory grains include minor mica (muscovite, biotite and chlorite), heavy minerals (zircon, rutile, chloritoid, sphene and epidote), glauconite, plus trace carbonaceous debris and zeolites. Minor amounts of pseudo-matrix (1%) and detrital matrix (1%) fill the primary porosity. Authigenic kaolinite (K - 1%) and illite (1%), plus trace chlorite and unidentified clays were also detected. Siderite spherules (2%), quartz overgrowths (2%), possible dolomite (1%), plus trace feldspar overgrowths and pyrite are cements. The visible pore system consist of intergranular (24%) and minor grain dissolution (2%) pores. Reservoir quality is considered to be good due to fine grain size, matrix content and diagenetic cements that reduce the interconnectiveness of the pore system.**x25 ppl**

2 High magnification view in feldspar stained portion of the thin section showing porous sand with framework and accessory grains consisting of mono- (MQ) to polycrystalline (PQ) quartz, detrital dolomite (DTD), silty organic rich shale (SRF), potassium feldspar (Kfsp), volcanic rock fragments (VRF), plagioclase feldspar (Plag), chert (Cht), coal debris (CD), chlorite mica (Chl) and glauconite peloids (G). The pore system is occluded by micro-crystalline siderite spherules and locally filled with dissolution fines (DF). Euhedral dolomite (Dol) has a partially diagenetic origin. **x100 ppl**

3 The pore system in this image is reduced by detrital matrix (Mtx), authigenic kaolinite (K), micro-crystalline siderite (Sid) and quartz overgrowths (Ov). The framework and accessory grains are as follows: monocrystalline quartz (MQ), plagioclase feldspar (Plag), detrital dolomite (DTD), volcanic (VRF) to plutonic (PRF) rock fragments biotite (Biot), chert (Cht), micaceous schist (MRF), tripolitic chert (TCht), shale (SRF), coal debris (CD) and zircon (Z). **x100 ppl**

4 Very high magnification view of a feldspathic litharenite showing local pore bridging authigenic chlorite (Chl), plus grain coating detrital matrix (Mtx), carbonaceous material (CD) and unknown authigenic clays (AC) that limit the intergranular pore system (IP). Minor grain dissolution pores (GD) occur in plagioclase feldspar grains (Plag). The other grains are volcanic (VRF) and plutonic (PRF) rock fragments, detrital dolomite (DTD), shale (SRF), chert (Cht), mono- (MQ) to polycrystalline quartz (PQ). **x200 ppl**

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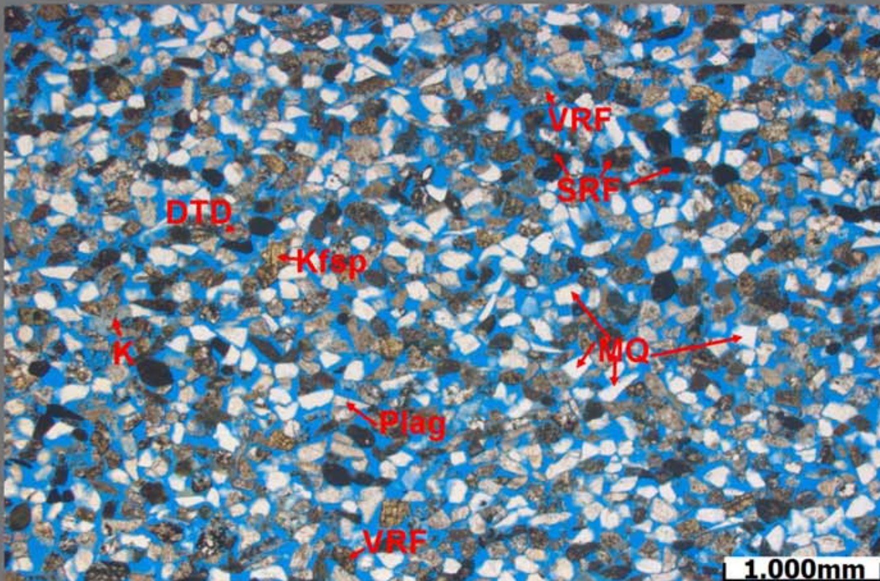
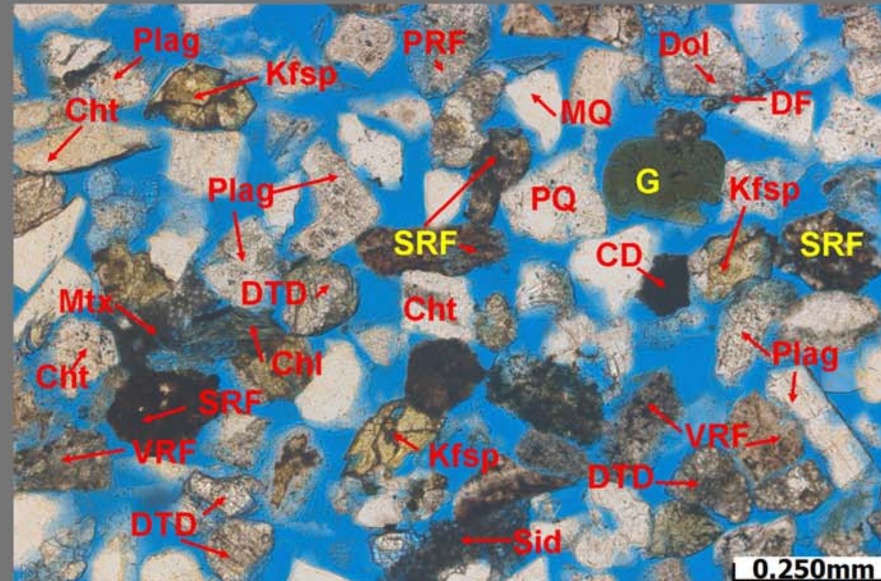
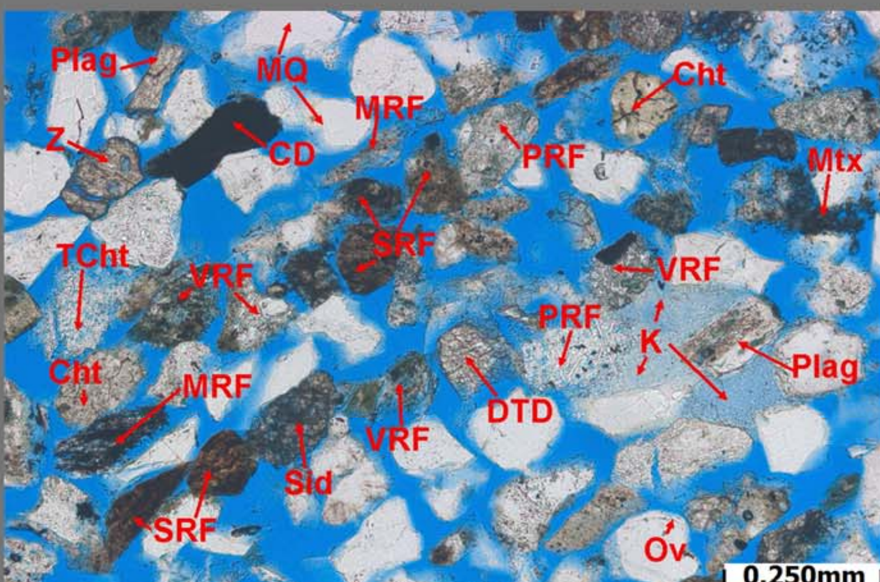
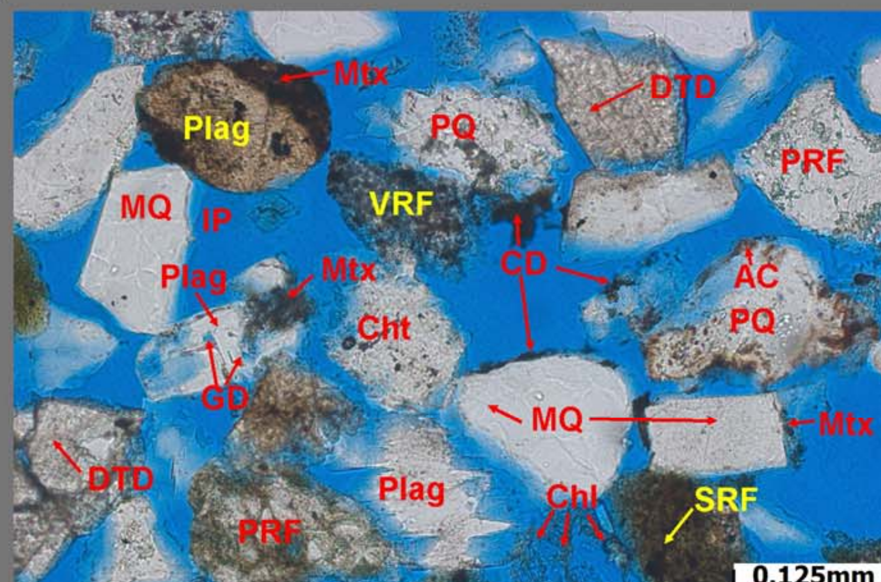




1 2 3 4 5 6 7 8 9 10 11 12 13 14

A B C D E F G H I J K L M N O P Q — 1|2 / 3|4 — A B C D E F G H I J K L M N O P Q





1 2 3 4 5 6 7 8 9 10 11 12 13 14

PLATE #6

Sample 7: 280.82m

AGAT Laboratories

THIN SECTION PHOTOMICROGRAPH DESCRIPTION: PLATE 7
LOCATION: SUNCOR ET AL HANGSTN 7-13-084-10 100/07-13-084-10W4M/00
FORMATION: GRAND RAPIDS
ROCK TYPE: FELDSPATHIC LITHARENITE

SAMPLE 8, 283.87m **Thin Section Porosity: 20%** **SAPD Porosity: 36%** **SAPD Permeability: 6201.20mD**

1 Low magnification view of a massive and moderately sorted feldspathic litharenite. Detrital grains range in size from coarse silt to medium lower (average of fine lower). The framework is comprised of quartz (mono- [MQ] and minor polycrystalline), rock fragments (sedimentary [SRF], volcanic [VRF], plutonic [PRF], and lesser metamorphic), feldspar (plagioclase [Plag] and potassium [Kfsp]), detrital dolomite and lesser amounts of chert. Accessory grains include minor mica (muscovite, biotite [biotite] and chlorite), carbonaceous debris, heavy minerals (zircon, tourmaline and chloritoid) and trace glauconite. Minor amounts of pseudo-matrix (2%) and detrital matrix (1%) fill the primary porosity. Authigenic kaolinite (K - 1%), plus trace chlorite, illite and unidentified clays were also detected. Siderite spherules (2%), quartz overgrowths (2%), possible dolomite (1%), and pyrite are diagenetic cements. The visible pore system consists of intergranular (20%) and trace grain dissolution porosity. Reservoir quality is considered to be good due to fine grain size, matrix content and diagenetic cements that reduce the interconnectiveness of the pore system. **x25 ppl**

2 High magnification view in feldspar stained portion of the thin section showing a relatively packed fabric with the pore system limited by authigenic kaolinite (K), pseudo-matrix (Pmtx) derived from altered lithoclasts, and rare pore bridging indistinct authigenic clays (AC). The framework and accessory grains consisting of monocrystalline quartz (MQ), detrital dolomite (DTD), silty organic rich shale (SRF), plagioclase feldspar (Plag), phyllite (MRF), volcanic (VRF) and plutonic (PRF) rock fragments, muscovite mica (Musc) and carbonaceous debris (CD). Grain dissolution pores (GD) occurs mostly due to leaching of feldspathic grains. **x100 ppl**

3 In this image the pore system is reduced by pseudo-matrix (Pmtx), authigenic grain coating chlorite (Chl) and siderite (Sid) spherules. The framework and accessory grains are as follows: monocrystalline quartz (MQ), plagioclase feldspar (Plag), detrital dolomite (DTD), volcanic (VRF) to plutonic (PRF) rock fragments, biotite mica (Biot), chert (Cht), micaceous schist (MRF), silty shale (SRF) and plagioclase feldspar (Plag). **x100 ppl**

4 Very high magnification view showing the minor limiting effect of detrital matrix (Mtx) and dissolution fines (DF) on the intergranular pore system. Overgrowths (Ov) occur on some monocrystalline quartz grains. The other framework and accessory grains are detrital dolomite (DTD), chert (Cht), slightly to highly altered volcanic rock fragments (VRF), micaceous schist (MRF), chert (Cht), sericitic plagioclase feldspar (Plag), silty shale (SRF) and biotite mica (Biot). **x200 ppl**

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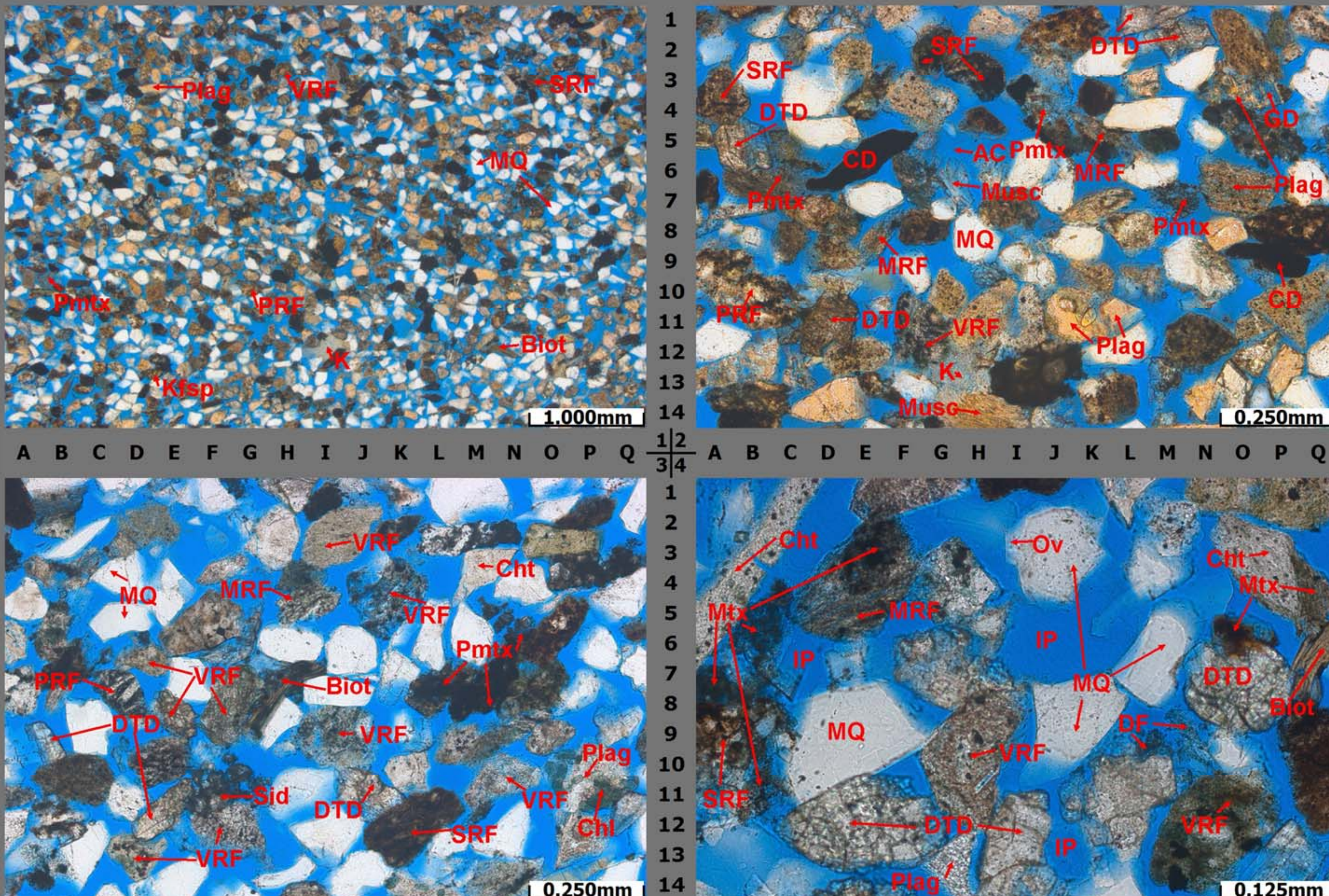

PLATE #7

Sample 8: 283.87m

AGAT Laboratories

THIN SECTION PHOTOMICROGRAPH DESCRIPTION: PLATE 8
LOCATION: SUNCOR ET AL HANGSTN 7-13-084-10 100/07-13-084-10W4M/00
FORMATION: GRAND RAPIDS
ROCK TYPE: FELDSPATHIC LITHARENITE

SAMPLE 10, 289.74m Thin Section Porosity: 26% SAPD Porosity: 35% SAPD Permeability: 6072.46mD

1 Low magnification views of a moderately sorted feldspathic litharenite with horizontally orientated sand grain fabric. Detrital grains range in size from coarse silt to medium lower (average of fine lower). The framework is comprised of quartz (mono- [MQ] and minor polycrystalline), rock fragments (volcanic [VRF], sedimentary [SRF], plutonic [PRF], and lesser metamorphic), feldspar (plagioclase [Plag] and potassium [Kfsp]), detrital dolomite and lesser amounts of chert. Accessory grains include moderate amounts of mica (muscovite, biotite and chlorite), carbonaceous debris (CD), plus trace heavy minerals (zircon, chloritoid and garnet) and glauconite. Minor amounts of pseudo-matrix (2%) and detrital matrix (1%) fill the primary porosity. Authigenic chlorite (2%), kaolinite (1%), illite (1%) and trace grain coating unidentified clays were also detected. Pyrite (2%) that is often associated with coal debris, siderite spherules (1%), quartz overgrowths (1%) and possible dolomite (1%) are the non-clay diagenetic minerals. The visible pore system consists of intergranular (25%) and minor grain dissolution (1%) porosity. Reservoir quality is considered to be good due to fine grain size, matrix content and diagenetic cements that reduce the interconnectiveness of the pore system. **x25 ppl**

2 High magnification view in feldspar stained portion of the thin section showing a patch of authigenic kaolinite (K). The porosity is also reduced by euhedral dolomite (Dol), detrital matrix (Mtx) and grain coating illite (ill). The framework and accessory grains consist of mono- (MQ) to polycrystalline (MQ) quartz, detrital dolomite (DTD), silty rich shale (SRF), potassium feldspar (Kfsp), volcanic (VRF) and plutonic (PRF) rock fragments, plus zircon (Z). **x100 ppl**

3 In this image the pore system is reduced by pseudo-matrix (Pmtx), authigenic kaolinite (K), detrital matrix (Mtx), pore bridging authigenic clays (AC) and quartz overgrowths (Ov). The framework and accessory grains are as follows: monocrystalline quartz (MQ), plagioclase feldspar (Plag), detrital dolomite (DTD), volcanic (VRF) to plutonic (PRF) rock fragments, micaceous phyllite (MRF), organic shale (SRF) and chloritoid (Chld). **x100 ppl**

4 Very high magnification view of the intergranular pore system (IP) slightly enhanced by grain dissolution (GD) but it is also reduced by detrital matrix (Mtx), grain coating indistinct clays (AC) and chlorite (Chl), pseudo-matrix (Pmtx), plus possible authigenic kaolinite (K?) and dolomite (Dol). The framework and accessory grains are mono- (MQ) to polycrystalline (PQ) quartz, detrital dolomite (DTD), highly altered volcanic (VRF) and plutonic (PRF) rock fragments (VRF), silty shale (SRF), sericitic plagioclase feldspar (Plag) and biotite mica (Biot). GD: grain dissolution pore in feldspar. **x200 ppl**

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3	**4**

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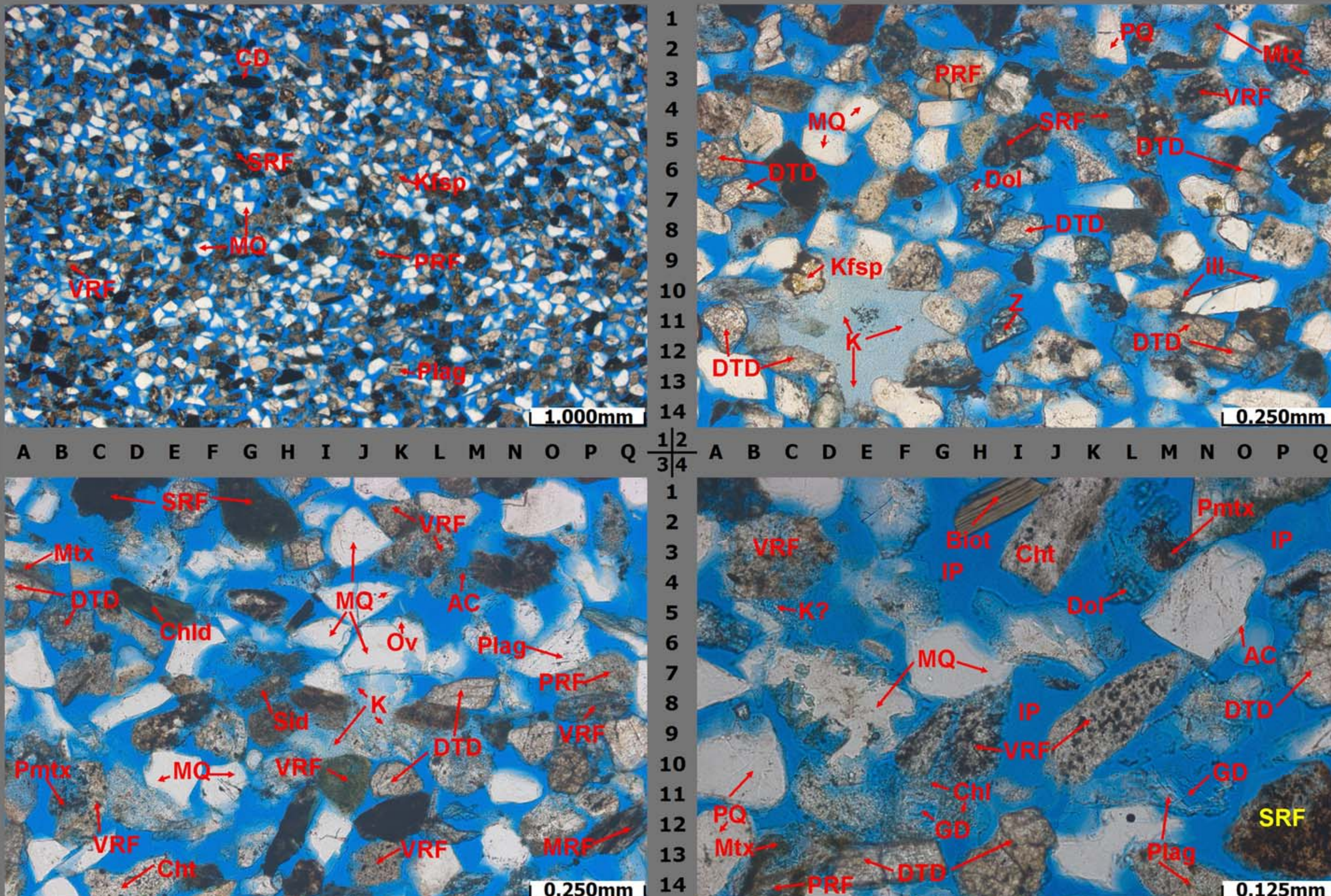

PLATE #8

Sample 10: 289.74m

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THIN SECTION PHOTOMICROGRAPH DESCRIPTION: PLATE 9
LOCATION: SUNCOR ET AL HANGSTN 7-13-084-10 100/07-13-084-10W4M/00
FORMATION: GRAND RAPIDS
ROCK TYPE: FELDSPATHIC LITHARENITE

SAMPLE 12, 297.16m Thin Section Porosity: 14% SAPD Porosity: 34% SAPD Permeability: 1077.37mD

1 Low magnification views of a horizontally laminated and moderately sorted feldspathic litharenite. Detrital grains range in size from coarse silt to fine lower (average of very fine upper). The framework is comprised of rock fragments (volcanic [VRF], sedimentary [SRF], plus lesser plutonic and metamorphic), quartz (mono- [MQ] and minor polycrystalline), plus lesser feldspar (plagioclase and potassium), detrital dolomite and minor amounts of chert. Accessory grains include relatively common horizontally orientated coal debris, plus moderate amounts of mica (muscovite, chlorite and biotite), heavy minerals (zircon) and trace glauconite. Significant amounts of pseudo-matrix (7%) and detrital matrix (4%) fill the primary porosity. Authigenic kaolinite (2%), illite (1%) and chlorite (1%) clays were also detected. Minor pyrite (1%), quartz overgrowths (1%), possible dolomite (1%) and trace siderite are the non-clay diagenetic minerals. The visible pore system consists of intergranular (13%) and minor grain dissolution (1%) porosity. Reservoir quality is considered to be moderate due to its very fine grain size, significant matrix content and compaction, plus minor diagenetic cements that overall reduce interconnectiveness of the pore system. **x25 ppl**

2 High magnification view showing sandstone with significant amounts of labile pseudo-matrix (Pmtx), detrital matrix (Mtx) and authigenic kaolinite (K) compacted between framework grains. The framework and accessory grains consist of monocrystalline quartz (MQ), detrital dolomite (DTD), silty to organic rich shale (SRF), potassium feldspar (Kfsp), volcanic rock fragments (VRF), plagioclase feldspar (Plag), chlorite mica (Chl) and carbonaceous debris (CD). **x100 ppl**

3 In this image the porosity (blue epoxy) is reduced by compaction of labile shale (SRF) and resultant pseudo-matrix (Pmtx) thus causing the moderately interconnected pore system. Detrital matrix (Mtx) and dissolution fines (DF) also limit porosity. The framework and accessory grains are as follows: monocrystalline quartz (MQ), altered plagioclase feldspar (Plag), detrital dolomite (DTD), volcanic (VRF) to plutonic (PRF) rock fragments, micaceous schist (MRF), organic rich shale (SRF), chlorite mica (Chl), and coal debris (CD). **x100 ppl**

4 Very high magnification view of the intergranular pore system (IP) limited by compaction and deformation of labile shale (SRF), pseudo-matrix (Pmtx) and biotite mica (Biot), plus pyrite (Py) cementation. The other framework and accessory grains are monocrystalline quartz (MQ), detrital dolomite (DTD), altered volcanic rock fragments (VRF), chert (Cht), sericitic plagioclase feldspar (Plag) and altered glauconite peloids (G). **x200 ppl**

1	**2**
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GRAND RAPIDS

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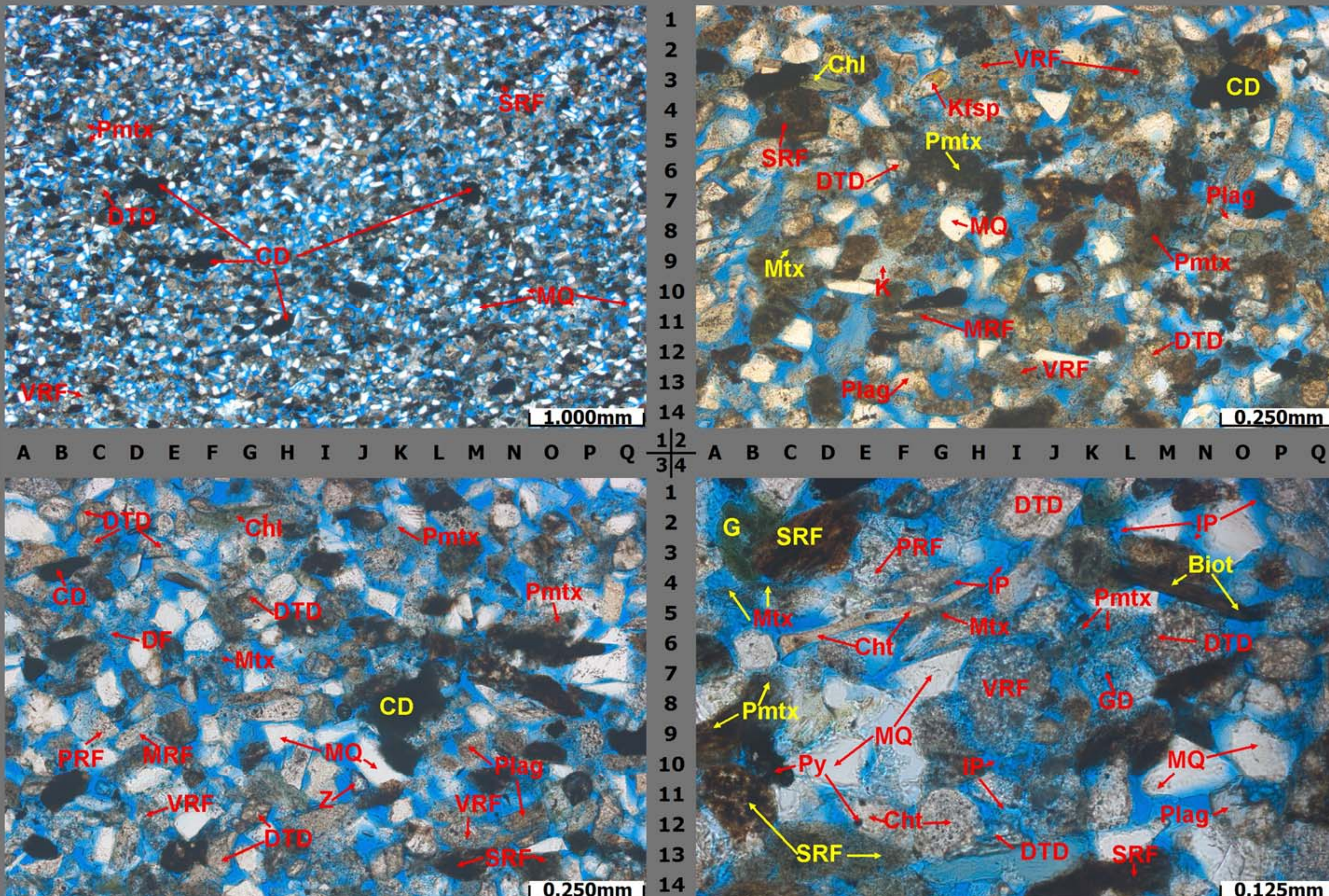

PLATE #9

Sample 12: 297.16m

AGAT Laboratories

PROFESSIONAL GEOLOGIST
Philip Haig
ALBERTA

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