

PETROGRAPHIC ANALYSIS
FOR
HOME OIL COMPANY LIMITED
HOME ET AL S. PIERSON 6-19-2-29
LSD 6-19-2-29 W1M
SOUTH PIERSON, MANITOBA

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TABLE OF CONTENTS

	<u>Page No.</u>
(1) Introduction	1
(2) Discussion	2
Recommendations for Well Completion	7
Table 1	10
(3) Petrographic Analysis:	
Sample 4	11
Sample 13.5	13
Sample 31.5	15
Sample 48	17
Sample 67.5	19
Sample 76.5	21
(4) Appendix:	
Sample Treatment	23
List of Abbreviations	24
Scanning Electron Microscope Photomicrograph Scale	25
Descriptive Terms of Porosity and Pore "Interconnectedness"	26

1

INTRODUCTION

Six samples from the Amaranth Formation from Home Scurry S. Pierson 6-19-2-29 were selected for a detailed scanning electron microscope (SEM) and x-ray diffraction analysis. The emphasis in this study is on the type and distribution of authigenic clays or other minerals that may produce reservoir completion, production and treatment problems. Listed below are sample number, depth, analysis and rock type (general).

<u>Sample Number</u>	<u>Depth (m)</u>	<u>Analysis</u>	<u>Rock Type</u>
4	1022.30	XRD, SEM	Siltstone
13.5	1023.77	XRD, SEM	Siltstone
31.5	1026.42	XRD, SEM	Siltstone
48	1028.40	XRD, SEM	Siltstone
67.5	1030.50	XRD, SEM	Siltstone
76.5	1032.25	XRD, SEM	Siltstone

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2

DISCUSSION

The six samples chosen for detailed analysis may be classified as siltstones. Samples 4 and 48 have slightly larger grain sizes with predominantly upper coarse silts and lower very fine sand grains. The remainder of the samples (13.5, 31.5, 67.5 and 76.5) may be classified as siltstones with varying amounts of argillaceous material contained within them. Sample 76.5 (1032.25 metres) is very argillaceous with a significantly higher shale content than the other samples.

X-Ray Diffraction Results

Samples 4 and 48 both have slightly larger grain sizes than the other samples in addition to having a lower percentage of argillaceous material. These samples contain between 59 and 61% quartz with lesser amounts of feldspars (17 to 20%) and dolomite (7 to 10%). Sample 48 contains a larger percentage of clay in general with 6% illite, 5% chlorite and trace amounts of mixed layer clays. Clay percentages within sample 4 are significantly lower with 1% illite, chlorite and smectite. Sample 4 also contains a large percentage of ferroan dolomite at 10% of the total bulk composition. Within the less than 2 micron fraction, illite was the most abundant mineral in samples 4 and 48 with 27% in sample 4 and 33% in sample 48. Sample 48 also contains a significantly higher percentage of swelling chlorite 31% compared to 13% in sample 4. Smectite comprises 17% of the less than 2 micron fraction within sample 4, however it was not detected within sample 48. Quartz, feldspar, dolomite and siderite are also present within the less than 2 micron fraction in both samples.

Samples 13.5, 31.5, 67.5 and 76.5 differ from the other samples in that they contain a much higher percentage of illite within the total bulk composition (18 to 33%). This is primarily due to a greater percentage of argillaceous material within these rocks. Quartz is still the most abundant mineral within these samples (30 to 36%) with lesser amounts of feldspar and

dolomite. Swelling chlorite (a rare mineral) is also found in abundance and is generally present between 6 and 9% of the total bulk volume. Illite is the most abundant mineral in the less than 2 micron fraction (35 to 50%) with lesser amounts of swelling chlorite (25 to 35%) and trace amounts of mixed layer clays. These samples differ from samples 4 and 48 in that there isn't any siderite detected in the less than 2 micron fraction. Samples 4 and 48 appear to be better reservoir prospects as they contain a significantly lower "less than 2 micron fraction" percentage (4.1 to 6.7%). The other four samples have a significantly higher "less than 2 micron fraction" at 10.4 to 10.5%. For more information on exact XRD results, please refer to Table 1 and the x-ray diffraction data sheets.

Lithotypes

On a previous report submitted by Core Laboratories-Canada, Ltd. reference was made to four distinct lithotypes which were discernable within the Amaranth sand. The report was submitted on November 24, 1986 and was based on 3 wells in the S. Pierson area; 4-21-2-29, 16-10-2-29 and 6-7-2-29. Lithotype A was recognized as a very argillaceous siltstone whereas lithotype B was moderately argillaceous and lithotype C had very little argillaceous material. Lithotype D contained anhydrite cemented very fine to fine grained sand lenses which were suspended in dolomitic siltstone. The size of the sample prevents accurate interpretation with reference to these lithotypes, however it would appear that samples 4 and 48 are of the lithotype C category while the remainder of the samples are of the lithotype B variety.

Samples 4 and 48

These two samples are similar in macroscopic appearance and in XRD composition in addition to having a similar appearance through scanning electron microscope observations. SEM observations show that these samples have a higher percentage of visible porosity due to lesser amounts of argillaceous material. As a result they have been classified as Lithotype C

rocks. Both of these rocks contain a significantly lower percentage of clay material relative to the other samples, however a very large portion of the intergranular pore space is infiltrated by siderite crystals and other non-clay fines. These non-clay fines are generally loosely attached and are susceptible to fines migration at higher elevated production rates. Often these fines are amalgamated with illite and swelling chlorite clays. X-ray diffraction data shows that for the less than 2 micron fraction, illite is the most abundant clay mineral (27 to 33%) with lesser amounts of chlorite (13 to 31%) and trace amounts of mixed layer clays. Smectite was only detected within sample 4 (17%). Quartz and feldspar overgrowth cements are additionally present and are also found on many of the detrital grains, however, extensive clay coverings prevent significant crystal development. The primary porosity type is intergranular porosity. Due to the large percentage of clay and non-clay fines, extensive amounts of microporosity is also present. Dissolution porosity is associated with preferentially dissolved feldspars. The main production problems to be wary of within these two samples is the migration of intergranular microcrystalline fine constituents (ie. quartz, feldspar, dolomite, siderite) and the migration of illite fibers. Sample 4 contains a significant amount of smectite and thus there is an additional swelling problem associated with this sample. XRD analysis indicates that chlorite has the potential to swell when exposed to fresh water or a non-equilibrant brine. Chlorite does not swell to nearly the same extent as smectite. In addition the high percentage of iron bearing minerals within these samples may give rise to further problems if an improper acid treatment is used. Details pertaining to ferroan sensitivity of HCl will be discussed later in the text.

Samples 13.5, 31.5, 67.5 and 76.5

These samples also may be described together as they are morphologically similar both macroscopically and through scanning electron microscope observations. They also have comparable XRD results. All samples contain a significantly lower percentage of quartz (30 to 46%) and a much higher percentage of illite (18 to 33%). The higher percentage of illite within these samples is directly related to the greater amount of argillaceous material and authigenic clays. Because of the higher percentage of argillaceous material, these samples have been put in the lithotype B category. Both XRD and SEM observations indicate that the intergranular clay portion is much higher within these samples, however, the non-clay portion is greatly reduced within the "less than 2 micron fraction". Illite is the most abundant mineral (35 to 50%) with lesser amounts of swelling chlorite (25 to 35%), feldspars (10 to 16%), quartz (10 to 14%), dolomite (2 to 5%) and trace amounts of mixed layer clays. Scanning electron microscope observations show that detrital grains are covered by flaky and crenulated authigenic chlorite with interlayered illite. These clays not only cover grains, but commonly bridge pore throats greatly reducing permeability within the constricted areas. These clays reduce permeability and have high surface to volume ratios and may trap significant amounts of irreducible water. Microporosity is also significant within these samples due to a large percentage of intergranular clays. Dissolution porosity in feldspars is also present, however, it does not contribute significantly to overall porosity. Fines migration problems will also be a factor in these samples due to the clay portion. Quartz, feldspars, dolomite and trace amounts of salt crystals were all detected in the intergranular pore space. All these grains, for the most part are loosely attached and susceptible to fines migration at elevated flow rates. Often these fines are bound by authigenic clays. Porosity is further reduced by the presence of intergranular anhydrite cement which is found in amounts up to 5% of the total bulk volume in samples 31.5

and 76.5. Other samples do not contain significant amounts of this mineral. For more detailed information on individual samples, refer to Table 1 and the scanning electron microscope photomicrographs.

The studied samples are similar in that they all contain significant amounts of iron. This is due to a large percentage of iron bearing minerals which are present in all samples. Siderite, ferroan dolomite and iron rich chlorite are present in varying amounts within all of the samples. Plate 7 shows polaroid pictures of the energy dispersive x-ray pattern for samples 4 and 76.5. Both samples show significantly high percentages of iron in comparison to other minerals present within the rock. The sources of iron is largely from siderite and chlorite within samples 4 and 48 and from the chlorite within the remainder of the samples.

Recommendations for Well Completions

The type and extent of cementation along with the composition and mineralogy of framework grains are all important factors in well completion design. The identification and morphology of intergranular components is of particular importance because they occur within the pore system of the reservoir and are fully exposed to the affects of any fluids introduced into the formation. It is difficult to predict how mineralogical compositions may be affected by the introduction of fluids under reservoir conditions. However, the following points should be kept in mind as options for further investigation.

- (1) Migration of clay and non-clay fines at elevated flow rates.
- (2) Iron sensitivity to acids and oxygenated waters.
- (3) Fresh water and non-equilibrant brine sensitivity of smectite and mixed layer clays.
- (4) Formation of scales due to changes in fluid chemistry.

(1) Fines migration along with iron sensitivity to hydrochloric acids are the two primary concerns to be wary of during production. The presence of illite, chlorite along with microcrystalline non-clay fines which are loosely attached give rise to fines migration problems. The main problems associated with the chlorite and illite is that their morphological forms tend to create large volumes of microporosity within the pore system and produce a large surface area to pore volume ratio. The large surface areas tend to bind large volumes of water within the pore system and create high irreducible water saturations. The crenulated and hairy forms typical of these clays are well illustrated in the photomicrographs. They significantly reduce permeability within the pore throat areas. These clays partially constrict, bridge and in many cases completely fill the pore area reducing both porosity and permeability. At high elevated flow rates these fibers may dislodge and form brush heaps in the pore throat areas. Other non-clay fines which are located in the intergranular pore space are also susceptible to migration at elevated flow rates.

Migration can be minimized by determining maximum flow rates and types of clays present through laboratory experiments. If possible, low to under balanced pressures should be used to prevent pressure surges. Illitic clays may be dissolved in a weak mixture of HF/HCl acids, however, additional caution in this method is necessary due to hydrochloric sensitivity of ferroan components (see below).

(2) Iron bearing minerals are present in significant amounts in all of the samples (ie. siderite and chlorite). Chlorite contains a large amount of iron in its octohedral layer and thus is extremely sensitive to acid and oxygenated waters. Chlorite dissolves easily in most acid systems and the iron which is freed as result of this reaction may reprecipitate as gelatinous ferric hydroxide $Fe(OH)_3$ when the acid is spent. Ferric hydroxide precipitates into small colloids which eventually amalgamate together covering the pore throat areas reducing permeability. To avoid the precipitation of ferric hydroxide, reducing the shut in time and returning the acid while it has a pH of less than 2 is imperative. It is important not to add sequestering agents indiscriminantly as they may precipitate out causing further reservoir damage. If ferric hydroxide has been precipitated in the reservoir due to a poorly designed acid job or mechanical problems it can be removed by treatment with weak HCl together with appropriate chelating agents and oxygen scavengers.

(3) Smectite, degraded illite and expandable chlorite are all minerals which have the potential to swell when placed under variable reservoir conditions. Many of these minerals expand to some degree when in contact with either fresh or unequilibrated brine fluid. The most damaging of the swelling clays are smectites which make up 1% in sample number 4 while the remainder of the samples do not contain any significant amounts of smectite. XRD analysis shows that chlorite within the samples has some degree of swelling associated with it which is rare. Swelling will be less than in the smectites, however exposure to fresh water or non-equilibrium brines will reduce

the permeability of the reservoir. Swelling is also expected from the mixed layer clay component. In reservoirs which contain swelling clays a number of approaches may be used. Swelling clays are in equilibrium with formation fluids therefore oil field brines will cause the least amount of clay swelling. If formation brine is not available, drilling with potassium and calcium treated waters will reduce the swelling. Oil based muds though expensive will keep the clays from coming into contact with fresh waters. If the reservoir has already been damaged, then the introduction of a mixture of hydrochloric and hydrofluoric acid solutions can return the reservoir to predamaged production rates. Care must be given to returning the acid before it has been spent as there is a potential for hydrous silica precipitation within the reservoir.

(4) Anhydrite was detected in significant amounts within samples 31.5 and 76.5 (5%). Anhydrite often has scale problems associated with it. Scale precipitation is due to changes in fluid chemistry, pressure temperature and agitation. Scale can form on machinery or within reservoirs leading to reduced production. Most scale problems occur as a result of mixing incompatible fluids. This will include mixing those concentrated in sulphate or bicarbonate with those containing calcium, barium or strontium ions. Scale can also be inhibited by maintaining temperature, pressure and pH found in the reservoir.

TABLE 1
XRD MINERALOGY

Home et al Scurry S. Pierson 6-19-2-29

Sample Number	Depth (m)	Bulk (%)														<2 Micron Fraction (%)					% Less Than 2 Microns		
		Quartz	Plagioclase	K-Spar	Calcite	Dolomite	Siderite	Illite	Chlorite/ Swelling Chlorite	Smectite	Mixed Layer Clays	Dolomite (Ferrous)	Anhydrite	Analcite	Illite	Chlorite/ Swelling Chlorite	Smectite	Mixed Layer Clays	Non-Clay Minerals				
4	1022.30	59	6	11	-	10	1	1	1	1	1	1	1	1	10	-	-	27	13	17	T	43	4.1
13.5	1023.77	34	10	7	7	-	33	9	-	T	T	T	T	T	T	T	T	51	36	-	T	13	12.5
31.5	1026.42	30	8	17	-	8	-	24	8	-	T	T	T	T	T	T	T	50	27	-	T	23	11.0
48	1028.40	61	11	9	T	7	1	6	5	-	T	-	-	-	-	-	-	33	31	-	T	36	6.7
67.5	1030.50	46	16	5	-	9	-	18	6	-	T	T	-	-	-	-	-	35	34	-	T	31	10.4
76.5	1032.25	36	6	7	-	15	-	25	6	-	T	T	5	T	T	T	T	45	25	-	T	30	4.1

3

X-RAY DIFFRACTION ANALYSIS

Sample Number: 4
Depth: 1022.30 m

	<u>Material Less than 2 Microns</u>	<u>Material Greater than 2 Microns</u>	<u>Calculated Bulk Composition</u>
Quartz	11	63	59
Plagioclase	Trace	6	6
K-Spar	7	11	11
Calcite	Nil	Nil	Nil
Dolomite	5	10	10
Siderite	20	Nil	1
Pyrite	Nil	Nil	Nil
Kaolinite	Nil	Nil	Nil
Illite	27	Nil	1
Chlorite/ Swelling Chlorite	13	Nil	1
Smectite	17	Nil	1
Mixed Layer Clays (Swelling)	Trace	Nil	Trace
Dolomite (Ferroan)	Nil	10	10

CLAY SEPARATION BY FLOATATION

Material Less Than 2 Microns: 4.1

Material Greater Than 2 Microns: 95.9

Sample Number: 4 (SEM)
Depth: 1022.30 metres
Formation: Lower Amaranth Sand

- A This low magnification overview shows a silt to lower very fine grained sandstone which is moderately well sorted. This rock is characterized by containing an abundance of microcrystalline siderite cement which is found filling the pore spaces. XRD data shows that siderite comprises 20% of the "less than 2 micron fraction" and 1% of the total bulk composition. (200x)
- B This higher detailed view further illustrates the intergranular and detrital components found within this reservoir. The view illustrates a large abundance of intergranular fines within the pore space. Also shown is degraded illite (arrows) which are often found filling the pore space and amalgamating intergranular fines. X-ray diffraction data shows that quartz fines comprise 11% of the less than 2 micron fraction, feldspar 7%, dolomite 5%, siderite 20%, illite 27%, swelling chlorite 13%, smectite 17% with trace amounts of mixed layer clays. (1000x)
- C This highly detailed view shows greater detail in the pore throat area. Shown here are siderite crystals with occasional dolomitic microcrystals filling the pore space area and are loosely attached to the detrital grains. Swelling chlorite and illite which cover the grain in the upper left hand corner are often cemented and attach these crystals to the grain surfaces. Also shown are poorly developed euhedral quartz overgrowths (arrows) which reduce overall porosity. (2000x)
- D This highly detailed view further illustrates how siderite and other intergranular fines are often amalgamated with authigenic clays within the sample. This sample contains 1% smectite, 1% chlorite and 1% illite in the calculated bulk composition and all these clays reduce permeability as discussed in the text. Note the pore bridging illite in the upper portion of the photomicrograph (H4). (2000 x)

X-RAY DIFFRACTION ANALYSIS

Sample Number: 13.5
Depth: 1023.77 m

	<u>Material Less than 2 Microns</u>	<u>Material Greater than 2 Microns</u>	<u>Calculated Bulk Composition</u>
Quartz	2	38	34
Plagioclase	11	10	10
K-Spar	Trace	8	7
Calcite	Trace	8	7
Dolomite	Nil	Nil	Nil
Siderite	Nil	Nil	Nil
Pyrite	Nil	Nil	Nil
Kaolinite	Nil	Nil	Nil
Illite	51	31	33
Chlorite/ Swelling Chlorite	36	5	9
Smectite	Nil	Nil	Nil
Mixed Layer Clays (Swelling)	Trace	Trace	Trace
Dolomite (Ferroan)	Nil	Trace	Trace
Anhydrite	Nil	Trace	Trace

CLAY SEPARATION BY FLOATATION

Material Less Than 2 Microns: 12.5

Material Greater Than 2 Microns: 87.5

Sample Number: 13.5 (SEM)
Depth: 1023.77 metres
Formation: Lower Amaranth Sand

- A This low magnification overview shows a siltstone with occasional very fine detrital grains throughout. Unlike the previous sample this rock contains a lower percentage of non-clay fines but a higher percentage of clay material. This sample is poor to moderately sorted with a variety of detrital grains throughout including quartz, feldspars and dolomites. Note how primary intergranular porosity is reduced by the presence of abundant clays. (200x)
- B This high magnification view illustrates many of the cements within the sample and their relationship to detrital framework components. Shown here is abundant degraded illite (L4) covering many of the grains which are intimately associated with swelling chlorite (M10). Also shown in this view are non-clay cements including dolomite (P7) and authigenic quartz cements (G3). (1000x)
- C This highly detailed view shows how authigenic clay cements (illite and chlorite) greatly lead to reduction in permeability throughout the reservoir. Shown in this view is a degraded feldspar fragment in the upper left hand corner of the view (A2) which has become dissociated as a result of extensive resorption. Additionally shown are various other fines within the intergranular pore space which are amalgamated with many of the authigenic clays. X-ray diffraction shows that of the components which are less than 2 microns in size quartz comprises 2%, feldspar 11%, dolomite 2%, illite 50%, swelling chlorite 35%, chlorite 35% and mixed layer clays are found in trace amounts throughout. (2000x)
- D This highly detailed view helps illustrate the detrimental affects on permeability these clays have. Shown here are pore bridging illites (arrow) which cover the pore throat areas, greatly reducing the permeability of the reservoir. The pore bridging affects of illite are also shown in the upper right hand corner of the photomicrograph (O5). It appears that this clay has trapped many of the non-clay fines reducing permeability fluid flow. (2000x)

X-RAY DIFFRACTION ANALYSIS

Sample Number: 31.5
Depth: 1026.42 m

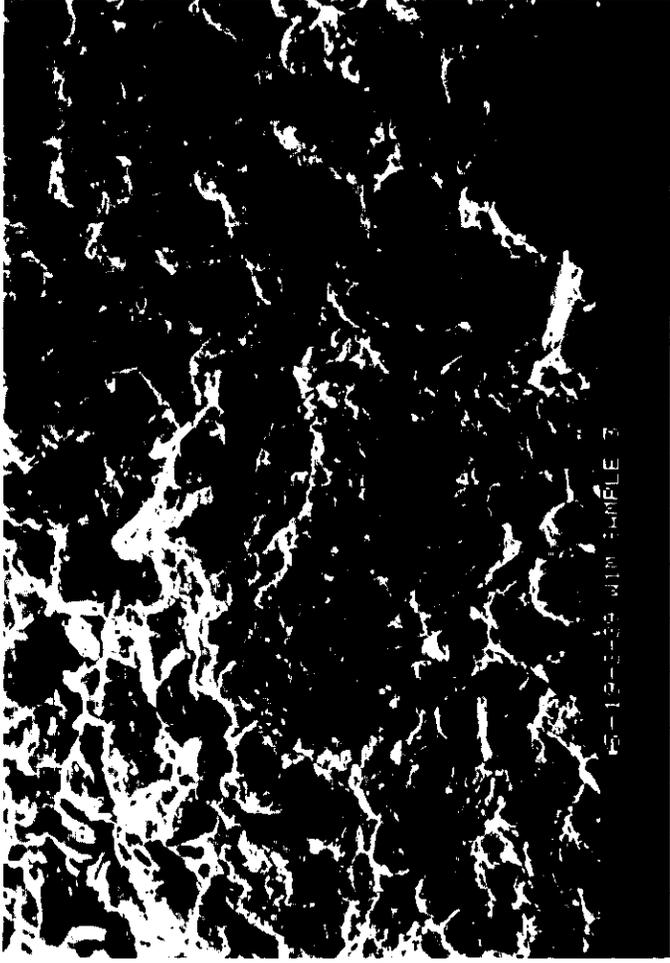
	<u>Material Less than 2 Microns</u>	<u>Material Greater than 2 Microns</u>	<u>Calculated Bulk Composition</u>
Quartz	9	33	30
Plagioclase	4	8	8
K-Spar	6	18	17
Calcite	Nil	Nil	Nil
Dolomite	4	9	8
Siderite	Nil	Nil	Nil
Pyrite	Nil	Nil	Nil
Kaolinite	Nil	Nil	Nil
Illite	50	21	24
Chlorite/ Swelling Chlorite	27	6	8
Smectite	Nil	Nil	Nil
Mixed Layer Clays (Swelling)	Trace	Nil	Trace
Anhydrite	Nil	5	5
Dolomite (Ferroan)	Nil	Trace	Trace

CLAY SEPARATION BY FLOATATION

Material Less Than 2 Microns: 11.0
Material Greater Than 2 Microns: 89.0

Sample Number: 31.5 (SEM)
Depth: 1026.42 metres
Formation: Lower Amaranth Sand

- A This low magnification overview gives a comparison of the porous and non-porous sections of the sample. The lithotype B samples typically have argillaceous streaks throughout and this is well illustrated in this view. Shown in the right hand portion is a sandy porous section while on the left hand side of the photomicrograph an argillaceous and less porous view is shown. The non-porous section of the photomicrograph is well cemented by intergranular anhydrite cement which further reduces the primary porosity. (200x)
- B This higher magnification view further illustrates many of the intergranular components within this sample. Shown here are quartz overgrowths on a detrital grain (D5) along with a feldspar overgrowth (arrow) and abundance of pore bridging illite and chlorite. Illite and chlorite are difficult to distinguish in these samples as they are intimately associated with each other and are often amalgamated to form a mixed layer clay. (1000x)
- C This view shows abundant crenulated and fibrous chlorite (L5) clays which cover many of the detrital grains in the sample. The growth of these clays into the pore system greatly reduces porosity. In addition the bridging of illite across the pore throats (N9) will reduce the permeability of the reservoir. Also shown here is a small halite crystal (arrow) which is found wedged in the intergranular pore space. Halite is generally not detected through x-ray diffraction methods as it is easily dissolved during the floatation process. (2000x)
- D This view shows an abundance of K-Spar overgrowths on a detrital feldspar grain (E6). Also shown in this view is a complex arrangement of chlorite, illite and mixed layer clays which cover many of the detrital grains within the sample and reduce permeability. Non-clay fine crystals (C10, F3) are occasionally found throughout. (2000x)



P-13-559 NIM SAMPLE 3

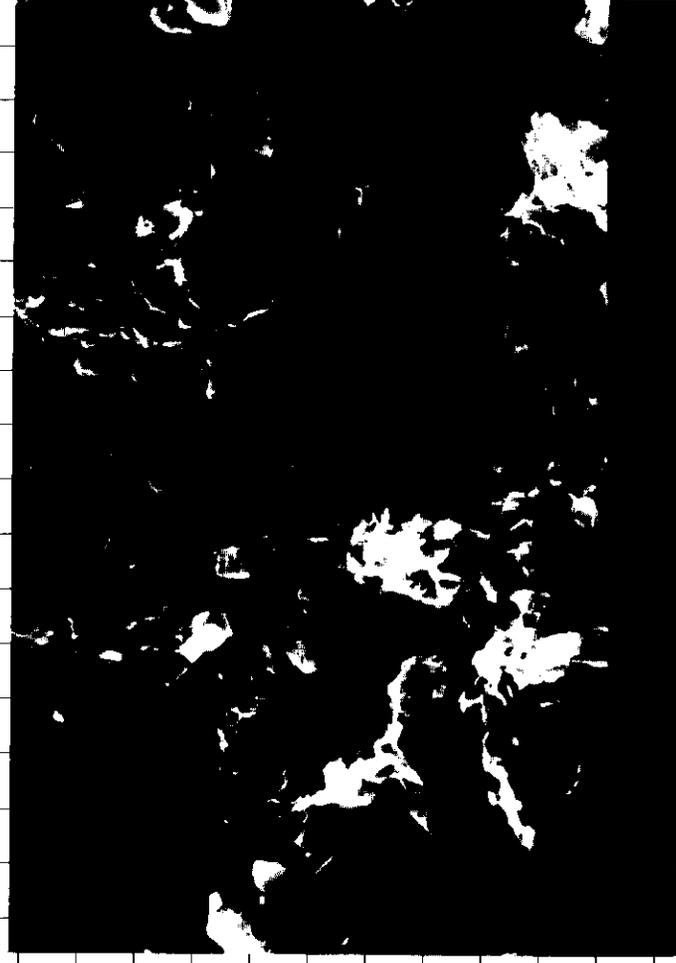
A B C D E F G H I J K L M N O P Q
R S T U V W X Y Z



A B C D E F G H I J K L M N O P Q
R S T U V W X Y Z



A B C D E F G H I J K L M N O P Q
R S T U V W X Y Z



A B C D E F G H I J K L M N O P Q
R S T U V W X Y Z

X-RAY DIFFRACTION ANALYSIS

Sample Number: 48
 Depth: 1028.40 m

	<u>Material Less than 2 Microns</u>	<u>Material Greater than 2 Microns</u>	<u>Calculated Bulk Composition</u>
Quartz	6	66	61
Plagioclase	3	11	11
K-Spar	4	9	9
Calcite	Nil	Trace	Trace
Dolomite	4	7	7
Siderite	19	Trace	1
Pyrite	Nil	Nil	Nil
Kaolinite	Nil	Nil	Nil
Illite	33	4	6
Chlorite/ Swelling Chlorite	31	3	5
Smectite	Nil	Nil	Nil
Mixed Layer Clays (Swelling)	Trace	Nil	Trace
Anhydrite	Trace	Nil	Trace

CLAY SEPARATION BY FLOATATION

Material Less Than 2 Microns: 6.7
 Material Greater Than 2 Microns: 93.3

Sample Number: 48 (SEM)
Depth: 1028.40 metres
Formation: Lower Amaranth Sand

A This low magnification view shows a moderately well sorted, well lithified silt to lower fine grained sandstone. This sample is similar to sample number 4 in that it has a coarser grain size and an abundance of intergranular siderite cement. The abundance of microcrystalline cement is well illustrated in this view. (200x).

B This view fully illustrates the abundance of non-clay and clay fine material within the intergranular pore system. XRD data shows that for the less than 2 micron fraction quartz comprises 6%, plagioclase 3%, K-Spar 4%, dolomite 4%, siderite 19%, illite 33%, swelling chlorite 31% and mixed layer clays are found in trace amounts in this sample. Because all these fines are in contact with the pore fluid one can expect greatly reduced permeabilities by their presence. (500x)

C This view denotes the presence of a large siderite grain (L7) and extensive K-Spar overgrowing on a detrital feldspar grain (F8). Feldspar and quartz overgrowths are all present within this sample however they do not lead to significant decreases in porosity. The main permeability and porosity reducers within these samples are fine materials (arrows) located in the intergranular pore space area. (1000x)

D This highly detailed view further illustrates the damaging affects of both non-clay and clay fractions which reduce reservoir quality. The non-clay fines are generally loosely attached or poorly cemented by the clay portion and are susceptible to fines migration. Because the illite and chlorite contain a high surface to volume ratio, higher irreducible water saturations are expected. Though the chlorite has a swelling potential, its ability to absorb water and expand is not as much as the smectite. (2000x)

X-RAY DIFFRACTION ANALYSIS

Sample Number: 67.5
Depth: 1030.50 m

	<u>Material Less than 2 Microns</u>	<u>Material Greater than 2 Microns</u>	<u>Calculated Bulk Composition</u>
Quartz	14	49	46
Plagioclase	12	17	16
K-Spar	Trace	6	5
Calcite	Nil	Nil	Nil
Dolomite	5	9	9
Siderite	Nil	Nil	Nil
Pyrite	Nil	Nil	Nil
Kaolinite	Nil	Nil	Nil
Illite	35	16	18
Chlorite/ Swelling Chlorite	34	3	6
Smectite	Nil	Nil	Nil
Mixed Layer Clays (Swelling)	Trace	Nil	Trace
Dolomite (Ferroan)	Nil	Trace	Trace

CLAY SEPARATION BY FLOATATION

Material Less Than 2 Microns: 10.4
Material Greater Than 2 Microns: 89.6

Sample Number: 67.5 (SEM)
Depth: 1030.50 metres
Formation: Lower Amaranth Sand

- A This view shows some of the more porous sections of the sample. This sample has been placed into the lithotype B category as a result of extensive argillaceous material which reduces permeability and porosity. XRD data shows that within the bulk composition, quartz is the most abundant mineral at 46% which lesser amounts of plagioclase 16%, K-Spar 5%, dolomite 9%, illite 18%, chlorite 6% and trace amounts of mixed layer clays and ferroan dolomite. (200x)
- B This view further denotes the presence of extensive K-Spar overgrowths (centre) on detrital feldspar grains. These overgrowths are occasionally found throughout and do not lead to significant decreases in overall porosity. Illite is found covering this feldspar overgrowth (K4) in addition to surrounding many of the detrital grains around it. (2000x)
- C This photomicrograph denotes the presence of halite within the intergranular pore system (arrows). Halite may be found both as isolated cubic crystals and detrital covering cement. Halite is not detected in XRD due mainly to its trace amounts and its easy dissolution during the X-ray preparation process. Also shown are an abundance of damaging clays which are found covering, filling and bridging many of the pore spaces. Illite is bridging the pores (H7) and the chlorite is covering the grains. (2000x)
- D This view shows an abundance of authigenic clays which have amalgamated and cemented many of the non-clay crystals to the detrital grain walls. X-ray diffraction data shows that of the "less than 2 micron fraction" quartz comprises 14%, feldspar 12%, dolomite 5%, illite 35%, swelling chlorite 34% with trace amounts of mixed layer clays. (2000x)

X-RAY DIFFRACTION ANALYSIS

Sample Number: 76.5
Depth: 1032.25 m

	<u>Material Less than 2 Microns</u>	<u>Material Greater than 2 Microns</u>	<u>Calculated Bulk Composition</u>
Quartz	10	39	36
Plagioclase	4	6	6
K-Spar	12	6	7
Calcite	Nil	Nil	Nil
Dolomite	4	16	15
Siderite	Nil	Nil	Nil
Pyrite	Nil	Nil	Nil
Kaolinite	Nil	Nil	Nil
Illite	45	24	25
Chlorite/ Swelling Chlorite	25	4	6
Smectite	Nil	Nil	Nil
Mixed Layer Clays (Swelling)	Trace	Nil	Trace
Analcite	Nil	Trace	Trace
Anhydrite	Nil	5	5
Dolomite (Ferroan)	Nil	Trace	Trace

CLAY SEPARATION BY FLOATATION

Material Less Than 2 Microns: 4.1
Material Greater Than 2 Microns: 95.9

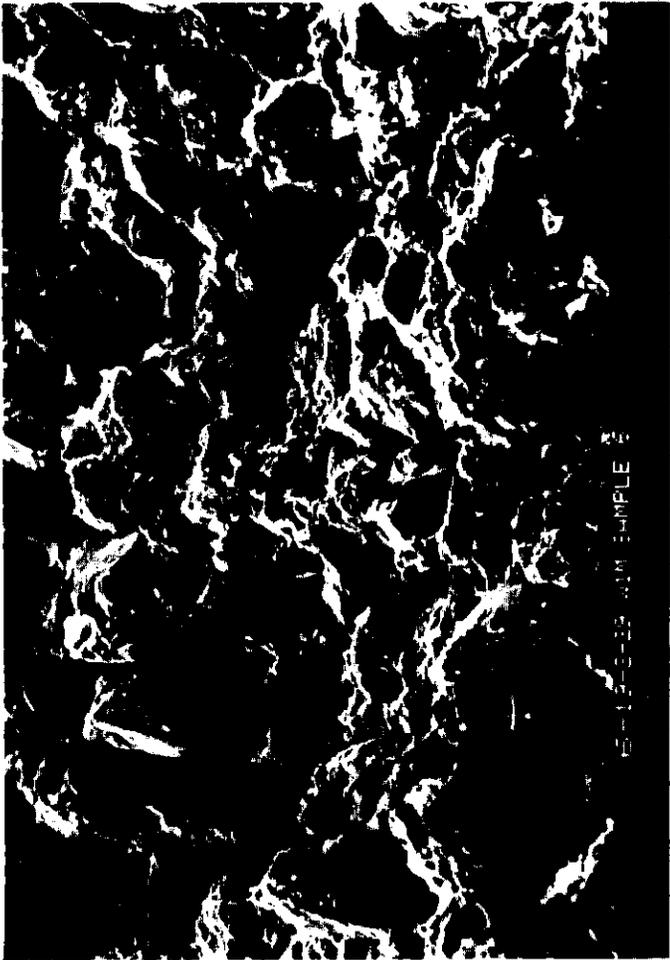
Sample Number: 76.5 (SEM)
Depth: 1032.25 metres
Formation: Lower Amaranth Sand

A This low magnification overview of an argillaceous siltstone shows the changing characteristics of the non-porous and porous sections. The non-porous sections in the upper right hand corner of the photomicrograph have reduced porosities as a result of anhydrite cement and argillaceous material in the sand. A reduction in clay material in the porous sections of the sample lead to greater permeabilities. (200x)

B This higher detailed view within the porous sections of the rock shows how decreased clay content leads to better pore interconnectedness within the sample, however the presence of abundant fines and pore bridging clays in other portions of the sample still gives this reservoir poor quality even in the porous sections of the sample. (1000x)

C This higher detailed view denotes the presence of abundant non-clay fines and pore bridging illite (arrows) and detrital grain covering chlorite and illite clays. Shown here is permeability barrier which contains pore bridging clays that entrap many of the finer crystalline particles in the pore throat areas. (2000x)

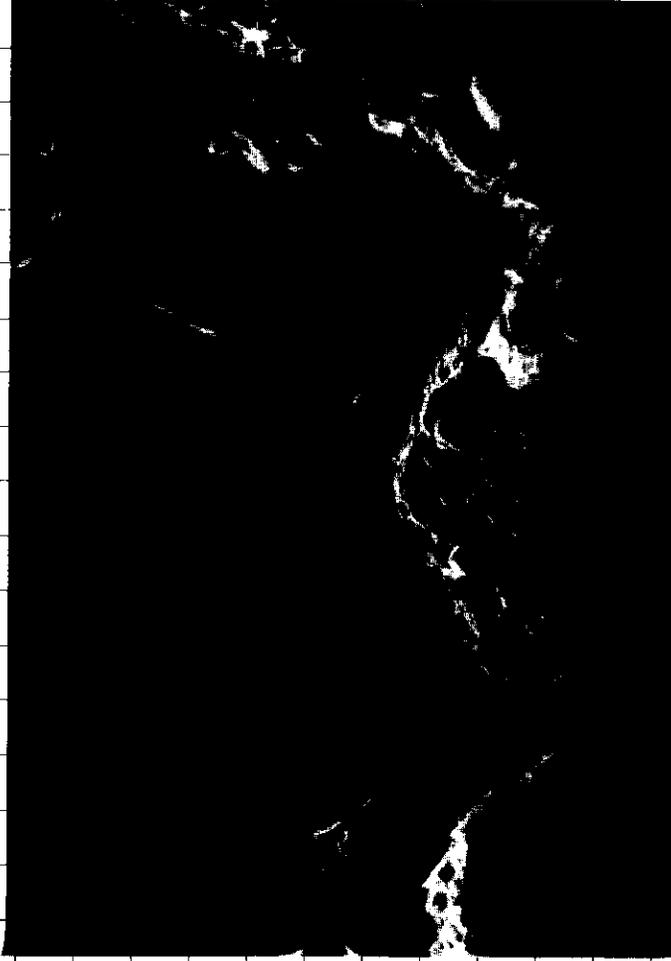
D This view of the intergranular pore space illustrates abundant non-clay fines and chlorite clays (F4). Also shown in this view are authigenic feldspar overgrowths on detrital feldspar grains (O5, M10). Within the material less than 2 microns quartz comprises 10%, plagioclase 4%, K-Spar 12%, dolomite 4%, illite 45%, chlorite 25% with trace amounts of mixed layer clays. The main problem associated with the chlorite within these samples is its sensitivity to hydrochloric acid followed by the potential precipitation of ferric hydroxide gels. (2000x)



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



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



4

SAMPLE TREATMENT

Routine X-Ray Diffraction Analysis: A representative sample is disaggregated and then separated by floatation into greater than and less than two (2) micrometre size fractions. Each fraction is analyzed separately, reported separately and mathematically recombined to provide a bulk composition. The less than two (2) micrometre size fraction (clay fraction) is subjected to a four step analysis: at room humidity, after glycolation and where necessary after heat treatment and acid digestion. The clay fraction is prepared by dispersion in sodium hexametaphosphate solution and flocculation in magnesium chloride solution. This also stabilizes the ionic state of some clays. The glycolation treatment is used to identify swelling clays such as smectites, vermiculite and mixed layer clays. The heat treatment aids in the identification of chlorite types and swelling clays. Where further identification of clay type in a chlorite-kaolinite mix is necessary, the sample is digested in warm dilute hydrochloric acid, which decomposes iron-rich chlorites.

Scanning Electron Microscopy: A typical sample for the interval indicated is taken from the centre of the core, providing a clean freshly broken surface for viewing. The pieces, approximately one centimetre square, are mounted on aluminum stubs using colloidal silver as the adhesive and then coated under high vacuum with a fine coating of gold. A Cambridge Stereoscan 604 with a Kevex Energy Dispersive X-Ray Analyzer is used to examine the specimen and produce photographs beginning with low magnification overviews and progressing to high magnification representative views of areas of interest.

LIST OF ABBREVIATIONSROCK CONSTITUENTS

A Apatite
 AF Authigenic Feldspar
 AN Anhydrite
 AQ Authigenic Quartz
 B Bitumen
 C Clay Minerals
 CA Calcite
 CH Chert
 CL Chlorite
 CM Carbonaceous Material
 CO Collophane
 D Dolomite
 F Feldspar
 FO Fossil
 G Glauconite
 I Illite
 IN Intraclast
 K Kaolinite
 M Mica
 MD Mud Damage
 O Opal
 OO Ooid
 P Pore Space
 PE Peloid
 PI Pyrite
 Q Quartz
 RF Rock Fragments
 S Siderite
 SM Smectite
 SRF Sedimentary Rock Fragments
 PRF Plutonic Rock Fragments
 MRF Metamorphic Rock Fragments

ROCK NAMES

QA Quartzarenite
 SA Subarkose
 SL Sublitharenite
 AR Arkose
 LA Lithic Arkose
 FL Feldspathic Litharenite
 LI Litharenite
 CGL Conglomerate
 SI Siltstone
 SH Shale
 LS Limestone
 DO Dolomite
 AN Anhydrite

OTHER

N Nil
 T Trace
 VP Very Poor
 P Poor
 M Moderate
 G Good
 VG Very Good
 W Well
 VW Very Well
 PPL Plane Polarized Light
 XPL Cross Polarized Light

POROSITY TYPES

MI Microporosity
 IG Intergranular Porosity
 S Secondary Porosity
 F Fracture Porosity
 V Vugular Porosity
 MO Moldic Porosity
 IA Intragranular Porosity
 IC Intercrystalline Porosity

SCANNING ELECTRON MICROSCOPE PHOTOMICROGRAPH SCALE

Scale for each photomicrograph is indicated by the insert at the lower left corner of each print. This scale measurement corresponds with the width of the black bar at the base of the photomicrograph.

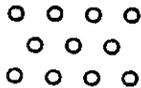
<u>Scale Width</u>	<u>Approximate Magnification</u>
1 mm	x20
400 μm	x50
200 μm	x100
100 μm	x200
40 μm	x500
20 μm	x1000
10 μm	x2000
4 μm	x5000
2 μm	x10000
1 μm	x20000
0.4 μm	x50000

DESCRIPTIVE TERMS OF
POROSITY AND PORE "INTERCONNECTEDNESS"

Porosity

<u>Term</u>	<u>Range Percent</u>
Very Good	24
Good	12 - 24
Moderate	6 - 12
Poor	3 - 6
Very Poor	1 - 3
Tite	No Visible Porosity

Pore "Interconnectedness" (≈ Permeability)

<u>Representation</u>	<u>Term</u>	<u>Description</u>
	Very Poor	Pore spaces are isolated
	Poor	Pore spaces are locally interconnected in pairs.
	Moderate	Local pore groups are interconnected.
	Good	Most pore spaces are simply interconnected.
	Very Good	Most pores are interconnected with complex pore interconnections.

The measurement error for porosity determinations based on thin-sections increases with decreasing grain size and is especially serious when the grains are fine sand size or smaller (ibid. Harrel, J. 1981 JSP V51: Halley, R.B., 1978 JSP V48).

