

RESERVOIR MICRO ANALYSIS

Glenaire 1/ST-1

Pretty Hill Formation

**Report for
Beach Petroleum Limited**

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Raw Data Folder Glenaire 1/ST-1 Raw Data in MS Excel format	
Permeability Folder Glenaire 1/ST-1 Permeability thickness & porosity in MS Excel format	
Plots Folder Glenaire 1/ST-1 Data plots in CGM and jpg formats	
Photos Folder Glenaire 1/ST-1 Micro Photographs of selected samples in jpg format	

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Summary

An interpretation of reservoir properties has been carried out using washed and dried drill cuttings over three separate intervals of the Glenaire 1/ST-1 wellbore. The intervals examined (in drillers depths) were from 3504 – 3537 m, 3588 – 3606 m and 3657 – 3690 m from the Early Cretaceous Pretty Hill Formation. A total of 84 m of section was logged in 3 m increments.

The intervals covered three sandstones designated Upper, Middle and Lower. Minor potential gas pay has been identified from log analysis.

Only the upper sandstone interval has the theoretical capacity to flow gas at a significant rate but any testing should be regarded as having a high risk of failure to produce any gas flow.

Each of the sandstones packages are composed of very fine to fine grained sediment with the matrix being clay filled with very low permeability's.

Samples are often composed of single sand grains with few aggregates. Evidence of pore spaces, location of adjacent grains and the presence of clay can be determined from features on individual grain surfaces.

The sandstones appear to be quartz arenites; only minor feldspars being present, lithics are rare.

Chert is a common component in the lower sandstone and may exist as thin interbeds or nodules. It is also present in small volumes in the middle sandstone.

Clay is the major matrix component but its texture is very fine and it is unable to be identified using the optical microscope.

The presence of clays and the fine grained nature of the framework grains make them very susceptible to formation damage.

Each of the sandstones appears to be texturally mature to sub mature.

A significant proportion of the total porosity estimated for the sandstones is present within the clay matrix and is considered to be ineffective.

Discrete fining upwards depositional cycles are recognisable within each of the sandstone packages.

The environment in which these sandstones were deposited could be fluvial overbank, distal crevasse splay or lacustrine fan. The latter environment is most likely for the lower sandstone as this could explain the presence of the significant quantities of chert present.

Introduction

Reservoir Micro Analysis Method

Drill cuttings collected at 3 m intervals at the wellsite are obtained over the required depth ranges. These cuttings are thoroughly washed through a 75 µm sieve. This sieve size retains all particles from very fine sand grain size and above but removes all silt and smaller sized particles. All traces of contamination from the drilling process are removed by washing and before examination the samples are air dried. This enables an accurate estimation to be made of the compositional make-up of the sample as well as the matrix content and surface lustre of the grains. Each cuttings interval is then described in detail using a high quality stereo microscope with variable magnification. The results are captured in an Excel spreadsheet and separate spreadsheets are also produced listing the relevant reservoir properties of porosity and permeability. A brief interpretation of the results of the reservoir micro analysis process is contained in this report. The raw excel spreadsheet data, calculation of the interval permeability thickness and a copy of all photographs taken during the reservoir micro analysis are included as separate files.

Comments on Glenaire 1/ST-1 drill cuttings

The drill cuttings used for the Glenaire 1/ST-1 interpretation were field washed and dried samples obtained from the Beach Petroleum Ltd sample set. These were further cleaned to enable the reservoir micro analysis procedure to be carried out.

The cuttings were found to be of varying quality but for most sample intervals are considered to be generally representative of the reservoir. The sample interval from 3669 – 3672 m (Drlr) contained a high percentage of chert fragments. It is likely that this is not entirely representative of the actual formation drilled and the actual rock contained a silt sized arenite that has not been retained after completing the sample washing process.

All depths quoted in this report are drillers depths. The plotted data has required compensation for minor depth discrepancies. This has dictated that two metres are required to be added to the drilled cuttings depths for the upper interval examined, three metres added to the middle interval examined and one metre added to the lower interval examined.

Interpretation

General Information

This interpretation is based on the information collected during the micro analysis of the drill cuttings and collated on the raw data spreadsheet that is included in the Raw Data file folder. All photographs taken during the examination of the cuttings are included in the Photos file folder.

It should be noted that *the data output of some of the rock properties is describing only the sand fraction of the total lithology present.* The raw data file can be used to

discriminate those rock properties that refer to just the sand fraction and those referring to the entire sample lithology.

Glenaire 1/ST-1 Interpretation

Glenaire 1/ST-1 was logged over three separate intervals from the Early Cretaceous Pretty Hill Formation, thirty three metres an upper sandstone, eighteen metres of a middle sandstone and thirty three metres of a lower sandstone package.

The upper sandstone interval examined was from 3504 metres to 3537 metres, the middle sandstone interval was from 3588 metres to 3606 metres and the lower sandstone interval was from 3657 metres to 3690 metres.

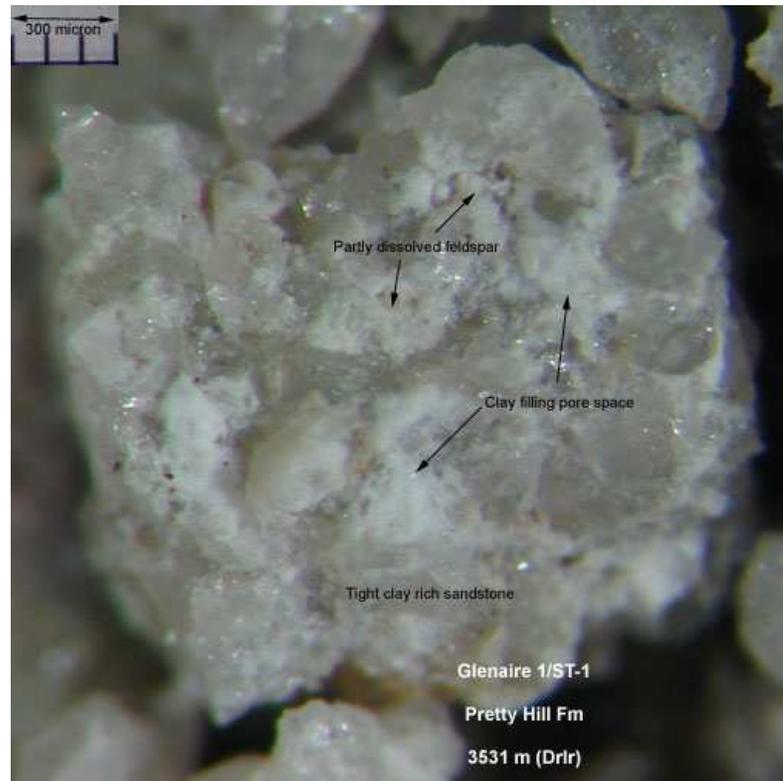
A total of 84 metres was examined and interpreted from the samples available.

The interpretation of each sandstone interval will be discussed separately. Detailed permeability data can be found in Table 2 and porosity data in Table 3. A discussion of the permeability and gas flow potential is in the Permeability Thickness Estimate section of this report.

Pretty Hill Formation

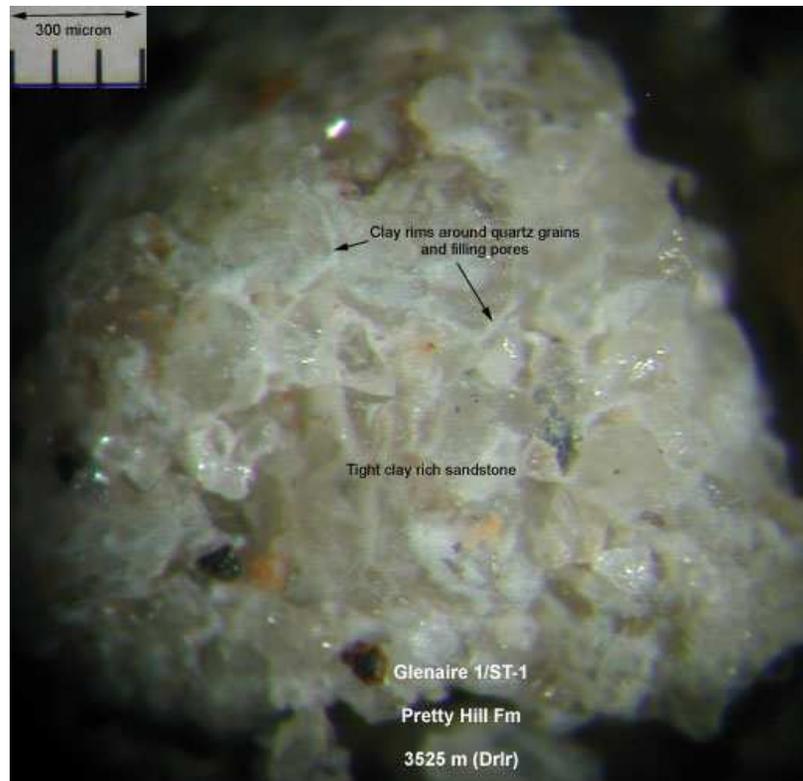
Upper Sandstone (3504 - 3537 m)

- The quality of the drill cuttings samples used for this interpretation is variable but for this sandstone is generally fair to occasionally good.
- Photographs of sandstones from several of the sample intervals examined in this upper sand package can be seen in Appendix 3.
- The sandstone present is dominantly very fine to fine grained. Some medium and rarely coarse grained sandstone is present in small volumes.
- Sands are moderately well to well sorted and composed dominantly of quartz. Feldspar is present in most samples and this generally shows evidence of dissolution; chert and rock fragments may also occur in the framework grains.
- The grain features of roundness, sphericity and sorting of the sandstone suggest that they are texturally mature.
- The matrix is dominated by fine clays the composition of which is unable to be determined with the resolution available from an optical microscope. Detrital matrix is also present in some of the sands at the top of the section examined. An example of a typical clay rich sandstone can be seen in Photograph 1.



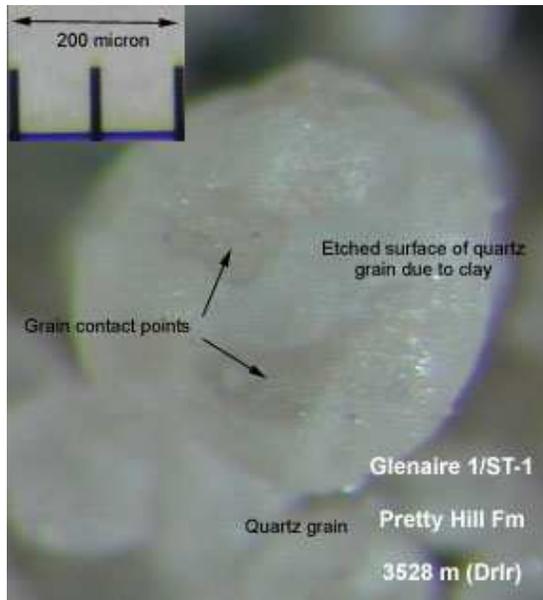
Photograph 1

- Clays can form rims around sand grains. It was not possible to identify the composition of these clay rims. An example is shown in Photograph 2.

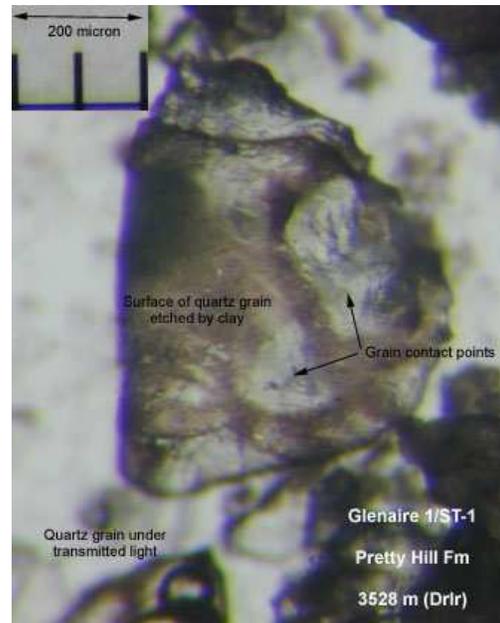


Photograph 2

- Quartz cements are only present in small volumes and do not form overgrowths.
- Minor volumes of calcite cement are also present in some sample intervals.
- Characteristics observed on individual sand grains show features that illustrate the compaction that has occurred within the sandstone and the volume of actual pore space prior to being filled with clay. The grain contact surfaces and the etching of the grain surface due to contact with clay particles can be clearly seen in Photographs 3 and 4 below.



Photograph 3



Photograph 4

- A percentage ranging from 30% to 60% of the total porosity estimated for this sandstone is ineffective porosity and is present in the matrix as micro-porosity. This detracts from the reservoir quality and also affects the permeability. The estimates of various porosity types are contained in Table 3.
- The dominance of very fine to fine grained sand, abundance of clay matrix and poor reservoir quality suggest this sandstone package could be derived from either
 - (i) a fluvial overbank deposit
 - (ii) a distal crevasse splay environment
 - (iii) a distal lacustrine fan
- The distribution of the sandstone grain size data suggests that at least three separate fining upwards depositional cycles have combined to produce this sandstone package. The cycles recognisable are from 3504 – 3516 m, 3516 -3525 m, 3525 – 3531 m. The remaining two sample intervals at the base of the package have very similar grain size distributions.

Middle Sandstone (3588 – 3606 m)

- Drill cuttings quality over this sandstone was only fair with one poor quality sample present. Many of the samples were composed dominantly of single, loose quartz grains and an example of one of these can be seen in Appendix 4; this can have an effect on the accuracy of the interpretation.
- Photographs of sandstones from this sand package can be seen in Appendix 4.
- Shales are also present together with the sandstones. These are possibly inter-bedded with the sand. In addition chert was noted as being present from around 3597 m. It is unclear whether these form discrete beds or occur within the sandstones as discontinuous layers. An example of a bedded chert can be seen in Photograph 5.



Photograph 5

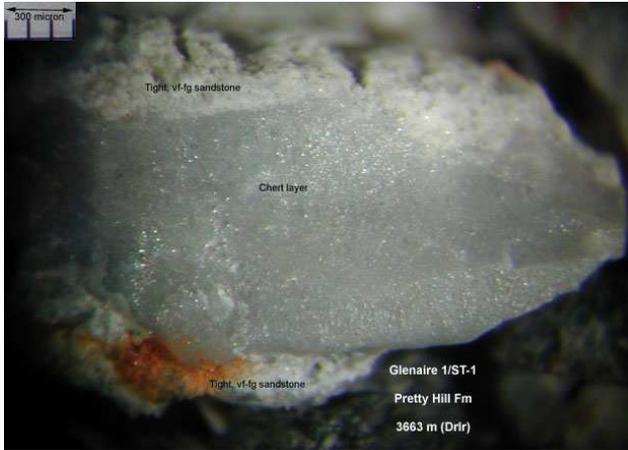
- Grain sizes of the sandstones are dominantly very fine to fine with only minor occurrences of medium grained sand. No grains above medium size were observed to be present.
- There is a dominance of quartz grains of similar size in the framework with the consequence that the sandstones are very well sorted. Feldspar was noted as component of the sand in only one sample.
- The majority of the sand grains are sub angular to sub round with moderate sphericity and are very well sorted. This suggests the sandstones are mature to sub mature.
- Clays comprise the majority of the material present in the sandstone matrix with only minor volumes of quartz cement. No calcite was seen in significant quantity. The clay(s) present are very fine and unable to be positively identified; they fill all

available pore space and form tight non reservoir quality rock. Examples of some of these can be seen in Appendix 4.

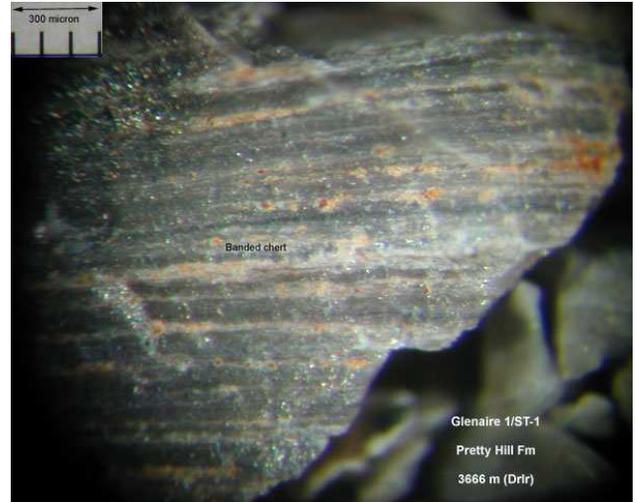
- Low porosities characterise this sand package with a maximum total porosity estimated of 7% and ranging down to 4%. Ineffective micro porosity within the clay matrix is generally around 50% or more of the total. Details can be seen in Table 3.
- The likely depositional environment of these sandstones would be similar to those of the upper sandstones, i.e. overbank, distal crevasse splay or lacustrine fan.
- The grain size distributions within the section examined would suggest that there are at least two broad fining upwards depositional cycles contained within this sand package. The cycles recognisable are from 3588 – 3597 m and from 3597 – 3606 m.

Lower Sandstone (3657 – 3690 m)

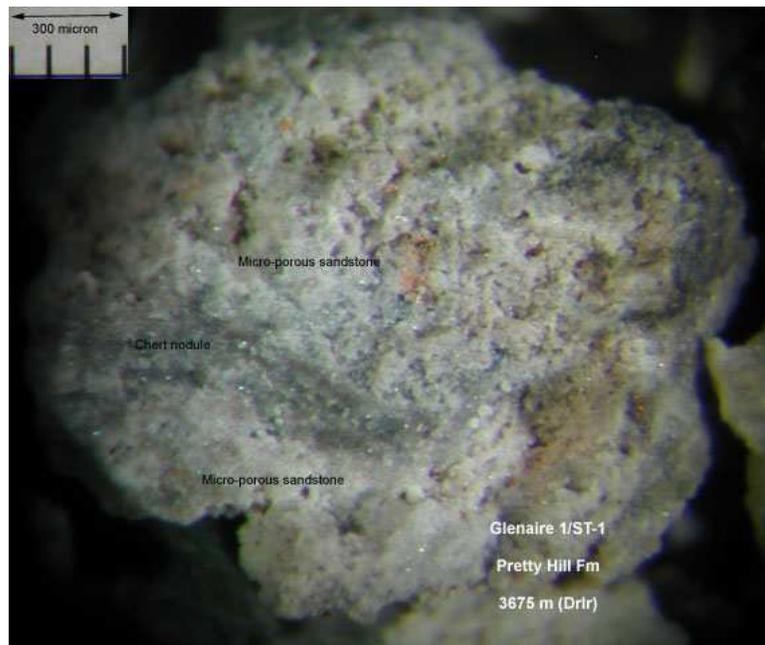
- The quality of the drill cuttings from these sandstones is only poor to fair with single sand grains being common. Shales and/or siltstones are also found throughout the section.
- Typical examples of the sandstones observed in this sand package can be seen in Appendix 5.
- As with the preceding two sandstone intervals the grain sizes present are dominated by very fine and fine grains with a general trend from very fine at the top to fine at the base. Some silty sandstone was also seen. A very small percentage of medium grained sand is also present near the base of the interval.
- Chert is also present in the majority of the sample intervals but is absent in the lower three samples. The quantity seen is generally consistent but in the sample from 3669 – 3672 m the majority of the sample was chert. This is inconsistent with the lithology descriptions on the wellsite mudlog and from the wellsite geologist. Those records describe sandstone in this sample interval. This may possibly be explained if the sandstones present are in fact very silty. The sample washing necessary to carry out the interpretation for this process would remove silt sized particles from the samples and concentrate the chert and other lithology's present.
- The chert may be present as interbeds within the sandstone and as nodules. It can be consistent in colour or banded. Examples of the bedded chert can be seen in Photographs 6 and 7 while a nodular variety is shown in Photograph 8.



Photograph 6



Photograph 7



Photograph 8

- A characteristic noted with some of the cherts was their association with permeable sandstone. This can be seen in Photograph 9. A small volume of sandstone adjacent to some of the chert nodules was permeable but the permeability does not appear to be extensive. It is possible that this permeability is due to dissolution of silica during the formation of the chert. It is difficult to ascertain with certainty whether this permeability is connected throughout the sand body but a minor percentage of permeable rock has been assigned to two sample intervals in the interpretation. This has not affected the overall reservoir quality which is still interpreted as being tight.



Photograph 9

- Textural characteristics of the sands are very similar to the previous intervals and suggest they are sub mature at the base and become more mature towards the top.
- Fine undifferentiated clay is again the most common material filling the pores of these sandstones but silty and some sandy detrital material is also present. Small amounts of silica cement occur throughout and at the base of the interval calcite cement is seen.
- Porosities are again low and range from a low of 3% to a high of 9%. Ineffective porosity constitutes from 22% up to a maximum of 75% of the total porosity with the majority being present within the clay matrix.
- The fine grain sizes present in the sands and the likelihood of the presence of silty sandstones makes deposition in distal environments most likely. It is not possible to determine with any certainty where these sands were deposited but the presence of significant volumes of chert could suggest a lacustrine environment. One means by which chert can form is by inorganic precipitation of silica where large fluctuations of pH occur. Evaporation of lake water could provide the required mechanism.
- Depositional cycles within this sand body are not as obvious as in the two previous examples but there is the suggestion of a fining upwards cycle from 3669 – 3675 m and another from 3675 – 3687 m.

Table 1 – Summary of Rock Properties – Glenaire 1/ST-1 Pretty Hill Formation

Interval (m)	Estimated Total Ø	Rock Type ¹	Comments
<u>Upper Sandstone</u>			
3504 - 3513	5 - 6%	2 - 3	Marginal tight to non reservoir
3513 – 3534	6 - 12%	1D - 2	Tight to marginal reservoir
3534 - 3537	6%	2 - 3	Marginal tight to non reservoir
<u>Middle Sandstone</u>			
3588 - 3603	4 - 5%		Non reservoir
3603 - 3606	7%	2 - 3	Marginal tight to non reservoir
<u>Lower Sandstone</u>			
3657 – 3672	3 – 4%	3	Non reservoir
3672 – 3678	9%	1D – 3	Do non reservoir, minor possible tight reservoir
3678 – 3690	7 – 8%	2 - 3	Marginal tight to non reservoir

¹ See Appendix 1 for explanation of rock types

Permeability Thickness Estimate

The detailed indicative permeability and permeability thickness data is included as Table 2 for each sandstone interval examined in the Pretty Hill Formation. This data provides a record of the likely productive and non-productive intervals in this well bore.

The ambient permeability's estimated from examination of the drill cuttings have both overburden pressure and Klinkenberg corrections applied prior to calculating a permeability thickness.

The cumulative permeability thickness data can provide an estimate of the theoretical gas flow rate that could be obtained from the well. This is obtained from a plot of data collected from numerous valid well tests conducted in an onshore Australian fluvial dominated basin. The gas flow rate recorded from the well tests is plotted against the permeability thickness calculated from the test data (see Figure 1).

It is only included to provide an indication of gas flow rates that are theoretically possible from the permeability thickness estimates. These **theoretical flow rates are for dry gas only**, any liquid content in the reservoir will affect this theoretical value. Other factors such as well bore damage, fractures or mechanical problems may also have an influence on the actual rate achieved.

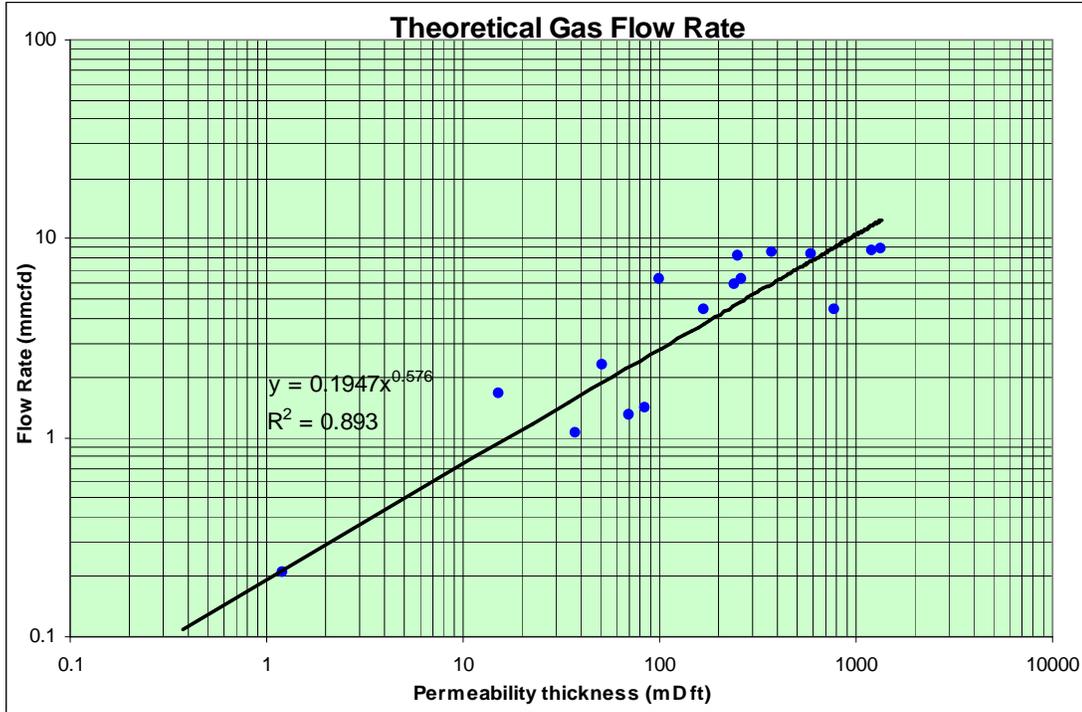


Figure 1

For Glenaire 1/ST-1 permeability thickness estimated from the rock types present has been estimated for each separate interval examined (see Table 2 below).

For the Pretty Hill upper sandstone the permeability thickness was estimated to be 12 mD ft. This could theoretically produce a gas flow rate of 1.0 MMCFD provided there has been no formation damage to the wellbore. As the reservoir has been observed to be composed of rock with only dominantly tight to marginal quality sandstones and containing a high clay content it is unlikely the reservoir would be able to produce gas at this rate. The fine texture of the clays present in the sands would make this reservoir highly susceptible to formation damage from water based drilling muds.

The Pretty Hill Formation middle sandstones are interpreted as being of non reservoir quality and would be incapable of producing gas.

The lower sandstones of the Pretty Hill Formation have a theoretical permeability thickness of 3 mD ft. In an undamaged state these could possibly produce gas at around 300 MCFD. However as noted in the detailed description of this reservoir the main interval with permeability is likely to be discontinuous and incapable of producing gas.

Note that these estimates are provided as a guide only and there is no guarantee that these flow rates or any gas flows can be achieved from this well.

Table 2 – Permeability Thickness – Glenaire 1/ST-1 Pretty Hill Formation

<u>TOP DEPTH (m)</u>	<u>BASE DEPTH (m)</u>	<u>Ka</u>	<u>Ko</u>	<u>Kok</u>	<u>Kh (imperial)</u>	<u>Kh (metric)</u>
<u>Pretty Hill Fm</u>						
<u>Upper Sst</u>						
3504	3507	0.0	0.0	0.0	0.0	0.0
3507	3510	0.0	0.0	0.0	0.0	0.0
3510	3513	0.1	0.0	0.0	0.6	0.2
3513	3516	0.2	0.1	0.0	1.5	0.4
3516	3519	0.7	0.3	0.2	5.1	1.6
3519	3522	0.3	0.1	0.1	6.9	2.1
3522	3525	0.3	0.1	0.1	8.4	2.6
3525	3528	0.3	0.1	0.1	10.2	3.1
3528	3531	0.2	0.1	0.1	11.4	3.5
3531	3534	0.2	0.1	0.0	12.2	3.7
3534	3537	0.1	0.0	0.0	12.4	3.8
				Total Kh:	12 mD ft	4 mD m
<u>Middle Sst</u>						
3588	3591	0.0	0.0	0.0	0.0	0.0
3591	3594	0.0	0.0	0.0	0.0	0.0
3594	3597	0.0	0.0	0.0	0.0	0.0
3597	3600	0.0	0.0	0.0	0.0	0.0
3600	3603	0.0	0.0	0.0	0.0	0.0
3603	3606	0.0	0.0	0.0	0.1	0.0
				Total Kh:	0.1 mD ft	<0.1 mD m
<u>Lower Sst</u>						
3657	3660	0.0	0.0	0.0	0.0	0.0
3660	3663	0.0	0.0	0.0	0.0	0.0
3663	3666	0.0	0.0	0.0	0.0	0.0
3666	3669	0.0	0.0	0.0	0.0	0.0
3669	3672	0.0	0.0	0.0	0.0	0.0
3672	3675	0.3	0.1	0.1	1.3	0.4
3675	3678	0.3	0.1	0.1	2.5	0.8
3678	3681	0.0	0.0	0.0	2.7	0.8
3681	3684	0.1	0.0	0.0	2.9	0.9
3684	3687	0.1	0.0	0.0	3.1	0.9
3687	3690	0.1	0.0	0.0	3.2	1.0
				Total Kh:	3 mD ft	1 mD m

Ka = Interval permeability to air; Ko = Interval permeability corrected for overburden; Kok = Interval permeability corrected for overburden & Klinkenberg; Kh = Cumulative permeability thickness

Porosity Estimates

Estimates of porosity have been made on rocks from each sample interval examined. These estimates are the **porosity of the best rock in each interval** and do not necessarily reflect the average porosity for the interval. In addition to the total porosity each estimate is broken down into the various percentages of effective and ineffective porosity as well as the proportion of macro porosity and micro porosity present in both the effective and non effective porosity types. The results of these estimates are shown below in Table 4.

Table 3 – Porosity Estimates – Glenaire 1/ST-1 Pretty Hill Formation

<u>BASE DEPTH</u> (m)	<u>BASE DEPTH</u> (m)	<u>EFFECT</u> (macro) %	<u>POROSITY</u> (micro) %	<u>TOTAL</u> <u>EFFECT</u> %	<u>INEFFECT</u> (macro) %	<u>POROSITY</u> (micro) %	<u>TOTAL</u> <u>INEFF</u> %	<u>TOTAL</u> <u>POROSITY</u> %
	<u>Upper</u> <u>Sst</u>							
3504	3507	0	2	2	0	3	3	5
3507	3510	0	2	2	0	3	3	5
3510	3513	0	3	3	0	3	3	6
3513	3516	2	3	5	0	2	2	7
3516	3519	0	10	10	2	0	2	12
3519	3522	0	6	6	0	5	5	11
3522	3525	0	6	6	0	4	4	10
3525	3528	0	5	5	0	7	7	12
3528	3531	2	4	6	0	5	5	11
3531	3534	1	3	4	0	2	2	6
3534	3537	0	3	3	0	3	3	6
	<u>Middle</u> <u>Sst</u>							
3588	3591	0	2	2	0	2	2	4
3591	3594	0	2	2	0	2	2	4
3594	3597	0	2	2	0	2	2	4
3597	3600	0	1	1	0	3	3	4
3600	3603	0	2	2	0	3	3	5
3603	3606	0	3	3	0	4	4	7
	<u>Lower</u> <u>Sst</u>							
3657	3660	0	1	1	0	2	2	3
3660	3663	0	1	1	0	2	2	3
3663	3666	0	1	1	0	3	3	4
3666	3669	0	1	1	0	3	3	4
3669	3672	0	1	1	0	2	2	3
3672	3675	5	2	7	0	2	2	9
3675	3678	1	2	3	4	2	6	9
3678	3681	2	3	5	0	3	3	8
3681	3684	1	2	3	2	2	4	7
3684	3687	1	3	4	2	2	4	8
3687	3690	1	2	3	0	4	4	7

Conclusions

- Each of the three Pretty Hill Formation sandstones examined is very fine to fine grained, has high clay matrix content and is tight. Only small percentages have slightly enhanced permeability.
- The presence of fine clay matrix in all of the sandstones examined in this well together with the very fine to fine grained nature of the sands diminishes the likelihood of their capacity to flow gas at significant rates.
- The theoretical permeability thickness calculated for the upper sandstone interval suggests it could be capable of flowing gas however any testing of this should be considered as having a high risk of failure to produce hydrocarbons.
- If any testing of these potential reservoirs is to be considered in the future then only the upper sandstone appears to have some potential. The middle sand appears to be entirely non reservoir quality and any potential permeability in the lower sand may not be interconnected.
- The sandstones appear to be derived from fluvial overbank deposits, distal crevasse splays or lacustrine fans. The presence of significant quantities of chert in the lower sand suggests a lacustrine origin may be most likely.
- The fine grained nature of the sandstones and the presence of fine clays in the matrix would make these very susceptible to formation damage.

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APPENDIX 1

Principles of Drill Cuttings Analysis

Reservoir Micro Analysis is a technique of microscopic examination of drill cuttings that is also referred to as rock typing. It is a quantitative method of assessing reservoir quality from cuttings and core samples. Unlike mud logging, the technique strives to quantify the samples in terms of their petrophysical properties. Numerous studies have shown petrophysical properties of sedimentary rocks are controlled by their textural attributes. Thus rocks with common attributes should bear common petrophysical properties. Cuttings analysis also is capable of predicting environmental properties of reservoirs. This can be invaluable for reservoir characterization as well as for exploration purposes.

Drill cuttings analysis discriminates rocks (both core and cuttings) into distinct groupings or types according to their properties as observed under a high power binocular microscope. This is based on the quantitative observation of key visual attributes such as porosity, pore and pore throat geometry, clay and cement types, grain size distribution and sorting, grain shape and consolidation. Rocks are classified as reservoir or non-reservoir and assigned to one of six major rock types that are correlative to ambient air permeability ranges.

Type 1 rocks are capable of gas production without natural or artificial fracturing. They are sub-divided into four classes.

Type 1A have a permeability > 100 md. These are classed as conventional reservoir rocks.

Type 1B have a permeability range between 10 - 100 md. These are classed as conventional reservoir rocks.

Type 1C have a permeability range between 1 - 10 md. These are classed as conventional reservoir rocks.

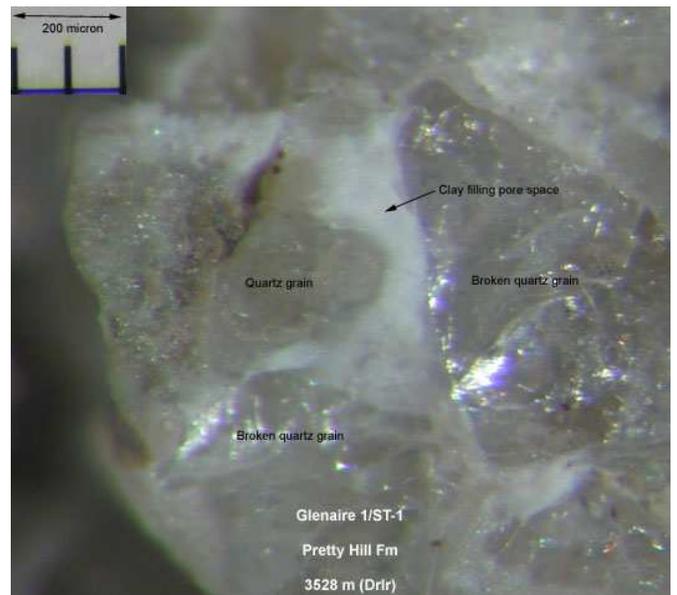
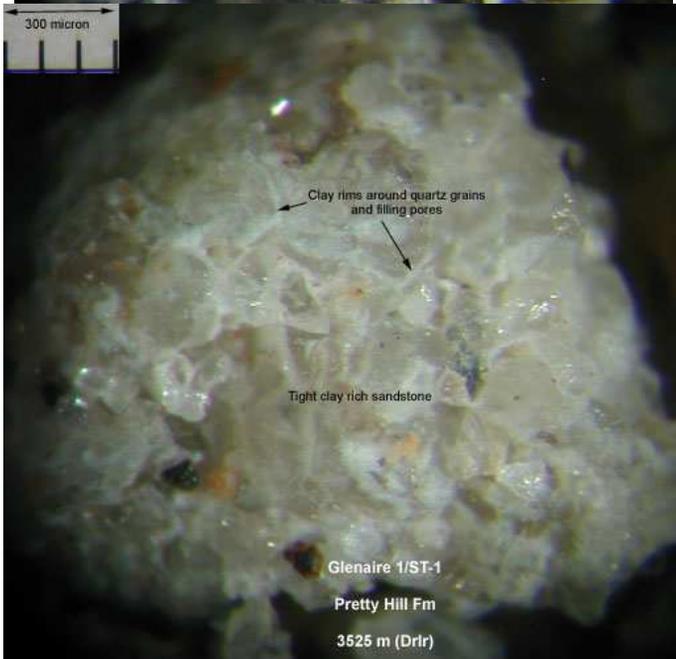
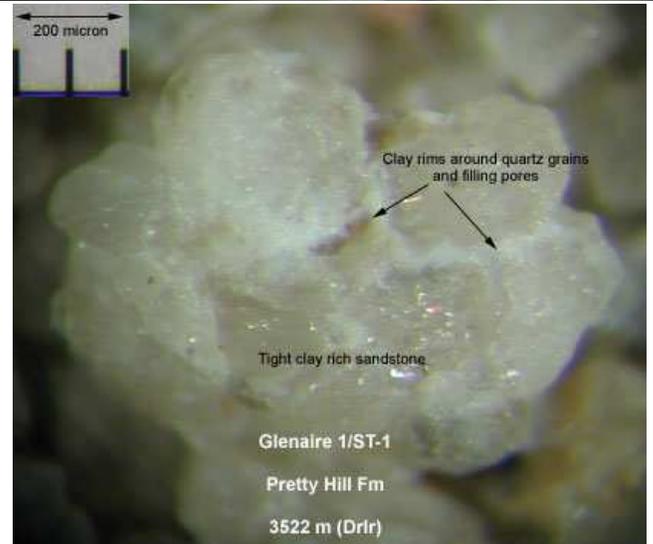
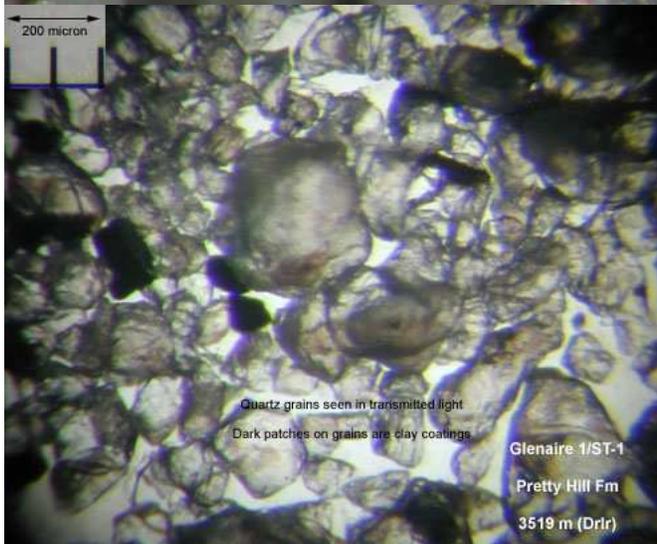
Type 1D have a permeability range between 0.5 - 1 md. These are classed as sub conventional reservoir rocks.

Type 2 rocks are capable of gas production when interbedded with Type 1 rocks or with natural and/or artificial fracturing. Permeability range is 0.07 - 0.5 md. These are classed as marginal non-conventional reservoir rocks.

Type 3 rocks are too tight to produce at commercial rates even with natural or artificial fracturing. Permeabilities are generally less than 0.07 md. These are classed as non-reservoir rocks.

APPENDIX 3

Photographs from Upper Sandstone Sample Intervals



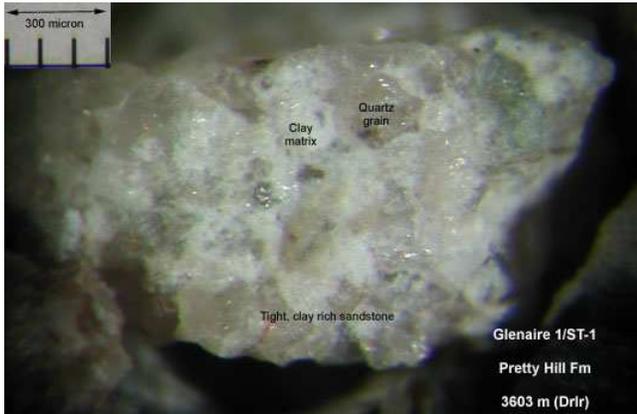
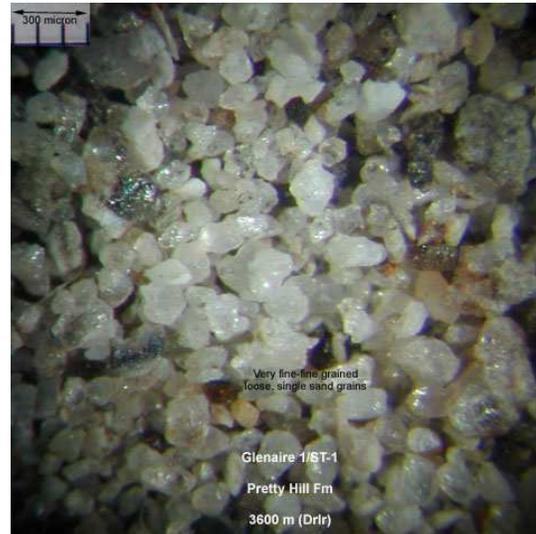
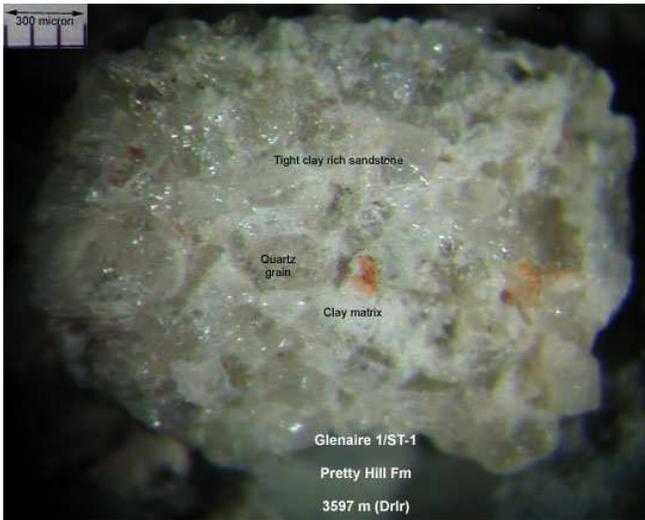
APPENDIX 3

Photographs from Upper Sandstone Sample Intervals (cont)



APPENDIX 4

Photographs from Middle Sandstone Sample Intervals



APPENDIX 5

Photographs from Lower Sandstone Sample Intervals

