Report prepared for:

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PETROLOGY REPORT

HILL-1

OTWAY BASIN

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Front cover:
Thin section photomicrograph of Hill-1, Swc 31, Depth 2007.5m. Plane light. Horizontal field of view 3.25mm.

1. SUMMARY

Petrological descriptions, grain size analysis and X-ray diffraction were used to characterise 10 sidewall cores and 6 cuttings samples from the Late Cretaceous Timboon Sandstone and Paaratte Formation. Samples were selected by Santos Ltd from the well Hill-1 which had been drilled in the Otway Basin (VIC/P 46). The study was designed to ascertain the reason for a high gamma response in sands from 1990 to 2020m, and to compare the sedimentological and diagenetic characteristics of the sand intervals.

Sidewall cores and cuttings described in this report had significant textural disruption and grain fracturing thus visual estimates of composition and especially of porosity, may not be accurate. Results from this petrology study are summarised in Table 1 below. No comments have been included on the Timboon Sandstone because cuttings from this interval were dominated by mudstone rather than sandstone.

Thin sandy sequences in the lower Paaratte Formation (21-9 & 20-7 sands) are characterised by laminated, fine to medium grained, very poorly sorted greywackes. The basal sand (22-7) is a medium grained, poorly sorted subarkose. Sandstones from the top Paaratte Formation are dominated by fine grained, poor to moderately well sorted, subarkoses. Near the base of this sequence there is a fine grained moderately well sorted sublitharenite and cuttings indicate the cemented interval is probably a wackestone.

Detrital grains in the Paaratte Formation were typically eroded from an igneous/metamorphic terrane with the igneous source slightly more important. This provenance is indicated by the dominance of polycrystalline quartz with straight crystal boundaries, abundance of fresh feldspars (including plagioclase) and micas, and igneous lithics. Detrital clays in the lower Paaratte where chlorite-smectite is abundant (21-9 & 20-7 sands) may have weathered from a volcanic provenance. Kaolinite and illite in the top Paaratte could reflect a more plutonic source. Higher concentrations (5-9%) of feldspars and micas in the top Paaratte at the time of deposition (now altered to kaolin) may have resulted from uplift and increased erosion of the igneous terrane.

Elevated gamma ray responses in the top Paaratte could be partially the result of radioactive minerals. A combination of muddy laminae, and variations in the percentages of feldspars and micas may also be responsible for these log characteristics.

Thin fining upward sequences in the lower Paaratte have been deposited very rapidly in a marine environment. The latter is indicated by the presence of calcareous fossils and minor glaucony. These sediments could represent storm deposits on the continental shelf. At the base of the top Paaratte the sequence which coarsens upwards to a fine grained sublitharenite might represent a transition zone to lower shoreface deposit. The wackestone may have accumulated in a nearshore setting such as a tidal flat or a lagoon. This sample has a high percentage of organic matter (8%) which includes cutinite derived from land plants designed to survive periods of aridity. Overlying stacked fining and coarsening upwards sequences are finer grained than the Paaratte at Mount Salt-1. These fine sands range from poor to moderately well sorted and have muddy laminae reflecting variations in the hydraulic regime from which they were deposited. Trace amounts of glaucony and phosphate suggest a marginal marine setting. It is possible that the top Paaratte may have been deposited as mouth bars/crevasse splays and point bars of interdistributary channels at a delta front.

Diagenetic alteration in the Paaratte Formation at Hill-1 was limited and dominantly early as indicated by the precipitation of glaucony, pyrite and siderite. Alteration of feldspars and micas to kaolin may have resulted from flushing by meteoric waters at the delta front. Excess silica from this reaction could have precipitated as minor quartz overgrowths in the cleaner sands. Concentration of late diagenetic calcite in the lower Paaratte may be related to the dissolution of calcareous fossils. A minor phase of dissolution resulted in grain size, honeycomb and intragranular pores. Evidence of mechanical compaction is difficult to assess due to extensive textural disruption.

Reservoir quality is probably facies controlled. Relatively good reservoirs may be preserved in the moderately well sorted sands that lack muddy laminae because primary intergranular pores could be present. Poor reservoirs are associated with poor sorting and muddy laminae that would restrict vertical permeability.

TABLE 1 SUMMARY OF LITHOLOGY, TEXTURE & MINERALOGY HILL-1

Sample	Swc 11	Swc 16	Cuttings*	Swc 21	Swc 22	Swc 26	Cuttings
Depth (m)	2281	2196	2079	2078.5	2075	2023	2020
Stratigraphy	22-7	21-9	20-7	20-7	20-7	Paaratte	Paaratte
Lithology	subarkose	greywacke	sublitharen	greywacke	greywacke	sublitharen	wackestone
Avg grain size (mm)	med (0.26)	med (0.28)	v fine	fine (0.23)	fine (0.24)	fine (0.22)	v fine
Sorting (phi)	poor (1.96)	vpoor (2.16)	mwell	vpoor (2.40)	vpoor (2.44)	mwell(0.56)	mwell
Structures	?clay lens	?bedding	laminae	?lam/biotur	?lam/biotur	?lithics	?bedding
	Visual estimate of composition (Volume %)						
Framework grains							
Quartz - mono	62	62	66	59	52	66	15
- poly	3	3	1	4	3	3	2
Feldspar - Kspar	3 M	2 M	2	2	2 M	2	1
- plag	tr A	tr A	tr	tr	1 A	tr	-
Lithics - sediment	tr	tr	tr	tr	tr	3	-
- igneous	1	2	tr	1	1	2	tr
- meta	1	tr	7	tr	1	tr	tr
Fossils	-	tr	tr	tr	-	-	-
Mica - muscovite	tr	tr	2	tr	tr	1	1
- biotite	-	-	tr	tr	tr	tr	-
Accessory	1	1	tr	tr	1	tr	tr
Matrix							
Clay	7 K,I,CS	15 CS,K,I	4	22	20 CS,K,I	-	-
Organic matter	tr	tr	2	1	2	tr	8
Authigenic							
Glaucony	5	3	tr	-	-	-	-
Quartz	tr	-	-	tr	1	1	-
Carbonate - clear	3 Ca	tr Ca	tr	tr	tr Ca	-	62
- Fe rich	2 Si	2 Si	4	2	-	-	2
Pyrite	2	1	tr	3	5	2	7
Kaolin	-	-	1	tr	-	5	-
Phosphate	-	-	-	-	-	-	-
?Barite	tr	1	-	tr	2	-	-
Porosity							
Intergranular	?5	?5	7	5	6	?12	-
Dissolution	3	2	3	tr	2	2	1
Micropores	-	-	-		-	tr	-

* cuttings described probably not representative of this depth interval

sublitharen=sublitharenite, vfine=very fine, med=medium, vpoor=very poor, mwell=moderately well, lam=laminae, biotur=bioturbated, mono=monocrystalline, poly=polycrystalline, plag=plagioclase, sediment=sedimentary, meta=metamorphic, tr=trace

Additional information from XRD results: M=microcline, A=albite, Ca=calcite, Si=siderite, K=kaolinite, I=illite, CS=chlorite-smectite (clays are listed in order of abundance for each sample)

TABLE 1 continued SUMMARY OF LITHOLOGY, TEXTURE & MINERALOGY HILL-1

Sample	Swc 29	Swc 31	Cuttings	Swc 33	Swc 34	Cuttings*	Swc 35	Cuttings*
Depth (m)	2016	2007.5	2004	1999	1995	1995	1992	1974
Stratigraphy	Paaratte	Paaratte	Paaratte	Paaratte	Paaratte	Paaratte	Paaratte	Timboon
Lithology	subarkose	subarkose	subarkose	subarkose	subarkose	grainstone	subarkose	mudstone
Avg grain size (mm)	fine (0.21)	fine (0.16)	v fine	fine (0.21)	fine (0.15)	fine	fine (0.18)	clay
Sorting (phi)	mwell (0.55)	poor (1.04)	poor	poor (1.43)	poor (1.43)	mwell	mod (0.87)	poor
Structures	?	laminae	laminae	laminae	lam/bioturb	-	laminae	?bedding
	Visual estimate of composition (Volume %)							
Framework grains								
Quartz - mono	56	54	66	58	49	30	60	12
- poly	4	4	2	5	2	1	1	1
Feldspar - Kspar	2	2	2	2	2 M	1	2	tr
- plag	2	2	1	3	3 A	2	3	-
Lithics - sediment	1	tr	-	1	1	-	tr	tr
- igneous	1	2	-	2	tr	-	tr	tr
- meta	1	1	1	1	3	tr	1	tr
Fossils	-	-	-	-	-	-	-	-
Mica - muscovite	1	2	tr	tr	2	-	3	1
- biotite	tr	3	2	1	tr	-	1	tr
Accessory	tr	tr	tr	tr	2	tr	1	-
Matrix								
Clay	-	3	10	5	10 K,I,CS	-	1	66
Organic matter	tr	4	7	1	5	-	1	4
Authigenic								
Glaucony	1	-	1	-	tr	tr	tr	3
Quartz	3	tr	-	1	1	-	2	-
Carbonate - clear	-	2	-	-	-	60	tr	-
- Fe	-	3	6	1	2 Si	-	tr	5
Pyrite	4	tr	tr	2	tr	5	4	7
Kaolin	9	6	-	5	6	-	6	-
Phosphate	-	-	-	-	-	-	tr	-
?Barite	tr	-	-	-	-	-	tr	-
Porosity								
Intergranular	?12	?9	-	?9	?9	-	?11	-
Dissolution	1	2	1	2	2	-	2	-
Micropores	1	tr	-	tr	tr	-	tr	-

* cuttings described probably not representative of this depth interval

sublitharen=sublitharenite, vfine=very fine, vpoor=very poor, mwell=moderately well, mod=moderately, lam=laminae, biotur=bioturbated, mono=monocrystalline, poly=polycrystalline, plag=plagioclase, sediment=sedimentary, meta=metamorphic, tr=trace

Additional information from XRD results: M=microcline, A=albite, Ca=calcite, Si=siderite, K=kaolinite, I=illite, CS=chlorite-smectite (clays are listed in order of abundance for each sample)

2. INTRODUCTION

Santos Ltd submitted 10 sidewall cores and 6 cuttings samples to PGPC for petrological description. Samples were selected from the Late Cretaceous Timboon Sandstone and Paaratte Formation in the well Hill-1 which had been drilled in the Otway Basin (VIC/P 46). The study was designed to:

- ascertain the reason for a high gamma response in sands from 1990 to 2020m,
- compare the sedimentological and diagenetic characteristics of the sand intervals.

The client supplied wireline logs covering the relevant depth intervals and the current stratigraphy to assist the petrology interpretation. Services provided by PGPC are listed in Table 2 below.

TABLE 2 SAMPLES & TYPES OF ANALYSES HILL-1

Sample type	No.	Depth (m)	Stratigraphy	Thin section	Grain size	XRD
Cuttings	-	1974	Basal Timboon St	*	-	-
Swc	35	1992	Top Paaratte	*	*	-
Cuttings	-	1995	Top Paaratte	*	-	-
Swc	34	1995	Top Paaratte	*	*	*
Swc	33	1999	Top Paaratte	*	*	-
Cuttings	-	2004	Top Paaratte	*	-	-
Swc	31	2007.5	Top Paaratte	*	*	-
Cuttings	-	2016	Top Paaratte	*	-	-
Swc	29	2016	Top Paaratte	*	*	-
Cuttings	-	2020	Top Paaratte	*	-	-
Swc	26	2023	Top Paaratte	*	*	-
Swc	22	2075	20-7	*	*	*
Swc	21	2078.5	20-7	*	*	-
Cuttings	-	2079	20-7	*	-	-
Swc	16	2196	21-9	*	*	*
Swc	11	2281	22-7	*	*	*

3. METHODS

Thin section
Sidewall cores and cuttings were impregnated with araldite prior to thin section preparation. Blue dye was used in the araldite to facilitate description of porosity and permeability. Thin sections were prepared using standard techniques to produce a thickness of 30 microns (Adams *et al*, 1984). Thin sections were systematically scanned to determine lithology, composition, porosity and textural relationships. Siliciclastics have been classified according to guidelines by Folk (1974) and carbonates are classified using the nomenclature of Tucker (2001). Grain morphology (both sphericity and roundness) was estimated by comparison with charts in Pettijohn *et al* (1987), grain fabric (packing and texture) from the diagram in Tucker (2001) and sorting from diagrams by Harrell (1984). All percentages of composition given in the detailed thin section descriptions are visual estimates (Terry & Chilingar, 1955) not point counts. The basic data for grain size analyses was collected by measuring the long axis of 100 representative grains in thin section. The graphic mean, mode and inclusive graphic standard deviation (Folk, 1974) were then calculated.

X-ray diffraction (XRD)
To determine bulk mineralogy by XRD, samples were ground in a Siebtechnick mill and back mounted into aluminium holders. Continuous scans were run of these powder pressings from 3^{o} to 75^{o} 2θ , at 1^{o}/minute, using Co $K\alpha$ radiation, 50kV and 35mA, on a Philips PW1050 diffractometer. For detailed clay mineralogy a less than 5 micron size fraction was separated. This was obtained by hand crushing, addition of dispersion solution, mechanical shaking for 10 minutes and settling of the dispersed material in a water column according to Stokes' Law. The less than 5 micron fraction was pipetted off and prepared as an oriented sample on ceramic plates held under vacuum. Samples were saturated with Mg solution and treated with glycerol. Continuous scans of oriented clay samples were run from 3^{o} to 45^{o} 2θ at 1^{o}/minute. Peaks were identified by comparison with JCPDS files stored in a computer program called XPLOT.

4. PETROLOGY

4.1 Hill-1, Cuttings, Depth 1974m

Rock classification: Sandy/silty mudstone

The only chips present in this sample are composed of sandy to silty mudstone (97%) and drilling mud (3%). There are rare silt to medium sand size grains in the drilling mud which could have been derived from either the mudstone or a disaggregated sandstone. These grains are subangular with low sphericity and composed of monocrystalline & polycrystalline quartz, K-feldspar, muscovite, calcareous globular forams, framboidal pyrite and angular carbonate spar. The description below is restricted to the sandy/silty mudstone chips.

Texture:

Sedimentary structures:	very weak grain alignment may indicate the orientation of bedding
Average grain size:	clay
Range in grain size:	clay to medium sand
Roundness / sphericity:	angular to subrounded with low sphericity
Sorting:	poor
Texture:	matrix supported
Packing / grain contacts:	open packing / rare point contacts
Pore types:	none apparent

Composition:

Detrital grains:	monocrystalline quartz, polycrystalline quartz with straight crystal boundaries, K-feldspars, lithics of quartzite, micaceous schist, chert & possible igneous origin (feldspar & quartz intergrowth), straight muscovite & biotite flakes up to 0.12mm length
Matrix:	dark brown anhedral clay, stringers & blocky opaque organic matter
Authigenic minerals:	bright green well rounded grains of glaucony up to coarse sand in size, framboidal pyrite, patches of micritic Fe rich carbonate in the matrix

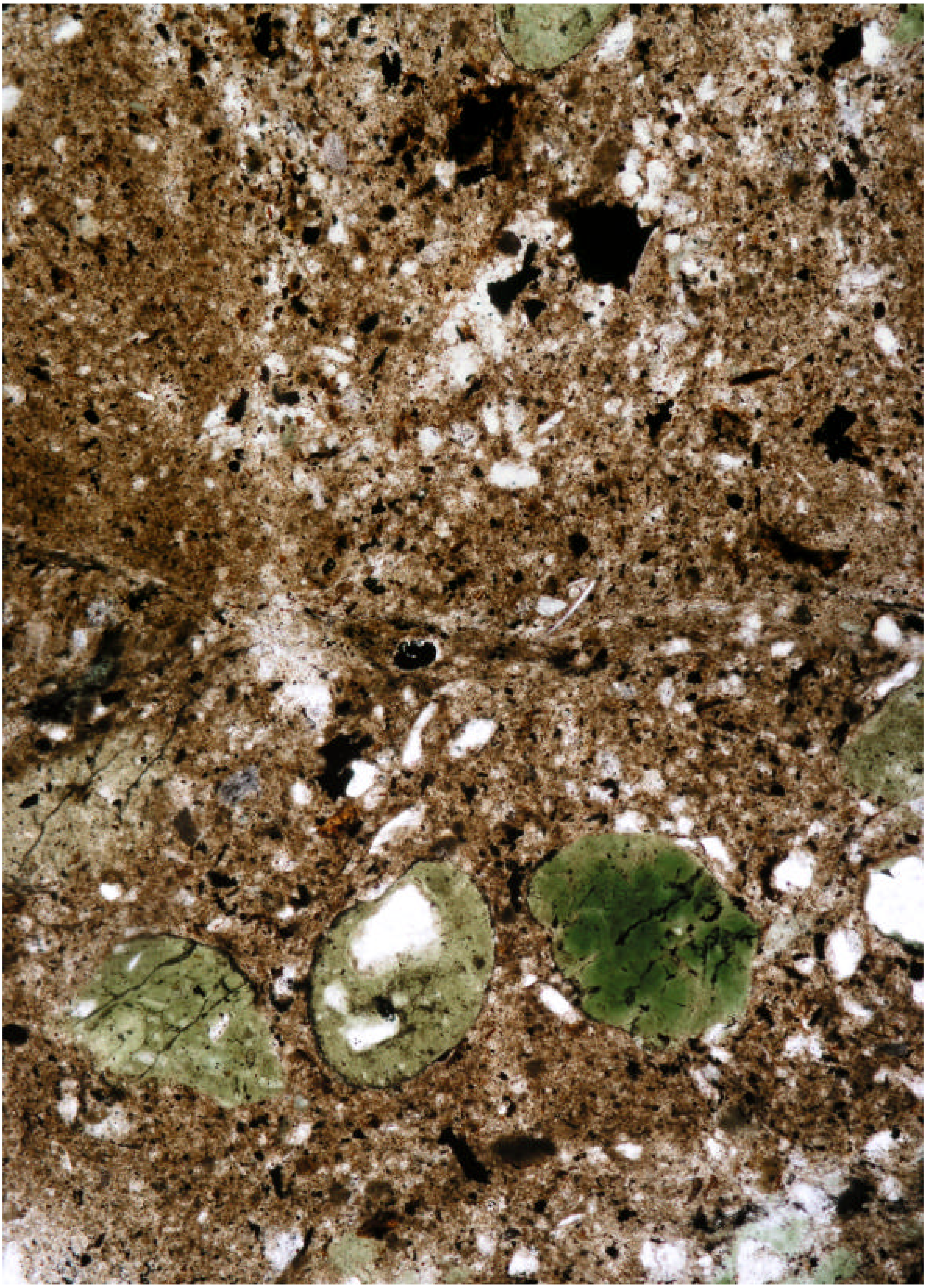


Figure 1

In this particular example of the silty mudstone coarse sand size grains of glaucony (green) are aligned in a laminae. Hill-1, Cuttings, Depth 1974m. Plane light. Horizontal field of view 1.30mm.

4.2 Hill-1, Swc 35, Depth 1992m

Rock classification: **Subarkose**

Texture:

Sedimentary structures:	extensive grain crushing & fracturing, stringers of organic matter & minute blocky pyrite crystals are concentrated in laminae
Average grain size:	fine sand (0.18mm)
Range in grain size:	clay to medium sand
Roundness / sphericity:	subangular to subrounded with low to moderate sphericity
Sorting:	moderate (0.87 ϕ)
Texture:	grain supported
Packing / grain contacts:	difficult to determine because of disruption during sampling, possibly moderately open packing with point & tangential grain contacts
Pore types:	primary intergranular pores, honeycomb pores associated with corroded feldspars & grain size pores, micropores associated with kaolin

Composition:

Framework grains:	monocrystalline quartz, polycrystalline quartz with straight crystal boundaries & rare examples with sutured, corroded & sericitised K-feldspars & relatively fresh K-feldspar with tartan twinning, partially altered plagioclase with albite & pericline twinning, lithics of silty mudstone, chert, chalcedony, ?volcanics, micaceous schist & quartzite, bent & splayed muscovite & biotite up to 0.5mm in length, accessory very fine sand size rutile, fine sand size tourmaline & silt size zircon with hydrocarbon envelopes
Matrix:	anhedral brown clay & blocky opaque organic matter in the laminae
Authigenic minerals:	rare fine sand size grains of glaucony with fibrous texture typical of chlorite, euhedral terminations may indicate the presence of quartz overgrowths, minute blocky & framboidal pyrite up to 5 microns in diameter concentrated in laminae where yellowish anhedral phosphate & detrital clay has been replaced, kaolin booklets have replaced micas, radial fibrous ?anhydrite/barite forms a localised cement, isolated grain replacing dusty Fe rich micrite, minute clear rhombs of carbonate spar postdate kaolin booklets

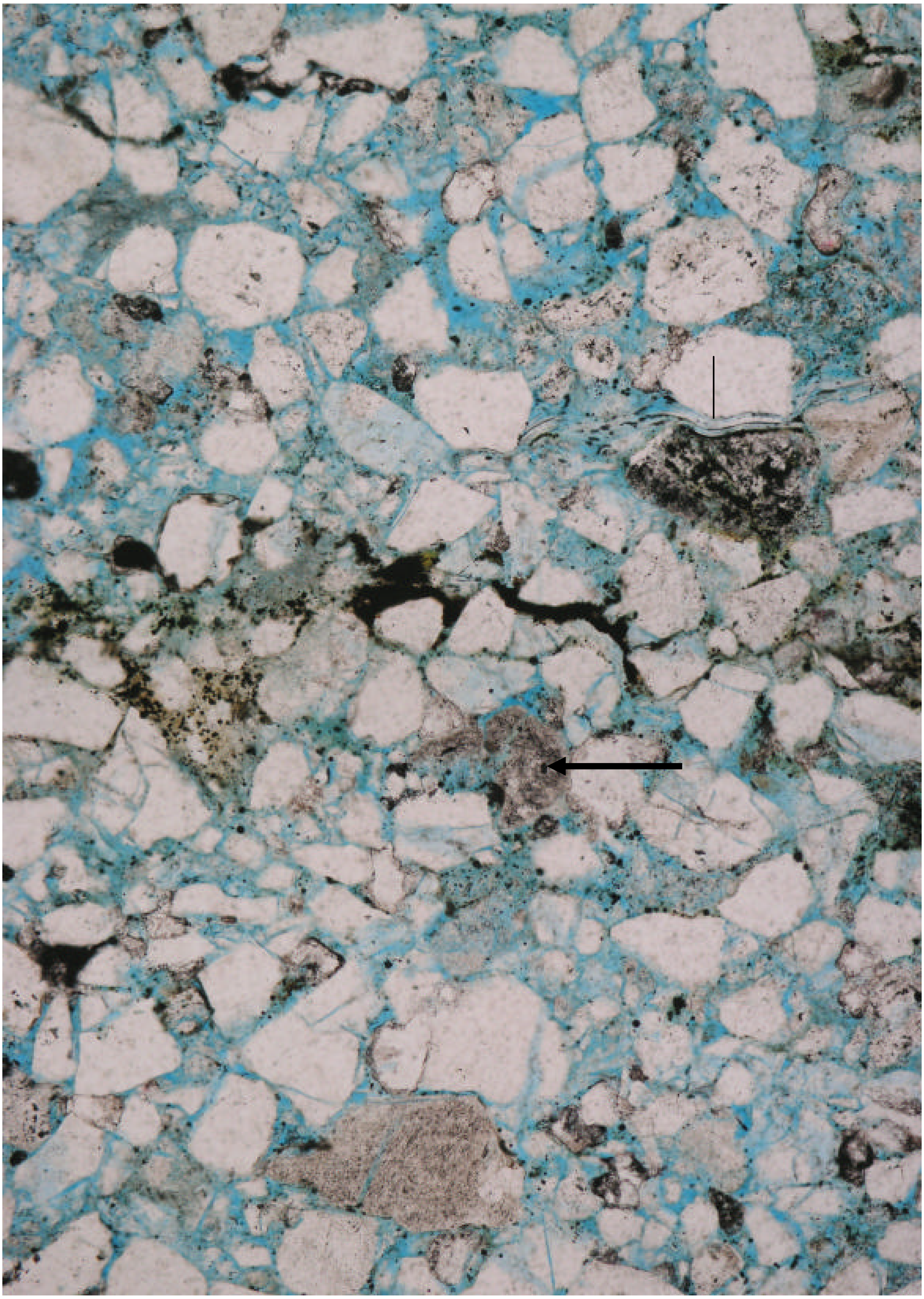


Figure 2

Stringers of opaque organic matter and minute pyrite crystals concentrate to outline the presence of laminae. Partially altered K-feldspars (large arrow) can be recognised from their dusty and corroded appearance, and a bent muscovite flake is apparent (small arrow). Hill-1, Swc 35, Depth 1992m. Plane light. Horizontal field of view 1.30mm.

4.3 Hill-1, Cuttings, Depth 1995m

Rock classification: **Grainstone**

Chips are dominated by silty/sandy mudstone (83%), drilling mud (10%) and minor single grains (5%). Rare chips of clean carbonate cemented fine grained sandstone (1%) and micrite (trace) are apparent. Single grains range from silt to fine sand in size, they are subangular to subrounded with low sphericity & composed of monocrystalline quartz, polycrystalline quartz, corroded K-feldspars, muscovite, biotite, calcareous forams, blocky pyrite & clear carbonate spar. The silty/sandy mudstone could either be a downhole contaminant or the muddy laminae noted in sidewall core 34. Single grains may have been derived either from the mudstone and/or a disaggregated sandstone. Since sidewall core 34 was taken from the same depth interval (1995m) it is a more accurate description of this depth interval than can be determined from these cuttings. The description below relates to the carbonate cemented fine sandstone (grainstone) because this lithology must occur above 1995m and is not represented by other samples.

Texture:

- Sedimentary structures: none apparent
- Average grain size: fine sand
- Range in grain size: silt to fine sand
- Roundness / sphericity: subangular to subrounded with low sphericity
- Sorting: moderately well
- Texture: cement supported
- Packing / grain contacts: very open packing / rare point contacts
- Pore types: none apparent but this cement may be patchy in the original sandstone

Composition:

- Framework grains: monocrystalline quartz, polycrystalline quartz with sutured crystal boundaries, K-feldspars, fresh plagioclase with albite twinning, lithics of quartzite, accessory very fine sand size tourmaline
- Authigenic minerals: clear blocky poikilotopic twinned spar has filled pores & partially replaced grains, remnants of green grains of glaucony, clusters of pyrite framboids scattered throughout the cement, patches of dusty micrite could represent crushed spar

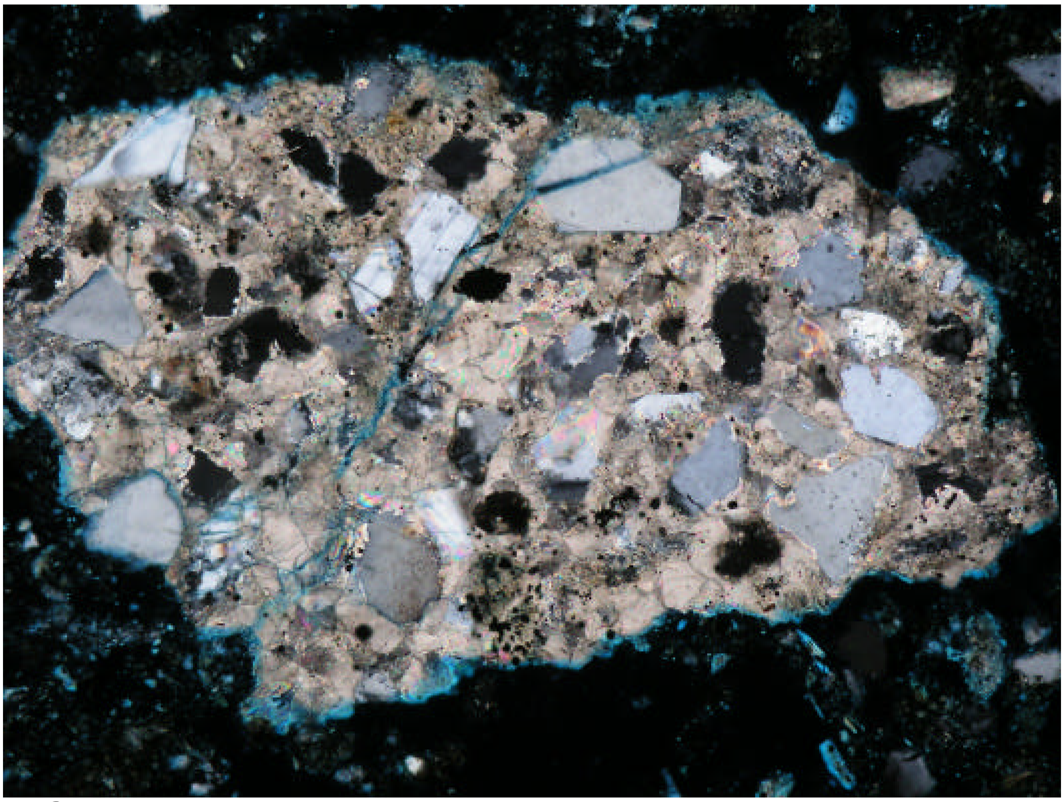


Figure 3

Chip of fine grained carbonate cemented sandstone or grainstone. Hill-1, Cuttings, Depth 1995m. Crossed nicols. Horizontal field of view 1.30mm.

4.4 Hill-1, Swc 34, Depth 1995m

Rock classification: **Subarkose**

Texture:

Sedimentary structures:	multiple planar clay & organic rich laminae up to 1mm thick with possible bioturbation, extensive disruption of intervening clean sands due to sampling
Average grain size:	fine sand (0.15mm)
Range in grain size:	clay to medium sand
Roundness / sphericity:	subangular to subrounded with low to moderate sphericity
Sorting:	poor (1.43 ϕ)
Texture:	grain supported in clean sands
Packing / grain contacts:	?moderately open in clean sands / tangential gain contacts
Pore types:	primary intergranular pores, grain size & honeycomb dissolution pores, micropores associated with kaolin

Composition:

Framework grains:	monocrystalline quartz, polycrystalline quartz with either straight or sutured crystal boundaries, corroded & sericitised K-feldspars that lack twinning & fresh K-feldspar with tartan twinning, relatively fresh plagioclase with albite & pericline twinning, lithics include ?granite (granophyric texture), volcanics (felsic laths in chloritic groundmass), micaceous schist, quartzite & chert, rare highly oxidised grains (?hematite), bent biotite & muscovite flakes up to 0.4mm length, accessory silt size zircon, opaques & tourmaline in the clay laminae, very fine to fine sand size zircon, rutile & tourmaline in the clean laminae
Matrix:	anhedral dark brown clay & blocky opaque organic matter, traces of reddish organic matter (?liptinite)
Authigenic minerals:	fine sand size grains of glaucony with either a fibrous or wormy texture, rare prismatic quartz overgrowths, anhedral micritic Fe rich carbonate partially replacing grains within the detrital clay, micas replaced by large kaolin booklets & booklets up to 20 microns where other grains replaced, rare pyrite framboids associated with organic matter

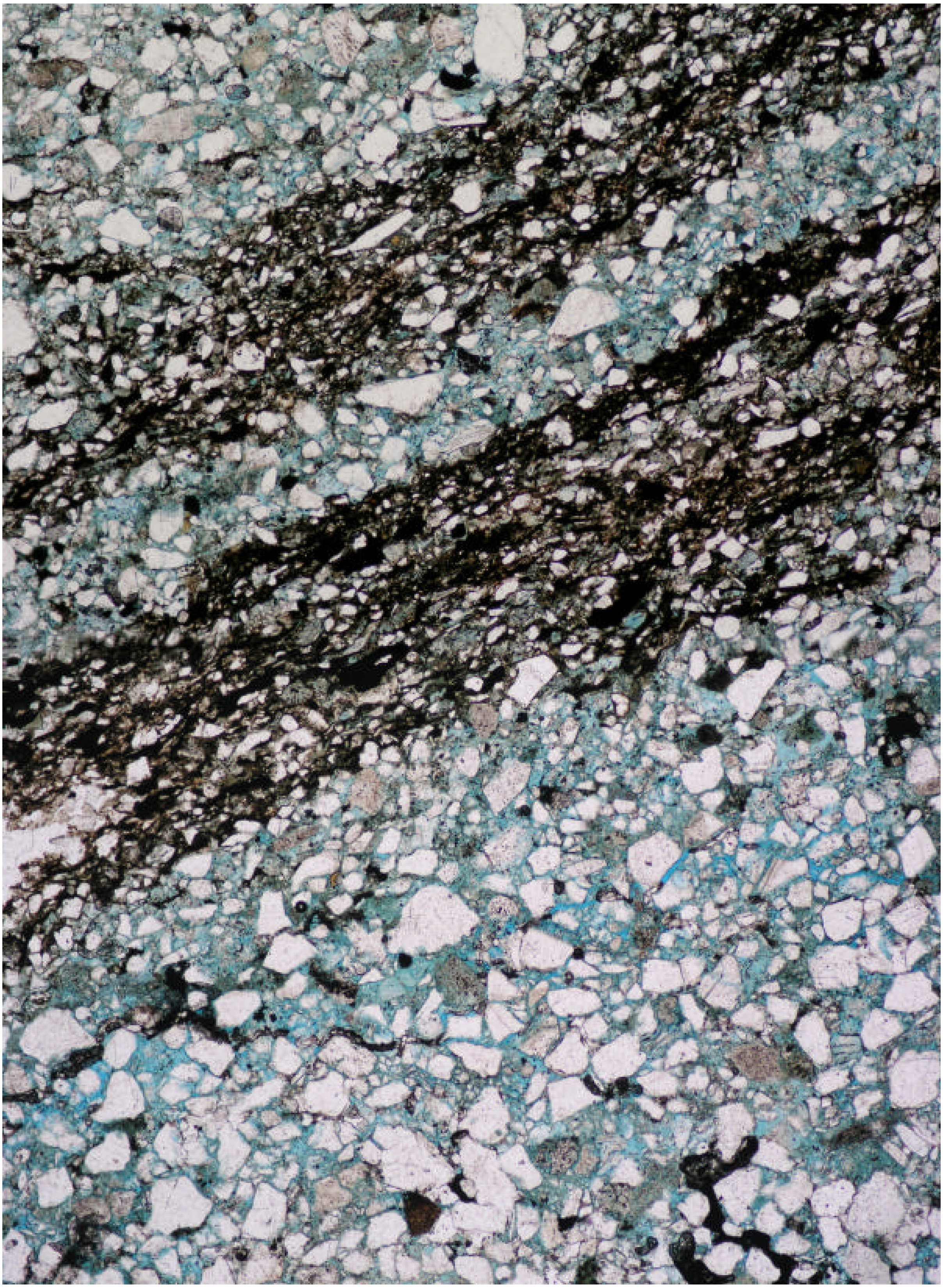


Figure 4

Detrital grains in the muddy laminae are finer than those in the clean laminae. These muddy laminae are more closely spaced than those elsewhere in the section. Hill-1, Swc 34, Depth 1995m. Plane light. Horizontal field of view 3.25mm.

4.5 Hill-1, Swc 33, Depth 1999m

Rock classification:	**Subarkose**
Texture:	
Sedimentary structures:	rare muddy laminae up to 1mm thick & isolated ?mudstone lithics
Average grain size:	fine sand (0.21mm)
Range in grain size:	clay to medium sand
Roundness / sphericity:	subangular to subrounded with low to moderate sphericity
Sorting:	poor (1.43 ϕ)
Texture:	grain supported
Packing / grain contacts:	texture only retained in laminae, probably originally moderately open with point & tangential contacts
Pore types:	primary intergranular pores, intragranular pores within lithics, honeycomb pores, micropores associated with kaolin
Composition:	
Framework grains:	monocrystalline quartz, polycrystalline quartz with either straight or sutured crystal boundaries, corroded K-feldspars lack twinning, fresh K-feldspars with tartan twinning, relatively fresh plagioclase with albite & pericline twinning, lithics include chert, granite (granophyric texture & polycrystalline quartz + feldspar), rare volcanics, quartzite & silty mudstone intraclasts, bent muscovite & biotite flakes up to 0.7mm in length concentrate in the clay laminae, accessory very fine to fine sand size zircon & tourmaline
Matrix:	anhedral brown clay & blocky opaque organic matter
Authigenic minerals:	prismatic & rhombohedral quartz overgrowths, anhedral Fe rich micrite & spar replacing grains especially in the clay rich laminae, framboidal pyrite up to 15 microns in diameter on grain margins or aligned along biotite cleavage, vermiform kaolin & booklets have replaced micas & other grains

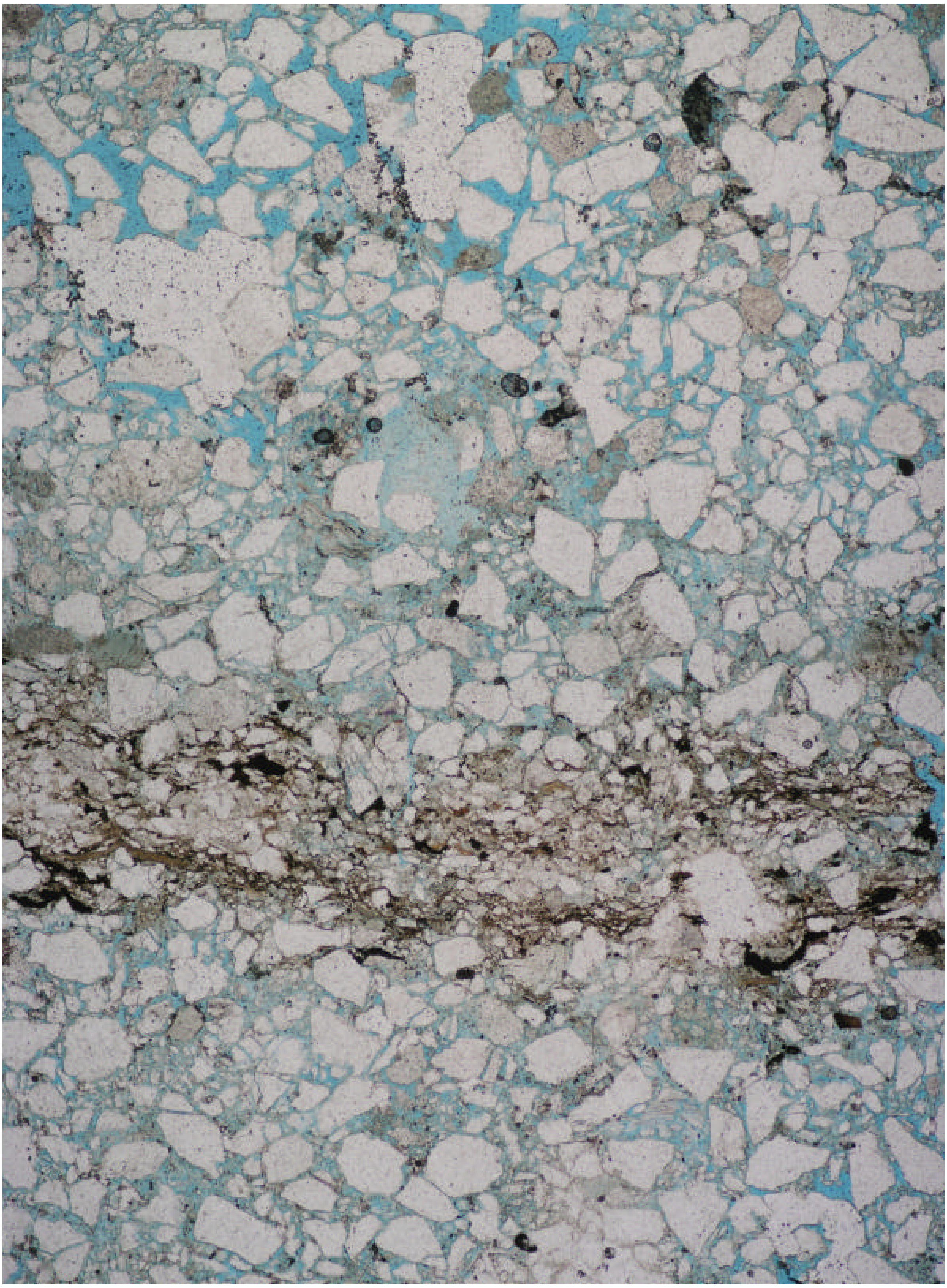


Figure 5

Texture has not been preserved in this sidewall core due to the lack of a significant cement. Only where muddy laminae are apparent is the texture partially intact. The angular nature of many grains is due to fracturing. Note the concentration of silt size grains in the laminae. Hill-1, Swc 33, Depth 1999m. Plane light. Horizontal field of view 3.25mm.

4.6 Hill-1, Cuttings, Depth 2004m

Rock classification: **Muddy subarkose**

Chips are dominated by silty/sandy mudstone (60%) with minor single grains (38%) and carbonate cemented sandstone (1%). The single grains are either mixed with drilling mud or loose. One chip of muddy sandstone (trace) was also identified. Single grains have the same range in grain size that is apparent in the mudstone. It is possible that the silty/sandy mudstone was derived from laminae within a poorly cemented sandstone similar to that described from sidewall core samples. Where calcareous forams and glauconite are evident in the mudstone this probably represents down hole contamination from shallower depths. Similarly the carbonate cemented sandstone is described in the cuttings from 1995m. Therefore this description is restricted to the one chip of muddy sandstone which may occur at this depth interval.

Texture:

Sedimentary structures:	discontinuous stringers & laminae in which clay & organic matter are concentrated
Average grain size:	very fine sand
Range in grain size:	clay to fine sand
Roundness / sphericity:	subangular with low to moderate sphericity
Sorting:	poorly sorted
Texture:	grain supported
Packing / grain contacts:	close packing / tangential, concavo-convex & sutured grain contacts
Pore types:	rare honeycomb pores where feldspars partially corroded

Composition:

Framework grains:	monocrystalline quartz, polycrystalline quartz with straight crystal boundaries, corroded & sericitised K-feldspars that lack twinning, fresh plagioclase with pericline twinning, lithics of quartzite, bent biotite & muscovite flakes up to 0.15mm length, accessory very fine sand size zircon
Matrix:	blocky opaque & reddish stringers of organic matter associated with anhedral brown clay
Authigenic minerals:	bright green fine sand size grains of glaucony with wormy texture typical of glauconite, anhedral Fe rich micrite partially replacing grains & matrix, rare pyrite framboids associated with grains of glaucony & detrital clay

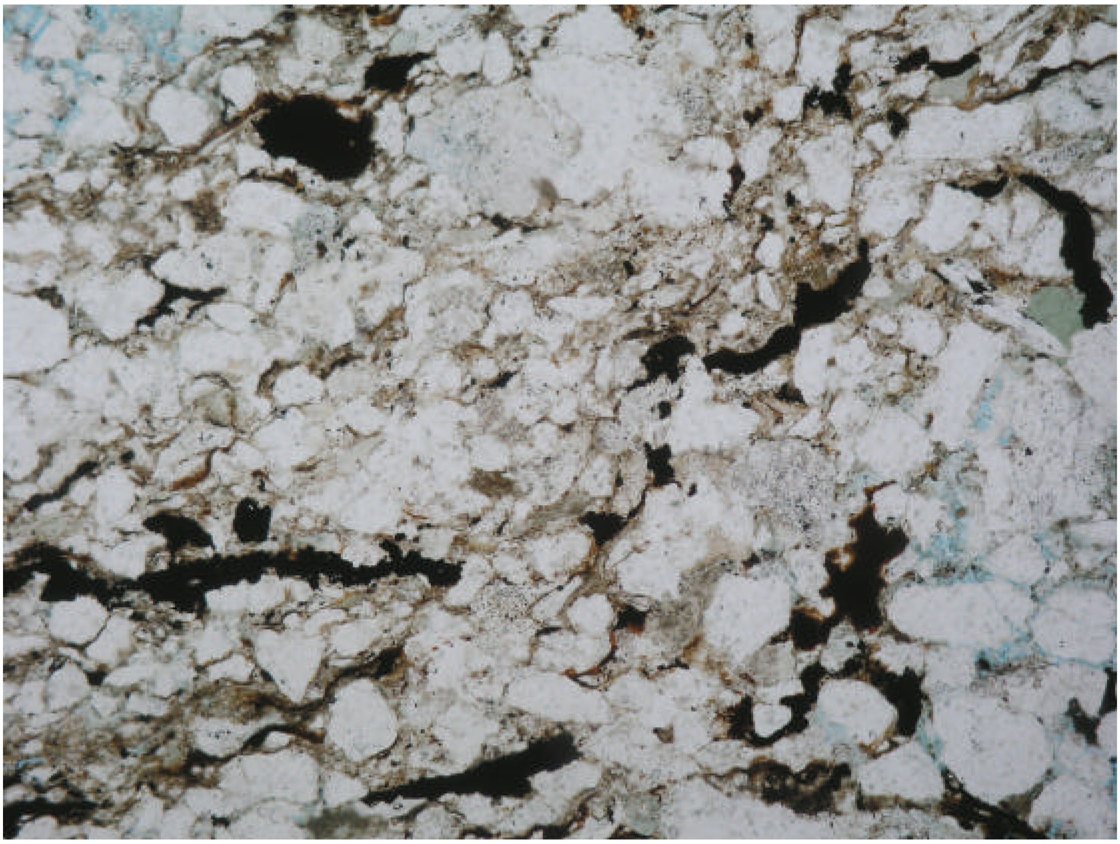


Figure 6
Texture in this chip of muddy subarkose indicates close packing and lack of significant authigenic cements. The opaque material is probably organic matter & the brown clay between grains has been partially replaced by micrite. Hill-1, Cuttings, Depth 2004m. Plane light. Horizontal field of view 1.30mm.

4.7 Hill-1, Swc 31, Depth 2007.5m

Rock classification: **Subarkose**

Texture:

- Sedimentary structures: extensive disruption & grain fracturing during sampling, invasion by drilling mud, remnants of discontinuous planar laminae up to 0.5mm in width & composed of clay & organic matter
- Average grain size: fine sand (0.16mm)
- Range in grain size: clay to medium sand
- Roundness / sphericity: subangular with low to moderate sphericity
- Sorting: poor (1.04 ϕ)
- Texture: grain supported
- Packing / grain contacts: ??moderately open in the clean laminae
- Pore types: primary intergranular pores, rare corroded feldspars & intragranular pores in dusty polycrystalline quartz, micropores associated with kaolin

Composition:

- Framework grains: monocrystalline quartz, polycrystalline quartz with either straight or sutured crystal boundaries, sericitised, corroded & dusty K-feldspars that lack twinning, fresh K-feldspar with tartan twinning, relatively fresh plagioclase with pericline & albite twinning, lithics of chert, quartzite, micaceous schist, ?granite (granophyric texture) & volcanics (laths in devitrified glass), bent muscovite & biotite flakes up to 0.7mm length, accessory silt to very fine sand size tourmaline, opaques & zircon
- Matrix: brown anhedral clay & blocky opaque & reddish organic matter
- Authigenic minerals: prismatic quartz overgrowths, kaolin booklets have replaced micas & other grains, minor anhedral Fe rich micrite forms a localised cement in the clay rich laminae, minute (up to 15 microns) anhedral crystals of clear spar scattered throughout the clean laminae, rare pyrite framboids

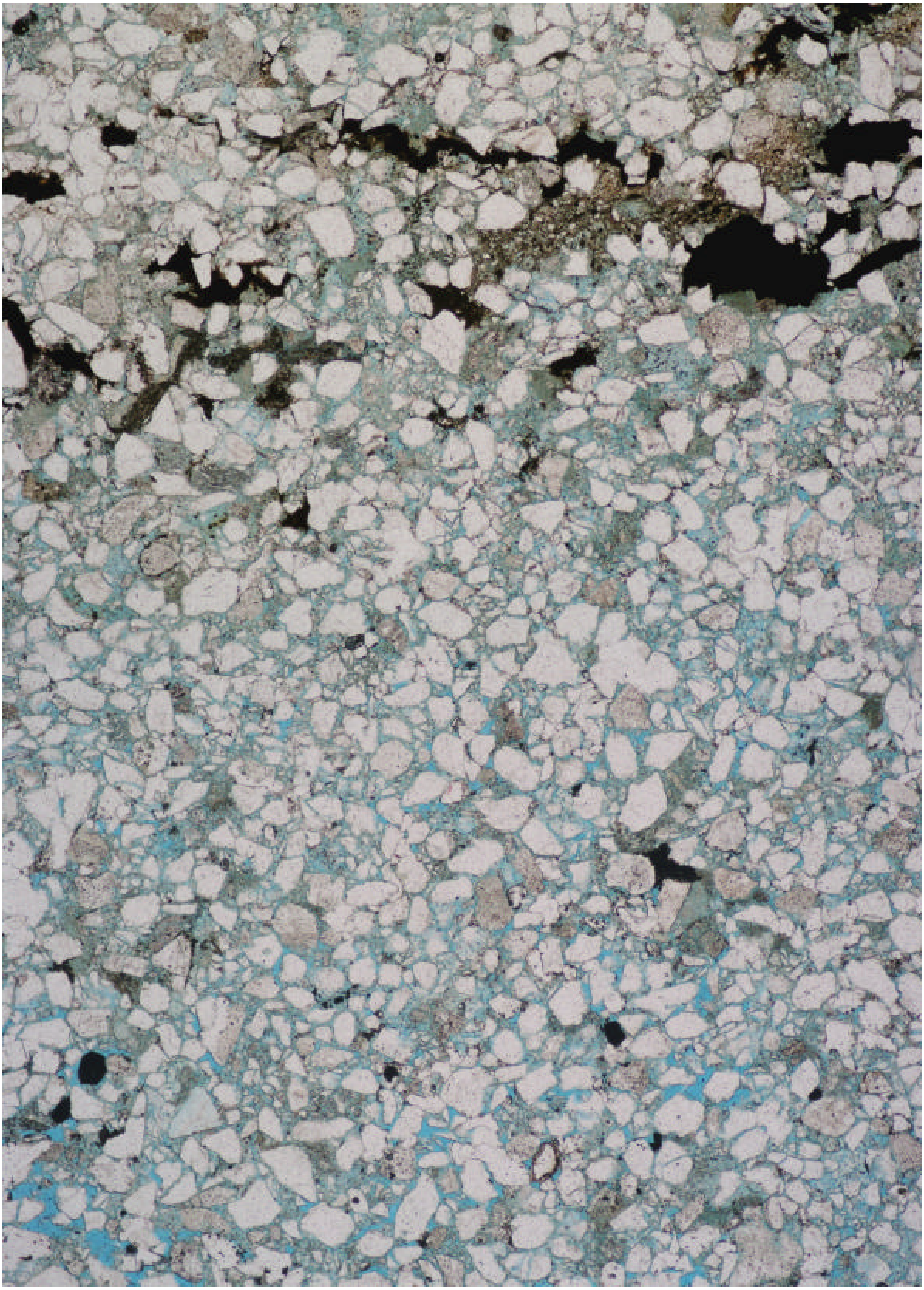


Figure 7

General field of view illustrating a thin laminae outlined by organic matter (opaque) & detrital clay. Clean laminae lack significant cements therefore textures were disrupted during sampling. Hill-1, Swc 31, Depth 2007.5m. Plane light. Horizontal field of view 3.25mm.

4.8 Hill-1, Cuttings, Depth 2016m

Rock classification:

Cuttings from this depth interval are comprised of mudstone (5%), silty/sandy mudstone (45%), carbonate cemented sandstone (trace), muddy sandstone (trace), one calcareous shell fragment (trace) & single grains (49%). The latter are either cemented by drilling mud or loose. All these lithologies have been described from shallower depths where they are more likely to be representative. Since sidewall core 29 is also from 2016m there would appear to be no additional information that can be obtained from the cuttings.

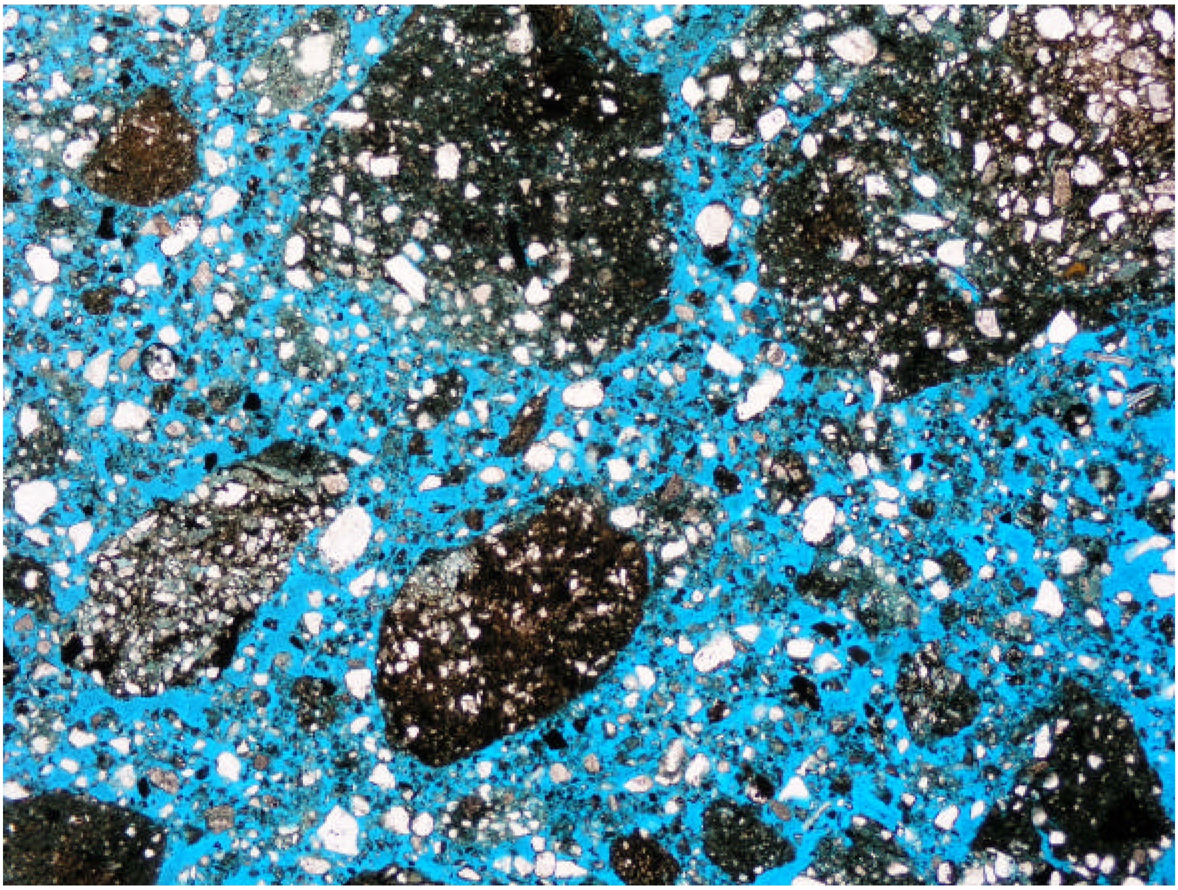


Figure 8

General field of view illustrating the highly disrupted nature of cuttings from this depth. The abundance of single grains indicates that a disaggregated sandstone similar to that described in sidewall core 29 was probably representative. Hill-1, Cuttings, Depth 2016m. Plane light. Horizontal field of view 6.5mm.

4.9 Hill-1, Swc 29, Depth 2016m

Rock classification: **Subarkose**

Texture:

Sedimentary structures:	none apparent, textural integrity not preserved
Average grain size:	fine sand (0.21mm)
Range in grain size:	coarse silt to coarse sand
Roundness / sphericity:	subangular to subrounded with low to moderate sphericity
Sorting:	moderately well (0.55 ϕ)
Texture:	grain supported
Packing / grain contacts:	?moderately open packing / point & tangential grain contacts
Pore types:	primary intergranular pores, honeycomb pores within feldspars, micropores associated with kaolin

Composition:

Framework grains:	monocrystalline quartz, polycrystalline quartz with either straight or sutured crystal boundaries, K-feldspars with perthite & tartan twinning, other corroded K-feldspars lack twinning, relatively fresh & highly corroded plagioclase with pericline & albite twinning, lithics of chert, quartzite, ?granite (granophyric texture) & volcanics (laths in a chloritic groundmass), bent muscovite & biotite flakes up to 0.35mm in length, accessory silt to fine sand size zircon, tourmaline, rutile & opaques
Matrix:	blocky opaque organic matter possibly partially replaced by pyrite
Authigenic minerals:	rounded fine sand size grains of fibrous green chlorite, prismatic & rhombohedral quartz overgrowths, single crystals of blocky pyrite & framboids up to 10 microns diameter scattered throughout the section both replacing grains & within pores, extensive pore filling & grain replacing kaolin booklets & verms of various sizes (10-50 microns), kaolin forms large patches (up to 1mm) which may be replacing lithics in one part of the section, localised patches of fibrous radial ?barite/anhydrite

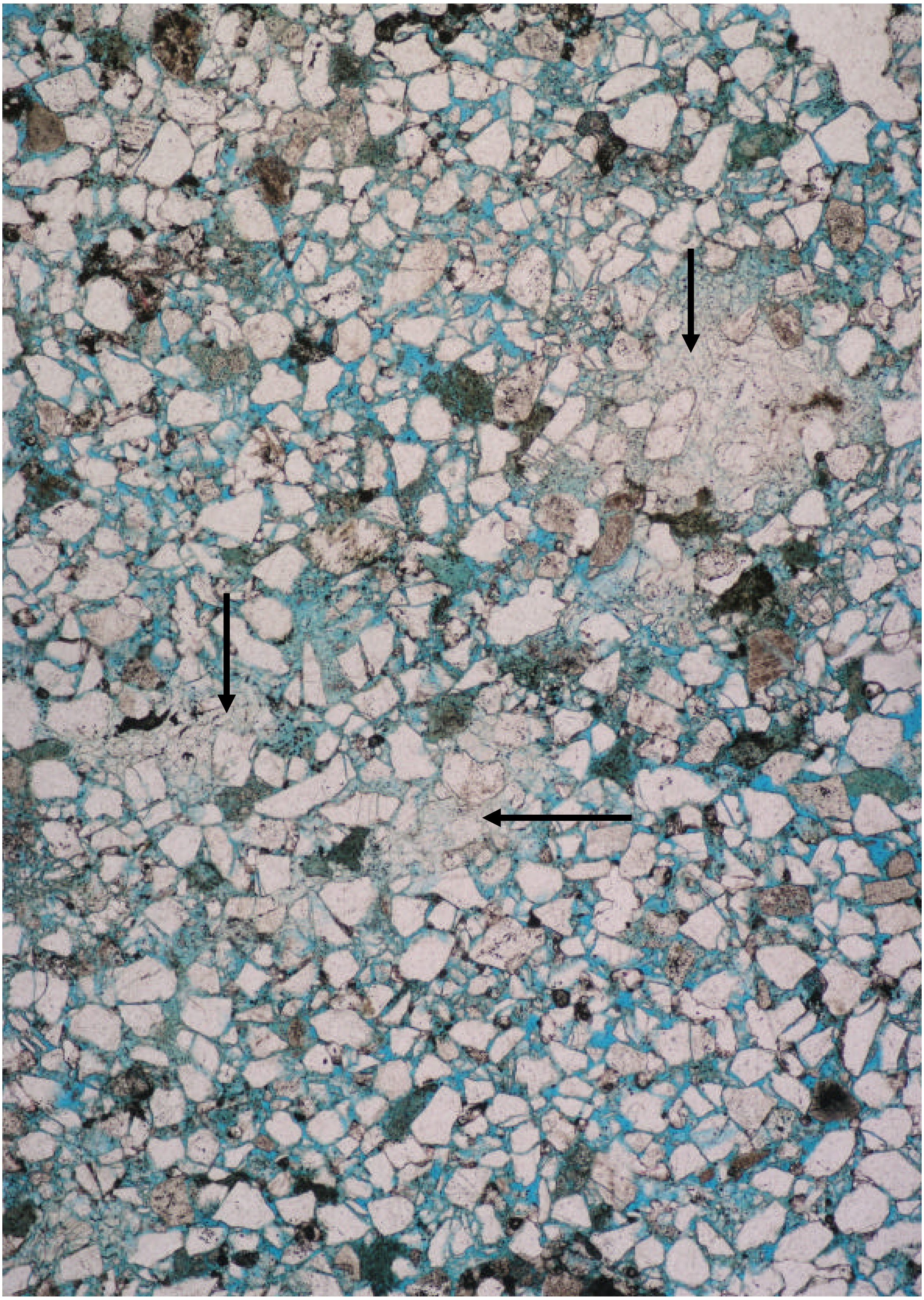


Figure 9

The concentration of large patches (up to 1mm diameter) of kaolin (arrows) is illustrated in this field of view. Dusty grains are commonly partially altered feldspars. Hill-1, Swc 29, Depth 2016m. Plane light. Horizontal field of view 3.25mm.

4.10 Hill-1, Cuttings, Depth 2020m

Rock classification: **Wackestone**

Chips of silty/sandy mudstone (75%), carbonate cemented sandstone (1%) and single grains (24%) are apparent in these cuttings. Single grains range in size from very fine to rare coarse sand, and are typically subangular to subrounded with low sphericity. Single grains are composed of monocrystalline & polycrystalline (straight crystal boundaries) quartz, fresh & corroded K-feldspar with tartan & perthite twinning & rare muscovite flakes. These single grains could have been either disaggregated from a sandstone and/or at least some derived from the sandy mudstone. Chips of carbonate cemented sandstone are not the same as those described from cuttings at 1995m therefore they could be representative of this depth.

Texture:

- Sedimentary structures: differences between chips suggest there is bedding related to concentrations of organic matter, pyrite & sand (Figs 10a, 10b & 10c)
- Average grain size: silt to very fine sand
- Range in grain size: silt to medium sand
- Roundness / sphericity: subangular to subrounded with low sphericity
- Sorting: moderately well sorted
- Texture: cement supported
- Packing / grain contacts: very open packing / rare point contacts
- Pore types: rare grain size & intragranular pores

Composition:

- Framework grains: monocrystalline quartz, polycrystalline quartz with either straight or sutured crystal boundaries, dusty K-feldspars, lithics of ?micaceous schist or quartzite, & ?volcanics, straight muscovite flakes up to 0.10mm in length, accessory silt size rutile
- Matrix: crenulated stringers of reddish organic matter rarely serrated as per cutinite, minor blocky opaque organic matter
- Authigenic minerals: pervasive anhedral dusty micrite to microspar (?neomorphism) fills pores & partially replaces grains, rare grain size patches of Fe rich anhedral spar, framboidal & blocky pyrite scattered throughout the carbonate, framboids up to 20 microns diameter

Figure 10a

There are three chips that are similar to this example of wackestone. Crenulated stringers of organic matter are apparent and remnants of detrital grains float in the dusty carbonate cement. Hill-1, Cuttings, Depth 2020m. Plane light. Horizontal field of view 1.30mm.

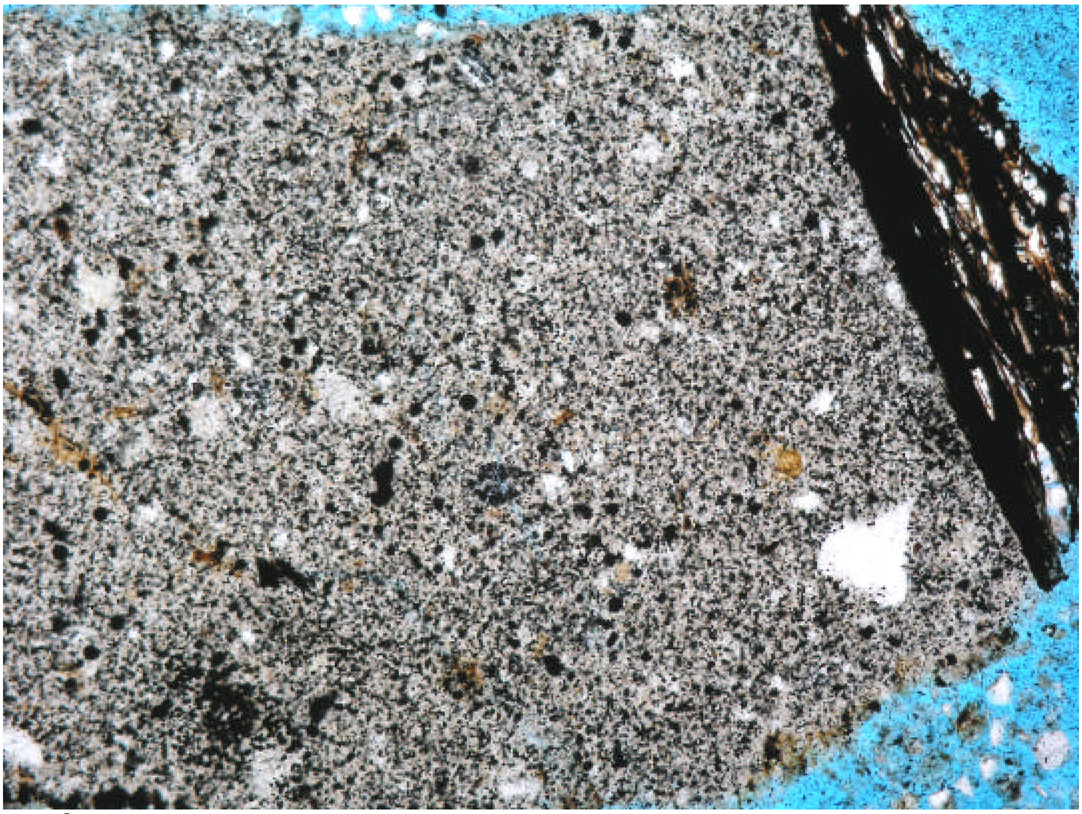


Figure 10b

This example of the wackestone has significantly less detrital grains but a high percentage of opaque pyrite within the dusty carbonate. Note the remnants of cellular structure in the organic matter on the RHS of this field of view. Hill-1, Cuttings, Depth 2020m. Plane light. Horizontal field of view 1.30mm.

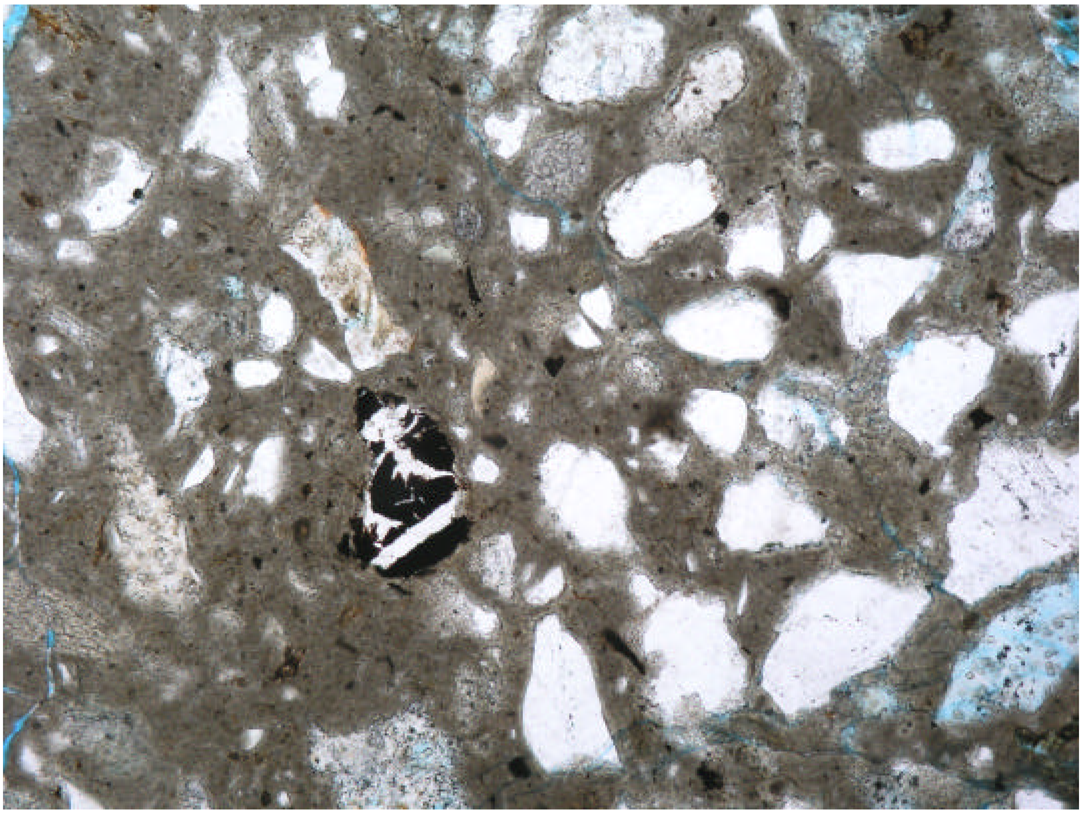


Figure 10c

Grain size in this chip of wackestone is up to medium sand compared to the very fine sand in the example illustrated in Figure 10a. Note the relative lack of organic matter. Hill-1, Cuttings, Depth 2020m. Plane light. Horizontal field of view 1.30mm.

4.11 Hill-1, Swc 26, Depth 2023m

Rock classification:	**Sublitharenite**
Texture:	
Sedimentary structures:	texture has been extensively disrupted, there are isolated highly deformed segments of silty mudstone up to 5mm in diameter that might represent lithics in the sandstone
Average grain size:	fine sand (0.22mm)
Range in grain size:	coarse silt to medium sand
Roundness / sphericity:	subangular to subrounded with low to moderate sphericity
Sorting:	moderately well (0.56 ϕ)
Texture:	grain supported
Packing / grain contacts:	??moderately open / probably point & tangential
Pore types:	primary intergranular pores, honeycomb pores within feldspars, micropores associated with kaolin
Composition:	
Framework grains:	monocrystalline quartz, polycrystalline quartz with either sutured or straight crystal boundaries, highly corroded, dusty & sericitised K-feldspar that lacks twinning, relatively fresh K-feldspar with tartan twinning, fresh & partially altered plagioclase with albite twinning, lithics of chert (rarely oxidised), silty mudstone, quartzite, ?granite (granophyric texture) & volcanics (felsic laths in chloritic groundmass), bent muscovite & rare biotite flakes up to 0.5mm in length, accessory silt to fine sand size zircon & tourmaline
Matrix:	fractured blocky opaque material was probably organic matter
Authigenic minerals:	rare prismatic quartz overgrowths, framboidal & blocky crystals of pyrite up to 10 microns diameter scattered throughout the section, grain replacing (including micas) & pore filling kaolin booklets

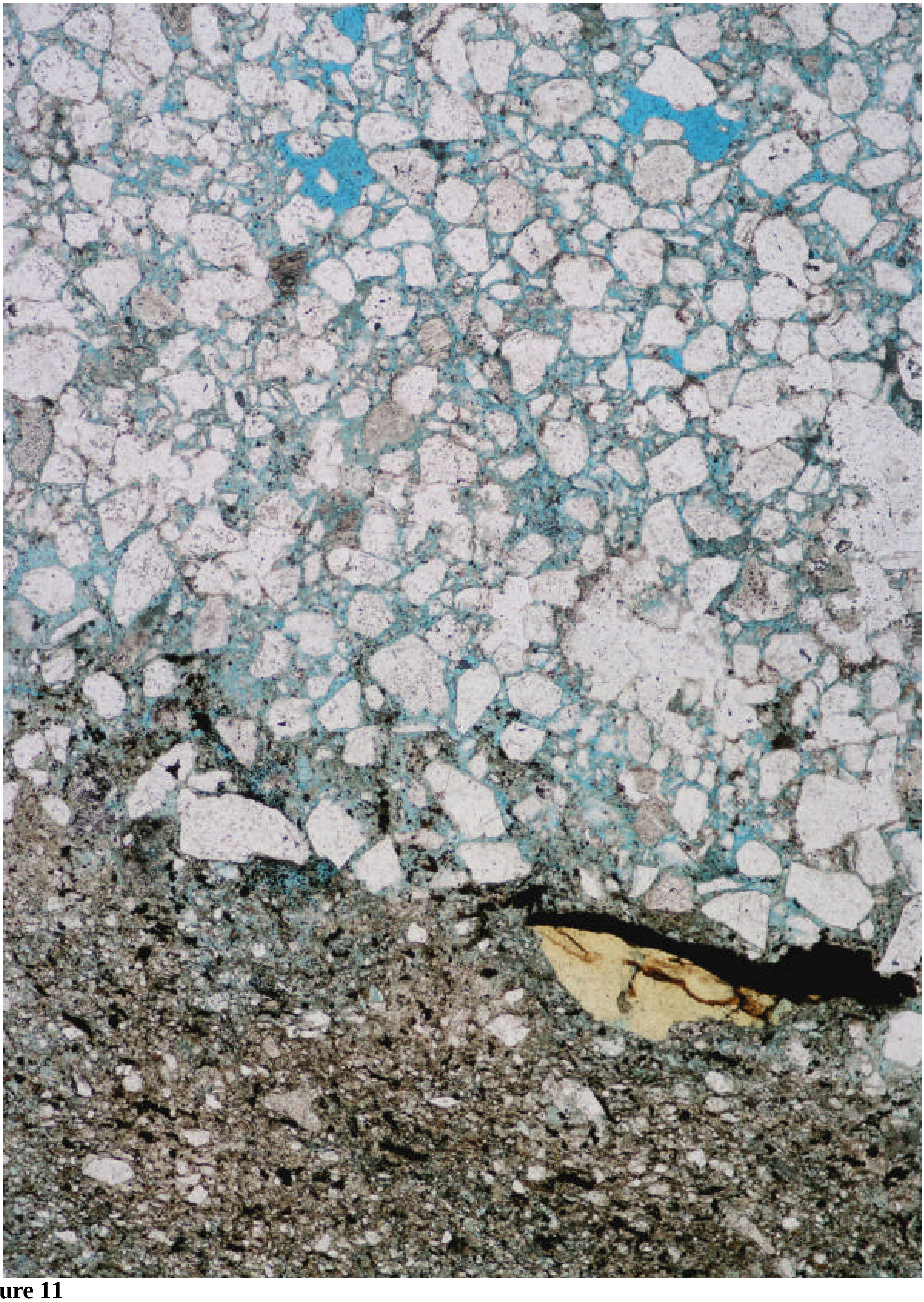


Figure 11

This field of view illustrates the irregular contact between a silty mudstone ?lithic and the sublitharenite. The large yellowish patch immediately below the opaque organic matter in the mudstone is probably phosphate. Hill-1, Swc 26, Depth 2023m. Plane light. Horizontal field of view 3.25mm.

4.12 Hill-1, Swc 22, Depth 2075m

Rock classification: **Greywacke**

Texture:

Sedimentary structures:	texture highly disrupted but there were probably muddy laminae or irregular patches (?burrows) of some type in the sandstone
Average grain size:	fine sand (0.24mm)
Range in grain size:	clay to coarse sand
Roundness / sphericity:	subangular to subrounded with low sphericity
Sorting:	very poor (2.44 ϕ)
Texture:	grain supported in clean laminae & matrix supported elsewhere
Packing / grain contacts:	?moderately open/ point & tangential grain contacts in the muddy patches
Pore types:	?intergranular pores in the clean areas, grain size dissolution pores, honeycomb pores

Composition:

Framework grains:	monocrystalline quartz commonly embayed, polycrystalline quartz with either straight or sutured crystal boundaries, highly altered & corroded K-feldspars, relatively fresh K-feldspars with tartan twinning, fresh & corroded plagioclase with albite twinning, lithics of chert, chalcedony, ?granite (granophyric texture, plagioclase & quartz), quartzite & micaceous schist, bent muscovite flakes up to 0.4mm in length & rare highly altered biotite, accessory silt to medium sand size zircon, opaques, tourmaline & hornblende
Matrix:	brown anhedral clay with illitic laths, blocky opaque organic matter
Authigenic minerals:	prismatic quartz overgrowths may be inherited, isolated patch of crushed spar on the section margin, minute pyrite framboids are scattered throughout the matrix & partially replace grains, radial laths of ?anhydrite/barite form a localised cement in the clean sandstone

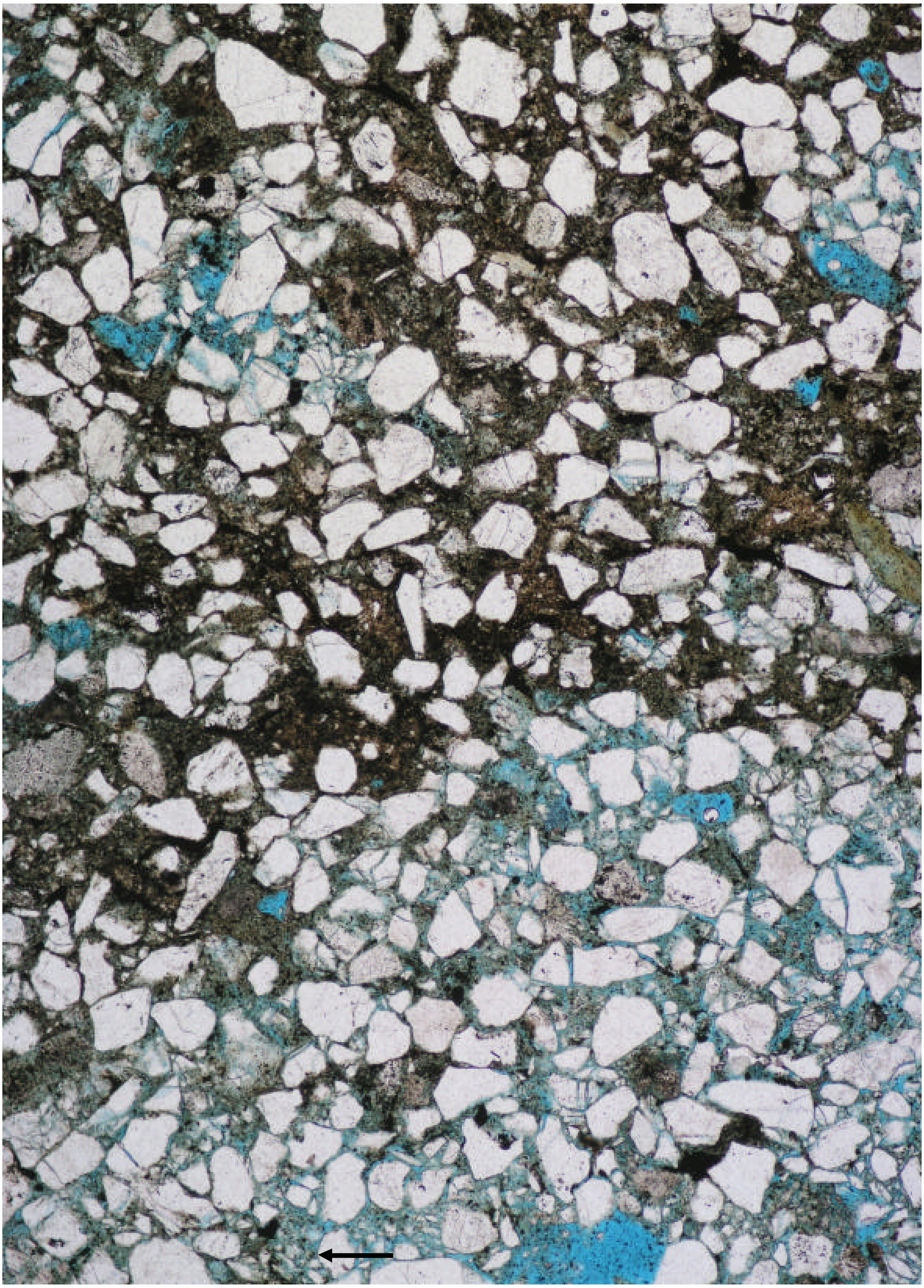


Figure 12

In the irregular patches of dark brown clay detrital grains are intact but typically fractured in the cleaner sands. Overall there is no change in detrital grain size between the clean and muddy sediments. Radial crystals of ?barite (arrow) are evident in the cleaner sands. Hill-1, Swc 22, Depth 2075m. Plane light. Horizontal field of view 3.25mm.

4.13 Hill-1, Swc 21, Depth 2078.5m

Rock classification: **Greywacke**

Texture:

Sedimentary structures:	sample has been fractured into large chips, irregular patches of clay could represent either drilling mud, lithics, ?filled burrows or ?laminae
Average grain size:	fine sand (0.23mm)
Range in grain size:	clay to coarse sand
Roundness / sphericity:	subangular to subrounded with low sphericity
Sorting:	very poor (2.40 ϕ)
Texture:	?grain supported in clean patches
Packing / grain contacts:	?moderately open / point & tangential grain contacts in the muddy laminae
Pore types:	primary intergranular pores in clean areas, rare honeycomb pores

Composition:

Framework grains:	monocrystalline quartz, polycrystalline quartz with either straight or sutured crystal boundaries, sericitised K-feldspar, fresh K-feldspar with perthite & tartan twinning, relatively fresh plagioclase with albite twinning, lithics of chert, quartzite, ?granite (granophyric texture), & ?volcanics (laths in chloritic groundmass), calcareous ovoid test 0.25mm diameter filled with pyrite, bent flakes of biotite & muscovite up to 0.25mm in length, accessory very fine to fine sand size zircon, tourmaline, rutile & opaques
Matrix:	brown illitic clay & blocky opaque organic matter
Authigenic minerals:	quartz overgrowths could be inherited, Fe rich micrite replacing grains & scattered throughout the matrix, rare patches on the edge of the section were cemented by crushed clear spar, framboidal pyrite scattered throughout the detrital clay, trace of vermiform kaolin, radial crystals of ?anhydrite/barite in the cleaner sands

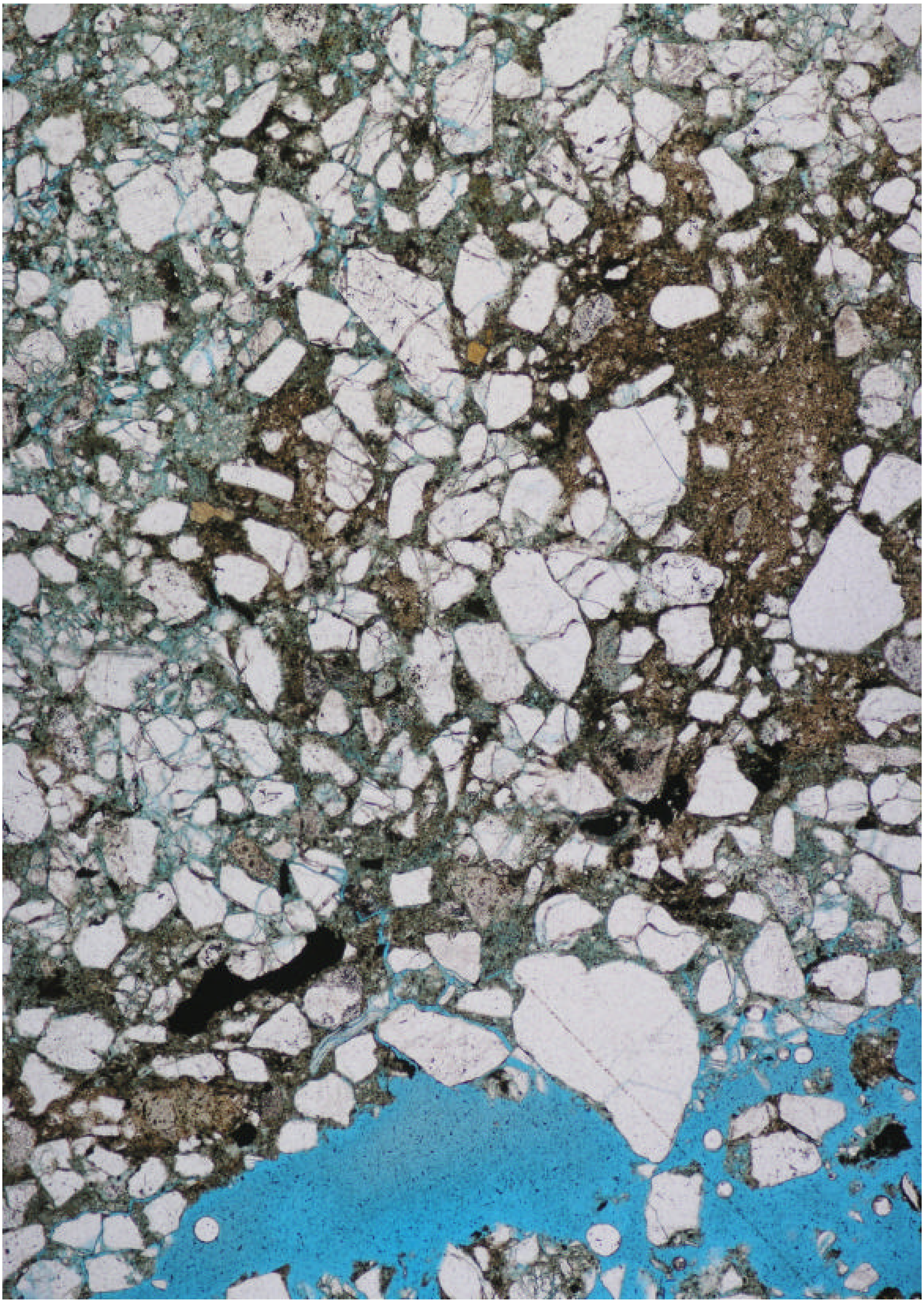


Figure 13

Disruption during sampling makes it impossible to determine the origin of the brown clay. If the clay represents matrix this sample is a greywacke, but if the clay occurs within lithics it would be a sublitharenite. Note the wide range in grain size. Hill-1, Swc 21, Depth 2078.5m. Plane light. Horizontal field of view 3.25mm.

4.14 Hill-1, Cuttings, Depth 2079m

Rock classification: **Sublitharenite**

Chips are composed of mudstone (3%), silty/sandy laminated mudstone (48%), muddy sandstone (5%), very fine grained sandstone (2%), carbonate cemented sandstone (2%) and single grains (40%). The latter range in grain size from silt to coarse sands and could have been disaggregated from any of the sandstones or sandy mudstone. It is highly likely that the lithology most representative of this depth is the muddy sandstone (greywacke) since this is the rock type in the overlying sidewall cores. The only lithology which has not been described from samples higher in the sequence is the very fine grained sandstone.

Texture:

Sedimentary structures:	laminae rich in clay & organic matter
Average grain size:	very fine sand
Range in grain size:	clay to medium sand
Roundness / sphericity:	subangular with low sphericity
Sorting:	moderately well
Texture:	grain supported
Packing / grain contacts:	moderately open/ tangential grain contacts
Pore types:	primary intergranular pores, honeycomb pores where feldspars are corroded

Composition:

Framework grains:	monocrystalline quartz, polycrystalline quartz with straight crystal boundaries, corroded K-feldspars with tartan twinning, other feldspars are sericitised, rare corroded plagioclase, lithics include ?granite (granophyric texture), quartzite, micaceous schist & dusty chert, one calcareous spine 0.04mm diameter, bent muscovite & biotite flakes up to 0.15mm in length, accessory silt size zircon
Matrix:	brown anhedral clay & blocky opaque & reddish stringers of organic matter
Authigenic minerals:	deformed grains of glaucony with a fibrous texture, ductile grains (possibly biotite & glaucony) replaced by Fe rich micrite, crushed spar forms a localised cement, rare blocky & framboidal pyrite, grain replacing kaolin booklets up to 25 microns in diameter

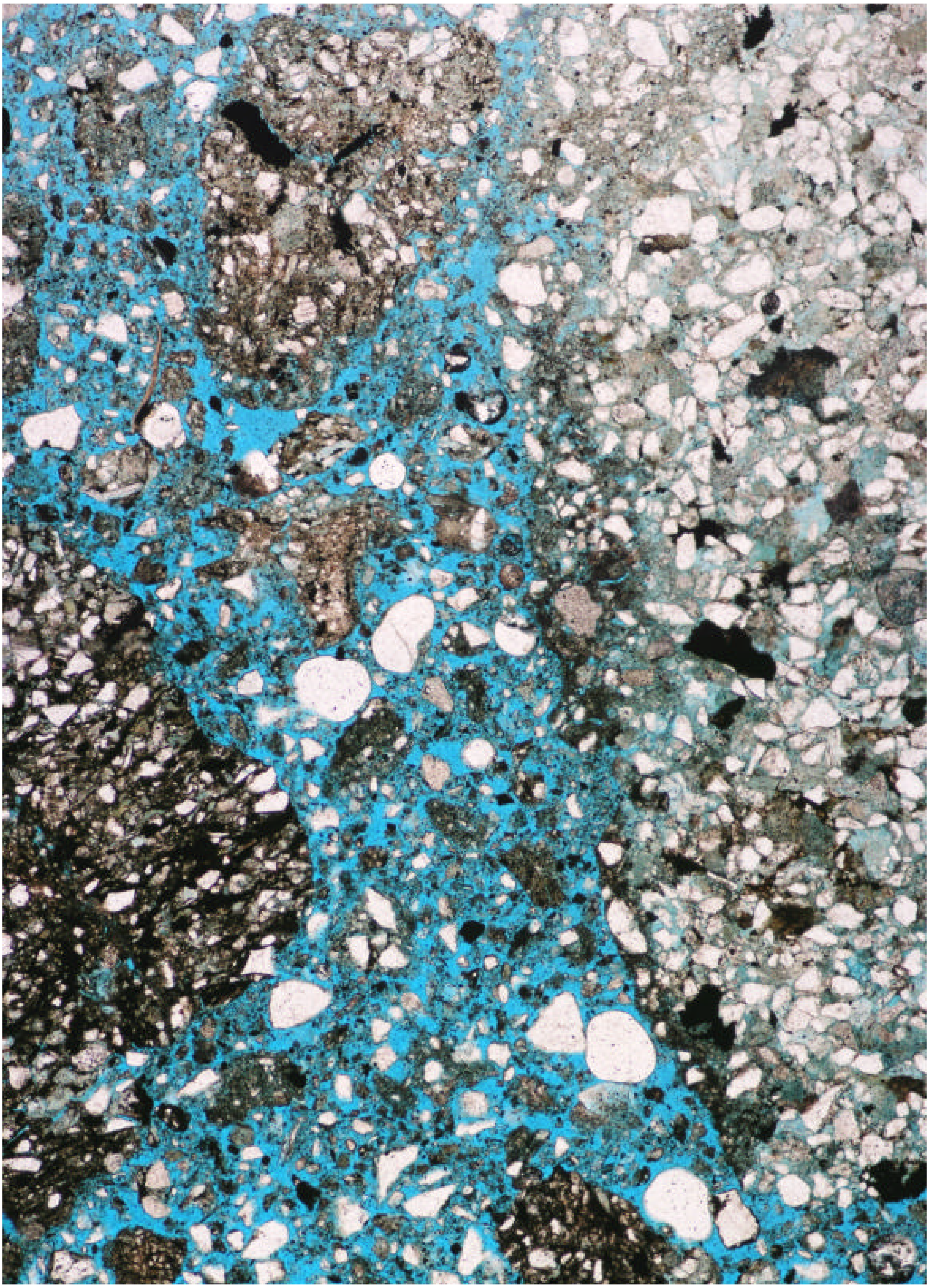


Figure 14

The largest chip in this field of view is composed of very fine grained sublitharenite. The edge of a chip of dark brown sandy mudstone is also apparent. Numerous single grains, some cemented by drilling mud occur between the two chips. Well rounded white patches are bubbles in the glue used to prepare the thin section. Hill-1, Cuttings, Depth 2079m. Plane light. Horizontal field of view 3.25mm.

4.15 Hill-1, Swc 16, Depth 2196m

Rock classification: **Greywacke**

Texture:

Sedimentary structures:	texture has been highly disrupted by sampling, irregular patches of dark brown clay matrix & cleaner sand, possibly bedding indicated by the distribution of very large sand grains
Average grain size:	medium sand (0.28mm)
Range in grain size:	clay to very coarse sand
Roundness / sphericity:	subangular to subrounded with low to moderate sphericity
Sorting:	very poor (2.16 ϕ)
Texture:	partially grain supported & patches of matrix supported
Packing / grain contacts:	?moderately open where matrix is abundant / point & tangential
Pore types:	possibly intergranular in cleaner sands, corroded feldspars produce honeycomb pores,

Composition:

Framework grains:	monocrystalline quartz, polycrystalline quartz with either straight or sutured crystal boundaries, corroded & sericitised K-feldspars with microperthitic textures & tartan twinning up to coarse sand in size, fresh plagioclase with albite twinning, lithics of granite (feldspar + polycrystalline quartz, granophyric texture), chloritised ?metamorphics, micaceous schist, volcanics, chalcedony & chert, calcareous foram test filled with pyrite, highly corroded calcareous cellular structure (?echinoid plate), elongate ?shell fragment, rare straight muscovite flakes, accessory fine sand size tourmaline & rutile, very fine sand size zircon
Matrix:	dark brown anhedral clay plus blocky opaque organic matter
Authigenic minerals:	rare anhedral to subhedral rhombs of clear spar float in the matrix, pyrite framboids & Fe rich anhedral micrite scattered throughout the clay matrix, highly deformed fibrous & wormy green grains (?chlorite) within the matrix could represent altered lithics, colourless radial ?barite has precipitated in the matrix & forms a localised cement in the cleaner sands

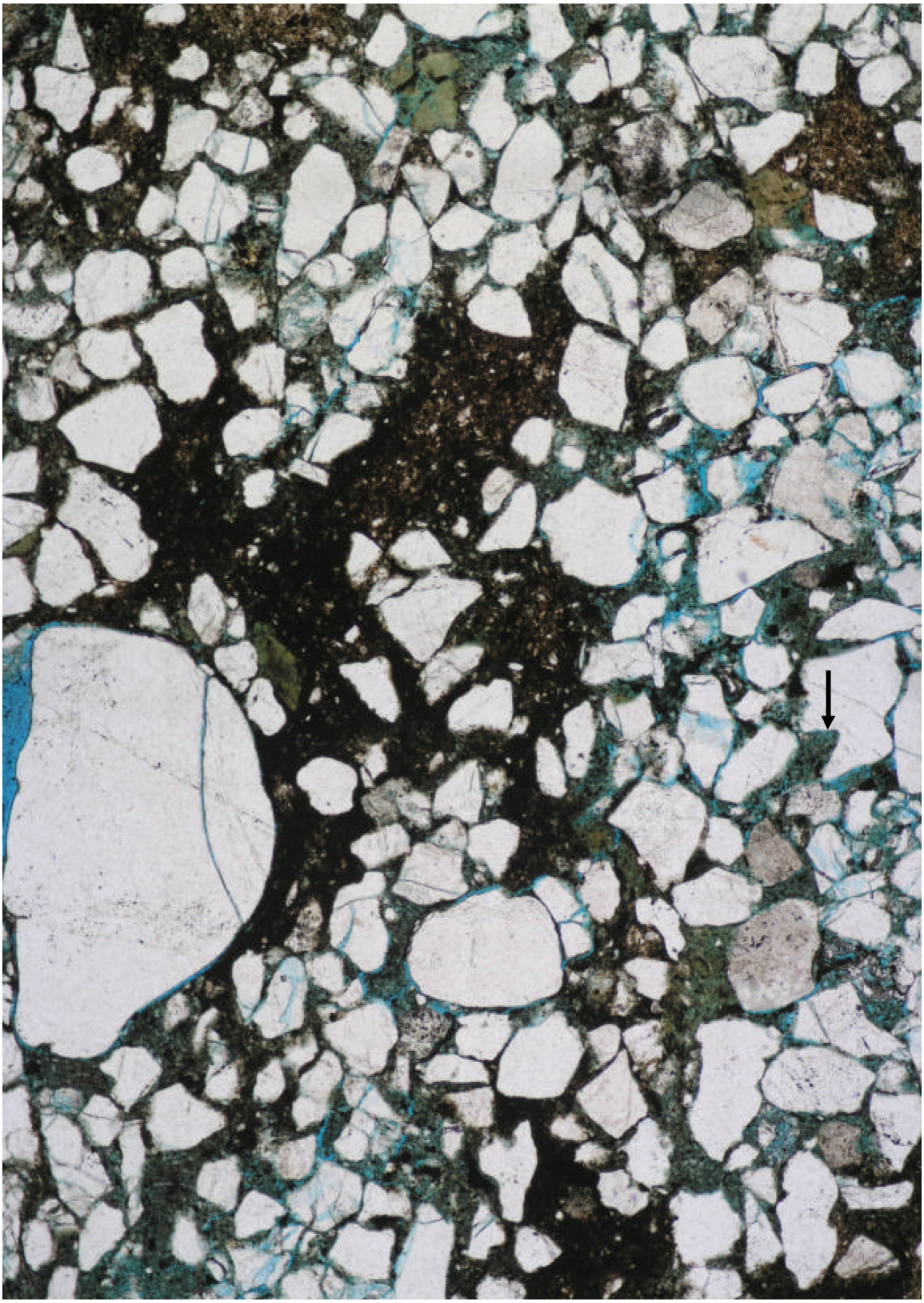


Figure 15

General field of view showing the poor sorting and irregular patchy distribution of anhedral dark brown clay matrix. Note the angular and embayed nature of selected quartz grains (arrow) which contrasts with the more rounded shape of coarser grains. Hill-1, Swc 16, Depth 2196m. Plane light. Horizontal field of view 3.25mm.

4.16 Hill-1, Swc 11, Depth 2281m

Rock classification: **Subarkose**

Texture:

Sedimentary structures:	no textural preservation, extensive grain fracturing, lenses of dark brown clay approximately 6mm in length could be either detrital or drilling mud forced into the sidewall core
Average grain size:	medium sand (0.26mm)
Range in grain size:	clay to coarse sand
Roundness / sphericity:	subangular with low sphericity
Sorting:	poor (1.96 ϕ)
Texture:	grain supported
Packing / grain contacts:	?moderately open / point & tangential grain contacts
Pore types:	honeycomb pores where feldspars have been corroded, possible intergranular pores

Composition:

Framework grains:	monocrystalline quartz, polycrystalline quartz with either straight or sutured crystal boundaries, fresh & corroded K-feldspars with tartan, pericline & carlsbad twinning, sericitised feldspars lack twinning, fresh plagioclase with albite twinning, lithics include volcanics, granite (quartz plus feldspar, granophyric texture), siltstone, quartzite & chert, fractured & splayed muscovite flakes, accessory very fine to fine sand size zircon, tourmaline & rutile, rare zircons with hydrocarbon envelopes
Matrix:	anhedral brown clay, & silt size framework grains concentrate in the muddy lenses, rare blocky opaque material that is possibly organic matter
Authigenic minerals:	grain replacing & pore filling clear euhedral rhombs of carbonate spar, highly deformed patches of fibrous to wormy green clay that could be glaucony (?chlorite), clusters of framboidal pyrite 5 to 20 microns diameter & micritic Fe rich carbonate throughout the detrital clay, rare rounded quartz overgrowths prior to glaucony & detrital clay could be inherited, radial colourless ?barite

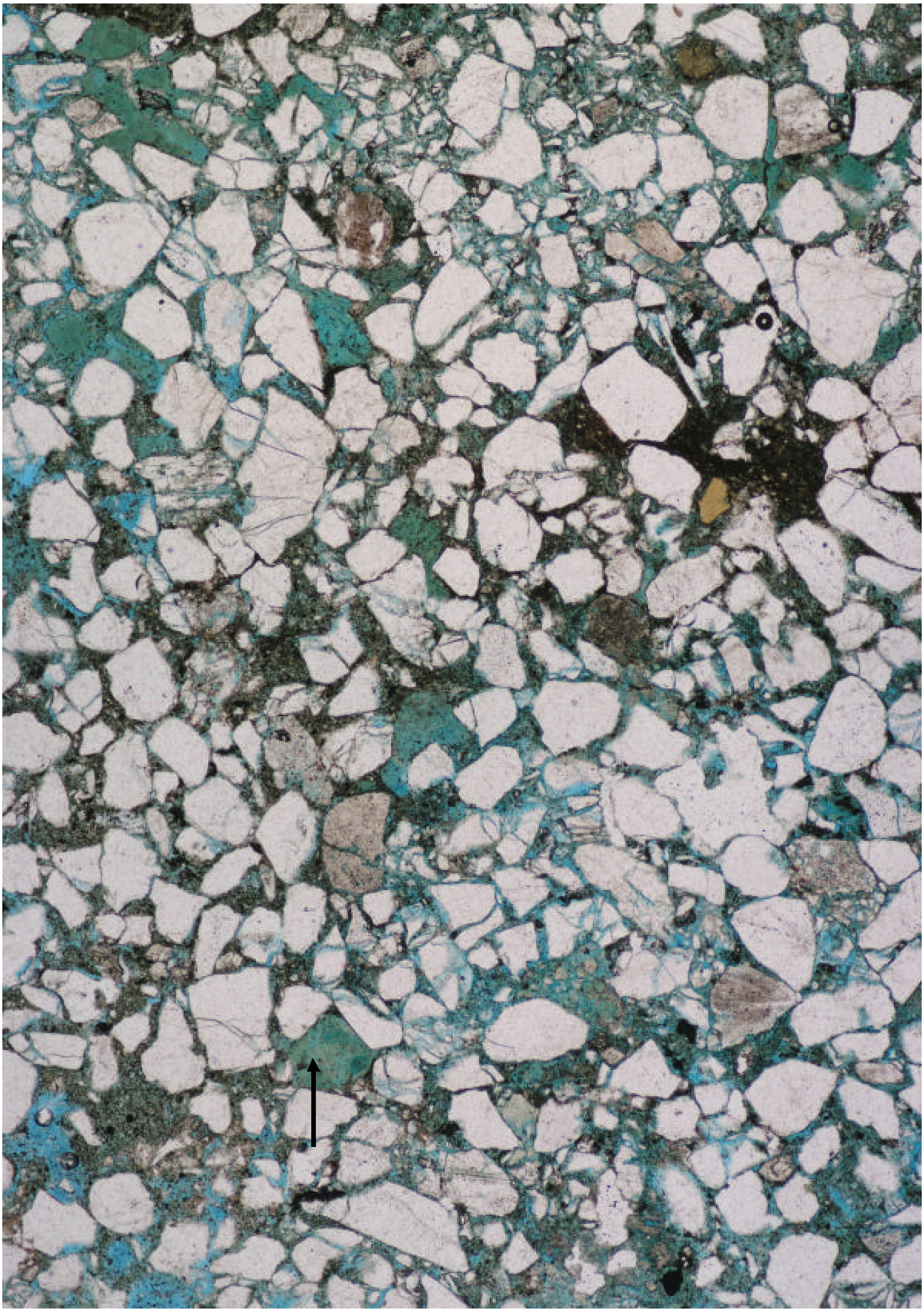


Figure 16

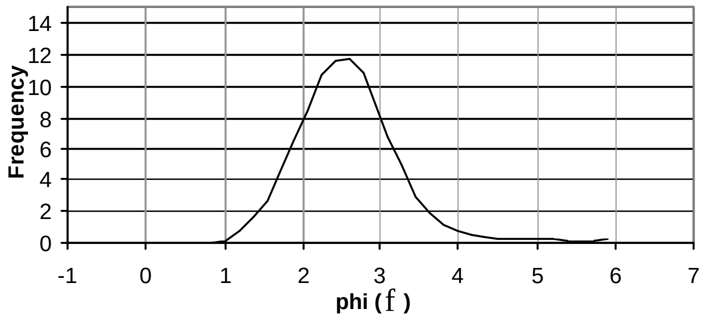
General field of view illustrating the textural disruption during sampling. Note the dark brown clay rich laminae & green grains of glaucony (arrow). Hill-1, Swc 11, Depth 2281m. Plane light. Horizontal field of view 3.25mm.

5. GRAIN SIZE ANALYSIS

Thin Section Statistics | **Frequency Distribution**

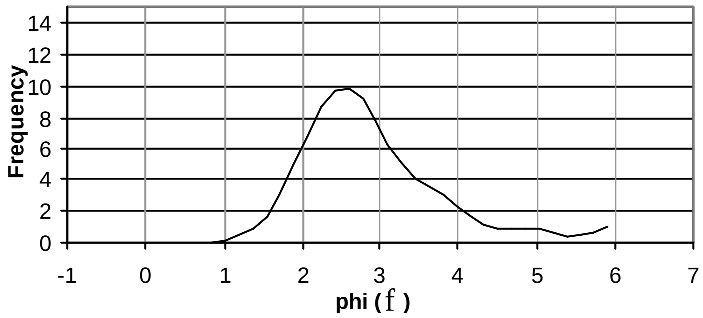
Sample: **35**
Depth (m) **1992.00**

Parameter		mm	φ
Mean		0.18 fine sand	2.65
Mode		0.17 fine sand	2.52
Range:	min	0.002	8.97
	max	0.37	1.43
Standard Deviation		0.07 moderately sorted	0.87



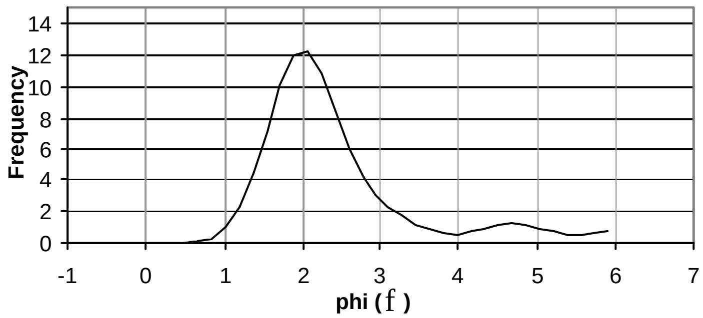
Sample: **34**
Depth (m) **1995.00**

Parameter		mm	φ
Mean		0.15 fine sand	3.15
Mode		0.18 fine sand	2.51
Range:	min	0.002	8.97
	max	0.41	1.29
Standard Deviation		0.08 poorly sorted	1.53



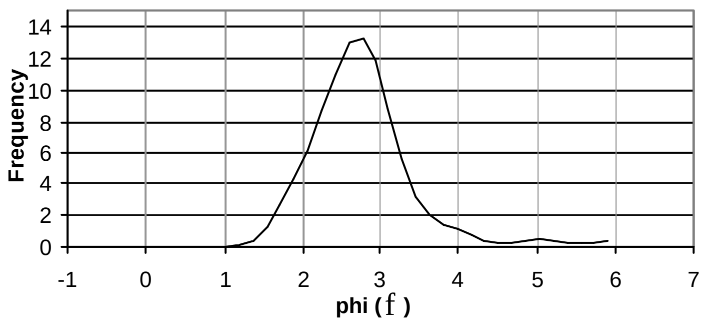
Sample: **33**
Depth (m) **1999.00**

Parameter		mm	φ
Mean		0.21 fine sand	2.57
Mode		0.25 medium sand	2.00
Range:	min	0.002	8.97
	max	0.45	1.15
Standard Deviation		0.10 poorly sorted	1.43



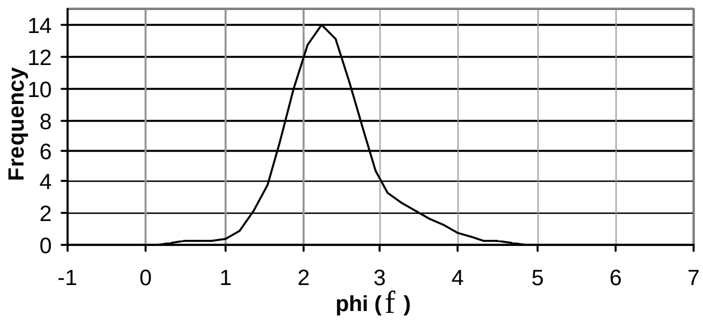
Sample: **31**
Depth (m) **2007.50**

Parameter		mm	φ
Mean		0.16 fine sand	2.87
Mode		0.15 fine sand	2.69
Range:	min	0.002	8.97
	max	0.30	1.74
Standard Deviation		0.06 poorly sorted	1.04

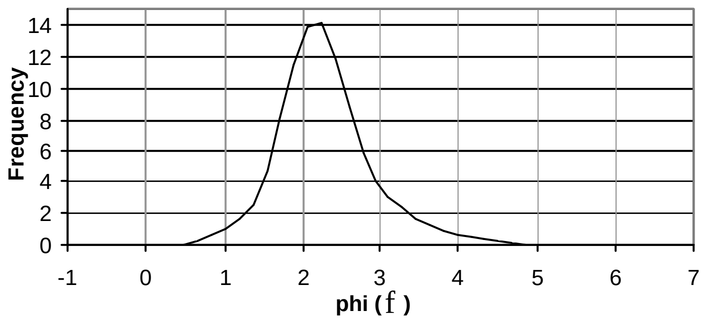


Thin Section Statistics		
Sample:	**29**	
Depth (m)	**2016.00**	
Parameter	mm	ϕ
Mean	0.21 fine sand	2.38
Mode	0.21 fine sand	2.26
Range: min	0.05	4.32
max	0.63	0.67
Standard Deviation	0.08 moderately well sorted	0.55

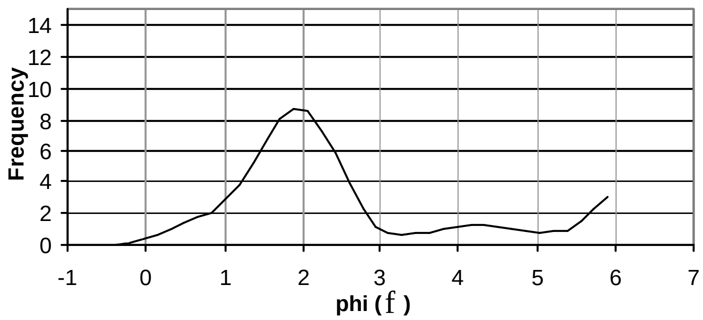
Frequency Distribution



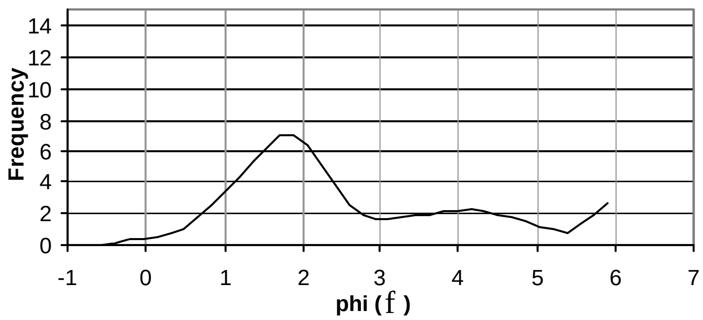
Sample:	**26**	
Depth (m)	**2023.00**	
Parameter	mm	ϕ
Mean	0.22 fine sand	2.30
Mode	0.22 fine sand	2.16
Range: min	0.05	4.32
max	0.48	1.06
Standard Deviation	0.08 moderately well sorted	0.56



Sample:	**22**	
Depth (m)	**2075.00**	
Parameter	mm	ϕ
Mean	0.24 fine sand	3.06
Mode	0.26 medium sand	1.96
Range: min	0.002	8.97
max	0.88	0.18
Standard Deviation	0.18 very poorly sorted	2.44

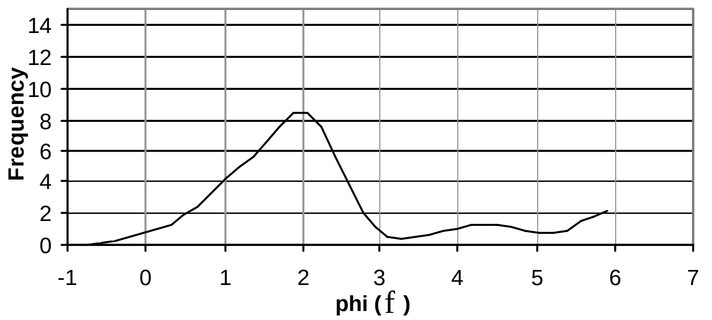


Sample:	**21**	
Depth (m)	**2078.50**	
Parameter	mm	ϕ
Mean	0.23 fine sand	3.19
Mode	0.29 medium sand	1.80
Range: min	0.002	8.97
max	0.97	0.04
Standard Deviation	0.19 very poorly sorted	2.40

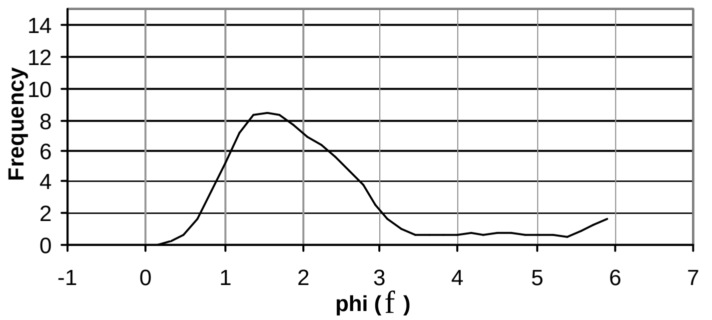


Thin Section Statistics			
Sample:		**16**	
Depth (m)		**2196.00**	
Parameter		mm	ϕ
Mean		0.28	2.66
		medium sand	
Mode		0.26	1.97
		medium sand	
Range:	min	0.002	8.97
	max	1.02	-0.03
Standard Deviation		0.21	2.16
		very poorly sorted	

Frequency Distribution



Thin Section Statistics			
Sample:		**11**	
Depth (m)		**2281.00**	
Parameter		mm	ϕ
Mean		0.26	2.55
		medium sand	
Mode		0.35	1.49
		medium sand	
Range:	min	0.002	8.97
	max	0.58	0.79
Standard Deviation		0.15	1.96
		poorly sorted	



6. X-RAY DIFFRACTION

All the XRD results are summarised in the tables below and the traces from which this data was obtained are presented in Figures 17 to 20. Quartz is the most abundant mineral in all bulk XRD traces. Feldspars of microcline and albite are also present in all samples but the highest proportions are noted in Swc 34 from the top Paaratte. Carbonate minerals of calcite and siderite were identified. Siderite typically has broad peaks suggesting it is poorly crystalline. Calcite concentrates in Swc 22 and !6 from the 20-7 and 21-9 sands. Pyrite was not detected in Swc 34 (top Paaratte) and appears to be most abundant in Swc 22 (20-7 sand).

Interstratified chlorite-smectite, illite and kaolinite in Swcs 22 and 16 dominate the clay fraction. Swcs 34 and 11 contain less chlorite-smectite and illite. Kaolinite is most abundant in Swc 11 (22-7 sand). The bulk trace of Swc 34 indicates the presence of dickite in addition to the kaolinite. Comparison of the XRD traces with calculated diffractometer patterns in Brindley & Brown (1980) suggest there is approximately 60-70% chlorite in the chlorite-smectite. Peak heights for the strongest kaolinite line used in the tables below would be enhanced by the overlap with a secondary chlorite peak.

TABLE 3. BULK XRD MINERALOGY HILL-1

Swc No	Depth (m)	I/M	Kaol	Qtz	Micr	Alb	Cal	Sid	Pyr
				Strongest peak height in counts					
34	1995	150	205*	6865	514	273	-	38	-
22	2075	-	132	5918	123	133	84	-	75
16	2196	-	128	4613	81	108	96	71	44
11	2281	103	107	5556	182	192	57	52	35

I/M=illite/muscovite, Kaol=kaolinite, Qtz=quartz, Micr=microcline, Alb=albite, Cal=calcite, Sid=siderite, Pyr=pyrite
* kaolinite value also includes dickite

TABLE 4. CLAY XRD MINERALOGY HILL-1

Swc No	Depth (m)	Smec	Chlor	Illite	Kaol	Qtz	Micr	Alb	Cal	Sid	Pyr
				Strongest peak height in counts							
34	1995	514	358	357	1693	2347	270	265	-	-	-
22	2075	1156	591	565	2055	2169	-	-	-	-	115
16	2196	1085	691	679	1942	2227	-	-	215	213	-
11	2281	558	480	549	2170	2001	-	-	-	200	-

Smec=smectite (montmorillonite), Chlor=chlorite, Kaol=kaolinite, Qtz=quartz, Micr=microcline, Alb=albite, Cal=calcite, Sid=siderite, Pyr=pyrite

To facilitate between-sample comparisons of relative abundance for the same mineral, the results in each table are given in counts of peak height. These figures are based on the strongest line for each mineral detected. Caution should be used in assessing relative abundance from these figures since peak height is also significantly affected by factors such as crystal size and crystallinity. For these reasons the figures are even more unreliable when comparing different minerals in the same sample. For example, based on peak height alone carbonate minerals will always appear less abundant than similar proportions of quartz because of differences in crystallinity. Clay minerals will also appear to be less abundant than quartz in a bulk XRD trace because of differences in crystal size. Furthermore, comparison should not be made between peak heights given for bulk samples and those for the clay fractions because results have been influenced by the sampling and preparation methods. XRD will not detect minerals that represent less than approximately 5% of the total rock composition.

Only the strongest peaks for each mineral identified have been labeled on the XRD traces. The vertical axis is in counts of peak height and the horizontal axis is degrees two theta. Both the Mg saturated and the glycerol saturated clay traces have been included to demonstrate peak movement. The following abbreviations have been used on the XRD traces:

A = albite
Ch = chlorite
C = calcite
D = dickite
I = illite
I/M = illite or muscovite in bulk traces
K = kaolinite
M = microcline
P = pyrite
Q = quartz
Sm = smectite
S = siderite

Hill-1, Sidewall core 34, depth 1995m

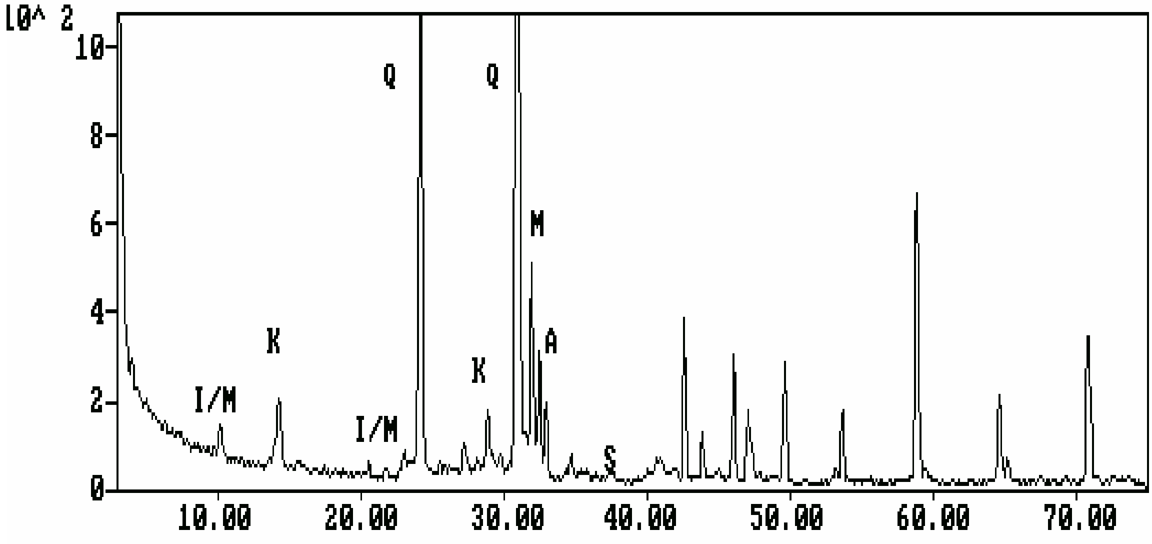


Figure 17a. Bulk XRD trace

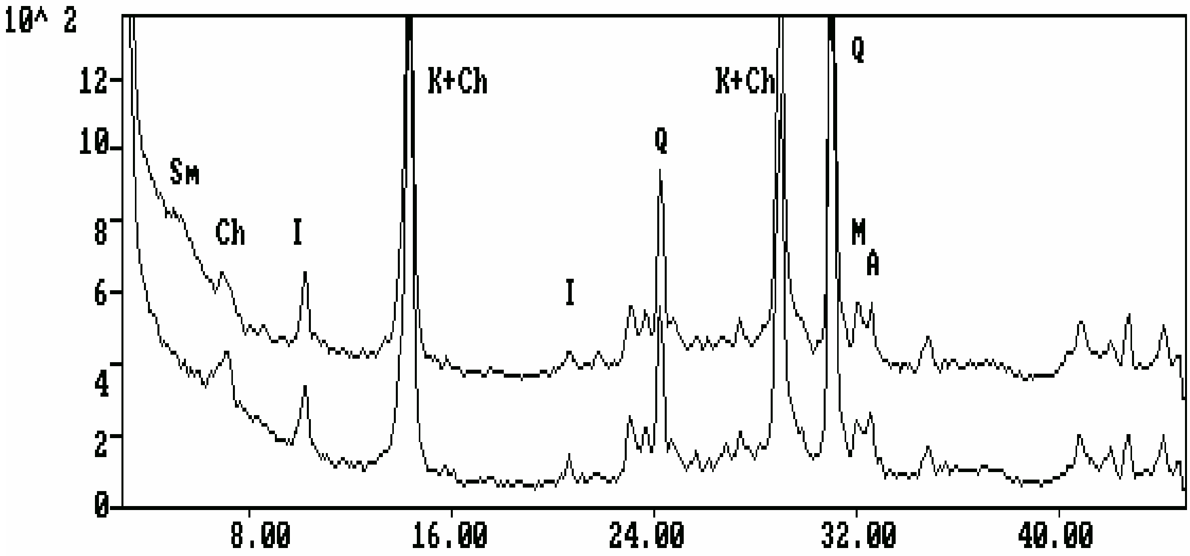


Figure 17b. Clay XRD traces. Lower trace Mg saturated and upper trace glycerol saturated.

Hill-1, Sidewall core 22, depth 2075m

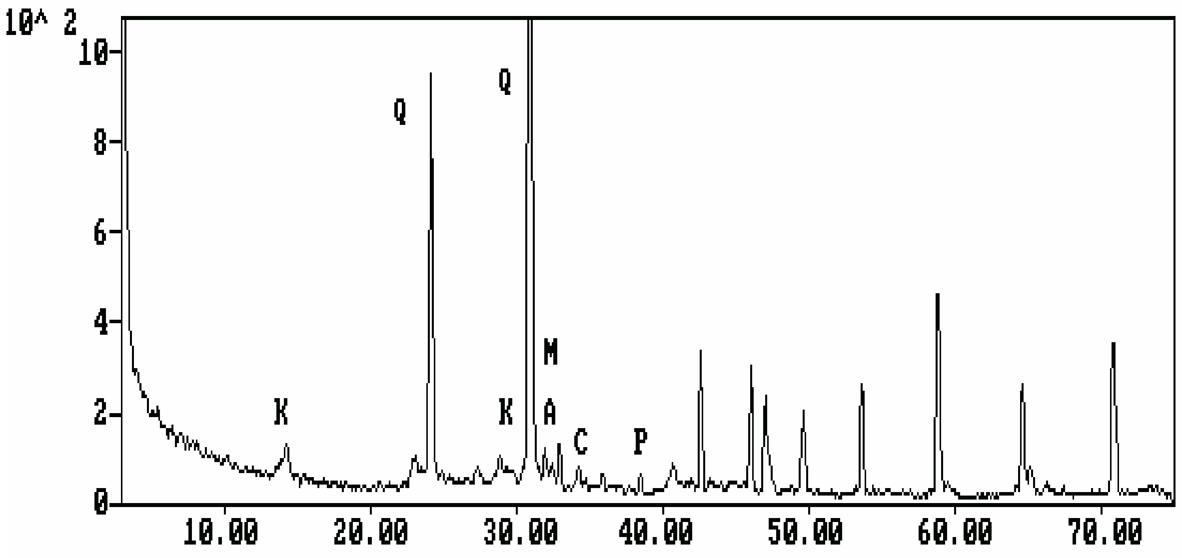


Figure 18a. Bulk XRD trace

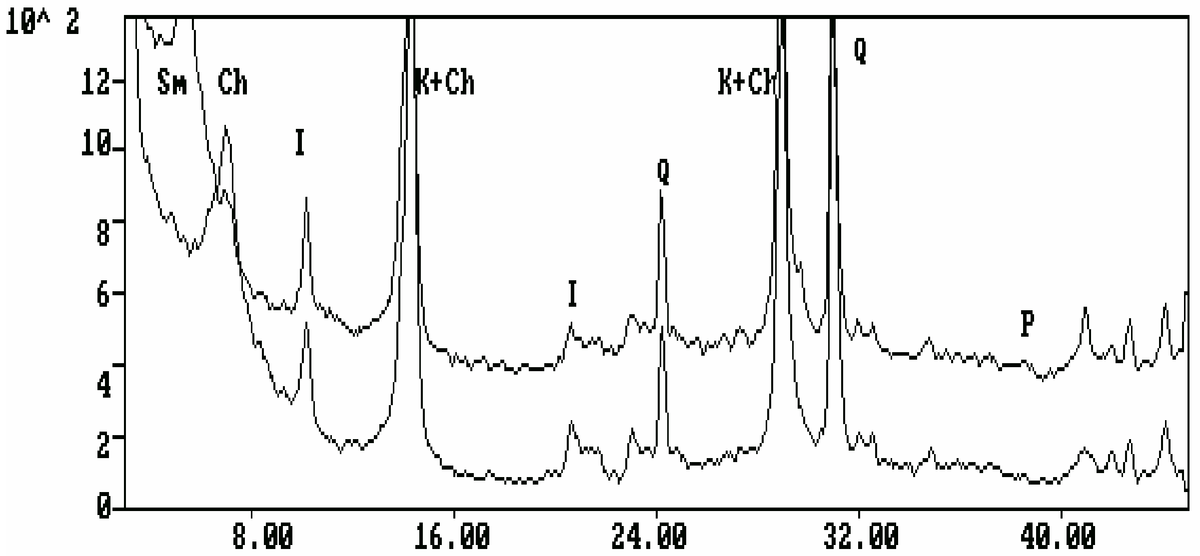


Figure 18b. Clay XRD traces. Lower trace Mg saturated and upper trace glycerol saturated.

Hill-1, Sidewall core 16, depth 2196m

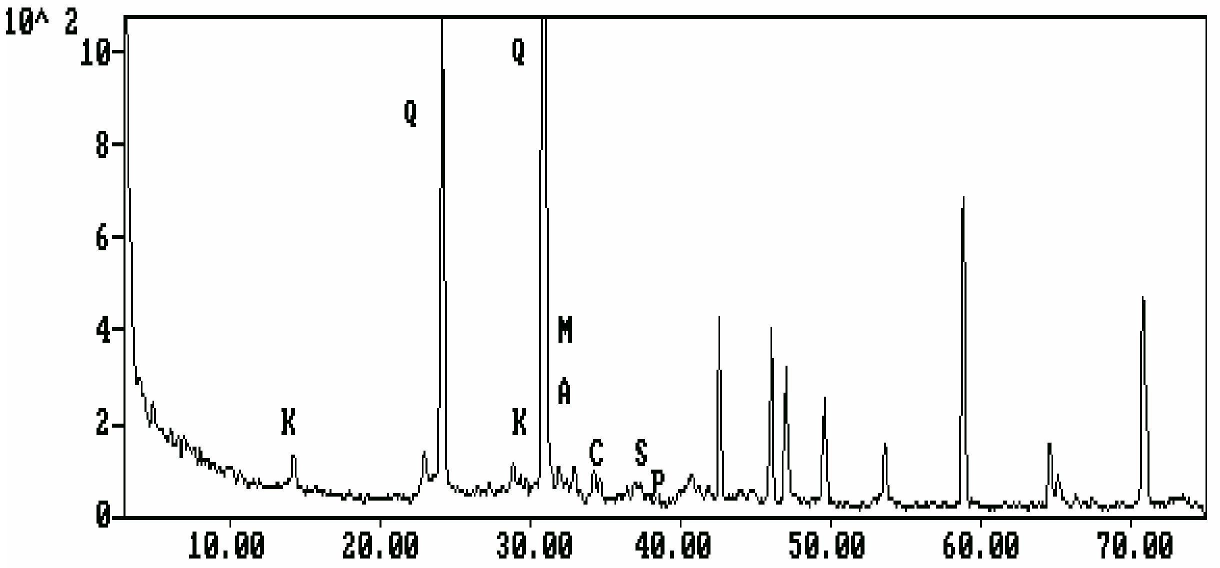


Figure 19a. Bulk XRD trace

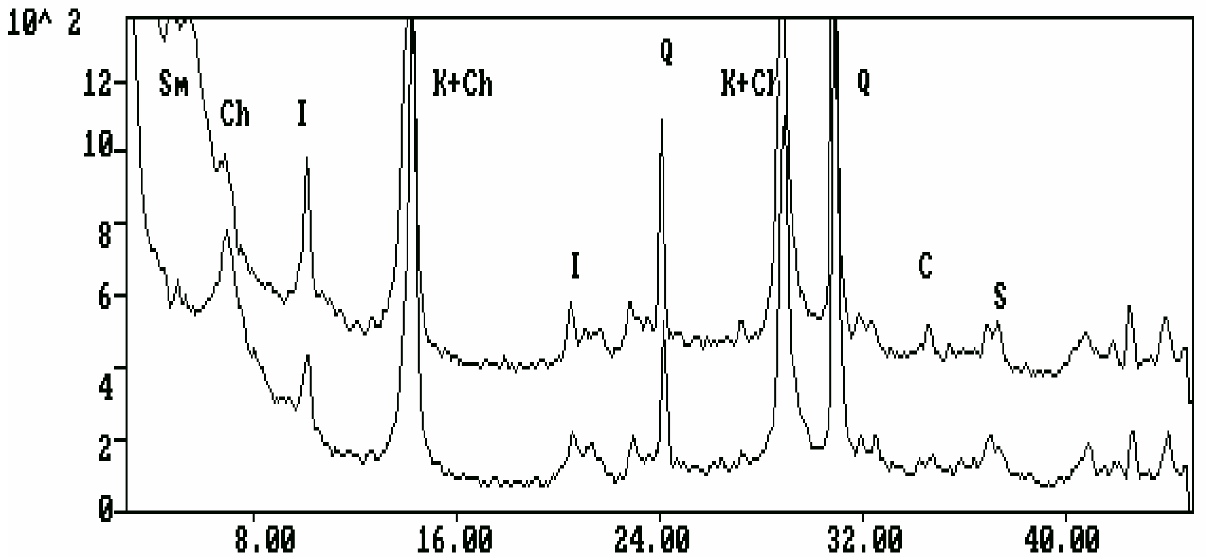


Figure 19b. Clay XRD traces. Lower trace Mg saturated and upper trace glycerol saturated.

Hill-1, Sidewall core 11, depth 2281m

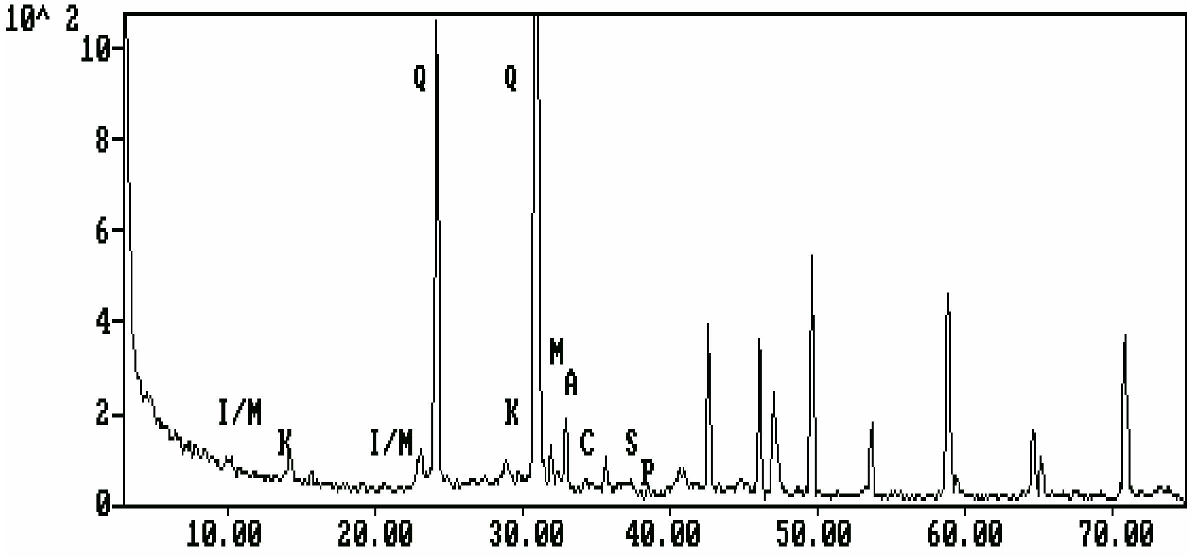


Figure 20a. Bulk XRD trace

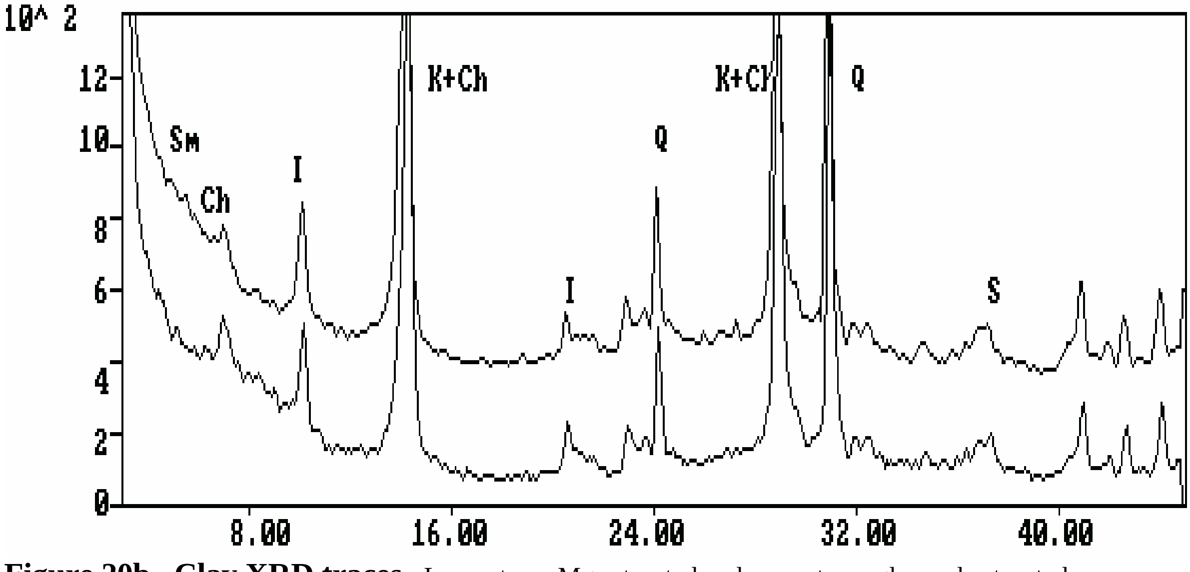


Figure 20b. Clay XRD traces. Lower trace Mg saturated and upper trace glycerol saturated.

7. DISCUSSION

Sidewall cores and cuttings samples from Hill-1 that have been described in this petrology report have extensive crushing and fracturing of framework grains and possible invasion by drilling mud. This lack of textural integrity means that all descriptions and visual estimates of composition must be considered with caution, especially estimates of porosity. These limitations should be born in mind when reading the following discussion.

7.1 Lithology

a. Sands 22-7, 21-9 and 20-7 lower Paaratte Formation

The basal 22-7 sand sample(Swc 11, 2281m) is a medium grained, poorly sorted subarkose that may contain clay lenses. Grain size distribution is positively skewed with a mode of 0.35mm that is higher than the mean grain size of 0.26mm. Typically grains are subangular with low sphericity.

The 21-9 sand (Swc 16, depth 2196m) is a medium grained, very poorly sorted greywacke. This lithology is similar to the overlying 20-7 sand (Swc 21, 2078.5m & Swc 22, 2075m) of fine grained, very poorly sorted greywacke. All the greywackes have possible evidence of bedding/laminae. Bioturbation may also be apparent in the 20-7 sand. Detrital grains are subangular to subrounded in the greywackes and grain size distributions are almost bimodal due to the abundance of both sand size grains and clay.

b. Top Paaratte Formation

The deepest sample from the top Paaratte Formation (Swc 26, 2023m) is a fine grained, moderately well sorted sublitharenite which contains a large silty mudstone ?lithic. If this muddy material is a lens of clay related to a ripple rather than a ?lithic, the sandstone would be classified as a subarkose. Grains are subangular to subrounded and have a symmetrical grain size distribution.

Cuttings from the cemented zone (depth 2020m) indicate the presence of a very fine grained, moderately well sorted wackestone. It is difficult to estimate grain shape in the wackestone due to partial replacement by carbonate. Packing in the wackestone may have been open at the time of cementation and there is evidence of bedding outlined by concentrations of organic matter, pyrite and sand.

Typically sidewall cores from the top Paaratte Formation (Swcs 29, 31, 33, 34 & 35; depths 2016, 2007.5, 1999, 1995 & 1992m) are lithologically very similar. They consist of fine grained, poor to moderately well sorted, subarkoses (Fig. 21). Clay rich laminae are common in these subarkoses and there is possible evidence of bioturbation in Swc 34 (depth 1995m). Detrital grains are subangular to subrounded with low sphericity and grain size distributions are symmetrical to very slightly positively skewed.

c. Basal Timboon Sandstone

Cuttings from the basal Timboon Sandstone (1974m) are probably more representative of the overlying Timboon Mudstone. The chips in these cuttings are dominantly (97%) composed of silty to sandy, poorly sorted mudstone with bedding outlined by the alignment of coarse sand size grains of glauconite. Cuttings from 1995m in the top Paaratte Formation contain a fine grained, moderately well sorted grainstone which could represent a downhole contaminant from within the overlying basal Timboon Sandstone.

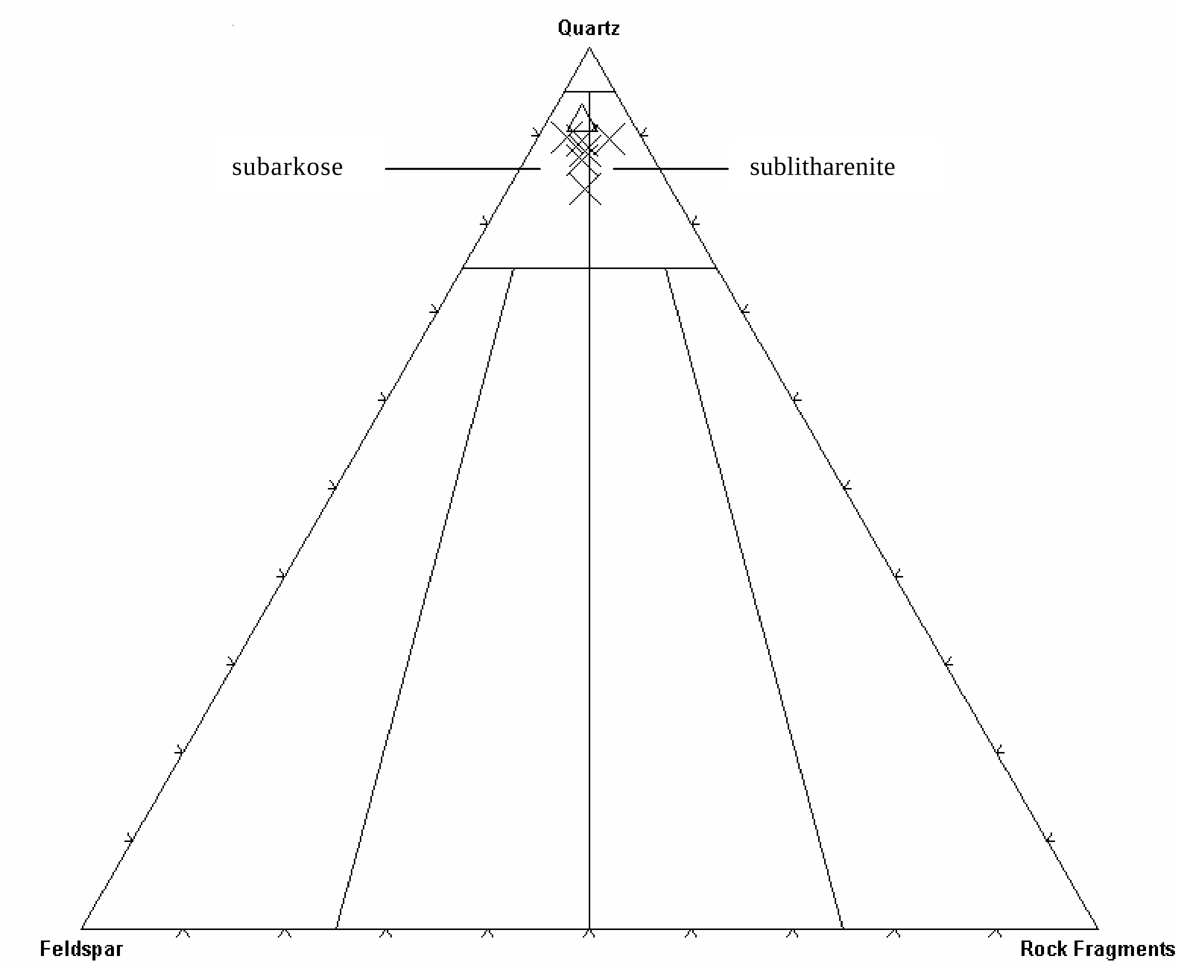


Figure 21. Folk Sandstone classification of sidewall cores from the Paaratte Formation in Hill-1. Cuttings samples and those samples with greywacke and carbonate lithologies have been omitted from the diagram.

Δ = 22-7 sand X = top Paaratte

7.2 Detrital mineralogy & sediment provenance

Sediment in the Paaratte Formation at Hill-1 has been derived from an igneous/metamorphic terrane with the igneous source being slightly more important. This observation is supported by the relative abundance of polycrystalline quartz with straight crystal boundaries, fresh feldspars and igneous lithics. Morton *et al* (1995) previously suggested a dominantly metamorphic provenance for the Paaratte Formation because of the abundance of composite (polycrystalline) quartz. It is possible that there was a phase of renewed erosion, possibly caused by uplift, between deposition of the lower and top Paaratte Formation. Feldspars and micas would have been more abundant (5-9%) in the top Paaratte at the time deposition than is now apparent. These grains were subsequently altered to kaolin during diagenesis.

Detrital grains in all the sandstones from Hill-1 are dominated by monocrystalline quartz (48-66%). Polycrystalline quartz (1-5%) has dominantly straight and rarely sutured crystal boundaries. The former is considered indicative of an igneous source and the latter a metamorphic source. Feldspars (~2-5%) in various states of alteration are up to coarse sand in size and comprised of microcline, orthoclase and albite. Fresh plagioclase (albite) in many samples may reflect short distances of transport since this mineral is chemically less stable than the K-feldspars and thus is not as commonly preserved in sandstones. Plagioclase is most abundant (3%) in the shallowest samples (Swcs 33, 34 & 35; 1999, 1995 & 1992m) from the top Paaratte

Formation. This observation supports the concept of a difference in the detrital mineralogy between the lower and top Paaratte. Lithics of sedimentary origin (trace - 3%, average 0.8%) include chert, chalcedony and mudstone throughout the sequence. The mudstone may represent intraclasts reworked within the depositional environment. Chert and chalcedony are both chemically very mature and could have been reworked from underlying sedimentary sequences. Igneous lithics (trace -2%, average 1.2%) include both plutonic (?granite) and volcanic varieties. Metamorphic lithics (trace - 3%, average 1%) are typically composed of quartzite with minor micaceous schist. In cuttings from the 20-7 sand at 2079m there are chips of sublitharenite that have up to 7% metamorphic lithics. Depending on the depth interval that these chips represent there may have been a localised influx of material reworked from the metamorphic terrane at this time. Flakes of muscovite and biotite (trace - 5%) are most abundant in sidewall cores from the top Paaratte Formation which have muddy laminae. Both micas can be derived from igneous and metamorphic rocks. However, biotite is chemically less stable and its relative abundance (up to 3% in Swc 31, 2007.5m) may reflect close proximity to the source. The accessory mineral assemblage (trace - 2%) of zircon, tourmaline, rutile, opaques and rare hornblende also reflects the mixed igneous/metamorphic sediment provenance.

Anhedral brown detrital clay matrix in thin section can not be differentiated into clay mineral types. X-ray diffraction on selected sidewall cores identified the presence of interstratified chlorite-smectite (60-70% chlorite), discrete illite and kaolinite in varying proportions. Chlorite-smectite and illite are most abundant in the greywackes of the 21-9 sand (Swc 16, 2196m) and the 20-7 sand (Swc 22, 2075m). It is not known what percentage of this illite has been diagenetically altered from the chlorite-smectite. Kaolinite and illite are more abundant in the 22-7 sand and the top Paaratte. Detrital clays are the result of the interaction of source area geology, climate and weathering processes. Smectite and chlorite can form as alteration products of volcanics, whilst illite and kaolinite result from the alteration of feldspars. Therefore the detrital clay mineralogy may also reflect the dominance of an igneous sediment provenance with a minor change from volcanic to plutonic between the lower and top Paaratte Formation.

Based on the detrital mineralogy there is no single explanation for the elevated gamma response in the top Paaratte Formation. It would appear that this response is the combined result of accessory minerals (eg Swc 34 has 2%) including zircon that can be radioactive, muddy laminae in the subarkoses and varying percentages of both feldspars and micas that could have high K values.

7.3 Depositional environments

Previous workers identified a lower delta plain (Morton *et el*, 1995) as the depositional setting for the Paaratte Formation. This was thought to include distributary channel, lagoon, beach barrier, shoreface and estuarine environments. More recently Partridge (2001) identified the Paaratte Formation as paralic, and Boyd & Gallagher (2001) recognised evidence for progradation from lower to upper deltaic and nearshore facies. There appears to be a consensus re interpretation of the Timboon Sandstone as marginal marine and upper deltaic (Morton *et al*, 1995; Boyd & Gallagher, 2001).

a. <u>Sands 22-7, 21-9 and 20-7 lower Paaratte Formation</u>

Evidence from Hill-1 re depositional environments is scant because of the textural disruption during sampling. Rapid rates of deposition are suggested by the very poor sorting of sediments and the presence of clay rich laminae and lenses indicate intervening quieter periods. The grain size distribution of the 22-7 sand (Swc 11, 2281m) is positively skewed a characteristic common in river sands rather than those of a beach (Tucker, 2001).

Greywackes of the 21-9 (Swc 16, 2196) and 20-7 (Swc 21, 2078.5m) sands contain various remnants of fossils that have been tentatively identified as calcareous foraminifera, possible echinoid plates and a calcareous ovoid test (?foram). There may also be a calcareous spine if the cuttings described from 2079m are representative of the 20-7 sand. Boyd & Gallagher (2001) also noted fossils (molluscs, agglutinated foraminifera and rare calcareous forams) at the base of the Paaratte Formation and within the Belfast Mudstone. The 21-9 sand at Hill-1 appears to include stacked fining upwards sequences on the gamma ray log. Given the marine depositional environment indicated by the fossils and rapid rates of deposition, this sequence might have been deposited by either turbidity currents or storm events since both produce fining upwards sequences. Possible evidence of bioturbation in Swc 21 (2078.5m) and Swc 22 (2075m) would also be consistent with reworking of the turbidites or tempestites during fairweather or return to accumulation of hemipelagic mud. Thick sequences of mud between the 21-9 and 20-7 sands could have been deposited on the continental shelf. The fact that sand is up to very coarse sand in size in the greywackes at Hill-1 could favour an interpretation of storm deposits because low density turbidity currents which produce fining upwards sequences normally only transport sediment up to medium sand in size. Individual beds in a storm deposit range from 0.5 to 3m thick (Johnson & Baldwin, 1996) and the upper limit would appear to be consistent with patterns in the gamma ray log of the 21-9 sand.

b. Top Paaratte Formation

The basal fine grained, moderately well sorted sublitharenite (Swc 26, 2023m) occurs near the top of a coarsening upward package. Grain size distribution for this sample is symmetrical and this may reflect a moderate hydraulic regime where finer sediment was winnowed. Segments of silty mudstone within the sublitharenite could represent either lithic intraclasts, or perhaps the filling of ripple troughs. Both scenarios would suggest fluctuations in flow strength. Within one segment of mudstone there is a patch of phosphate. The isolated nature of this phosphate may suggest it is a vertebrate skeletal fragment rather than marine phosphorite formed on the outer edge of the continental shelf. Given the possibility that the underlying sequence is comprised of storm deposits on the shelf then this fine grained coarsening upward sand may represent the transition zone or lower shoreface of a prograding sequence.

Cuttings from 2020m include a wackestone which is tightly cemented and could produce the high resistivity spike noted on the logs at this depth. Tidal flats and lagoons are common sites where micritic carbonates accumulate. Lack of forams may preclude a deep water origin for the micrite. High percentages of organic matter (8%) in the wackestone, including cutinite derived from plant leaves or stems, is consistent with juxtaposition to a near-shore environment that experienced periods of aridity. Pyrite replacing the wackestone may also confirm this marginal marine setting because its precipitation is favoured by sea water containing dissolved sulphate.

Sidewall cores above the wackestone are lithologically very similar being comprised of fine grained subarkoses. Sorting varies from moderately well to poor but most of the grain size distributions are positively skewed and this might reflect a fluvial influence. Although the gamma ray log signature may be slightly elevated due to variable amounts of accessory minerals, detrital clays, micas and feldspars, the pattern would appear to be a combination/alternation of fining and coarsening upwards sequences. These patterns are approximately 4 to 6m in thickness and could reflect mouthbar/crevasse splay and fluvial channel deposits in a deltaic sequence.

At Mount Salt-1 the Paaratte Formation as described by Boyd & Gallagher (2001) has a thick siderite cement at the base overlain by medium to coarse grained sands with laminations, burrows in the finer sands and minor siderite cement. They interpreted the depositional environment as lower delta plain. Grain size in the sequence at Hill-1 is significantly finer, but the other features are similar. Finer grain size might suggest either a more distal setting near the delta front and/or greater distance from the main distributaries. These fine grained sediments might include crevasse splays, mouth bars and interdistributary point bars. Crevasse splays typically coarsen upwards and vary in thickness prior to compaction from 2 to 10m (Reading & Collinson, 1996). Mouth bars also coarsen upwards due to reworking during storms and can be characterised by laminated very fine sand to clay with occasional bioturbation and soft sediment deformation or siderite nodules (Payenberg & Lang, 2003). Muddy laminae with associated organic matter and rare examples of possible bioturbation (Swc 34, depth 1995m) are also evident in the fine grained subarkoses of Hill-1. Oxidised grains recognised in Swc 34 may be the result of exposure during bioturbation or reworking. Fining upwards sequences could represent the point bars of interdistributary channels near the delta front.

Identification of trace amounts of glauconite in Swc 34 (1995m) and phosphate in Swc 35 (1992m) are indicative of a marine depositional setting at the top of the Paaratte Formation. Sands coarsen upwards between these two samples and the frequency of muddy laminae and bioturbation decreases. It is possible that these sediments accumulated as a mouth bar at a delta front that was prograding into more marine and possibly deeper waters.

7.4 Diagenetic alteration

One of the major reasons for extensive disruption to sidewall cores from the Paaratte Formation was the relative lack of diagenetic cement. Most of the alteration that is apparent is relatively early diagenetic. It is difficult to assess the degree of compaction in these sandstones because of the textural disruption during sampling. The diagenetic sequence was probably very similar for sands of both the lower and top Paaratte Formation. However, there is significantly more kaolin in the top Paaratte Formation.

Early diagenetic minerals of micritic siderite and framboidal pyrite occur in association with detrital muddy sediments and organic matter throughout the sequence. Detrital clays and organic matter may have been the source of Fe^{2+} for both these minerals. When the pore waters were saline then bacteria would have reduced the dissolved sulphate to enable the precipitation of pyrite. Micritic siderite would have formed after a lowering of sulphide activity and an increase in carbonate activity. This might occur due to flushing of sediments by meteoric waters in the depositional environments. Meteoric waters can be transported long distances offshore during storms and would have flushed mouthbars during these times.

Grains of glaucony identified in four sidewall cores (Swcs 11, 16, 29 & 34) include both fresh green grains with a wormy texture and more commonly a fibrous habit. The latter was interpreted as evidence of chlorite rather than glauconite but this could be misleading. Highly-evolved glaucony (8% K_2O) can also have lamella up to 5-10 microns long arranged in sub-parallel alignment (Weaver, 1989) which would produce a fibrous habit. Glauconite forms when sedimentation rates were low, pH is neutral (7-8) and Eh slightly reducing. Typically it is thought to form on the continental shelf and this would be consistent with the concentration of glaucony grains (3-5%) in the 22-7 and 21-9 sands. Glauconite forms by the replacement of other minerals including micas thus it is very difficult to differentiate from chlorite replacing biotite. Chlorite forms when pore fluids are alkaline and have minimal K^+ activity but sufficient Mg^{2+}.

All samples have evidence of minor dissolution (trace - 3%) of labile grains including the corrosion of feldspars to produce honeycomb pores and partial dissolution of lithics to form intragranular pores. Some of this alteration of feldspars and lithics could have occurred during transport to the depositional environment but at least the grain size pores must postdate compaction. Meteoric waters flushing sediments soon after burial may have caused this dissolution. Similar conditions favour the alteration of feldspars to kaolin and the excess silica from this reaction can form associated quartz overgrowths.

Prismatic and rare rhombohedral quartz overgrowths are poorly developed (trace to 3%), especially where detrital clays are abundant. Detrital clay inhibits the number of sites available for silicification. Silica is also thought to be a by-product of the transformation of smectite to illite which occurs during deep burial. Alternatively silica may be mobilised during mechanical compaction and chemical dissolution at grain-mica contacts. It would appear that the source of silica in the Paaratte Formation was internal and very limited.

There are large patches up to 1mm diameter where kaolin has extensively replaced grains within lithics in Swc 29 (2016m). These were not mudstone lithics but probably much coarser grained intrusive igneous rocks with a high percentage of feldspars and/or micas. Kaolin commonly forms when meteoric waters with a pH of 4-7 and low K^+ activity flush a sandstone. This might occur during early burial for continental sediments, or after uplift of marine sediments. Since the highest percentages of kaolin (5-9%) occur within the possible delta front deposits (mouth bars/crevasse splays and point bars) of the top Paaratte Formation it is assumed that flushing occurred soon after burial. Micas and feldspars have been replaced by vermiform and pseudohexagonal booklets of kaolin up to 50 microns in diameter. This would suggest that sediments of the top Paaratte Formation were more feldspathic/micaceous at the time of deposition than is now apparent. Relative lack of kaolin in sands from the lower Paaratte may reflect both more marine depositional environment of these sediments where there was very minimal influence from meteoric waters and/or the lack of feldspars and micas in the original sediment.

Clear calcite spar postdates the kaolin, it has replaced isolated grains and rarely forms a localised intergranular cement (0 - 3%). All samples from the lower Paaratte Formation contain calcite and this might reflect the possible source of Ca which could be the dissolution of calcareous fossils noted in the 21-9 and 20-7 sands. Reprecipitation may have occurred when CO_2 was released due to decarboxylation of organic matter prior to hydrocarbon migration. It is possible that aggrading neomorphism of the micrite in the wackestone at 2020m also occurred at this time.

Barite was the only other diagenetic mineral identified (0-2%). Typically barite concentrates in clean laminae of the lower Paaratte Formation. It is bladed and has a radial habit. The most likely source for barite is the drilling mud which would have been more heavily weighted at this depth due to the presence of reactive clays (chlorite-smectite).

A possible paragenetic sequence for the Paaratte Formation at Hill-1 is presented in the table below.

Event	Diagenetic Stage Early Middle Late
Glaucony	---
Pyrite	---
Siderite	----
Dissolution	----
Kaolin	----
Quartz	----
Compaction	------------------------------
Calcite	-----
?Hydrocarbons	----

7.5 Reservoir quality

Visual estimates of porosity from crushed sidewall cores and cuttings are very unreliable. More accurate values of total porosity should be obtained from the wireline logs. At best the petrology provides information re the pore types and hence the probability of effective porosity.

Reservoir quality was probably controlled by the depositional environments. Those samples that are poorly sorted and have clay rich laminae are unlikely to have good reservoir quality. Poor sorting would have minimised the original intergranular porosity prior to burial and compaction. Vertical permeability may be limited by the planar muddy laminae in samples throughout the sequence. Sidewall cores from near the base of the top Paaratte (Swcs 26 & 29; 2023 & 2016m) appear to have the best reservoir quality due to better preservation of primary intergranular pores (?12%). These sandstones are moderately well sorted and thus probably had higher porosity at the time of burial. Similarly the subarkose at the top of the Paaratte (Swc 35, 1992m) is moderately sorted and may have retained relatively high intergranular porosity (?11%).

Diagenesis would appear to be a less important control of reservoir quality because there has been relatively minimal development of authigenic cements to occlude pores. Rare quartz overgrowths (1-3%) are evident in those samples with higher retention of intergranular pores. These overgrowths would have slightly reduced mechanical compaction. However, the influence of mechanical compaction is difficult to assess because of textural disruption during sampling. Where detrital clay is abundant it can be hypothesised that compaction was greatest because of the lack of a rigid framework. Grain size, honeycomb and intragranular pores that developed due to the dissolution of labile grains form up to 3% of total porosity. These pores are unlikely to be interconnected and thus contribute to effective porosity. Micropores associated with grain replacing kaolin would also contribute to total porosity but may not represent effective porosity if the micropores are too small to allow hydrocarbon migration.

8. CONCLUSIONS

1. Thin sandy sequences in the lower Paaratte Formation (22-7, 21-9 & 20-7 sands) are characterised by laminated, fine to medium grained, very poor to poorly sorted greywackes and one subarkose. Sandstones from the top Paaratte Formation are dominated by fine grained, poor to moderately well sorted, subarkoses. Near the base of this sequence there is a fine grained moderately well sorted sublitharenite and possibly a wackestone.

2. Sediment in the Paaratte Formation was derived from an igneous/metamorphic terrane with slightly more input from the igneous source. Detrital clays in the lower Paaratte where chlorite-smectite is abundant may have a volcanic provenance, whilst kaolinite and illite in the top Paaratte could reflect a more plutonic source. Increased erosion, possibly due to uplift, caused a higher concentration of feldspars and micas in the top Paaratte.

3. Elevated gamma ray responses in the top Paaratte have probably been caused by a combination of radioactive minerals, muddy laminae, and variations in the percentages of feldspars and micas.

4. Thin fining upward sequences in the lower Paaratte could represent storm deposits on the continental shelf. These may be overlain by a transition zone to lower shoreface deposit at the base of the top Paaratte. The wackestone may have accumulated in a nearshore setting such as a tidal flat or a lagoon. Overlying stacked fining and coarsening upwards sequences are finer grained than the Paaratte elsewhere. These sands may have been deposited as mouth bars/crevasse splays and point bars of interdistributary channels at a delta front.

5. Diagenetic alteration was limited and dominantly early as indicated by the precipitation of glaucony, pyrite and siderite. Alteration of feldspars and micas to kaolin resulted from flushing by meteoric waters at the delta front. Excess silica from this reaction may have precipitated as minor quartz overgrowths in the cleaner sands. Concentration of late diagenetic calcite in the lower Paaratte could be related to the dissolution of calcareous fossils.

6. Reservoir quality was probably facies controlled given the lack of authigenic cements. Relatively good reservoirs may be preserved in the moderately well sorted sands that lack muddy laminae. Poor reservoirs are associated with poor sorting and high percentages of detrital clay.

9. GLOSSARY OF TERMS

Framboid
A cluster of pyrite crystals with a spheroidal outline.

Glaucony
A term used to describe green minerals without any genetic connotations. If the green minerals can be identified, a specific mineral name is given.

Glauconite
An Fe-rich dioctahedral illite. The term is also used to refer to a family of Fe-rich dioctahedral clays with varying ratios of expanded (smectite) and non-expanded layers.

Granophyric Texture
A variety of micrographic intergrowth of quartz and alkali feldspar that is either crudely radiate or is less regular than micrographic texture.

Honeycomb Porosity
Secondary porosity produced by the corrosion (etching) of detrital grains.

Micrographic Intergrowth
A regular intergrowth of two minerals.

Microporosity
Porosity directly associated with clay minerals.

nd
Abbreviation meaning not detected.

Neomorphism
All transformations between a mineral and the same mineral, or another of the same general composition.

Poikilotopic
A sedimentary textural term denoting a single crystal of carbonate enclosing more than one framework grain.

Porphyritic
A textural term applied to igneous rocks in which there are two distinct grain sizes present.

Spherulitic
The presence of more or less globular masses of generally acicular crystals, having a radial arrangement. spherulites form as a result of devitrification of volcanic glass.

Trachytic
A textural term applied to the groundmasses of volcanic rocks in which there is a subparallel arrangement of microcrystalline, lath shaped feldspars. The term is not restricted in use to rocks of trachyte composition.

Vacuole
Gas or liquid filled inclusion.

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