AER/AGS Special Report 109

Alberta Energy Regulator

Petrographic Analysis of Selected Alberta Strata (Doe Creek, Dunvegan)

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Petrographic Analysis of Selected Alberta Strata (Doe Creek, Dunvegan)

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Abstract

This report is a release of thin section descriptions from selected Alberta strata. Twenty thin sections were created to our specifications for very fine grained, transmitted-light microscopy on Doe Creek and Dunvegan strata.

The analysis and description of each thin section, performed by Calgary Rock and Materials Services Inc., includes visual estimations (in percent) of grain-size distribution, mineralogy, cement, allochem, opaque material, and organic material. Physical and biogenic primary and secondary sedimentary structures, fractures, and porosity were identified and described if present. General sample descriptions, rock classifications, and microphotographs are included for each sample.

1 Introduction

In 2012, the Alberta Geological Survey (AGS) published a report that determined the quantity and spatial extent of shale- and siltstone-hosted hydrocarbons (oil, gas, and natural gas liquids) in the province (Rokosh et al., 2012). The AGS is releasing client reports and digital data to disseminate knowledge from the project. These data and reports can be accessed from the AGS website (http://ags.aer.ca).

This report disseminates petrographic description on thin sections from selected strata in Alberta.

2 Sample Locations and Descriptions

Table 1 lists the samples and sites examined in the study.

Table 1. Samples collected for petrographic analysis.

Count	Sample_ID	Well_ID	Depth_m	Lithology	Formation
1	**13768**	100/16-11-070-06W6/00	1168.2	sandstone	Doe Creek
2	**13769**	100/16-11-070-06W6/00	1168.9	sandstone	Doe Creek
3	**13771**	100/12-35-072-13W6/00	1120.2	sandstone	Doe Creek
4	**13775**	100/12-35-072-13W6/00	1128.3	sandstone	Doe Creek
5	**13779**	100/12-34-075-08W6/00	747.9	sandstone	Doe Creek
6	**13782**	100/04-23-076-08W6/00	587.7	shale	Doe Creek
7	**13784**	100/04-23-076-08W6/00	591.5	sandstone	Doe Creek
8	**13787**	100/07-12-079-08W6/00	247.4	shale	Doe Creek
9	**15167**	100/08-06-072-01W6/00	812.3	sandstone	Dunvegan
10	**15170**	100/08-06-072-01W6/00	826.9	siltstone	Dunvegan
11	**15172**	100/14-22-072-10W6/00	1133.5	siltstone	Dunvegan
12	**15176**	100/08-07-057-03W6/00	3200.7	sandstone	Dunvegan
13	**15177**	100/08-07-057-03W6/00	3204.9	shale	Dunvegan
14	**15180**	100/03-30-073-12W6/00	938.1	sandstone	Dunvegan
15	**15182**	100/03-30-073-12W6/00	942.4	sandstone	Dunvegan
16	**15185**	100/03-30-073-12W6/00	949.7	sandstone	Dunvegan
17	**15186**	100/16-18-071-10W6/00	1323.4	shale	Dunvegan
18	**15188**	100/16-18-071-10W6/00	1330.9	shale	Dunvegan
19	**15191**	100/16-18-071-10W6/00	1339.7	shale	Dunvegan
20	**15223**	100/14-36-078-11W6/00	352.8	siltstone	Doe Creek

References

Rokosh, C.D., Lyster, S., Anderson, S.D.A., Beaton, A.P., Berhane, H., Brazzoni, T., Chen, D., Cheng, Y., Mack, T., Pana, C. and Pawlowicz, J.G. (2012): Summary of Alberta's shale- and siltstone-hosted hydrocarbon resource potential; Energy Resources Conservation Board, ERCB/AGS Open File Report 2012-06, 327 p., URL < http://ags.aer.ca/publications/OFR_2012_06.html > [March 2017].

Petrographic Descriptions

Alberta Geological Survey (103454)

100/16-11-070-06W6/00, 100/12-35-072-13W6/00, 100/12-34-075-08W6/00,100/04-23-076-08W6/00, 100/07-12-079-08W6/00, 100/08-06-072-01W6/00, 100/14-22-072-10W6/00, 100/08-07-057-03W6/00, 100/14-22-072-10W6/00, 100/08-07-057-03W6/00, 100/03-30-073-12W6/00, 100/16-18-071-10W6/00 and 100/14-36-078-11W6

6 May, 2014

Calgary Rock and Materials Services Inc.

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1. INTRODUCTION

The purpose of this study is to evaluate the grain-size distribution, mineralogy, organic-matter distribution, primary and secondary structures, porosity and any other notable characteristics for well locations 100/16-11-070-06W6/00, 100/12-35-072-13W6/00, 100/12-34-075-08W6/00,100/04-23-076-08W6/00, 100/07-12-079-08W6/00, 100/08-06-072-01W6/00, 100/14-22-072-10W6/00, 100/08-07-057-03W6/00, 100/14-22-072-10W6/00, 100/08-07-057-03W6/00, 100/03-30-073-12W6/00, 100/16-18-071-10W6/00 and 100/14-36-078-11W6. The study was commissioned by the Alberta Geological Survey. The format of this report has been modified to reflect the requirements of the client, Alberta Geological Survey.

The thin-sections were produced by impregnating selected core with pink-dyed epoxy to identify porosity and to reduce the likelihood of delicate structures (e.g. clays) from being destroyed during preparation. The samples were half stained with alizarin red S to distinguish calcite and potassium ferricyanide to distinguish ferroan carbonates. These thin sections are ground down to ~ 30 microns in thickness which is typical for sandstones and carbonates. Thin sections that have a higher argillaceous content with associated carbonaceous material (i.e. shales) are ground thinner to ~22 microns. This is done in order to view the fine-gained materials obscured by the carbonaceous materials.

Petrographic results are summarized in Appendix A: Table 1. Overview and described thin-section photomicrographs are presented after the text and petrographic tables.

CR Sample ID	AGS Sample ID	Depth (m)	Location	Rock Name	Stratigraphic Unit
TS1	13768	1168.2	100/16-11-070-06W6/00	sublitharenite	n/a
TS2	13769	1168.9	100/16-11-070-06W6/00	sublitharenite	n/a
TS3	13771	1120.2	100/12-35-072-13W6/00	clayey sublitharenite	n/a
TS4	13775	1128.3	100/12-35-072-13W6/00	clayey sublitharenite	n/a
TS5	13779	747.9	100/12-34-075-08W6/00	sublitharenite	n/a
TS6	13782	587.7	100/04-23-076-08W6/00	sublitharenite	n/a
TS7	13784	591.5	100/04-23-076-08W6/00	sideritic mudstone	n/a
TS8	13787	247.4	100/07-12-079-08W6/00	clayey sublitharenite	n/a
TS9	15167	812.3	100/08-06-072-01W6/00	clayey litharenite	n/a
TS10	15170	826.9	100/08-06-072-01W6/00	clayey siltstone	n/a
TS11	15172	1133.5	100/14-22-072-10W6/00	silty litharenite	n/a
TS12	15176	3200.7	100/08-07-057-03W6/00	clayey litharenite	n/a
TS13	15177	3204.9	100/08-07-057-03W6/00	clayey siltstone	n/a
TS14	15180	938.1	100/03-30-073-12W6/00	clayey litharenite	n/a
TS15	15182	942.4	100/03-30-073-12W6/00	clayey siltstone	n/a
TS16	15185	949.7	100/03-30-073-12W6/00	clayey litharenite	n/a
TS17	15186	1323.4	100/16-18-071-10W6/00	clayey siltstone	n/a
TS18	15188	1330.9	100/16-18-071-10W6/00	siltstone	n/a
TS19	15191	1339.7	100/16-18-071-10W6/00	siltstone	n/a
TS20	15223	352.8	100/14-36-078-11W6/00	siltstone	n/a

2. PETROGRAPHIC OBSERVATIONS AND DESCRIPTIONS

2.1 Petrology and Mineralogy Overview

To evaluate the factors controlling porosity and permeability, fluid-sensitivity issues and reservoir quality within the study well, petrological and mineralogical information was collected using thin-section analysis. Porosity and permeability values were estimated.

Classification of samples was determined using Folk (1974) and Dunham, modified by Embry & Klovan (1971) as well as Gregg & Sibley (1984) for dolomite texture characterization.

For grain/particle/crystal size the Wentworth Scale was used and is as follows:

Microcrystalline or clay size	<0.004mm	<4µm
Silt size crystalline or silt-size-grained	0.0040-0.0310mm	4-31µm
Coarse silt size crystalline or coarse silt-grained	0.0310-0.0625mm	31-63µm
Very fine crystalline or very fine-grained	0.0625-0.125mm	63-125µm
Fine crystalline or fine-grained	0.125-0.250mm	125-250µm
Medium crystalline or medium-grained	0.250-0.500mm	250-500µm
Coarse crystalline or coarse-grained	0.500-1.000mm	500-1000µm
Very coarse-grained	1.000-2.000mm	1000-2000µm

2.2 Petrological Descriptions

Sample ID 13768
Map ID n/a
Strat. Unit n/a

UWI 100/16-11-070-06W6/00
Depth 1168.2 m

Grain Size	%	Variety (%)	Variety (%)	Variety (%)	Variety (%)	Variety (%)
fine sand	6	quartz (60)	rock frag. (40)			
v. fine sand	85	quartz (86)	rock frag. (10)	feldspar (3)	mica (1)	phosphate (<1)
silt	trace	quartz (100)				
clay	2	kaolinite (70)	other clays (30)			
Cement	5	ankerite (30)	clay (30)	quartz (40)		
Allochems						
Organics	1	amorphous (100)	plant matter?			
Opaques	1	pyrite (100)				
	100					

Roundness	subangular to subrounded
Sphericity	high
Sorting	well-sorted

Sedimentary Structures

Primary	massive
Biogenic	none observed

Fractures	none
Porosity	intergranular porosity is the main porosity observed with secondary porosity attributed to partial/complete grain dissolution

Description

The rock sample is characterized as a massive sublitharenite. The sample mainly consists of very-fine sand-sized grains. Quartz is the main mineral observed in the sample and is commonly observed with overgrowths. Rock fragments are the next most common mineral which are identified as chert and clay clasts. Clays are mainly identified as kaolinite and are observed within the secondary porosity of leached grains. Organic components are observed as specks where larger fragments have been compacted parallel to bedding.

Thin section Quality

Thickness of the section is consistent. Good quality. ½ stained for carbonates.

Rock Classification

sublitharenite (Folk, 1974)

Sample ID 13180, 100/16-11-070-06W6/00, 1168.2 m

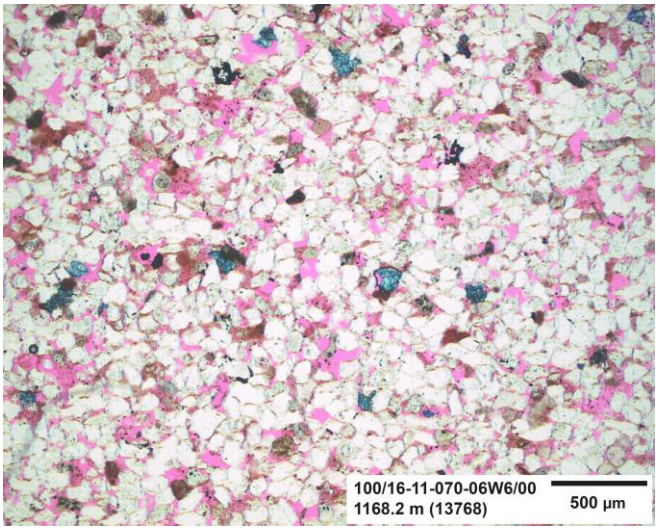

Figure 1: This figure is a low magnification image photographed under plane-polarized light. Note the very-fine sand-sized rock sample comprised mainly of quartz and rock fragments. Intergranular porosity is abundant in this sample.

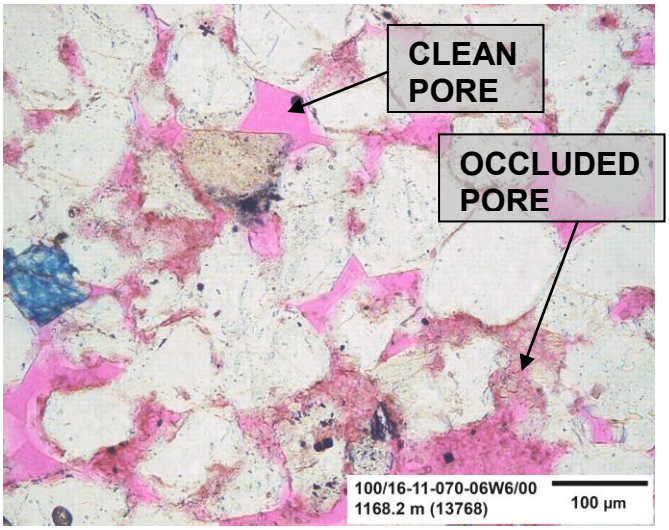

Figure 2: This figure is a high magnification image photographed under plane-polarized light. Clean pores are characterized by quartz overgrowths lining the pore throats. Occluded pores have been replaced by clays.

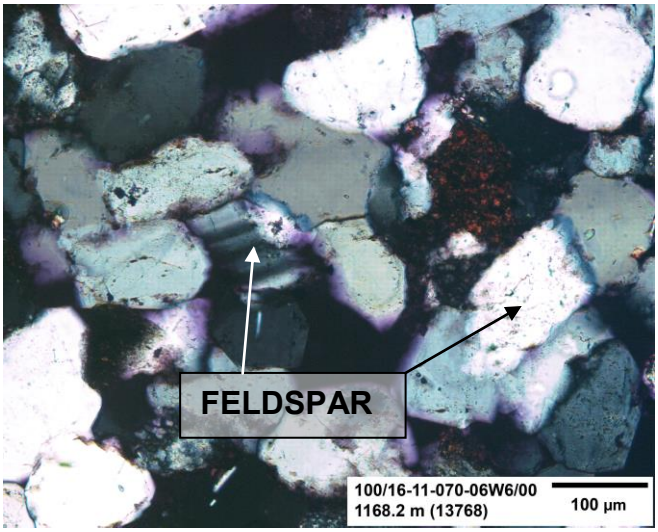

Figure 3: This figure is a high magnification image photographed under cross-polarized light. Under cross-polarized light feldspars and other siliciclastics can be identified twinning or other optical characteristics. However, it is important to note that not all feldspars exhibit twinning and could be misidentified as quartz grains. X-ray diffractometry is recommended to accurately quantify feldspar content.

Sample ID 13768, 100/16-11-070-06W6/00, 1168.2 m

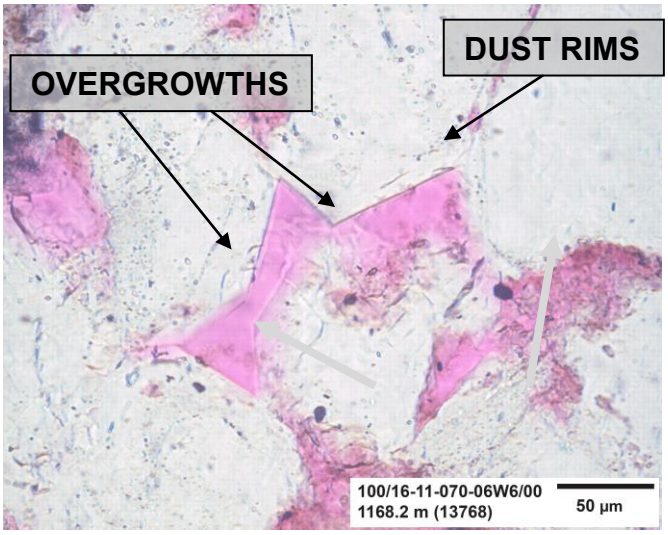

Figure 4: This figure is a high magnification image photographed under plane-polarized light. The euhedral faces observed on the detrital grains are identified as cement and present as overgrowths. The original detrital grain boundary is still visible and can be identified as dust rims.

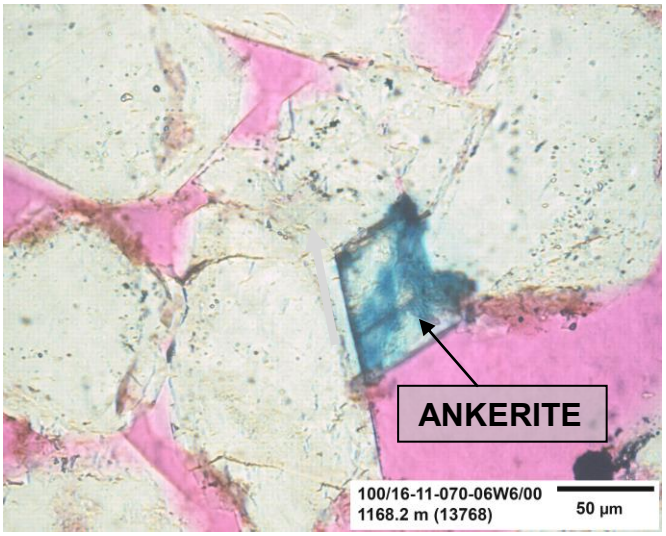

Figure 5: This figure is a high magnification image photographed under plane-polarized light. The stained blue rhomb in the image is a ferroan dolomite (ankerite). The cross-cutting relationship between the quartz cement and dolomite cement indicates that the ankerite was a later stage diagenetic cement.

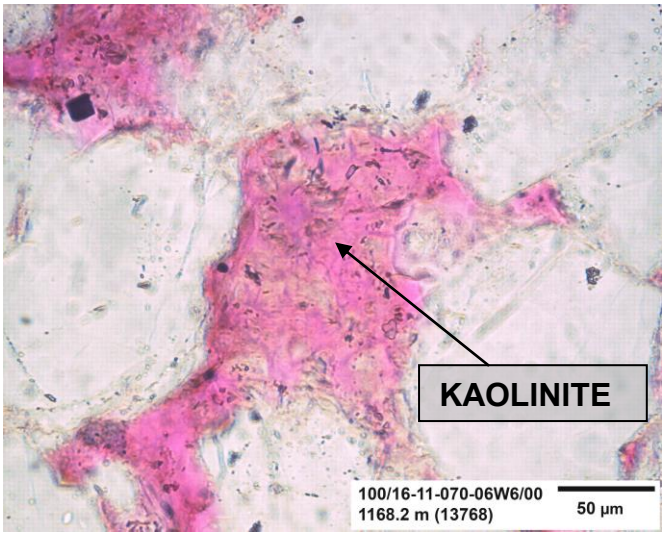

Figure 6: This figure is a high magnification image photographed under plane-polarized light. The center of the image illustrates a grain that has been almost completely dissolved. Replacing the secondary porosity is authigenic kaolinite booklets. The porosity contribution by this clay is mainly microporosity.

Sample ID	**13769**	**UWI**	**100/16-11-070-06W6/00**	
Map ID	**n/a**	**Depth**	**1168.9 m**	
Strat. Unit	**n/a**			

Grain Size	**%**	**Variety (%)**	**Variety (%)**	**Variety (%)**	**Variety (%)**	**Variety (%)**
fine sand	10	quartz (50)	rock frag. (40)	mica (10)		
v. fine sand	80	quartz (82)	rock frag. (15)	feldspar (3)	mica (<1)	
silt						
clay	2	kaolinite (40)	other clay (60)			
Cement	5	ankerite (40)	quartz (30)	clay (40)		
Allochems						
Organics	1	amorphous (100)				
Opaques	1	pyrite (100)				
	100					

Roundness	subangular to subround
Sphericity	moderate to high
Sorting	well-sorted

Sedimentary Structures

Primary	weak planar bed textures
Biogenic	none

Fractures	none
Porosity	intergranular porosity with minor secondary porosity (grain dissolution)

Description

The rock sample is characterized as a planar bedded sublitharenite. This sample is predominantly composed of very-fine sand-sized quartz grains with minor amounts of rock fragments. The rock fragments identified include illitic shale clasts, chert and other clay clasts. Feldspar grains that exhibit twinning and/or distinct crystal habit are only included in the mineral estimations, x-ray diffractometry (XRD) is recommended to refine this estimation and identify different species. Feldspars are observed undergoing chemical alterations which include seritization and vacuolization. The horizontal beds are not readily identifiable with microscopy and can be observed with the unaided eye on the thin section. Minor amounts of organics and opaques are observed within the thin section.

Thin section Quality

Thickness of the section is consistent. Good quality. ½ stained for carbonates.

Rock Classification

sublitharenite (Folk, 1974)

Sample ID 13769, 100/16-11-070-06W6/00, 1168.9 m

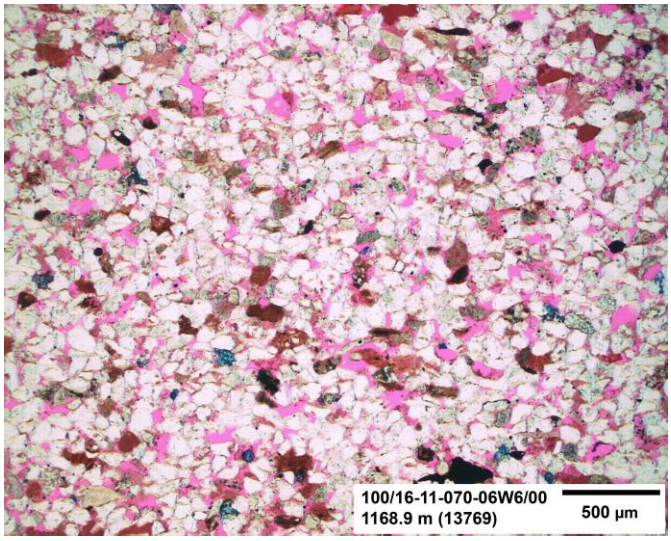

Figure 7: This figure is a low magnification image photographed under plane-polarized light. It is difficult to observe the planar beds within this sample under low magnification. With the unaided eye these beds are visible and average 2 to 3 mm in thickness. The majority of this rock sample consists of very-fine sand-sized quartz grains.

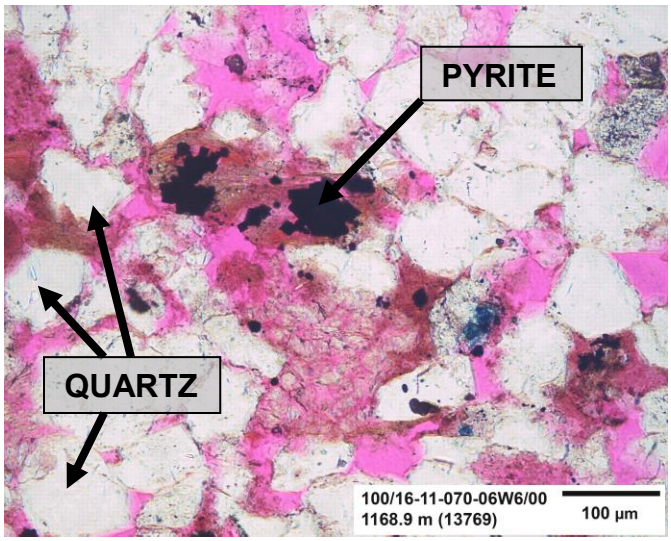

Figure 8: This figure is a high magnification image photographed under plane-polarized light. The grains in the image are primarily composed of quartz. The majority of these quartz grains have partial overgrowths which reduces overall pore-sizes. Pyrite is also observed in its characteristic cubic form.

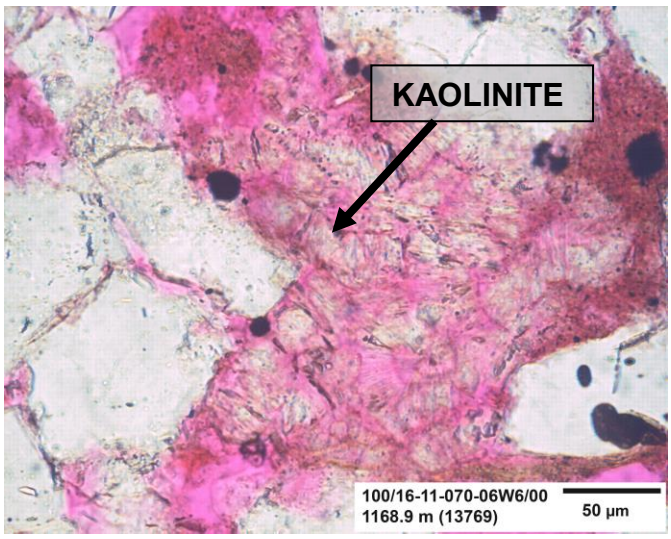

Figure 9: This figure is a high magnification image photographed under plane-polarized light. This image shows a leached grain that has been completely replaced by authigenic kaolinite. The kaolinite is present in a vermicular “worm-like” form comprised of individual plates forming booklets.

Sample ID 13769, 100/16-11-070-06W6/00, 1168.9 m

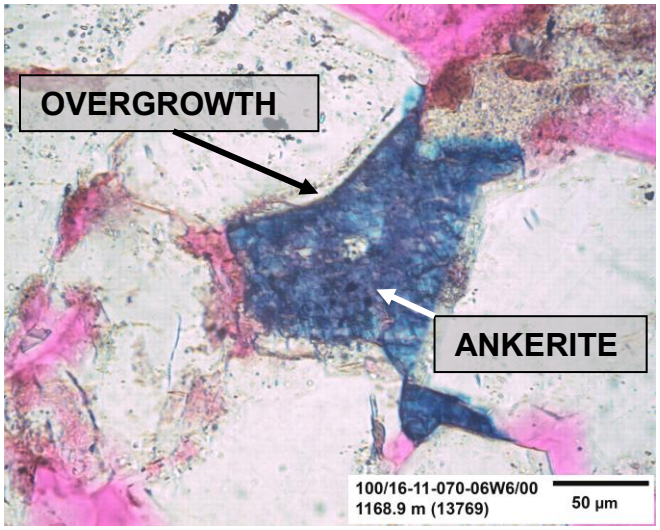

Figure 10: This figure is a high magnification image of the sample under plane-polarized light. Two types of cement are illustrated in this image which are a quartz overgrowths and ankerite. The cross-cutting relationship of the cements indicates that the quartz overgrowth precipitated first then the ankerite cement precipitated afterwards.

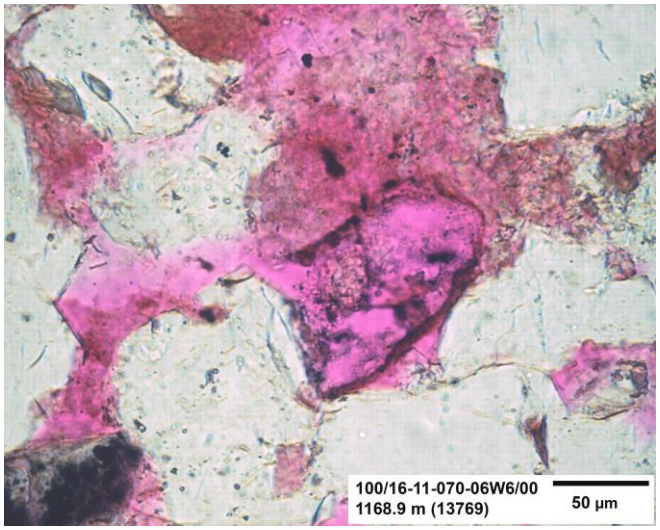

Figure 11: This figure is a high magnification image of the sample under plane-polarized light. The center of the image has a partially leached grain, most likely feldspar. The coating surrounding this previously intact grain has survived and consists of clay/organic materials.

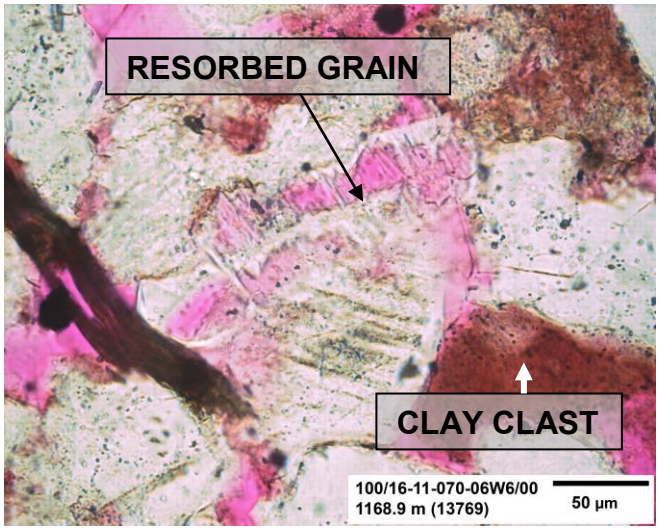

Figure 12: This figure is a high magnification image of the sample under plane-polarized light. Note the resorbed grain in the center of the image. This is chemical alteration is commonly observed within this rock sample. Also note the clay clast undergoing mild ductile deformation.

Sample ID	**13771**	**UWI**	**100/12-35-072-13W6/00**	
Map ID	**n/a**	**Depth**	**1120.2 m**	
Strat. Unit	**n/a**			

Grain Size	**%**	**Variety (%)**	**Variety (%)**	**Variety (%)**	**Variety (%)**	**Variety (%)**
fine sand	5	quartz (70)	mica (30)			
v. fine sand	79	quartz (86)	rock frag. (10)	feldspar (3)	mica (1)	glauconite (<1)
silt	5	quartz (100)				
clay	10	detrital clay (100)	quartz (<1)			
Cement	1	quartz (1)	ankerite (<1)			
Allochems						
Organics	<1	amorphous (100)				
Opaques	<1	pyrite (100)				
	100					

Roundness	angular to subangular
Sphericity	moderate
Sorting	well-sorted

Sedimentary Structures

Primary	weakly bedded with clay-rich/quartz-rich lenses and beds
Biogenic	none observed

Fractures	fractures concentrated within clay-rich sedimentary structures
Porosity	primarily intercrystalline porosity with minor intraparticle and secondary porosity

Description

The rock sample is characterized as a clayey sublitharenite that is weakly bedded containing clay-rich/quartz-rich lenses. The primary mineral observed is very-fine sand-sized grains. Clays are the next major component and are composed mainly of detrital clays observed forming lenses, beds and discontinuous beds. Fractures occur in higher frequencies within these clay-rich sedimentary structures. Organic components are observed as specks where larger fragments have been compacted parallel to bedding.

Thin section Quality

Thickness of the section is consistent. Good quality. ½ stained for carbonates.

Rock Classification

clayey sublitharenite (Folk, 1974)

Sample ID 13771, 100/12-35-072-13W6/00, 1120.2 m

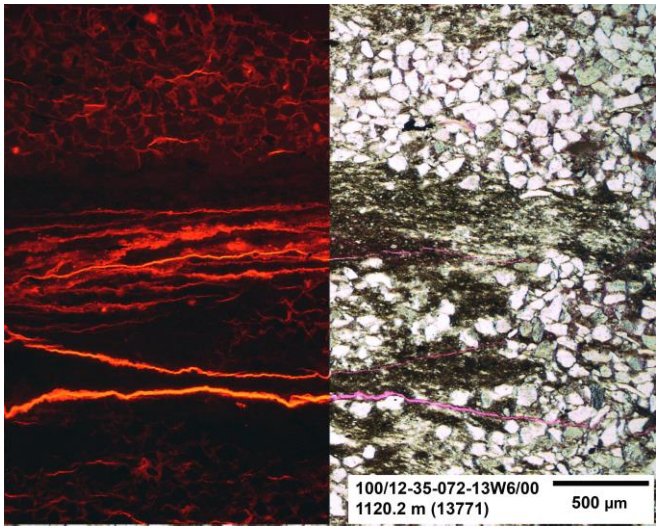

Figure 13: This figure is a low magnification image of the sample under plane-polarized light (right) and ultra-violet light (left). The porosity contributions differ depending on which lithology is present. The quartz-rich structures are mainly associated with intergranular porosity, whereas the clay-rich structures are mainly associated with fracture porosity.

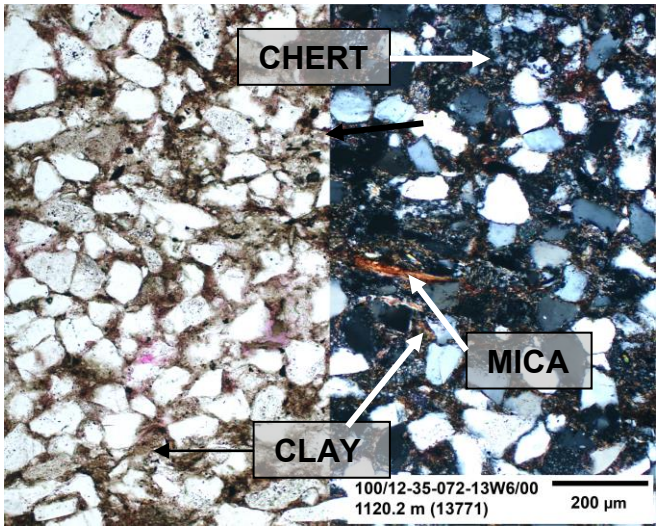

Figure 14: This figure is a medium magnification image of the sample under plane-polarized light (left) and cross-polarized light (right). The majority of the grains observed in this image are very-fine sand-sized quartz grains. Other components in the rock sample are mica and chert. The matrix of the rock is predominantly clay-rich.

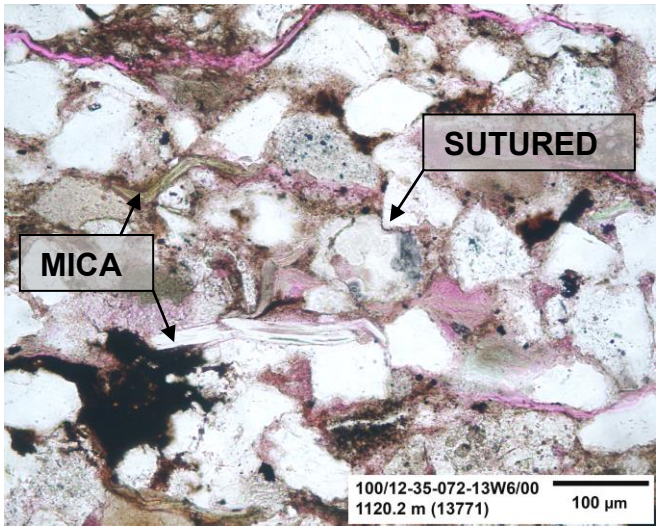

Figure 15: This figure is a high magnification image of the sample under plane-polarized light. This image illustrates the compacted texture of the rock sample. Note the two mica grains in the image undergoing brittle deformation. There are also grain suturing and high relief grain boundaries between quartz grains.

Sample ID 13771, 100/12-35-072-13W6/00, 1120.2 m

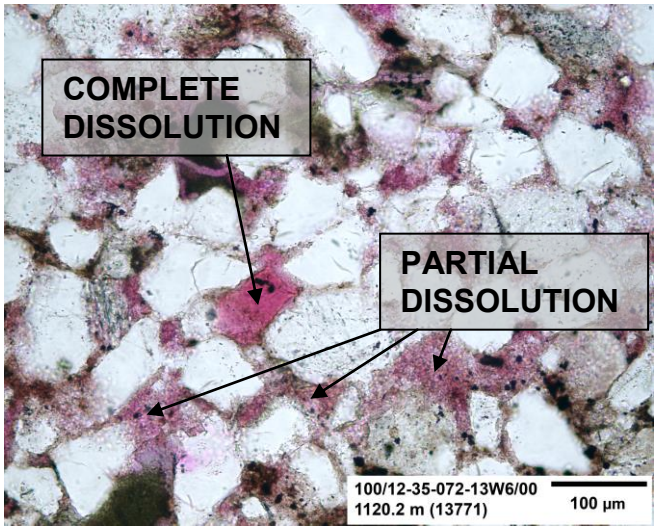

Figure 16: This figure is a high magnification image of the sample under plane-polarized light. This sample shows various stages of grain dissolution which ranges from partial to complete. Grains undergoing partial dissolution contribute to microporosity. Grains undergoing complete dissolution contribute to effective secondary porosity.

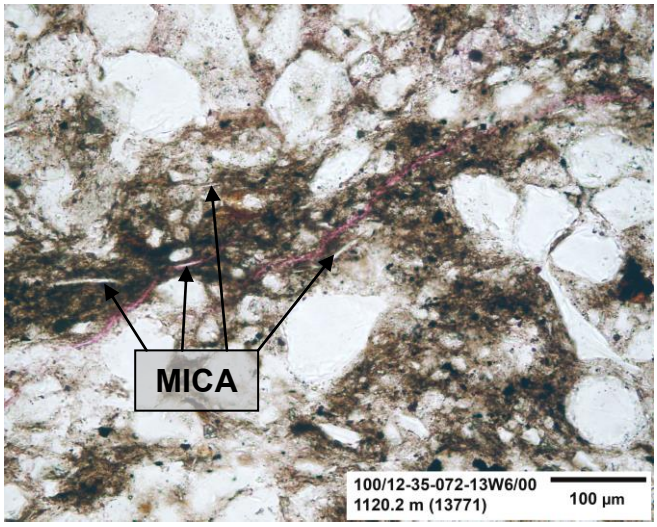

Figure 17: This figure is a high magnification image of the sample under plane-polarized light. Note the fracture associated with clay-rich lens. Mica grains embedded within the clay-rich lens are oriented parallel to the lens which infers detrital deposition of the clay-rich lens and its constituents.

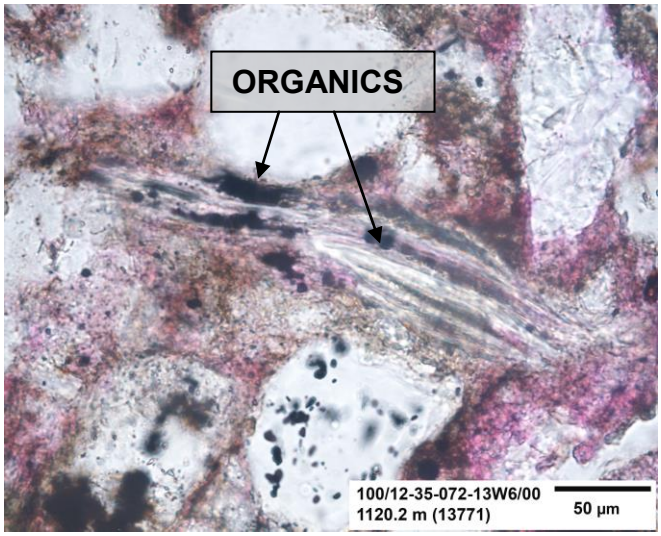

Figure 18: This figure is a high magnification image of the sample under plane-polarized light. A mica grain is observed in the center of the image. Intraparticle porosity is observed within this grain, highlighted by the pink epoxy, in which organics are found partially occupying this porosity.

Sample ID	**13775**	**UWI**	**100/12-35-072-13W6/00**
Map ID	**n/a**	**Depth**	**1128.3 m**
Strat. Unit	**n/a**		

Grain Size	**%**	**Variety (%)**	**Variety (%)**	**Variety (%)**	**Variety (%)**	**Variety (%)**
fine sand	5	quartz (60)	mica (20)	rock frag. (20)		
v. fine sand	76	quartz (90)	rock frag. (8)	feldspar (2)	mica (<1)	
silt	10	quartz (94)	mica (5)	feldspar (1)		
clay	8	detrital clay (100)				
Cement	1					
Allochems	<1	radiolarian (100)				
Organics	<1	amorphous (100)				
Opaques	<1	pyrite (100)				
	100					

Roundness	subangular to subround
Sphericity	moderate to high
Sorting	well-sorted

Sedimentary Structures

Primary	wavy cross-bedding with clay-rich lenses
Biogenic	none observed

Fractures	Artificial and natural fractures observed, approximately 5 to 8 natural fractures
Porosity	intergranular porosity main contributor with minor microporosity

Description

The rock sample is characterized as a clayey sublitharenite that has wavy bedforms with cross-bedding features. Two textural features are observed, in which the main is a very-fine, sand-sized framework-supported texture and the minor is a silt-sized, clay-rich, matrix-supported texture. Quartz is the primary mineral observed in this rock sample. Some clay-rich lenses have been plucked out which may be sign of water-sensitivity. Organic components are observed to be associated with pyrite. Organics associated with the clay-rich lithology are compacted and oriented to bedding.

Thin section Quality

Thickness of the section is consistent with minor pluck out of clays. Average quality. ½ stained for carbonates.

Rock Classification

clayey sublitharenite (Folk, 1974)

Sample ID 13775, 100/12-35-072-13W6/00, 1128.3 m

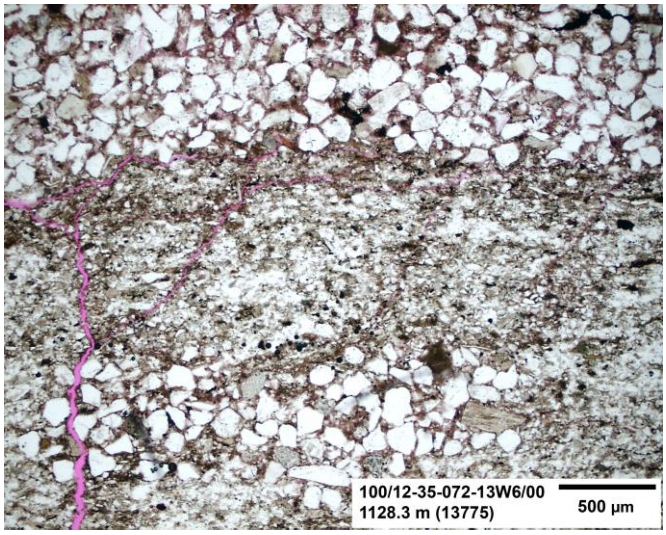

Figure 19: This figure is a low magnification image of the sample under plane-polarized light. This image shows a distinct lithology change between the very-fine sand-sized grains and the clay-rich silt-sized grains. The majority of the clay observed is associated with this silt-sized clay-rich bed.

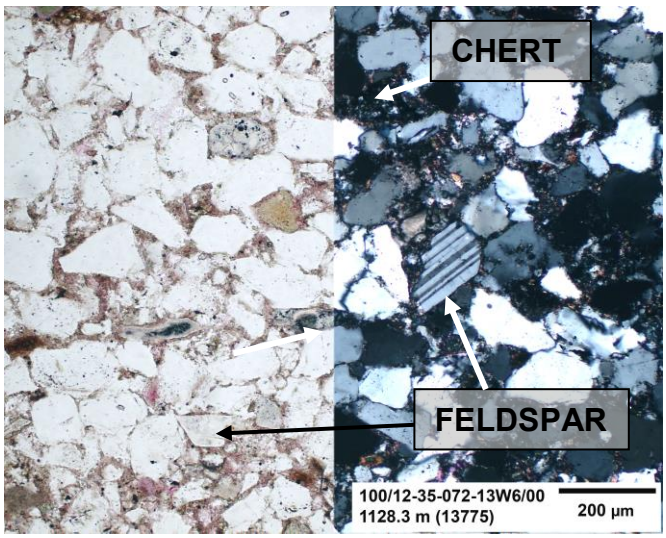

Figure 20: This figure is a medium magnification image of the sample under plane-polarized light (left) and cross-polarized light (right). This texture is the primary texture observed throughout this rock sample. The majority of the grains observed are quartz grains. Feldspars are difficult to identify if twinning and/or distinct crystal habit is absent and can be misidentified as quartz. Feldspar estimations are to be used with caution.

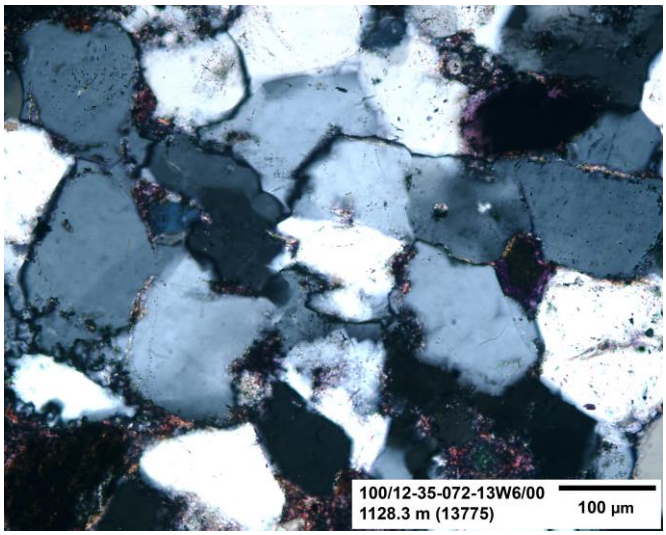

Figure 21: This figure is a high magnification image of the sample under cross-polarized light. Note the compactional features of the rock sample which are identified as suture grain contacts, high relief grain boundaries and undulatory extinction.

Sample ID 13775, 100/12-35-072-13W6/00, 1128.3 m

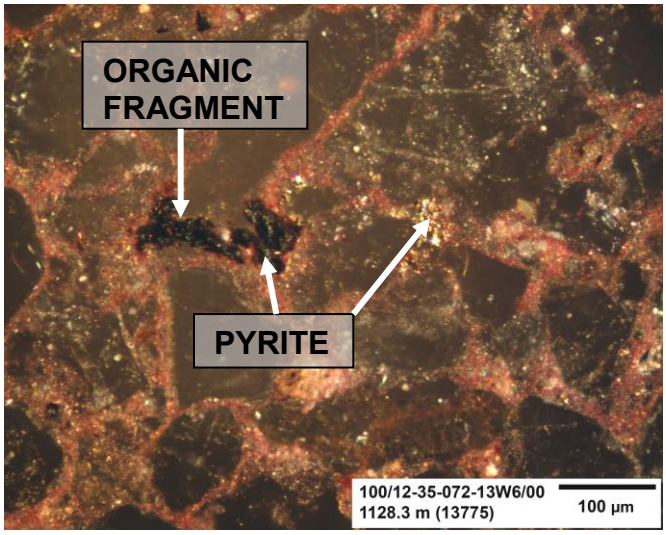

Figure 22: This figure is a high magnification image of the sample under reflected light. Reflected light microscopy is key in the identification of certain opaque minerals such as pyrite. This is most apparent when pyrite is incorporated within organic fragments in which lustrous pyrite can be discriminated from opaque organics under reflected light.

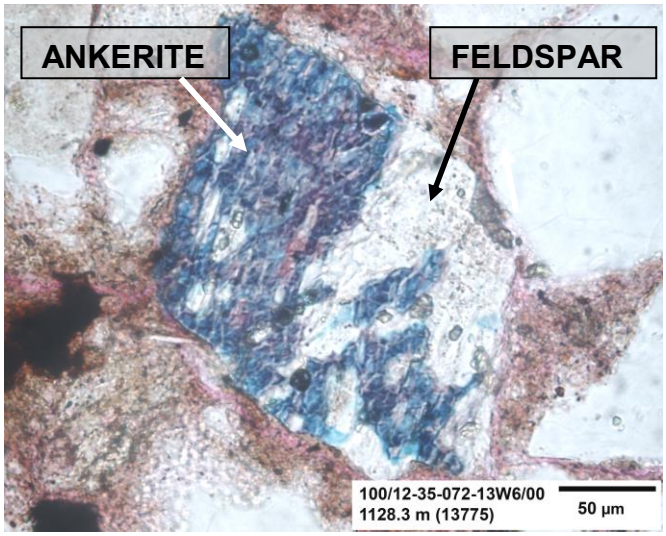

Figure 23: This figure is a high magnification image of the sample under plane-polarized. Note the ankerite replacement of the host feldspar grain.

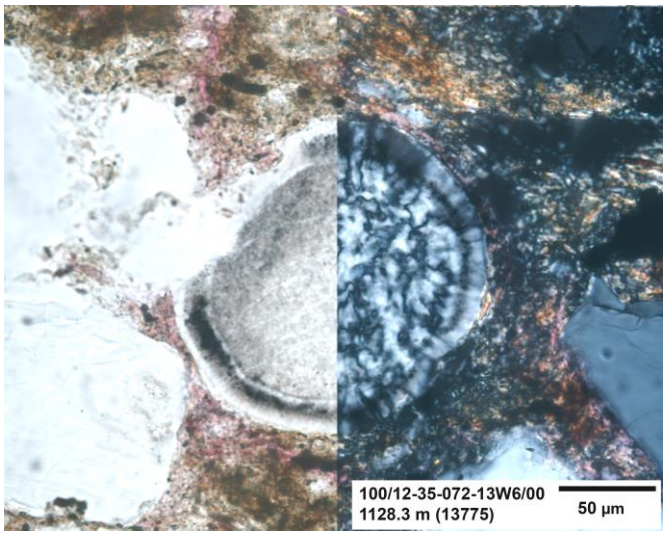

Figure 24: This figure is a high magnification image of the sample under plane-polarized light (left) and cross-polarized light (right). This image is highlights a silicified radiolarian fragment. The exterior test can be differentiated from the interior structure.

Sample ID	**13779**	**UWI**	**100/12-34-075-08W6/00**
Map ID	**n/a**	**Depth**	**747.9 m**
Strat. Unit	**n/a**		

Grain Size	**%**	**Variety (%)**	**Variety (%)**	**Variety (%)**	**Variety (%)**	**Variety (%)**
fine sand	10	quartz (78)	rock frag. (20)	feldspar (1)	mica (1)	
v. fine sand	76	quartz (86)	rock frag. (10)	feldspar (3)	mica (1)	
silt	10	quartz (100)				
clay	1	kaolinite (50)	detrital (50)			
Cement	3	quartz (90)	dolomite (10)			
Allochems						
Organics	<1	amorphous (100)				
Opaques	<1	pyrite (100)				
	100					

Roundness	subangular to subround
Sphericity	moderate to high
Sorting	moderate to well-sorted

Sedimentary Structures

Primary	massive
Biogenic	none observed

Fractures	none
Porosity	intergranular porosity main contributor with minor secondary porosity

Description

The rock sample is characterized as a sublitharenite that is massively bedded. Very-fine sand-sized grains are the dominant grain-size of which the majority are identified as quartz. Angularity of the grains is mainly attributed to the overgrowths observed surrounding the detrital grain and is the main cement observed in this rock sample. Only trace amounts of organic material is observed in the sample. Porosity contributions are primarily intergranular with minor amounts attributed to partial to complete grain dissolution.

Thin section Quality

Thickness of the section is consistent. Good quality. ½ stained for carbonates.

Rock Classification

sublitharenite (Folk, 1974)

Sample ID 13779, 100/12-34-075-08W6/00, 747.9 m

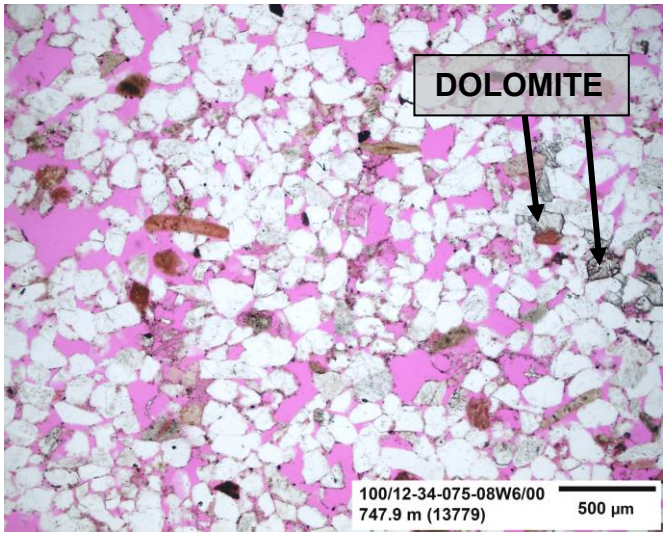

Figure 25: This figure is a low magnification image of the sample under plane-polarized light. The majority of the grains is very-fine sand-sized and is mainly comprised of quartz. Dolomite and quartz cement are the dominant cements in this sample.

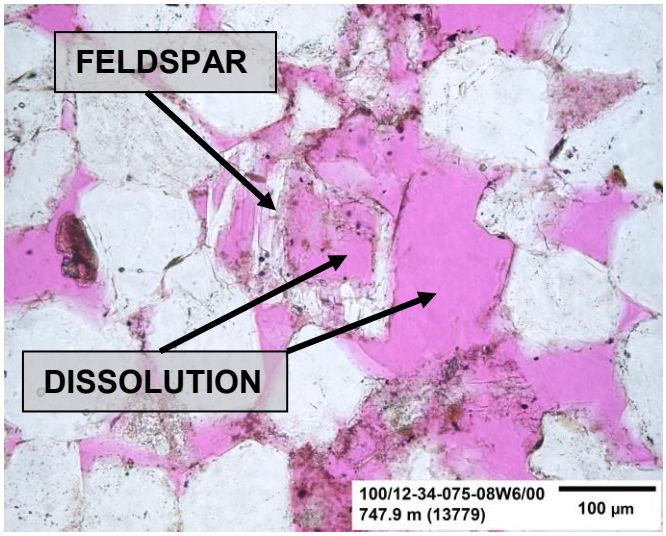

Figure 26: This figure is a high magnification image of the sample under plane-polarized light. Note feldspar grain undergoing partial dissolution and the neighboring porosity which is a grain completely dissolved.

Figure 27: This figure is a high magnification image of the sample under plane-polarized light. The kaolinite occupying this pore is authigenic and is present as vermicular booklets.

Sample ID 13779, 100/12-34-075-08W6/00, 747.9 m

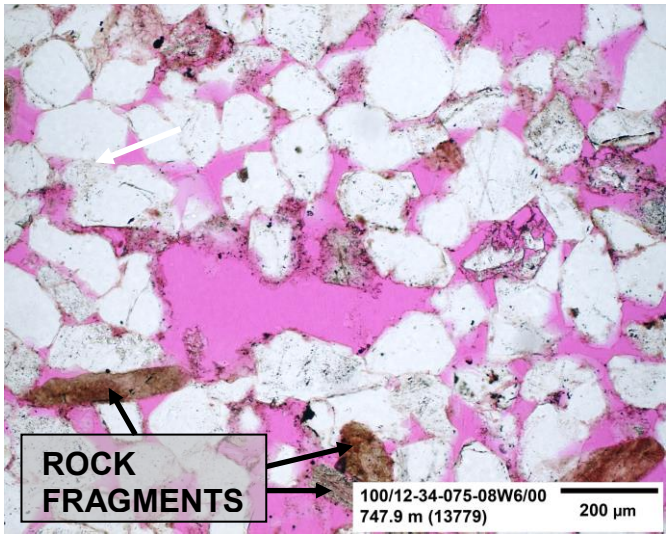

Figure 28: This figure is a medium magnification image of the sample under plane-polarized light. The grains in the sample do not appear arranged into any sedimentary structures and appear as a massive texture. Rock fragments in this image are primarily identified as clay clasts.

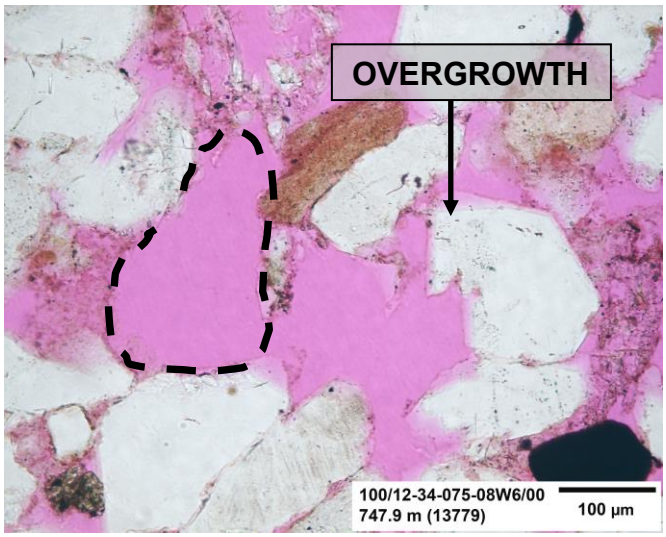

Figure 29: This figure is a high magnification image of the sample under plane-polarized. An outline of a leached grain is identified in the image. Quartz overgrowths are also present which reduces the overall porosity in the sample.

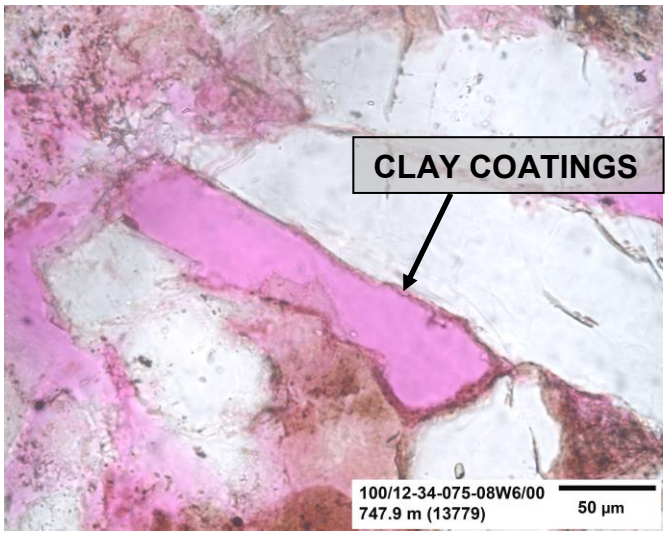

Figure 30: This figure is a high magnification image of the sample under plane-polarized light. This elongate pore may be a dissolved grain as evidenced by the remnant clay coating outlining the previous grain boundary.

Sample ID	**13782**	**UWI**	**100/04-23-076-08W6/00**	
Map ID	**n/a**	**Depth**	**587.7 m**	
Strat. Unit	**n/a**			

Grain Size	**%**	**Variety (%)**	**Variety (%)**	**Variety (%)**	**Variety (%)**	**Variety (%)**
fine sand	2	quartz (90)	rock frag. (10)			
v. fine sand	55	quartz (88)	rock frag. (10)	feldspar (2)	glauconite (<1)	
silt	30	quartz (100)	glauconite (<1)			
clay	10	kaolinite (10)	detrital (90)			
Cement	1	quartz (90)	dolomite (10)			
Allochems						
Organics	1	amorphous (100)				
Opaques	1	pyrite (100)				
	100					

Roundness	subround
Sphericity	moderate to high
Sorting	moderate

Sedimentary Structures

Primary	wavy bedforms with clay-rich lenses
Biogenic	bioturbation observed

Fractures	associated with clay-rich structures, approx.. 1 to 3 fractures per lens/bed
Porosity	intergranular porosity main contributor and associated with quartz-rich beds

Description

The rock sample is characterized as a sublitharenite. This rock sample has two main textural types based on the grain-size and lithology. The primary textural type is a quartz-rich, framework-supported texture and the secondary type is a silt-sized, clay-rich, matrix-supported texture. The clay-rich texture is mainly associated with fracture porosity. The quartz-rich texture is mainly associated with intergranular porosity. Bioturbation is also observed in the sample as vertical structures with glauconite observed within the structures. Organics are observed in minor amounts.

Thin section Quality

Thickness of the section is consistent with minor pluck out of clays. Average quality.

Rock Classification

sublitharenite (Folk, 1974)

Sample ID 13782, 100/04-23-076-08W6/00, 587.7 m

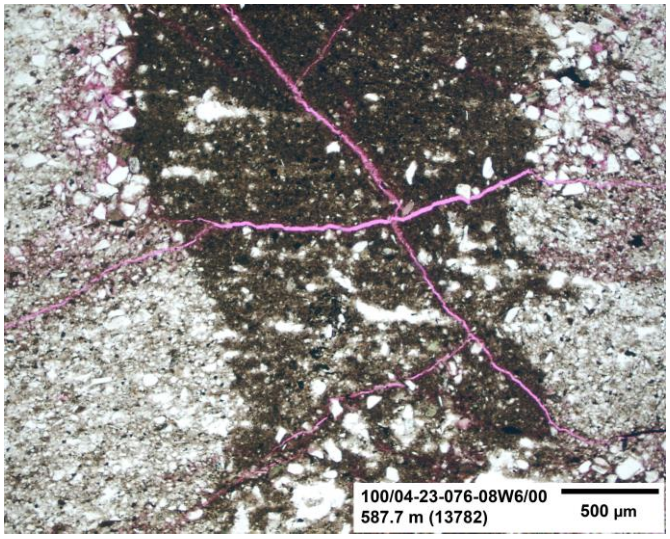

Figure 31: This figure is a low magnification image of the sample under plane-polarized light. Within this image is a bioturbation trace which is highlighted by the darker brown structure.

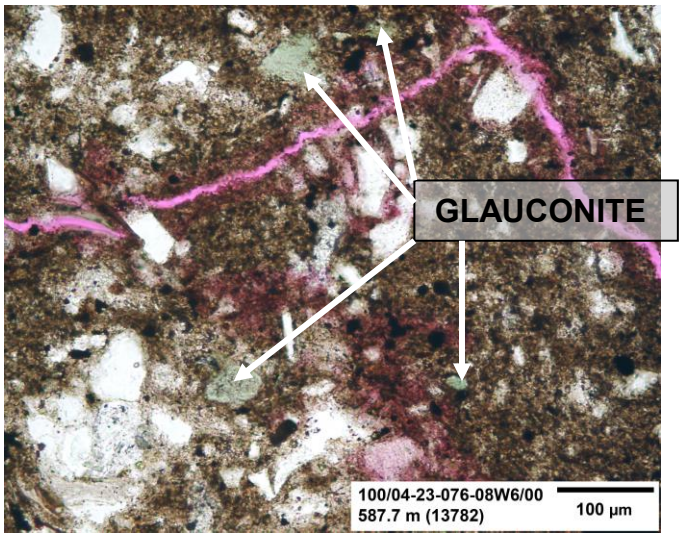

Figure 32: This figure is a high magnification image of the bioturbation trace observed in Figure 31. Note the glauconite pellets observed within this trace.

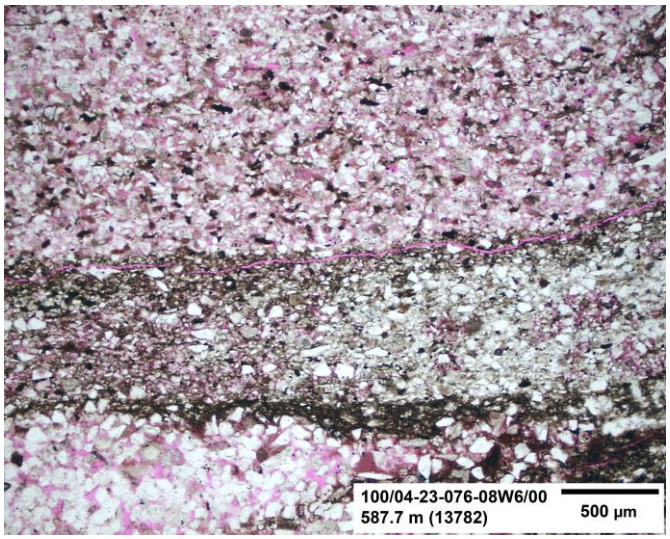

Figure 33: This figure is a low magnification image of the sample under plane-polarized light. Differences between the quartz-rich beds and clay-rich beds are apparent from porosity distribution. The pink epoxy highlights the intergranular porosity abundant in the quartz-rich beds and the fracture porosity is mainly observed within clay-rich structures.

Sample ID 13782, 100/04-23-076-08W6, 587.7 m

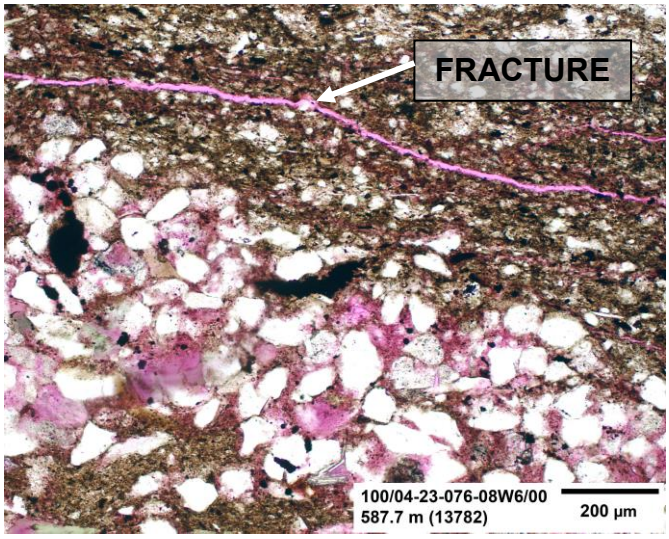

Figure 34: This figure is a medium magnification image of the sample under plane-polarized light. Porosity contributions differ depending on the lithology present. The brown clay-rich beds are often observed fractured. The lighter quartz-rich beds are often observed with intergranular porosity.

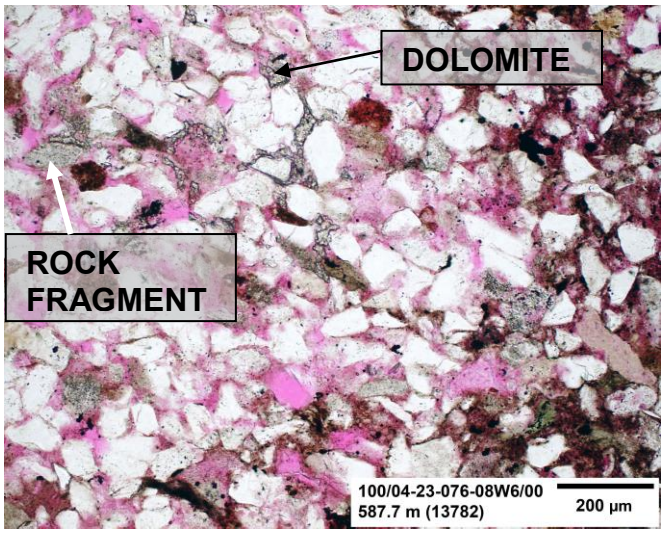

Figure 35: This figure is a medium magnification image of the sample under plane-polarized light. Dolomite cement is observed replacing some primary porosity in the sample. Rock fragments observed in the sample are identified as chert and illitic shale clasts.

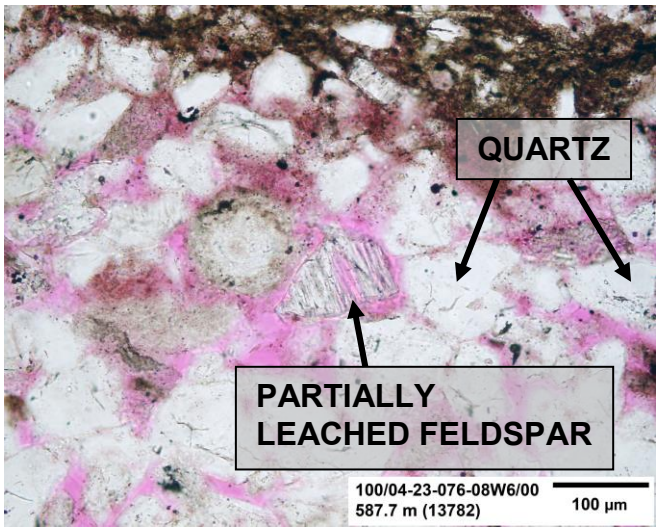

Figure 36: This figure is a high magnification image of the sample under plane-polarized light. The majority of the grains observed are identified as quartz grains. The feldspar in the center of the image has the characteristic cleavage of feldspar and is observed partially dissolved.

Sample ID	**13784**		**UWI**	**100/04-23-076-08W6/00**	
Map ID	**n/a**		**Depth**	**591.5 m**	
Strat. Unit	**n/a**				

Grain Size	**%**	**Variety (%)**	**Variety (%)**	**Variety (%)**	**Variety (%)**	**Variety (%)**
sand	5	quartz (80)	rock frag. (18)	feldspar (2)		
upper silt						
lower silt						
clay						
Cement	95	siderite (99)	dolomite (1)	ankerite (<1)		
Allochems						
Organics	<1	amorphous (100)				
Opaques	<1	pyrite (100)				
	100					

Sedimentary Structures

Primary	massively bedded
Biogenic	none observed

Fractures	trace fractures observed
Porosity	minor amount of intercrystalline porosity

Description

The rock sample is characterized as a sideritic mudstone. There are two lithologies present in this sample which are identified as a sideritic mudstone and a sublitharenite. The sideritic mudstone lithology accounts for 95% of the entire sample and is the dominant texture/lithology. Embedded throughout the matrix of the mudstone are angular quartz /feldspar grains and rounded dolomitic structures. The sublitharenite lithology has abundant intergranular porosity. There is no observable transition between the mudstone to sublitharenite lithologies. Trace organics observed randomly distributed throughout the sample.

Thin section Quality

Thickness of the section is consistent. Good quality. ½ stained for carbonates.

Rock Classification

sideritic mudstone (Dunham, 1971)
sideritic micrite (Folk, 1974)

Sample ID 13784, 100/04-23-076-08W6/00, 591.5 m

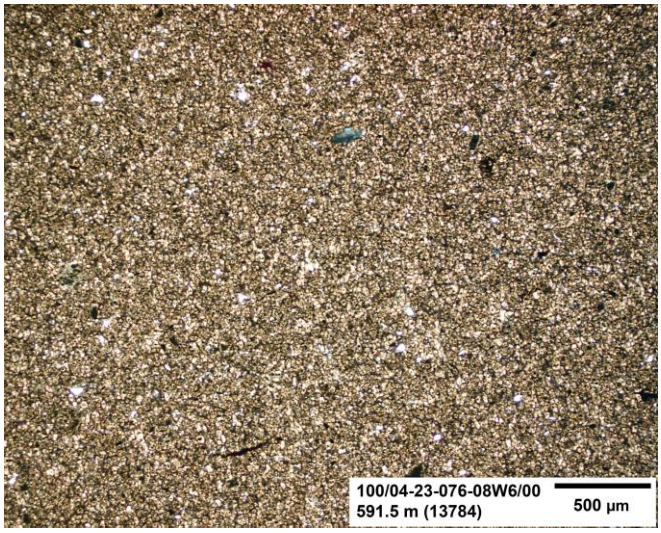

Figure 37: This figure is a low magnification image of the sample under plane-polarized light. This texture/lithology in the image is the dominant texture/lithology and accounts for 95% of the sample.

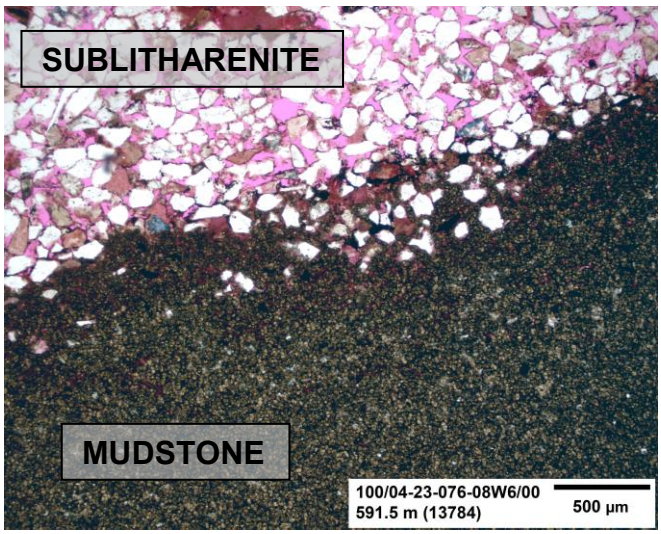

Figure 38: This figure is a low magnification image of the sample under plane-polarized light. Note the lack transition zone when the lithology changes from mudstone to sublitharenite.

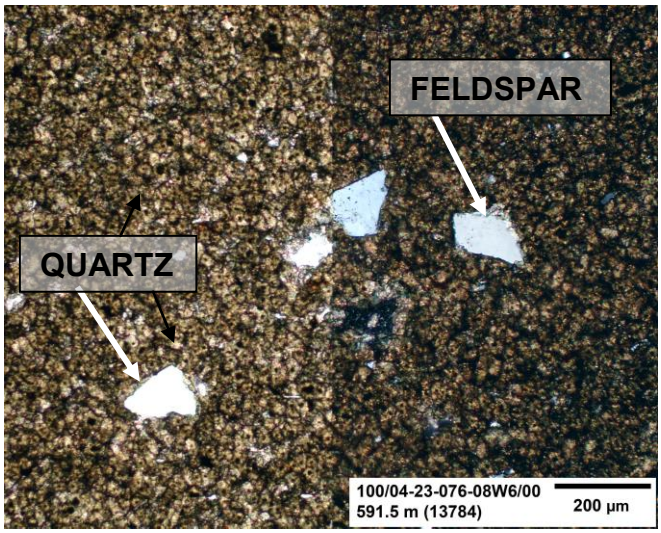

Figure 39: This figure is a medium magnification image of the sample under plane-polarized light (left) and cross-polarized light (right). Throughout the sideritic matrix are quartz and feldspar grains embedded throughout. There are no visible sedimentary structures observed in this matrix.

Sample ID 13784, 100/04-23-076-08W6/00, 591.5 m

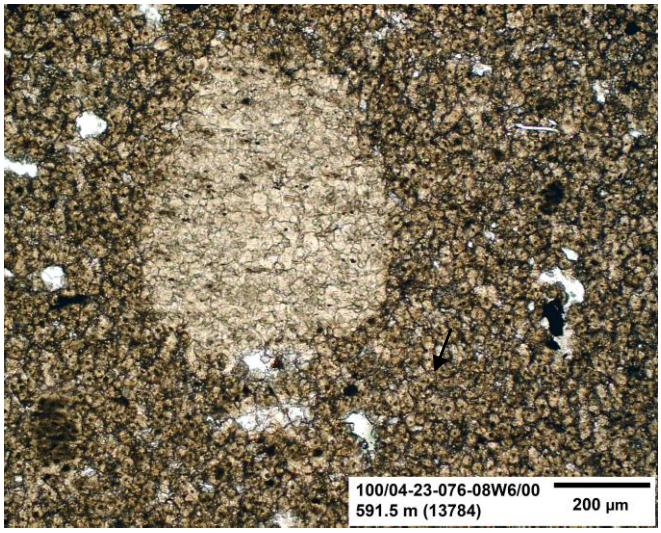

Figure 40: This figure is a high magnification image of the sample under plane-polarized light. There are rounded structures embedded within the matrix. Texturally they are different than the matrix and lighter colored and are composed of dolomite.

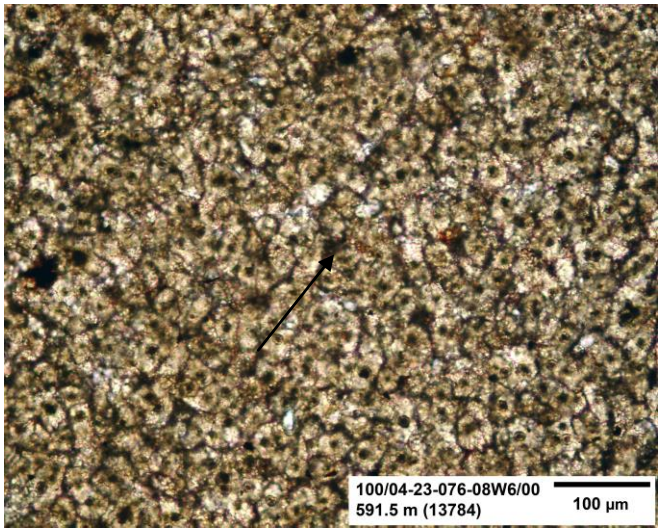

Figure 41: This figure is a high magnification image of the sample under plane-polarized light. The matrix is composed of tightly knit siderite crystals. Siderite crystals have the characteristic “flatten rhomb” appearance with a brownish color.

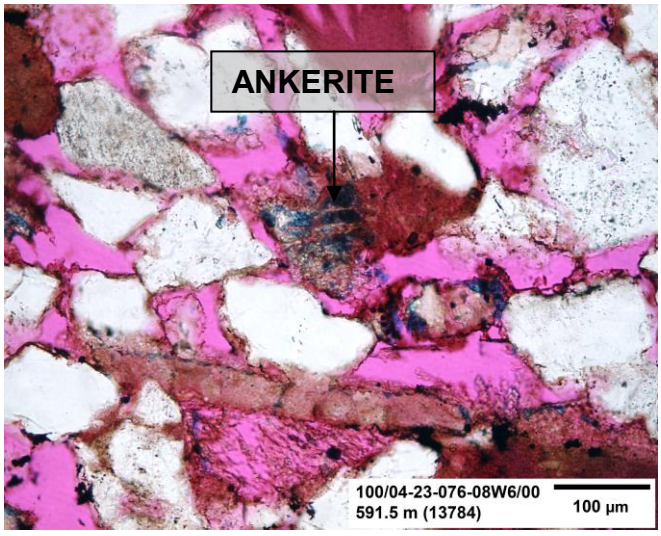

Figure 42: This figure is a high magnification image of the sample under plane-polarized light. This image shows the sublitharenite lithology. Quartz is the primary mineral associated with this lithology and also contains rock fragments and feldspar. Note the ankerite cement present replacing a mineral.

Sample ID	**13787**	**UWI**	**100/07-12-079-08W6/00**	
Map ID	**n/a**	**Depth**	**247.4 m**	
Strat. Unit	**n/a**			

Grain Size	**%**	**Variety (%)**	**Variety (%)**	**Variety (%)**	**Variety (%)**	**Variety (%)**
fine sand	5	quartz (85)	rock frag. (10)	feldspar (5)		
v. fine sand	82	quartz (86)	rock frag. (10)	feldspar (3)	mica (1)	
silt	1	quartz (100)				
clay	10	detrital clay (70)	kaolinite (30)			
Cement	2	ankerite (40)	quartz (60)			
Allochems						
Organics	<1	amorphous (100)				
Opaques	<1	pyrite (100)				
	100					

Roundness	subangular to subround
Sphericity	moderate
Sorting	well-sorted

Sedimentary Structures

Primary	wavy bedforms with clay-rich lenses
Biogenic	none observed

Fractures	natural fractures associated with clay-rich structures, approx. 2 to 3 fractures
Porosity	intergranular porosity main contributor observed

Description

The rock sample is characterized as a clayey sublitharenite that has wavy bedforms. Two textural features are observed, in which the main is a very-fine sand-sized, framework-supported texture and the minor is a silt-sized, clay-rich, matrix-supported texture. Quartz is the primary mineral observed in this rock sample. Cements observed in the sample mainly consist of ankerite and quartz. Organics associated with the clay-rich lithology are compacted and oriented to bedding.

Thin section Quality

Thickness of the section is consistent. Good quality. ½ stained for carbonates.

Rock Classification

clayey sublitharenite (Folk, 1974)

Sample ID 13787, 100/07-12-079-08W6/00, 247.4 m

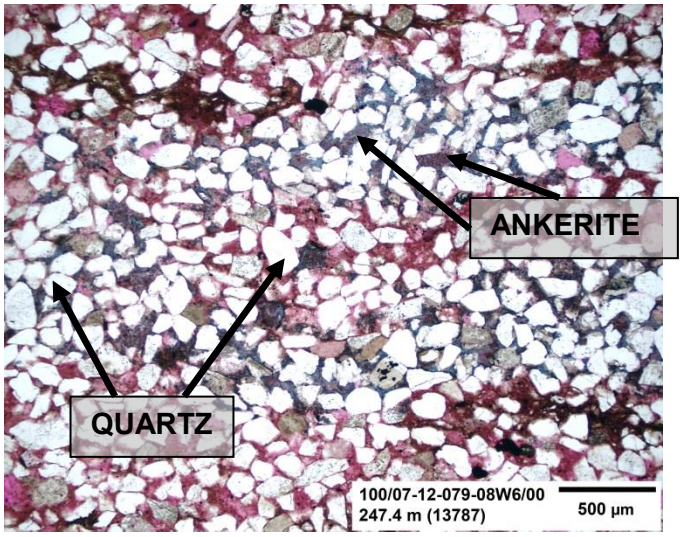

Figure 43: This figure is a low magnification image of the sample under plane-polarized light. The majority of grains in this sample are characterized as very-fine sand-sized quartz. Ankerite cement is observed in this image replacing primary porosity.

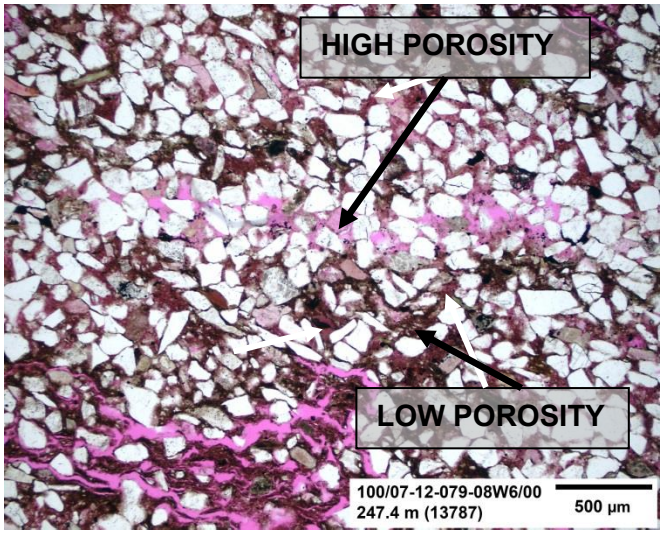

Figure 44: This figure is a low magnification image of the sample under plane-polarized light. Note the highly localized porosity as a result of heterogeneous replacement of pore spaces by clays, cements and ductile deformation of softer minerals. This reduces overall connectivity of the rock sample.

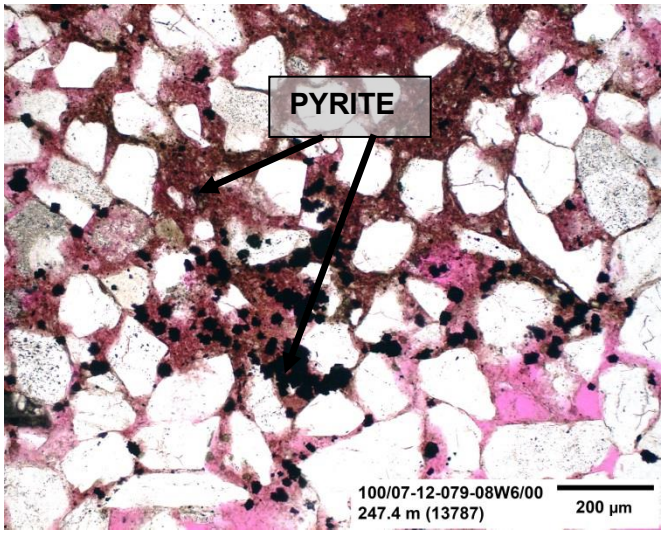

Figure 45: This figure is a medium magnification image of the sample under plane-polarized light. Pyrite is present as disseminated cubic forms replacing primary porosity.

Sample ID 13787, 100/07-12-079-08W6/00, 247.4 m

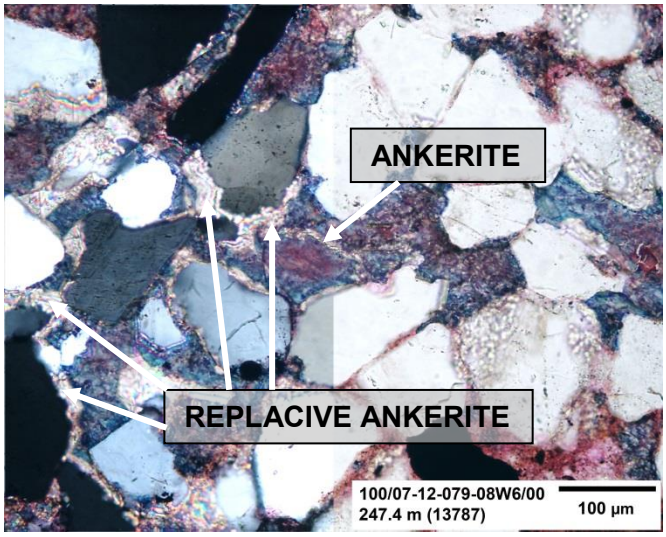

Figure 46: This figure is a high magnification image of the sample under cross-polarized light (left) and plane-polarized light (right). Ankerite cement is observed replacing the primary porosity in the sample. Closer examination of the grain boundaries of the framework grains shows highly birefringent lineations. This texture is commonly associated with mineral replacement and represents partial ankerite replacement of some framework grains.

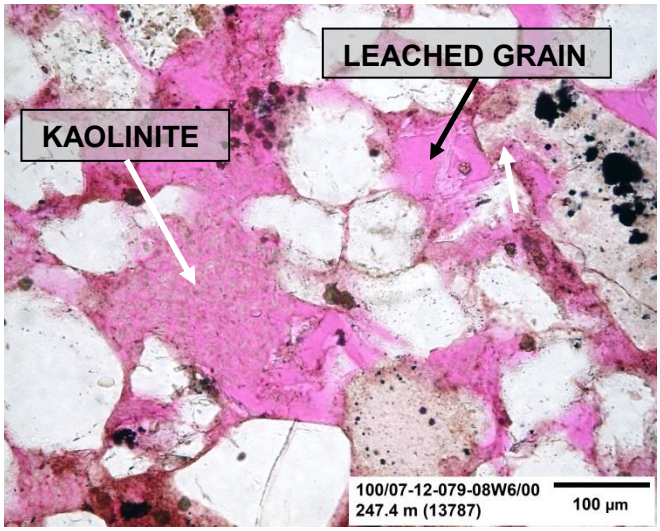

Figure 47: This figure is a high magnification image of the sample under plane-polarized. There are leached grains in this image where the secondary porosity of some has been completely replaced by authigenic kaolinite.

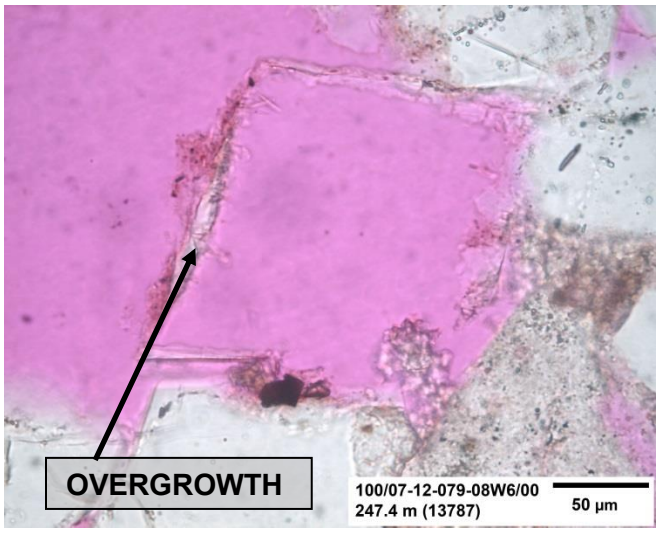

Figure 48: This figure is a high magnification image of the sample under plane-polarized light. Note the intact overgrowth and the leached host grain. Compositional differences between the host mineral and overgrowth may explain the preferential dissolution of the host mineral over the overgrowth.

Sample ID	**15167**	**UWI**	**100/08-06-072-01W6/00**
Map ID	**n/a**	**Depth**	**812.3 m**
Strat. Unit	**n/a**		

Grain Size	**%**	**Variety (%)**	**Variety (%)**	**Variety (%)**	**Variety (%)**	**Variety (%)**
fine sand	1	quartz (80)	feldspar (20)			
v. fine sand	80	quartz (77)	rock frag. (15)	feldspar (5)	mica (3)	glauconite (<1)
silt	5	quartz (90)	feldspar (10)			
clay	10	kaolinite (50)	detrital (50)			
Cement	1	quartz (100)				
Allochems						
Organics	3	amorphous (90)	plant material (10)			
Opaques	<1	pyrite (100)				
	100					

Roundness	subangular to subround
Sphericity	moderate
Sorting	well-sorted

Sedimentary Structures

Primary	lightly laminated with wavy bedforms
Biogenic	none observed

Fractures	associated with clay-rich structures
Porosity	intergranular porosity main contributor with minor secondary porosity

Description

The rock sample is characterized as a clayey litharenite. Very-fine sand-sized grains are the dominant grain-size in which the majority is identified as quartz. The majority of the sedimentary structures are observed as multiple weak laminations of wavy bedforms. Angularity of the grains is mainly attributed to the overgrowths observed surrounding the detrital grain and is the most abundant cement observed in this rock sample. Rock samples are identified as chert, metamorphic rock fragments (MRF) and clay clasts. Only trace amounts of organic material are observed in the sample. Porosity contributions are primarily intergranular with minor amounts attributed to fracture porosity.

Thin section Quality

Thickness of the section is consistent. Good quality. ½ stained for carbonates.

Rock Classification

clayey litharenite (Folk, 1974)

Sample ID 15167, 100/08-06-072-01W6/00, 812.3 m

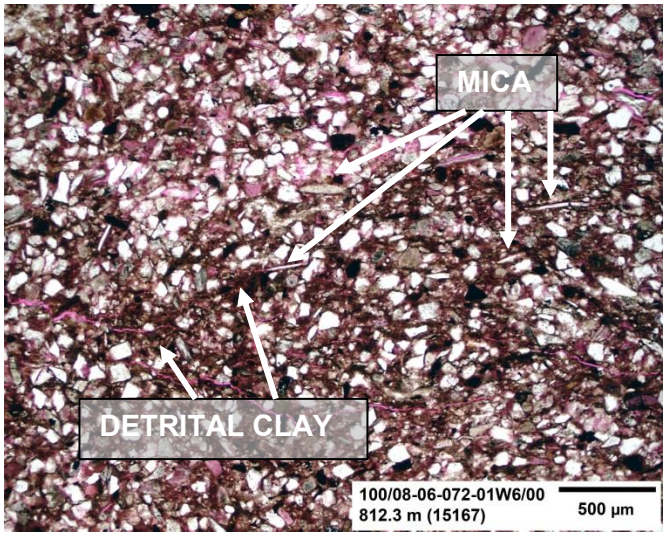

Figure 49: This figure is a low magnification image of the sample under plane-polarized light. The matrix in the bottom half of the image consists of clay. Mica grains embedded in this argillaceous matrix are oriented parallel to one another indicating detrital deposition.

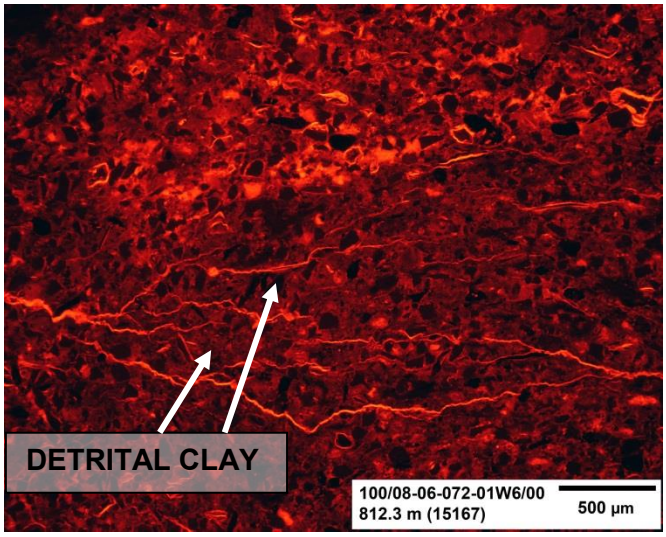

Figure 50: This figure is a low magnification image of the sample under ultra-violet light. Fracture porosity is concentrated in the portions of the rock common with clay.

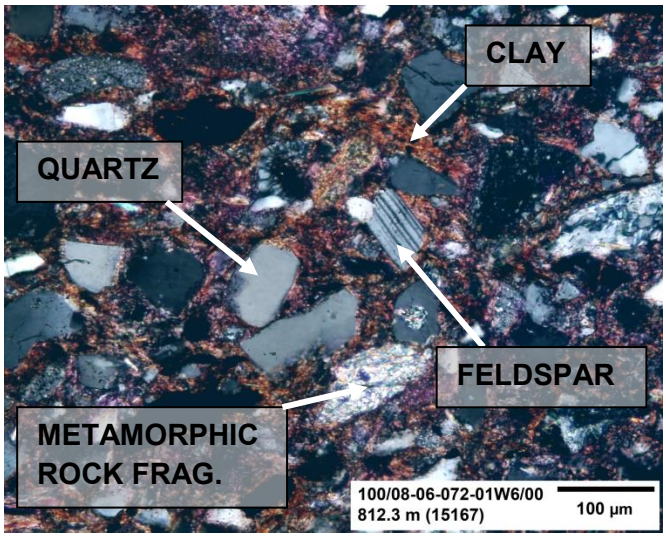

Figure 51: This figure is a high magnification image of the sample under cross-polarized light. There is a variety of minerals present in this image and have been annotated. The metamorphic rock fragment in the image consists almost entirely of muscovite and isidentified as a micaceous schist.

Sample ID 15167, 100/08-06-072-01W6/00, 812.3 m

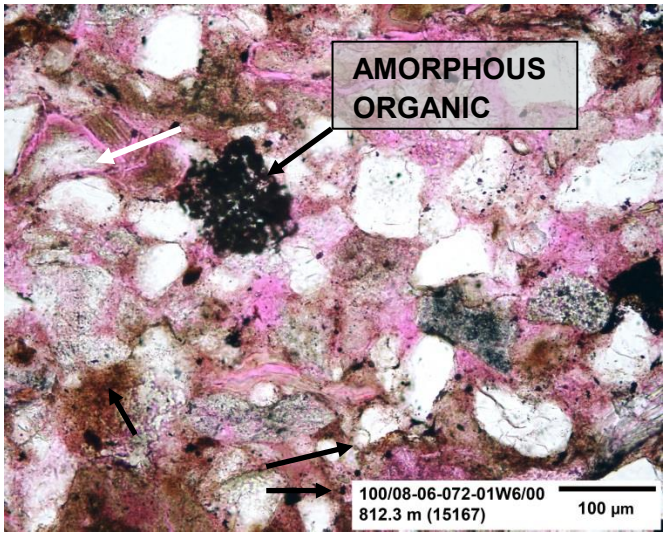

Figure 52: This figure is a high magnification image of the sample under plane-polarized light. The majority of the pores are partially replaced by clays/fines which reduces overall porosity/permeability. There is an amorphous organic component also present

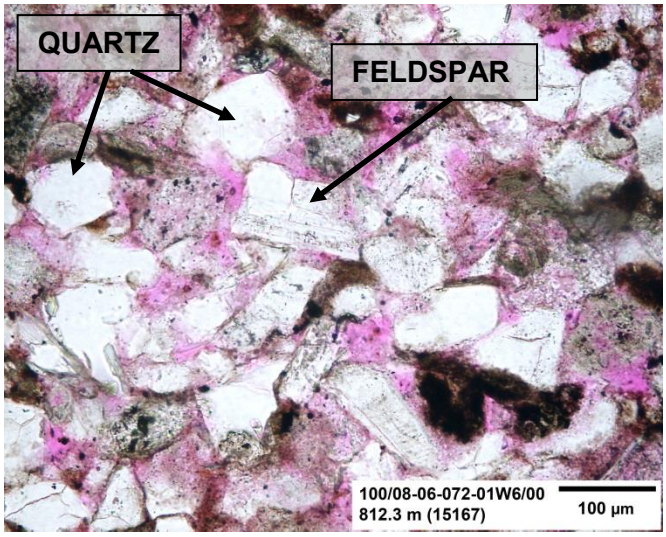

Figure 53: This figure is a high magnification image of the sample under plane-polarized light. Quartz and feldspar grains are identified in the image and are characterized as subangular to subrounded and well-sorted.

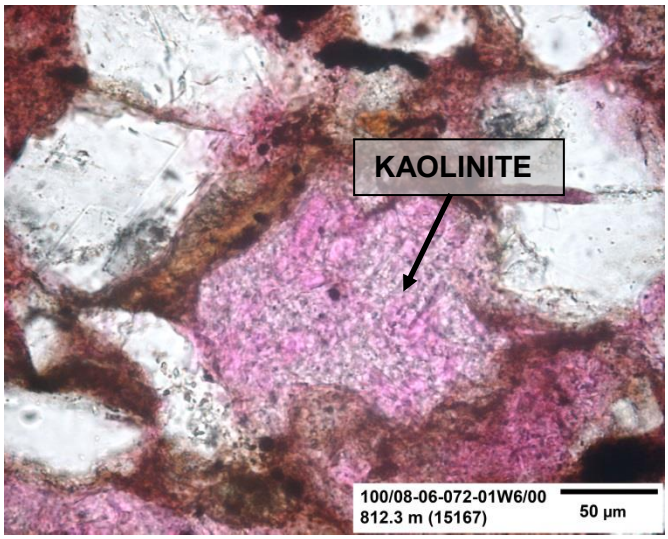

Figure 54: This figure is a high magnification image of the sample under plane-polarized light. The leached grain in the center of the image has been replaced by authigenic kaolinite.

Sample ID	**15170**	**UWI**	**100/08-06-072-01W6/00**
Map ID	**n/a**	**Depth**	**826.9 m**
Strat. Unit	**n/a**		

Grain Size	**%**	**Variety (%)**	**Variety (%)**	**Variety (%)**	**Variety (%)**	**Variety (%)**
sand	1	mica (100)				
upper silt	10	quartz (89)	mica (10)	feldspar (1)		
lower silt	73	quartz (89)	mica (10)	feldspar (1)		
clay	10	kaolinite (10)	detrital (90)			
Cement	1	quartz (90)	dolomite (10)			
Allochems						
Organics	5	amorphous (100)				
Opaques	1	pyrite (100)				
	100					

Roundness	subround
Sphericity	moderate to high
Sorting	well-sorted

Sedimentary Structures

Primary	laminated with clay-rich/quartz-rich lenses
Biogenic	none

Fractures	artificial and natural fractures observed with an estimated 20+ fractures
Porosity	intergranular porosity main contributor and associated with quartz-rich beds

Description

The rock sample is characterized as a laminated clayey siltstone. Throughout the sample beds/lenses of clay-rich/quartz-rich lithologies are observed forming a laminated structure. Quartz and mica are the main detrital grains observed in the sample. Clays are the second most abundant component and are mainly identified as detrital in origin. Organics are commonly observed and found compacted and oriented parallel to bedding.

Thin section Quality

Thickness of the section is consistent with minor pluck out of clays. Average quality.

Rock Classification

clayey siltstone (Folk, 1974)

Sample ID 15170, 100/08-06-072-01W6/00, 826.9 m

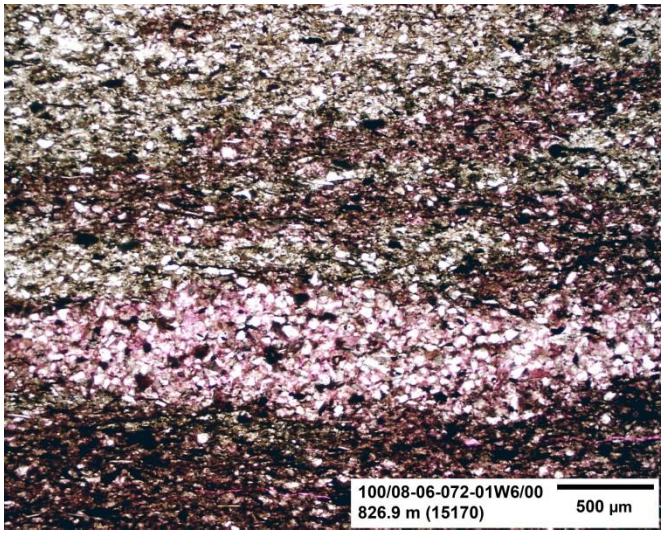

Figure 55: This figure is a low magnification image of the sample under plane-polarized light. The quartz-rich lens in the image is easily distinguished due to its high amount of intergranular porosity. The clay-rich structures in this image have a high amount of fracture porosity.

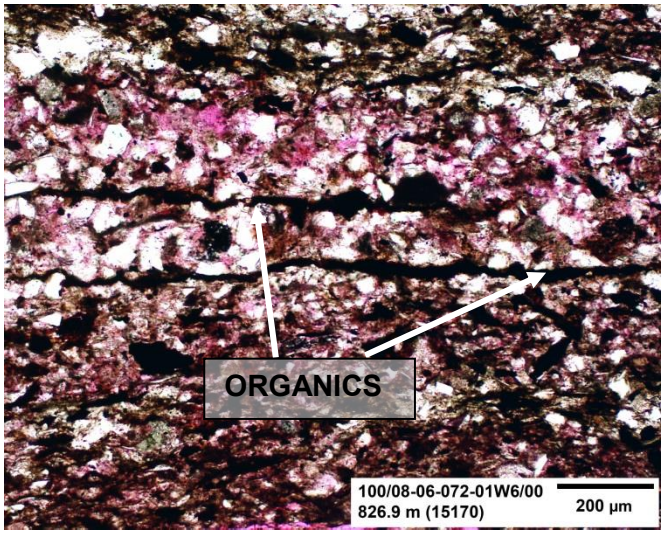

Figure 56: This figure is a medium magnification image of the sample under plane-polarized light. The organics in the image have been compacted and flatten parallel to bedding.

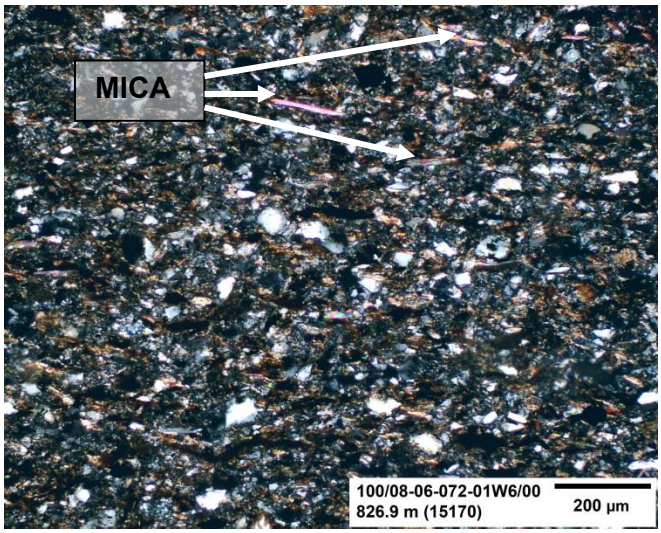

Figure 57: This figure is a medium magnification image of the sample under cross-polarized light. The mica in this sample is often observed coarser-grained to the quartz and feldspar in this rock sample. Quartz and feldspar are observed to be predominately silt-sized.

Sample ID 15170, 100/08-06-072-01W6/00, 826.9 m

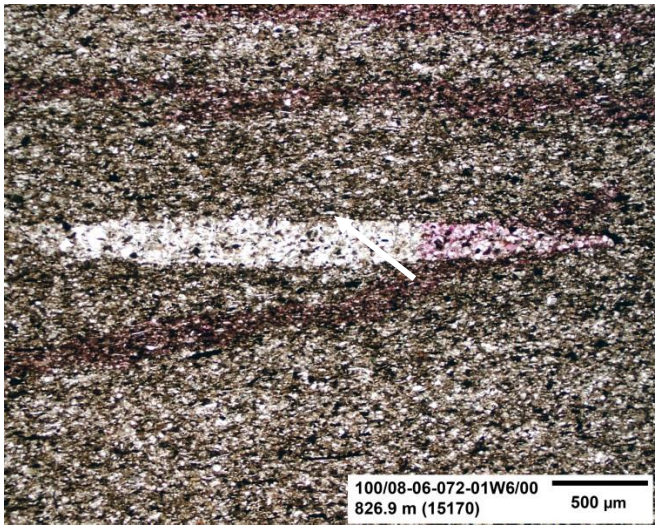

Figure 58: This figure is a low magnification image of the sample under plane-polarized light. Isolated in the clay-rich structure is a quartz-rich lens. Note the intergranular porosity associated with the quartz-rich lens.

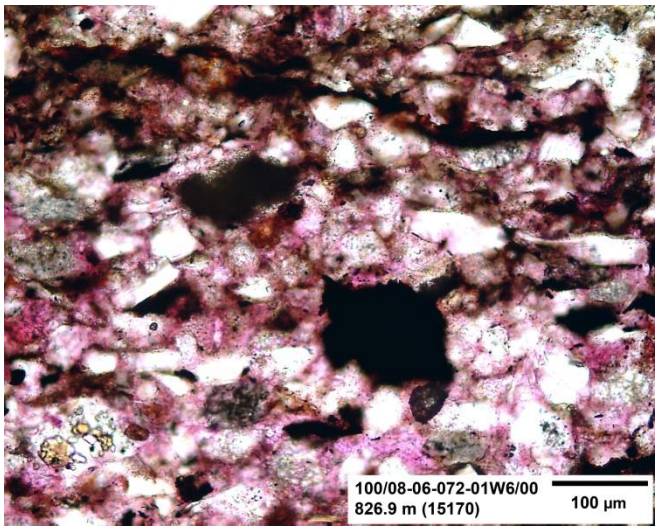

Figure 59: This figure is a high magnification image of the sample under plane-polarized light. The organic component can be difficult to distinguish from the opaque minerals under plane-polarized light. Note the different morphologies of the organics in this image.

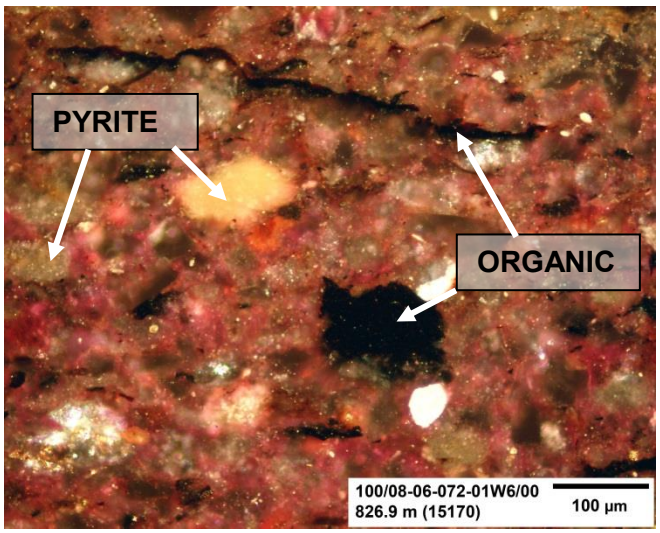

Figure 60: This figure is a high magnification image, as in Figure 59, of the sample under reflected light Note how pyrite is easily differentiated from the organic material in reflected light.

Sample ID	**15172**	**UWI**	**100/14-22-072-10W6/00**
Map ID	**n/a**	**Depth**	**1133.5 m**
Strat. Unit	**n/a**		

Grain Size	**%**	**Variety (%)**	**Variety (%)**	**Variety (%)**	**Variety (%)**	**Variety (%)**
fine sand	10	quartz (50)	rock frag. (30)	feldspar (10)	mica (10)	
v. fine sand	49	quartz (62)	rock frag. (30)	feldspar (5)	mica (3)	gluaconite (<1)
upper silt	30	quartz (62)	rock frag. (30)	feldspar (5)	mica (3)	glauconite (<1)
lower silt	10	quartz (80)	mica (20)			
clay	8	kaolinite (10)	detrital (90)			
Cement	<1	ankerite (40)	quartz (60)			
Organics	3	amorphous (100)				
Opaques	<1	pyrite (100)				
	100					

Roundness	angular to subangular
Sphericity	low to moderate
Sorting	moderately-sorted

Sedimentary Structures

Primary	laminated with some wavy cross-beds
Biogenic	none observed

Fractures	natural fractures associated with clay-rich structures
Porosity	intergranular porosity associated with quartz-rich beds

Description

The rock sample is characterized as a silty litharenite that has thin planar laminations as well as wavy bedforms. The bedforms observed in the sample are mainly characterized by grain-sizes. Silt-sized grains are observed forming well-sorted planar beds and are associated with clays. Sand-sized beds are also observed and commonly forming moderately-sorted beds. Sand-sized beds are commonly associated with mica, rock fragments and feldspars. Rock fragments consist of chert, illitic shale clasts and other clay clasts. Organic fragments are commonly observed embedded in the matrix and are commonly observed compacted and oriented to bedding.

Thin section Quality

Thickness of the section is consistent but has minor pluckout. Average quality. ½ stained for carbonates.

Rock Classification

silty litharenite (Folk, 1974)

Sample ID 15122, 100/14-22-072-10W6/00, 1133.5 m

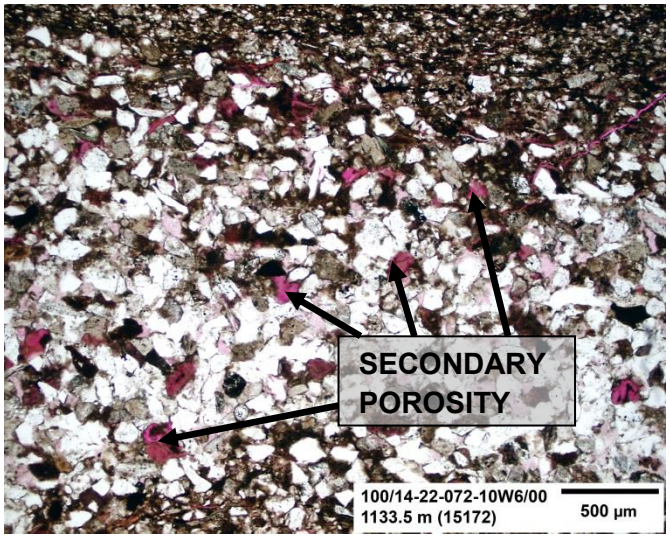

Figure 61: This figure is a low magnification image of the sample under plane-polarized light. The majority of the image focuses on the quartz-rich bed where the majority of the porosity is attributed to secondary porosity.

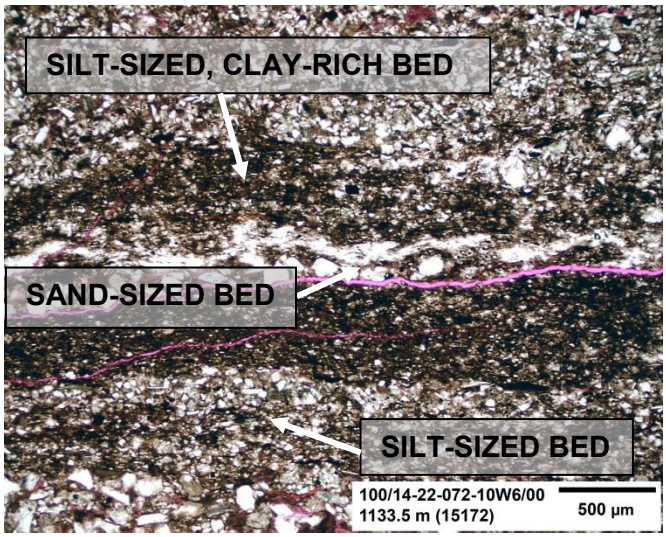

Figure 62: This figure is a low magnification image of the sample under plane-polarized light. Note the laminated bedforms in the image consisting of a silt-sized clay-rich bed, silt-sized bed and sand-sized bed. Fracture porosity is associated with the silt-sized beds and especially with the silt-sized clay-rich beds.

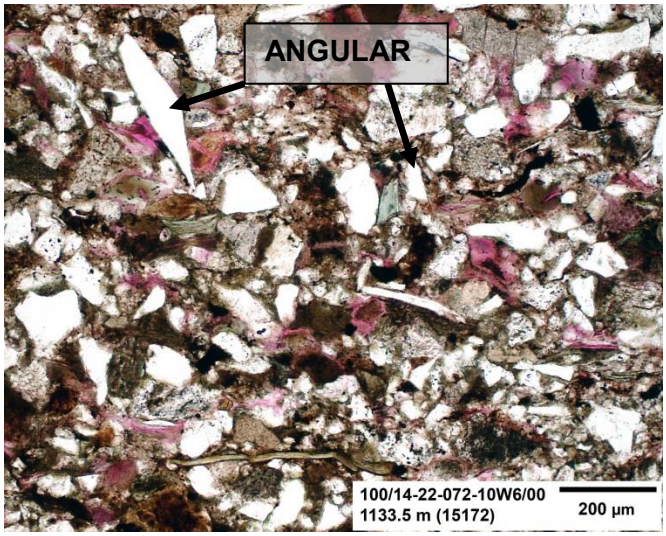

Figure 63: This figure is a medium magnification image of the sample under plane-polarized light. This image highlights textures commonly observed in the rock sample. Note the angular grains with low sphericity and moderate-sorting. This sand-sized- bed is texturally immature.

Sample ID 15122, 100/14-22-072-10W6/00, 1133.5 m

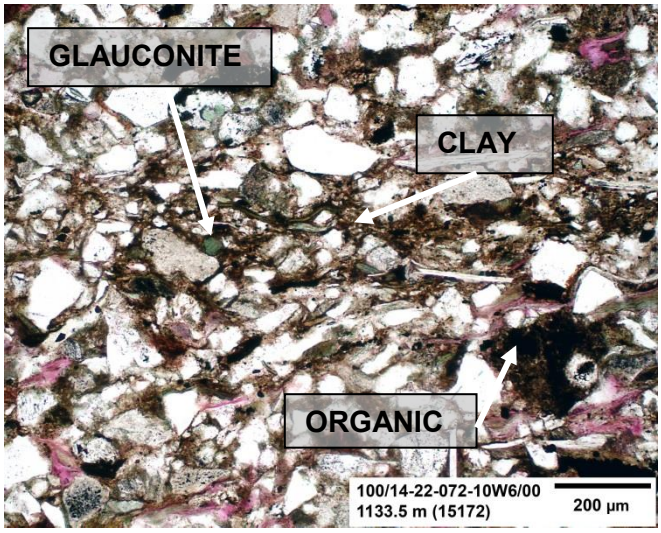

Figure 64: This figure is a medium magnification image of the sample under plane-polarized light. The image illustrates the dominant texture observed in this rock sample which is a very-fine sand-sized texture that is quartz-rich. Identified in this image are organic fragments, glauconite and clays.

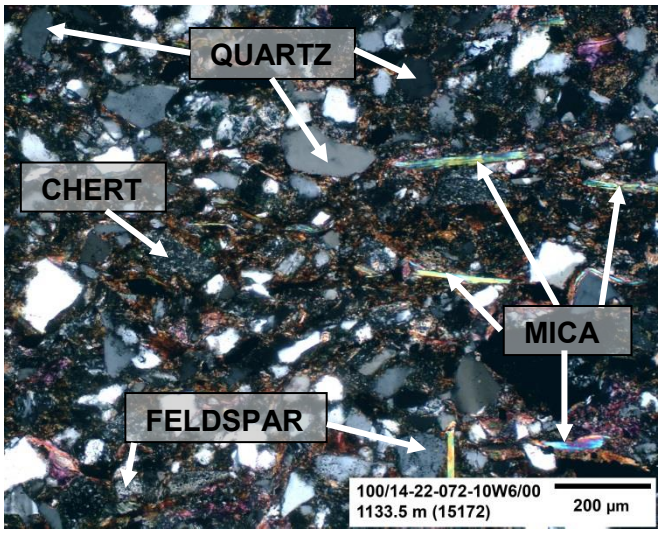

Figure 65: This figure is a medium magnification image of the sample, as in Figure 64, under cross-polarized light. Under cross-polarized light distinct properties of certain minerals are more readily apparent. Minerals identified are chert, quartz, feldspar and mica.

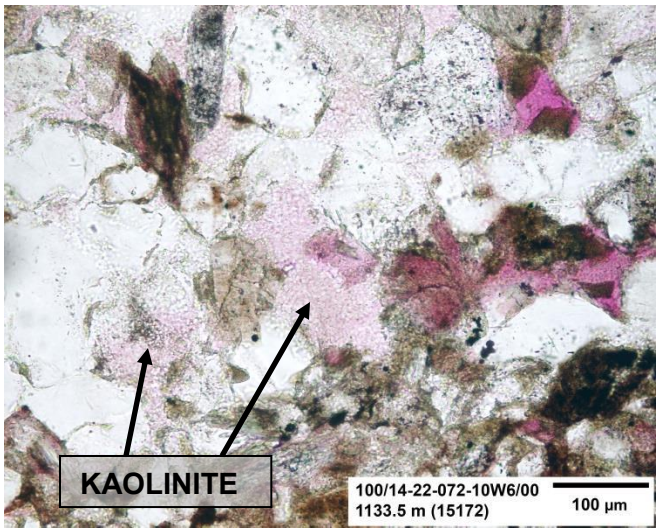

Figure 66: This figure is a high magnification image of the sample under plane-polarized light. The pores in this image have been replaced by authigenic kaolinite.

Sample ID	**15176**	**UWI**	**100/08-07-057-03W6/00**
Map ID	**n/a**	**Depth**	**3200.7 m**
Strat. Unit	**n/a**		

Grain Size	**%**	**Variety (%)**	**Variety (%)**	**Variety (%)**	**Variety (%)**	**Variety (%)**
v. fine sand	70	quartz (62)	rock frag. (30)	feldspar (5)	mica (3)	
upper silt	5	quartz (97)	mica (3)			
lower silt	10	quartz (90)	feldspar (10)			
clay	10	detrital (100)				
Cement	1	quartz (100)				
Allochems						
Organics	3	amorphous (90)	plant material (10)			
Opaques	1	pyrite (100)				
	100					

Roundness	subround to subangular
Sphericity	moderate
Sorting	moderate to well-sorted

Sedimentary Structures

Primary	laminated
Biogenic	none observed

Fractures	associated with clay-rich structures
Porosity	secondary porosity with minor intergranular porosity

Description

The rock sample is characterized as a clayey litharenite. Very-fine sand-sized grains are the dominant grain-size in which the majority is identified as quartz. The majority of the sedimentary structures are attributed to compaction. Some of these features are observed as clay-rich matrix that is undergoing ductile deformation around quartz-rich clasts giving an appearance of a “mylonitic” texture. The majority of the very-fine sand-sized components are observed associated with secondary porosity. The clay-rich component is mainly associated with fracture porosity. Organic fragments are commonly observed embedded in the matrix and commonly observed compacted and oriented to bedding.

Thin section Quality

Thickness of the section is consistent and has pluck out. Average quality.

Rock Classification

clayey litharenite (Folk, 1974)

Sample ID 15176, 100/08-07-057-03W6/00, 3200.7 m

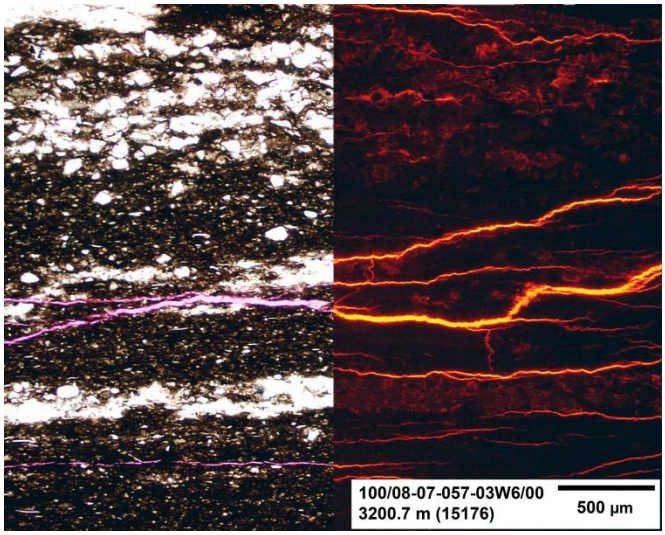

Figure 67: This figure is a low magnification image of the sample under both plane-polarized light (left) and ultra-violet light (right). The brown clay-rich bedding is associated with fracture porosity. The lighter quartz-rich layers are associated with secondary porosity.

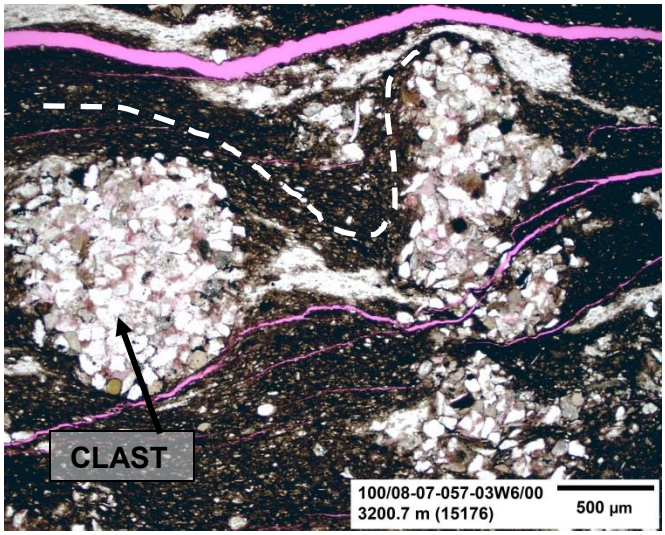

Figure 68: This figure is a low magnification image of the sample under plane-polarized light. Note the detrital clay matrix undergoing ductile deformation around the clast in the image.

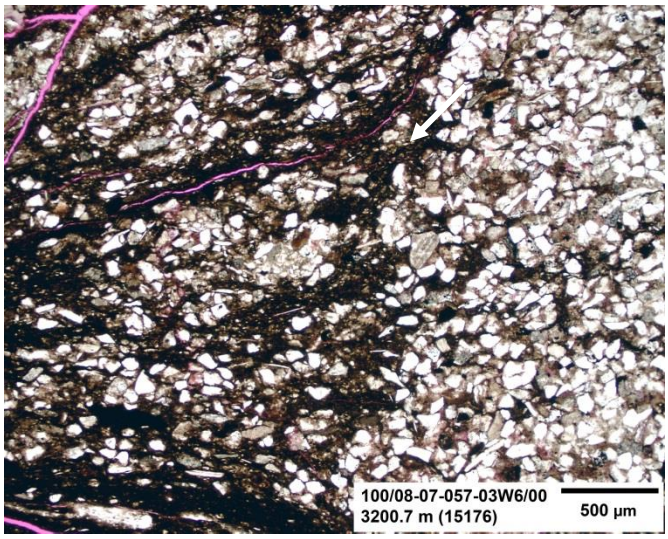

Figure 69: This figure is a low magnification image of the sample under plane-polarized light. The primary mineral observed in this sample is very-fine sand-sized quartz grains. Organic components can occasionally obscure the argillaceous components which can cause misidentification.

Sample ID 15176, 100/08-07-057-03W6/00, 3200.7 m

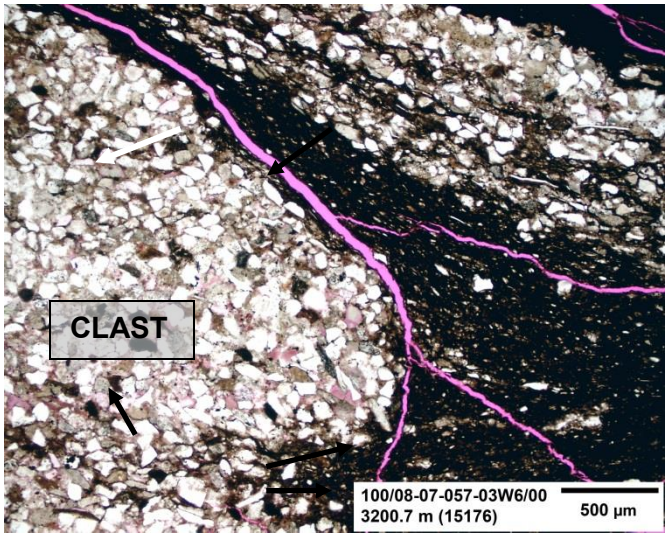

Figure 70: This figure is a low magnification image of the sample under plane-polarized light. Note the fracture porosity associated with the clay-rich matrix that traces around the clast. The clast is associated with secondary porosity.

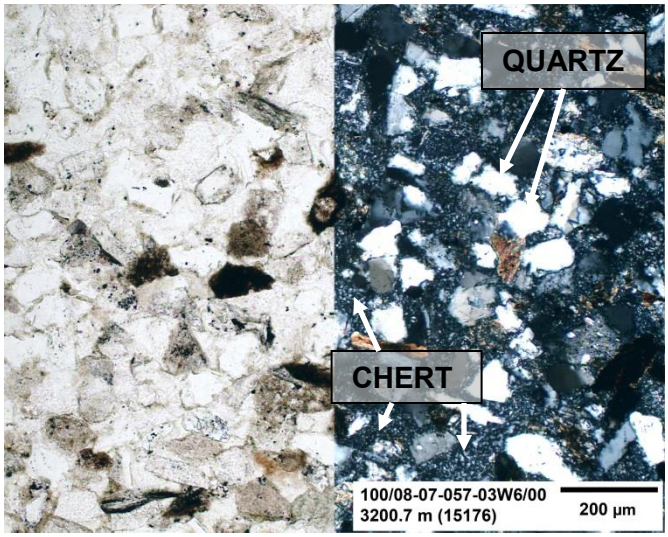

Figure 71: This figure is a medium magnification image of the sample under plane-polarized light (left) and cross-polarized light (right). Quartz and chert grains are both composed of silica and cannot be differentiated from XRD analysis. Under cross-polarized light chert is differentiated from quartz by its microcrystalline cryptocrystalline texture.

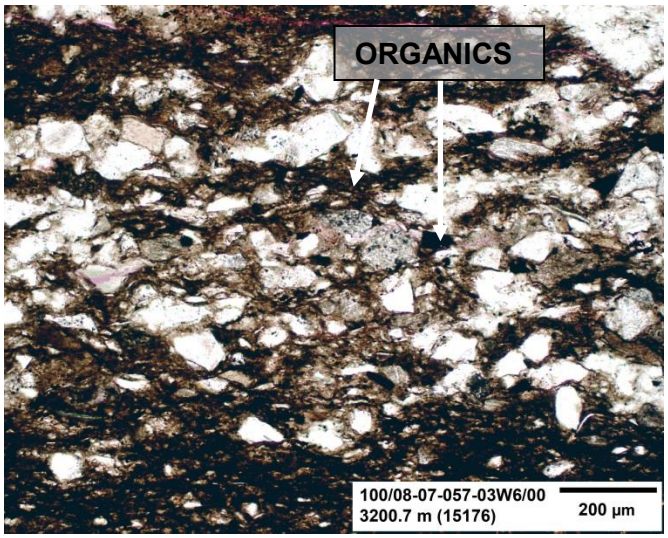

Figure 72: This figure is a medium magnification image of the sample under plane-polarized light. Organic components observed in this sample have compacted and oriented parallel to bedding.

Sample ID	**15177**	**UWI**	**100/08-07-057-03W6/00**	
Map ID	**n/a**	**Depth**	**3204.9 m**	
Strat. Unit	**n/a**			

Grain Size	**%**	**Variety (%)**	**Variety (%)**	**Variety (%)**	**Variety (%)**	**Variety (%)**
sand						
upper silt	40	quartz (57)	rock frag. (30)	mica (10)	feldspar (3)	phosphate (<1)
lower silt	17	quartz (87)	mica (10)	feldspar (3)		
clay	30	detrital (100)				
Cement	5	ankerite (70)	dolomite (30)			
Allochems						
Organics	6	amorphous (100)				
Opaques	2	pyrite (100)				
	100					

Roundness	subangular to subround
Sphericity	moderate
Sorting	moderate to well-sorted

Sedimentary Structures

Primary	laminated beds with cross-bedding and lenses
Biogenic	none

Fractures	natural fractures associated with lower silt-rich beds, estimated >20 fractures
Porosity	fracture porosity main contributor

Description

The rock sample is characterized as a laminated clayey siltstone. Throughout the sample beds/lenses of clay-rich/quartz-rich lithologies are observed forming a laminated structure. Quartz and rock fragments are the main detrital grains observed in the sample. Clays are the second most abundant component and are mainly classified as detrital. Ankerite cement is also observed in minor amounts and is associated with upper silt-sized beds. Organics are commonly observed concentrated in the lower silt-rich beds and are found compacted/oriented parallel to bedding.

Thin section Quality

Thickness of the section is consistent with minor pluck out of clays. Average quality. ½ stained for carbonates.

Rock Classification

clayey siltstone (Folk, 1974)

Sample ID 15177, 100/08-07-057-03W6/00, 3204.9 m

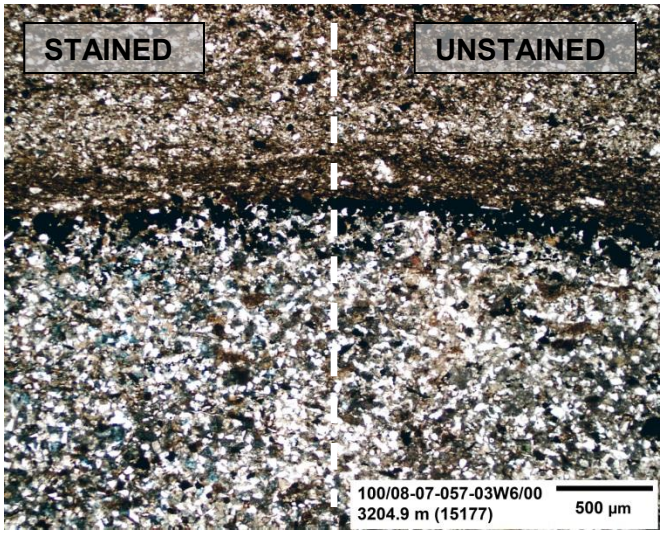

Figure 73: This figure is a low magnification image of the sample under plane-polarized light. This sample has been half-stained with double carbonate stain. Ankerite cement (stained blue) is readily identifiable on the left side of the image.

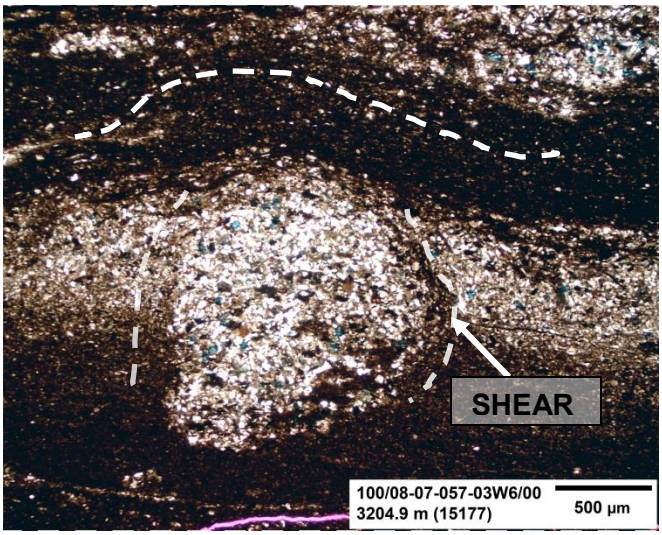

Figure 74: This figure is a low magnification image of the sample under plane-polarized light. Features within this image show elements of strain/shearing. Strain is observed within the clay-rich beds above and below the clast which are identified as signs of ductile deformation around the clast. Shear is present as clast rotation and is observed as a clay-rich "rim" partially surrounding the quartz-rich clast.

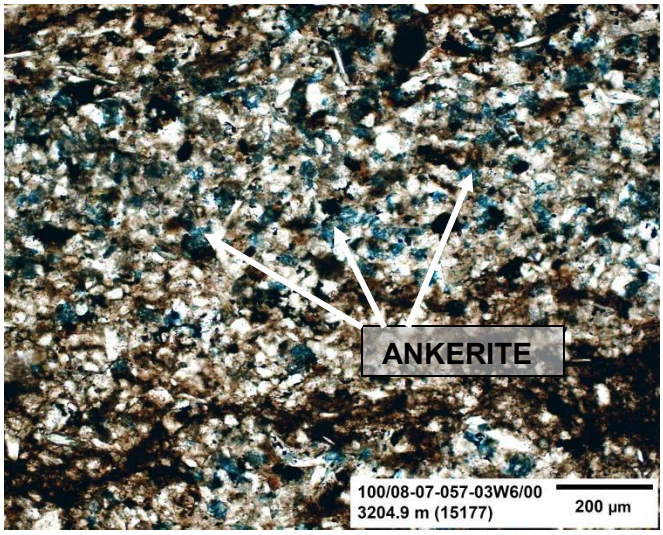

Figure 75: This figure is a medium magnification image of the sample under plane-polarized light. Ankerite cement is observed replacing the primary porosity within the upper silt-rich beds.

Sample ID 15177, 100/08-07-057-03W6/00, 3204.9 m

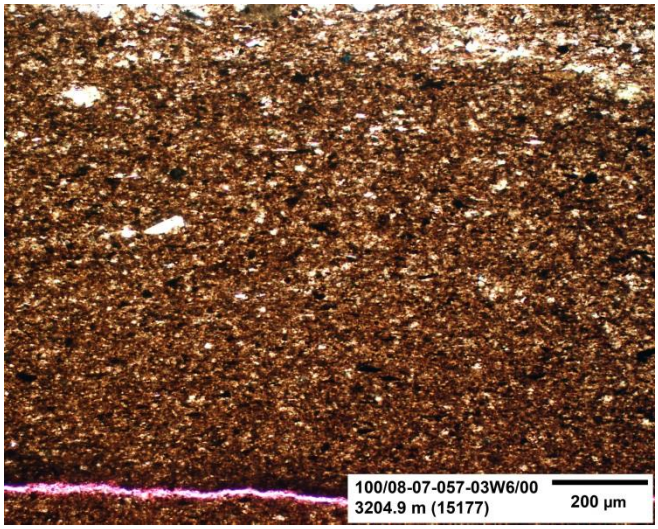

Figure 76: This figure is a medium magnification image of the sample under plane-polarized light. This image shows the texture commonly associated with the clay-rich beds observed within this sample.

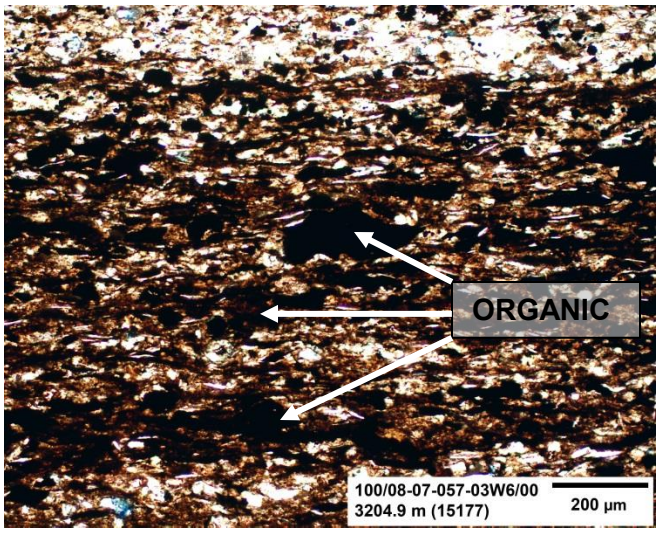

Figure 77: This figure is a medium magnification image of the sample under plane-polarized light. This image shows the texture commonly associated with beds containing well-sorted, lower silt-rich grains. Note the organic material that has been compacted and oriented parallel to bedding. Organic material appears to be concentrated preferentially with the lower silt-rich beds.

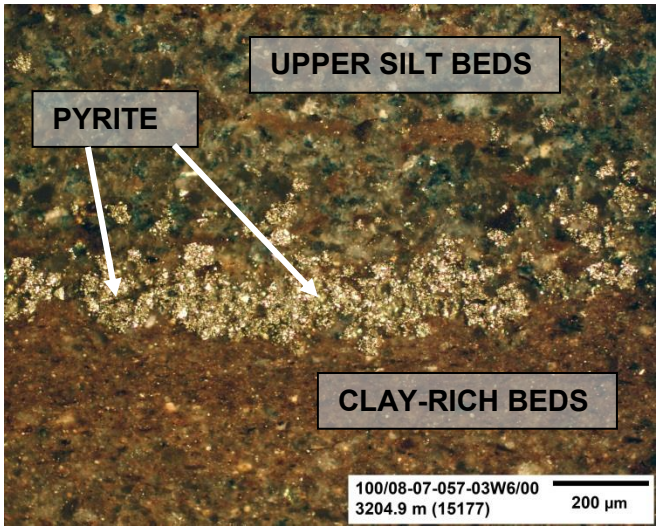

Figure 78: This figure is a medium magnification image of the sample under reflected light. This picture shows the interface between a bed containing well-sorted upper silt-rich grains and clay-rich beds. Note how the contact layer is concentrated with pyrite.

Sample ID	**15180**	**UWI**	**100/03-30-073-12W6/00**
Map ID	**n/a**	**Depth**	**938.1 m**
Strat. Unit	**n/a**		

Grain Size	**%**	**Variety (%)**	**Variety (%)**	**Variety (%)**	**Variety (%)**	**Variety (%)**
v. fine sand	60	quartz (74)	rock frag. (20)	feldspar (5)	mica (1)	
upper silt	20	quartz (76)	rock frag. (20)	feldspar (3)	mica (1)	glauconite (<1)
lower silt	10	quartz (70)	rock frag. (30)			
clay	8	detrital clay (70)	kaolinite (30)			
Cement	2	siderite (40)	quartz (60)			
Allochems						
Organics	1	amorphous (100)				
Opaques	1	pyrite (100)				
	100					

Roundness	subangular to subround
Sphericity	high
Sorting	well-sorted

Sedimentary Structures

Primary	wavy bedding with clay-rich lenses
Biogenic	bioturbation traces observed

Fractures	micro-fractures associated with clays
Porosity	intergranular porosity with minor secondary porosity

Description

The rock sample is characterized as a clayey litharenite that has wavy bedforms. The texture of this rock sample is characterized as a very-fine sand-sized, framework-supported texture with quartz and rock fragments as the primary components. Rock fragments have been identified as dolomitic clasts, chert and illitic shale clasts. Clay is observed distributed heterogeneously throughout the sample. Cements observed in the sample mainly consist of siderite and quartz. Organics are observed compacted and oriented to bedding.

Thin section Quality

Thickness of the section is slightly thick. Good quality. ½ stained for carbonates.

Rock Classification

clayey litharenite (Folk, 1974)

Sample ID 15180, 100/03-30-073-12W6/00, 938.1 m

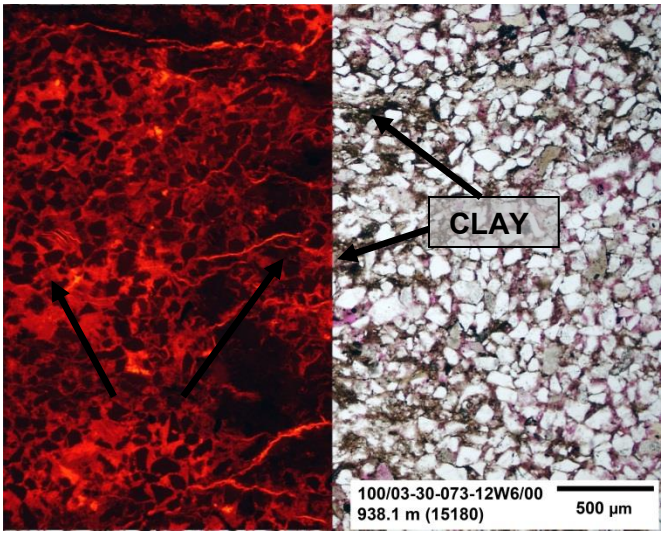

Figure 79: This figure is a low magnification image of the sample under plane-polarized light (right) and ultra-violet light (left). Small discontinuous micro-fractures are observed within the matrix and associated with clays.

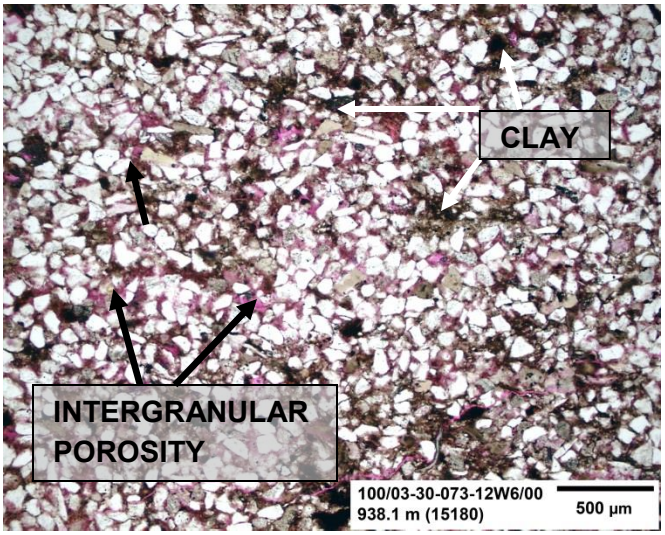

Figure 80: This figure is a low magnification image of the sample under plane-polarized light. Note the highly localized porosity as a result of heterogeneous replacement of pore spaces by clays, cements and ductile deformation of softer minerals. This reduces overall connectivity of the rock sample.

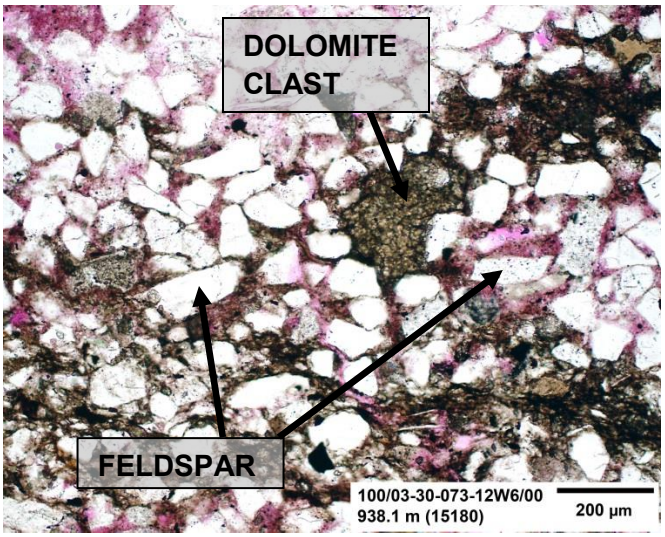

Figure 81: This figure is a medium magnification image of the sample under plane-polarized light. Other grains present in this sample are feldspars and dolomite clasts. Feldspar can be difficult to differentiate from quartz. Identifying features of feldspar are mainly rectangular crystal form and visible chemical alterations common to feldspars (sceritization and vacuolization).

Sample ID 15180, 100/03-30-073-12W6/00, 938.1 m

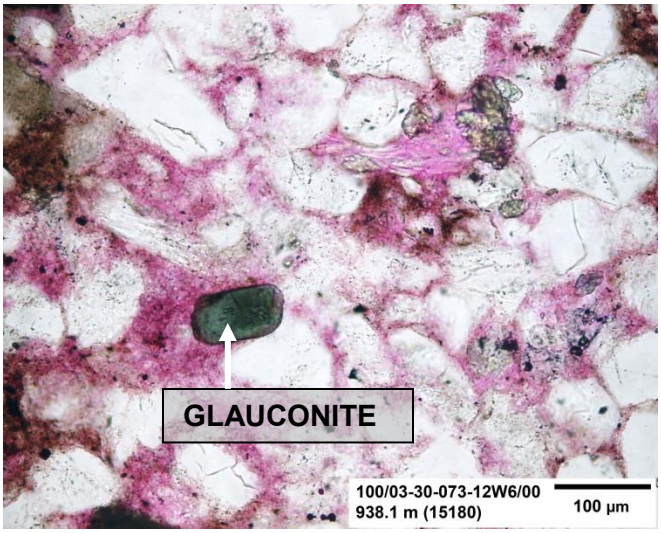

Figure 82: This figure is a high magnification image of the sample under plane-polarized light. This image is taken within a bioturbation trace, note the glauconite pellet observed.

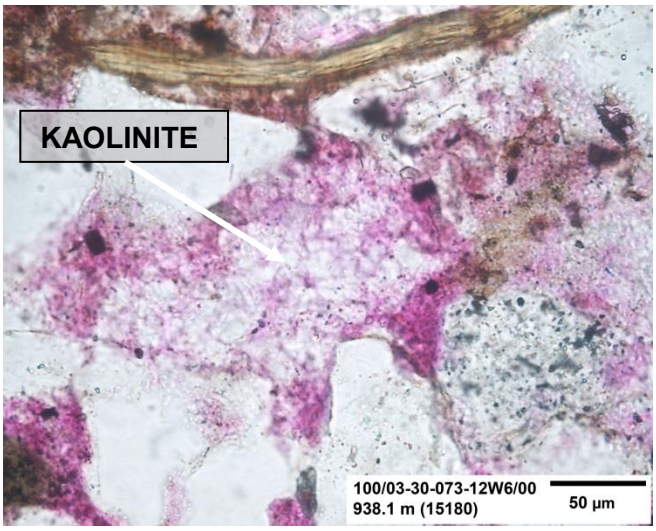

Figure 83: This figure is a high magnification image of the sample under plane-polarized. There are completely dissolved grains in this image where the secondary porosity has been completely replaced by authigenic kaolinite.

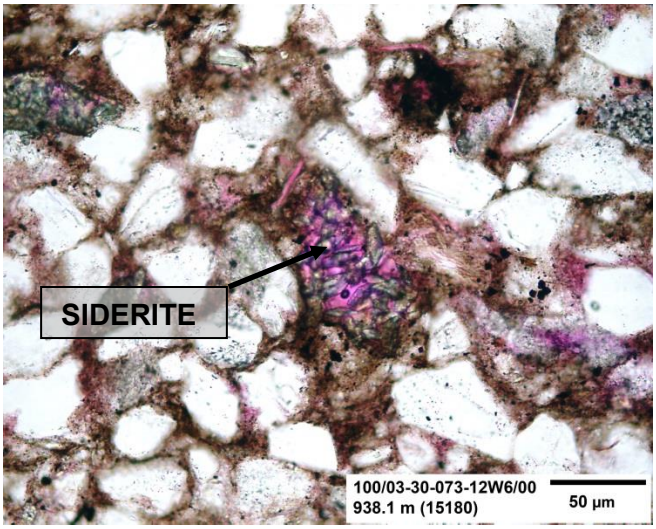

Figure 84: This figure is a high magnification image of the sample under plane-polarized light. Note the secondary porosity being replaced by sideritic cement.

Sample ID	**15182**	**UWI**	**100/08-06-072-01W6/00**
Map ID	**n/a**	**Depth**	**942.4 m**
Strat. Unit	**n/a**		

Grain Size	**%**	**Variety (%)**	**Variety (%)**	**Variety (%)**	**Variety (%)**	**Variety (%)**
sand	1	quartz (100)				
upper silt	65	quartz (77)	rock frag. (15)	mica (5)	feldspar (3)	glauconite (<1)
lower silt	15	quartz (90)	rock frag. (10)	mica (3)	zircon (<1)	
clay	15	detrital (95)	kaolinite (5)			
Cement	1	quartz (100)				
Allochems						
Organics	2	amorphous (90)	plant material (10)			
Opaques	1	pyrite (100)				
	100					

Roundness	subangular to subround
Sphericity	moderate to high
Sorting	well-sorted

Sedimentary Structures

Primary	weakly laminated with wavy bedforms
Biogenic	none observed

Fractures	mix of natural and artificial fractures, approx. 5 to 8 natural fractures
Porosity	fracture porosity main contributor

Description

The rock sample is characterized as a clayey siltstone. Silt-sized grains are the dominant grain-size in which the majority is identified as quartz. The majority of the sedimentary structures are weak laminated composed of wavy bedforms. Angularity of the grains is mainly attributed to the overgrowths observed surrounding the detrital grain. Rock samples are identified as chert, metamorphic rock fragment (MRF) and clay clasts. Only minor amounts of organic material are observed in the sample. Porosity contributions are primarily intergranular with minor amounts attributed to fracture porosity.

Thin section Quality

Thickness of the section is consistent, plucked out areas due to water-sensitive clays. Poor to moderate quality. ½ stained for carbonates.

Rock Classification

clayey siltstone (Folk, 1974)

Sample ID 15182, 100/03-30-073-12W6/00, 942.4 m

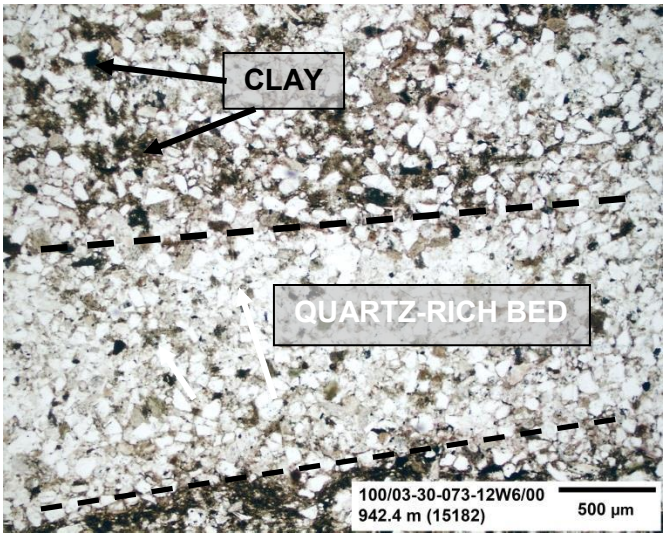

Figure 85: This figure is a low magnification image of the sample under plane-polarized light. Bedding in this sample is defined by the absence or abundance of clays in the matrix. A quartz-rich bed is observed in the sample.

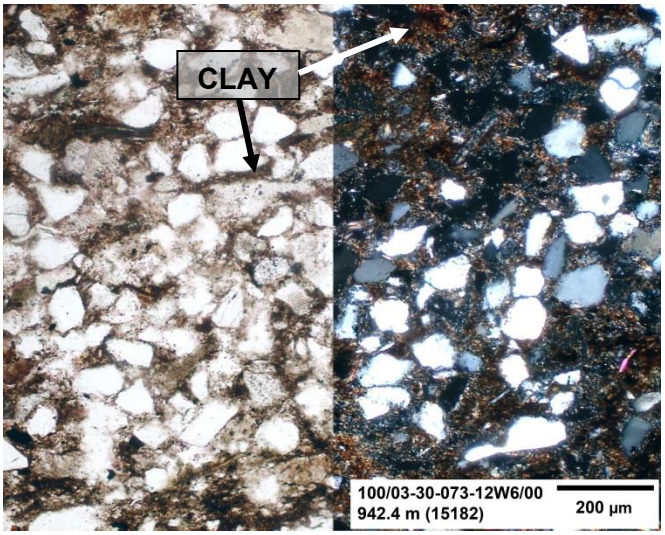

Figure 86: This figure is a medium magnification image of the sample under plane-polarized light (left) and cross-polarized light (right). Due to compaction it is difficult to discriminate detritally deposited clay from compacted clay clasts. Compaction destroys primary textures used for identification.

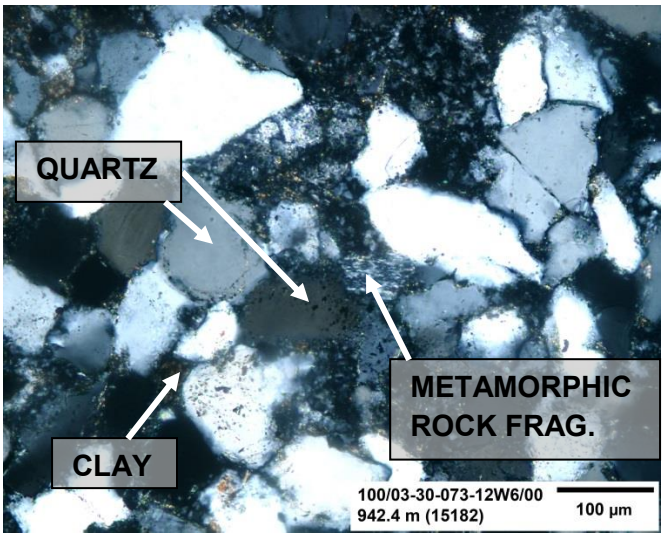

Figure 87: This figure is a high magnification image of the sample under cross-polarized light. There is a variety of minerals present in this image and have been annotated (quartz, clay and metamorphic rock fragment).

Sample ID 15182, 100/03-30-073-12W6/00, 942.4 m

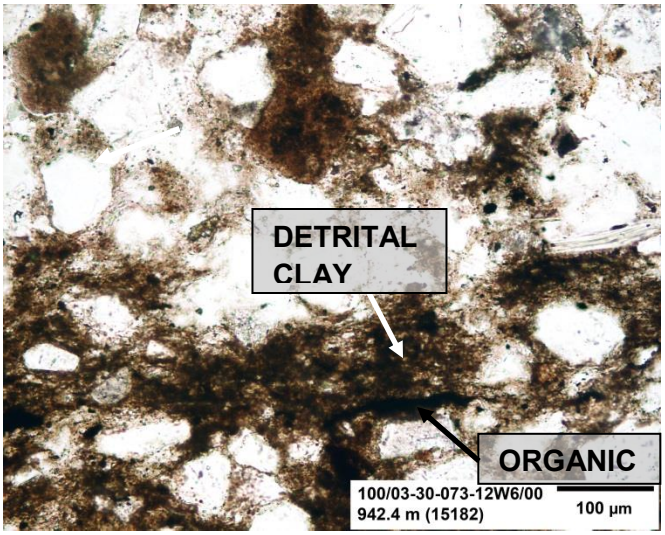

Figure 88: This figure is a medium magnification image of the sample under plane-polarized light. The clay lens in this image is composed of detrital clay. Note the elongate organic fragment that has been compacted and incorporated into the clay lens.

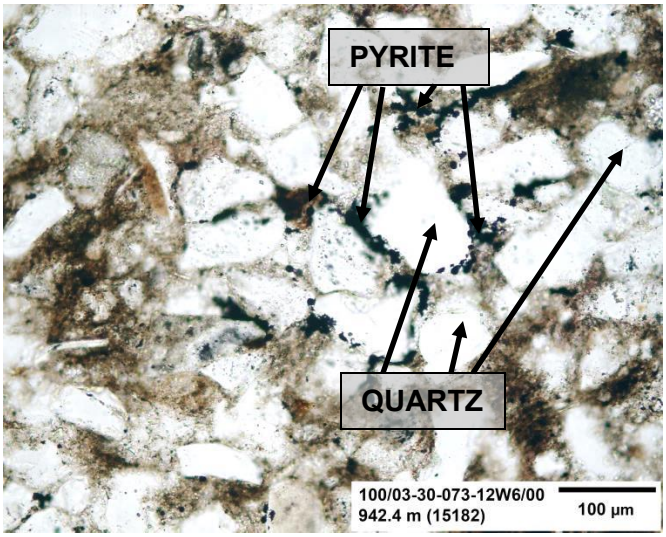

Figure 89: This figure is a high magnification image of the sample under plane-polarized light. Quartz grains are identified in the image and are characterized as upper silt-sized, subangular to subround grains. Pyrite is observed partially surrounding these quartz grains.

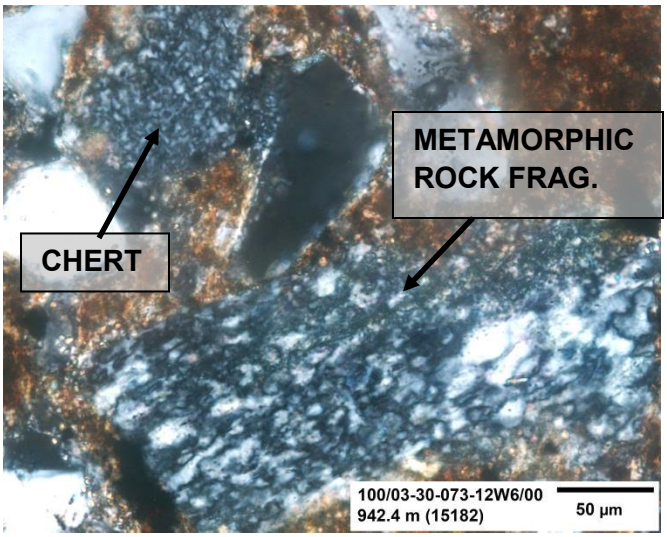

Figure 90: This figure is a high magnification image of the sample under cross-polarized light. At first glance the chert and metamorphic rock fragment (MRF) appear texturally similar and can be confused for one another. The distinguishing factor of the MRF is the elongate crenulate quartz crystals that comprise the grain. These sutured high relief crystals are indications that this grain was subjected to compaction forces. The chert grain is characterized by its cryptocrystalline texture.

Sample ID	**15185**	**UWI**	**100/03-30-073-12W6/00**
Map ID	**n/a**	**Depth**	**949.7 m**
Strat. Unit	**n/a**		

Grain Size	**%**	**Variety (%)**	**Variety (%)**	**Variety (%)**	**Variety (%)**	**Variety (%)**
fine sand	5	quartz (60)	rock frag. (40)			
v. fine sand	60	quartz (65)	rock frag. (25)	feldspar (5)	mica (2)	glauconite (<1)
silt	10	quartz (72)	rock frag. (20)	mica (3)		
clay	20	detrital (10)	detrital (90)			
Cement	3	quartz (100)				
Allochems						
Organics	1	amorphous (100)				
Opaques	1	pyrite (100)				
	100					

Roundness	subangular to subround
Sphericity	moderate to high
Sorting	moderate to well-sorted

Sedimentary Structures

Primary	wavy bedforms with clay-rich/quartz-rich lenses
Biogenic	none

Fractures	artificial and natural fractures observed with an estimated 20+ fractures
Porosity	secondary and fracture porosity main contributors

Description

The rock sample is characterized as a clayey litharenite with wavy bedforms. Throughout the sample beds/lenses of clay-rich/quartz-rich lithologies are observed forming a weakly laminated structure. Quartz and rock fragments are the main detrital grains observed in the sample. Rock fragments are mainly observed as chert, clay clasts and some metamorphic rock fragments. Clays are the second most abundant component and are mainly characterized as detrital in origin. Organics are commonly observed and found compacted and oriented parallel to bedding.

Thin section Quality

Thickness of the section is consistent with pluck out of clays. Poor to moderate quality.

Rock Classification

clayey litharenite (Folk, 1974)

Sample ID 15185, 100/03-30-073-12W6/00, 949.7 m

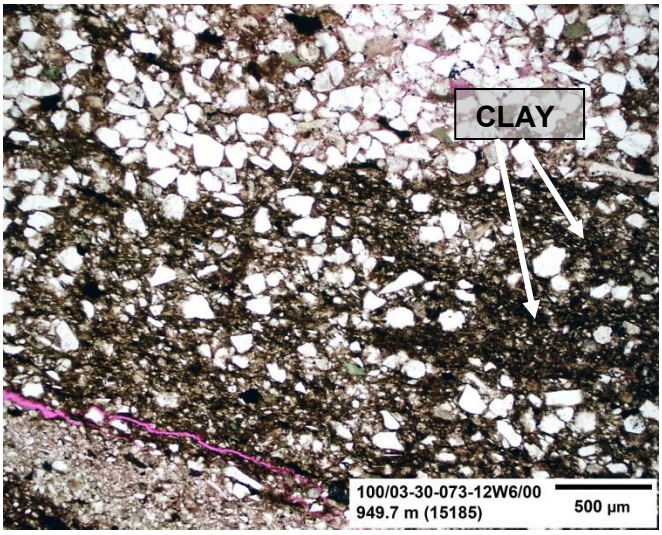

Figure 91: This figure is a low magnification image of the sample under plane-polarized light. The overall texture in this image appears immature which is characterized by heterogeneous distribution of clays, subangular grains and silt-sized to sand-sized grains distributed together (moderate-sorting).

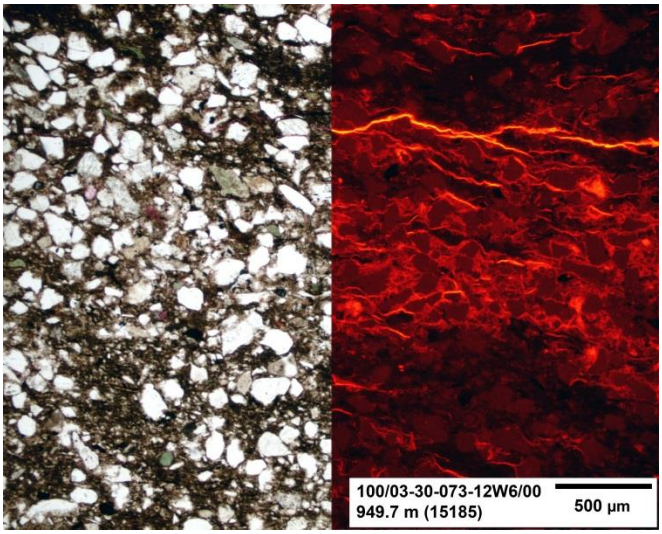

Figure 92: This figure is a low magnification image of the sample under both plane-polarized light (left) and ultra-violet light (right). This sample has high fracture frequency, however the majority of the fractures are artificially induced.

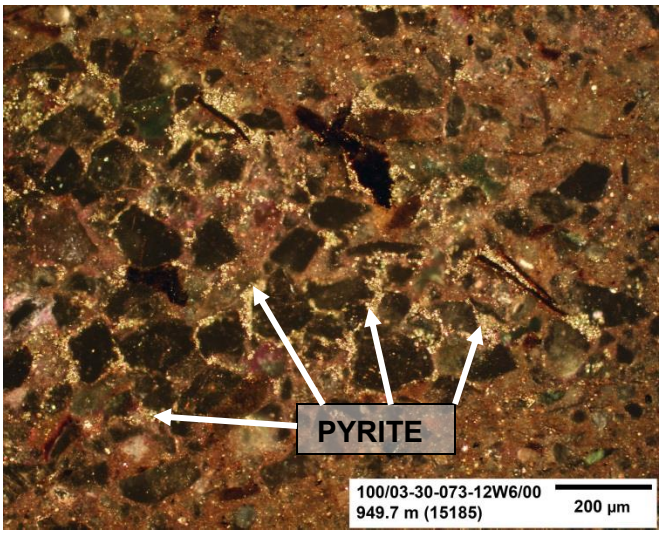

Figure 93: This figure is a medium magnification image of the sample under reflected light. Pyrite is observed as the lustrous mineral observed partially surrounding the framework grains in the image.

Sample ID 15185, 100/03-30-073-12W6/00, 949.7 m

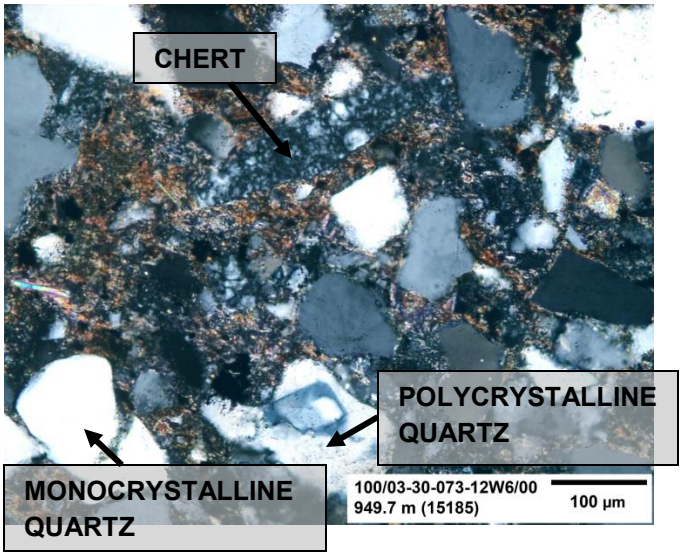

Figure 94: This figure is a high magnification image of the sample under cross-polarized light. There are a variety of quartz species in this sample which can only be differentiated with microscopy.

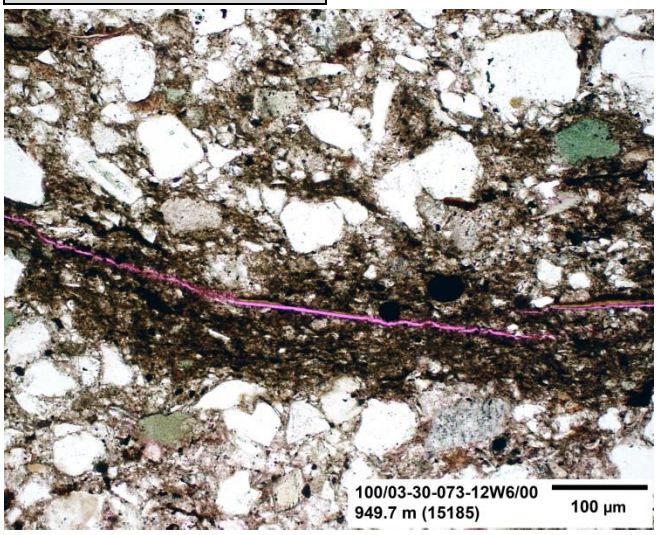

Figure 95: This figure is a high magnification image of the sample under plane-polarized light. The brown clay-rich lens in the sample is associated with fracture porosity.

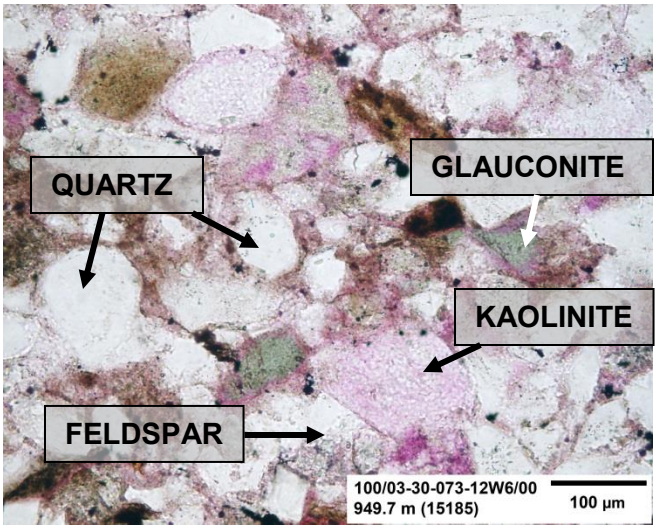

Figure 96: This figure is a high magnification image of the sample under plane-polarized light. Quartz, feldspar and glauconite grains are observed in the sample. Authigenic kaolinite is observed replacing the porosity in this image.

Sample ID	**15186**	**UWI**	**100/16-18-071-10W6/00**
Map ID	**n/a**	**Depth**	**1323.4 m**
Strat. Unit	**n/a**		

Grain Size	**%**	**Variety (%)**	**Variety (%)**	**Variety (%)**	**Variety (%)**	**Variety (%)**
v. fine sand	3	mica (95)	quartz (5)	phosphate (<1)		
upper silt	20	quartz (65)	rock frag. (20)	mica (15)		
lower silt	50	quartz (65)	rock frag. (20)	mica (15)	glauconite (<1)	
clay	20	detrital (80)	kaolinite (20)			
Cement	<1	ankerite (40)	quartz (60)			
Allochems						
Organics	6	amorphous (100)				
Opaques	1	pyrite (100)				
	100					

Roundness	subangular to subround
Sphericity	high
Sorting	well-sorted

Sedimentary Structures

Primary	highly laminated with planar beds and thin laminations
Biogenic	minor bioturbation

Fractures	majority of fractures artificially induced with 3 to 5 natural fractures
Porosity	minor intergranular porosity

Description

The rock sample is characterized as a clayey siltstone that has thin planar laminations. The bedforms observed in the sample are planar and mainly characterized by grain-sizes. Silt-sized grains are observed forming well-sorted planar beds and are associated with clays. Sand-sized beds are also observed and are commonly forming moderately-sorted beds. Sand-sized beds are commonly associated with mica, rock fragments and feldspars. Rock fragments consist of chert, illitic shale clasts and other clay clasts. Organic fragments are commonly observed embedded in the matrix and are commonly observed compacted and oriented to bedding.

Thin section Quality

Thickness of the section is consistent but has minor pluckout. Good quality. ½ stained for carbonates.

Rock Classification

clayey siltstone (Folk, 1974)

Sample ID 15186, 100/16-18-071-10W6/00, 1323.4 m

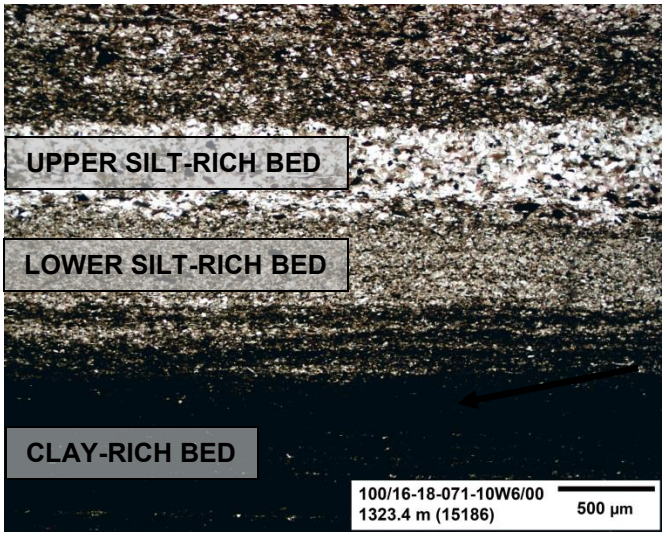

Figure 97: This figure is a low magnification image of the sample under plane-polarized light. Each bed in this sample can be characterized by grain-sizes. Individually the beds are well-sorted and form planar beds and thin laminations.

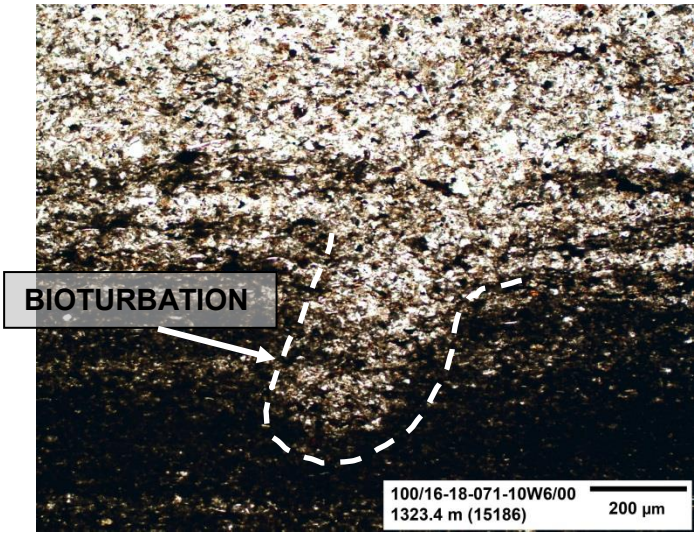

Figure 98: This figure is a low magnification image of the sample under plane-polarized light. Note the bioturbation trace that has disrupted the planar beds.

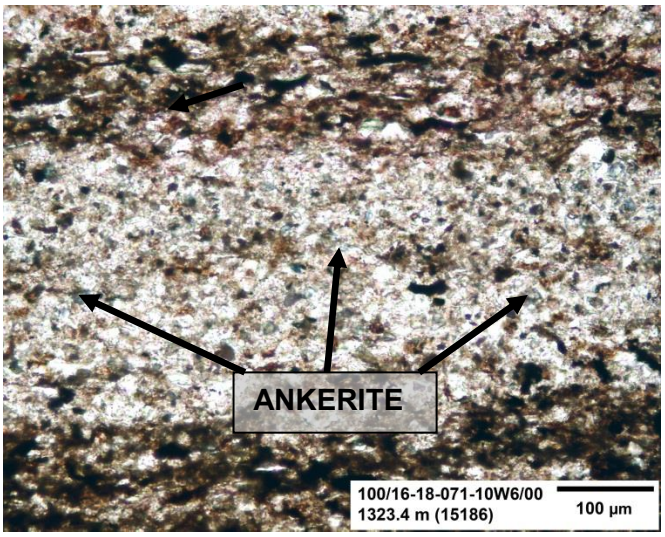

Figure 99: This figure is a medium magnification image of the sample under plane-polarized light. This image highlights the beds composed of upper silt-sized grains which are associated with ankerite cement.

Sample ID 15186, 100/16-18-071-10W6/00, 1323.4 m

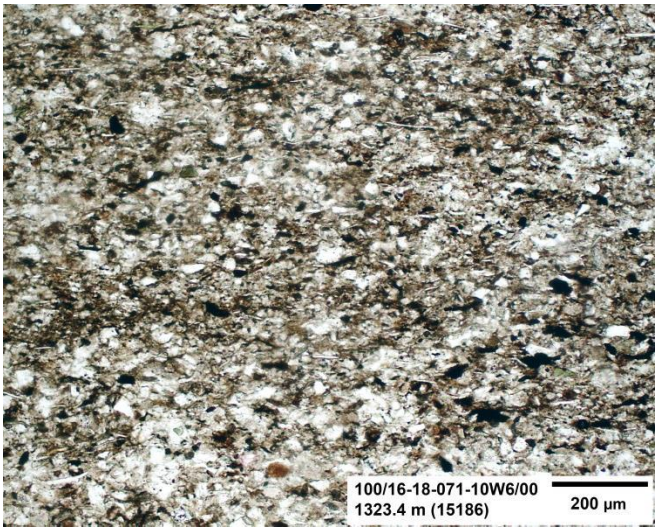

Figure 100: This figure is a medium magnification image of the sample under plane-polarized light. The texture observed in this planar bed lacks any structure (e.g. grain gradation) and has the appearance of massive bedding.

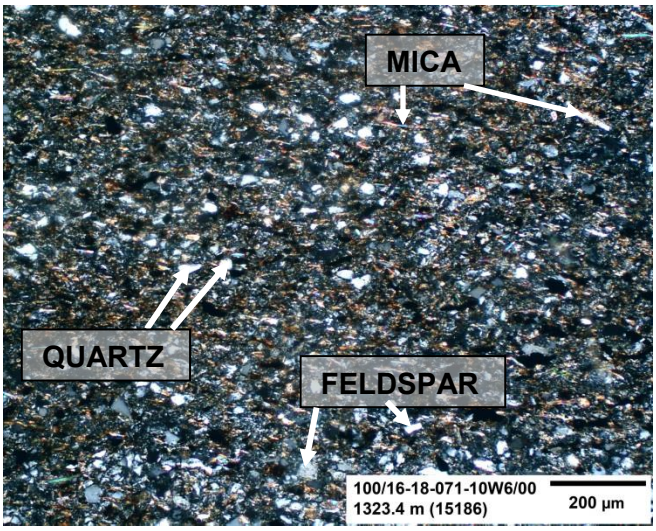

Figure 101: This figure is a medium magnification image of the sample, as in Figure 100, under cross-polarized light. Under cross-polarized light distinct properties of certain minerals are more readily apparent. Minerals identified are quartz, feldspar and mica.

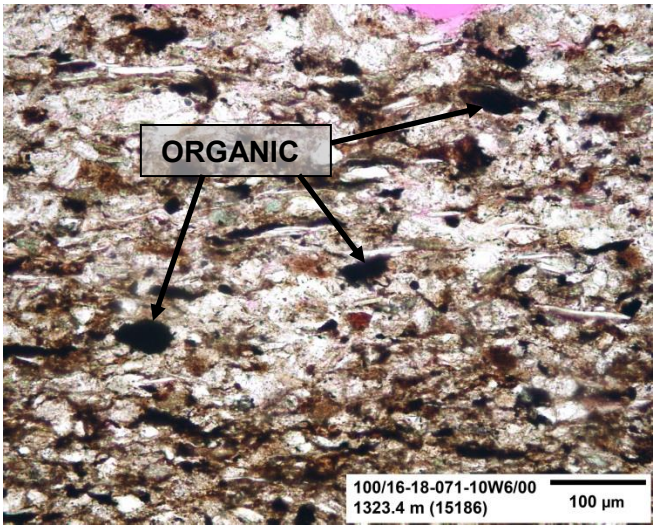

Figure 102: This figure is a high magnification image of the sample under plane-polarized light. The organic fragments observed in this sample are identified mainly as amorphous material.

Sample ID	**15188**	**UWI**	**100/16-18-071-10W6/00**
Map ID	**n/a**	**Depth**	**1330.9 m**
Strat. Unit	**n/a**		

Grain Size	**%**	**Variety (%)**	**Variety (%)**	**Variety (%)**	**Variety (%)**	**Variety (%)**
sand	2	mica (80)	quartz (10)	feldspar (10)		
upper silt	78	quartz (72)	rock frag. (20)	feldspar (5)	mica (3)	
lower silt	10	quartz (100)				
clay	3	detrital (80)	kaolinite (20)			
Cement	1	quartz (100)				
Allochems						
Organics	5	amorphous (90)	plant material (10)			
Opaques	1	pyrite (100)				
	100					

Roundness	subangular
Sphericity	moderate
Sorting	well-sorted

Sedimentary Structures

Primary	massive
Biogenic	none observed

Fractures	none observed
Porosity	secondary porosity with minor intergranular porosity and intraparticle

Description

The rock sample is characterized as a siltstone. Silt-sized grains are the dominant grain-size of which the majority is identified as quartz. The primary texture observed is a massive bedding with no other significant sedimentary structures observed. Rock fragments are the next most abundant component and have been identified as dolomite clasts, clay clasts, chert and metamorphic rock fragments. Organic fragments are commonly observed embedded in the matrix and are commonly observed compacted and oriented to bedding.

Thin section Quality

Thickness of the section is consistent. Good quality. ½ stained for carbonates.

Rock Classification

siltstone (Folk, 1974)

Sample ID 15188, 100/16-18-071-10W6/00, 1330.9 m

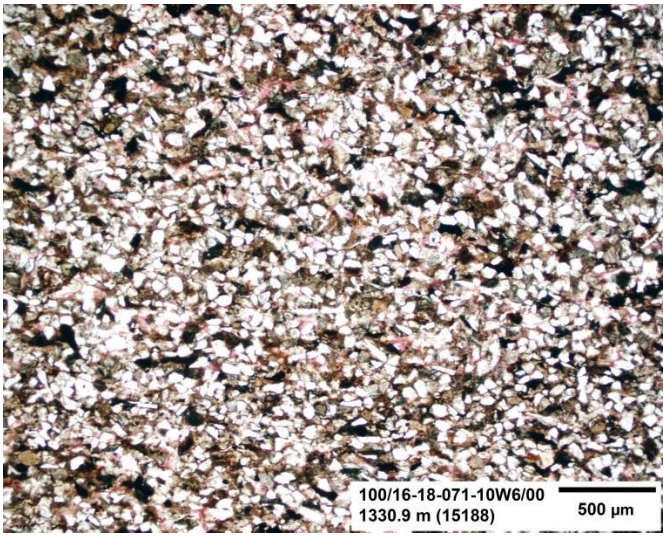

Figure 103: This figure is a low magnification image of the sample under plane-polarized light. Note the massive bedding texture observed in this image. The framework grains in this image are characterized as silt-sized, subangular, moderate sphericity and well-sorted.

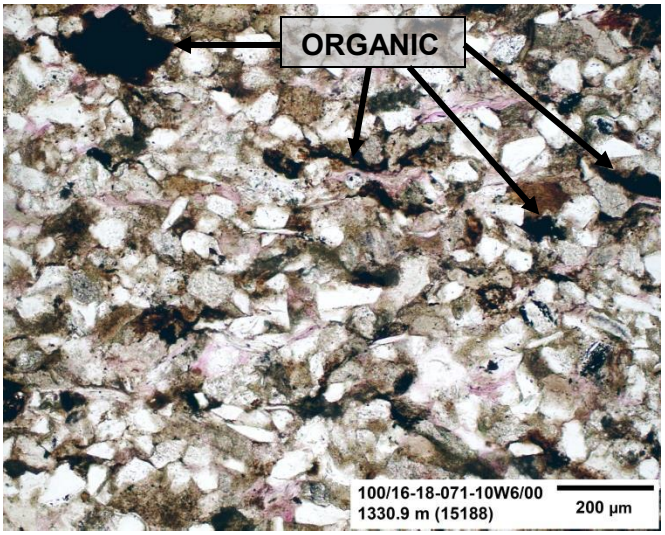

Figure 104: This figure is a medium magnification image of the sample under plane-polarized light. Organic components are observed throughout the matrix of the sample. The majority has been identified as amorphous material with some plant material.

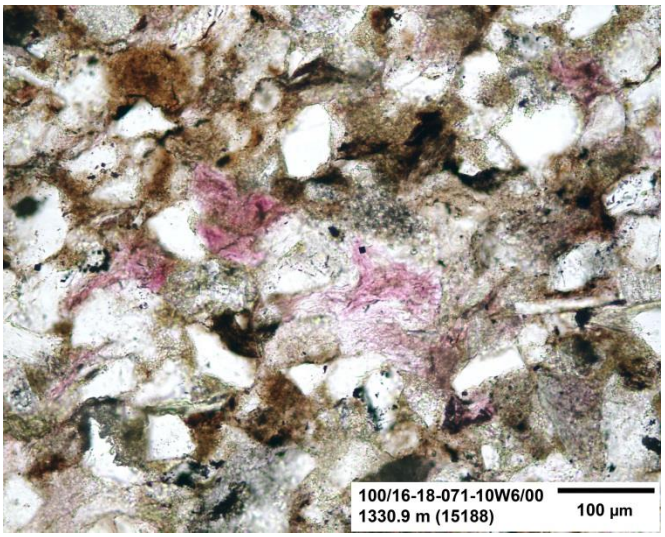

Figure 105: This figure is a high magnification image of the sample under plane-polarized light. This is the dominant texture observed in the sample which mainly is composed of quartz, rock fragments, mica, organic material and clays.

Sample ID 15188, 100/16-18-071-10W6/00, 1330.9 m

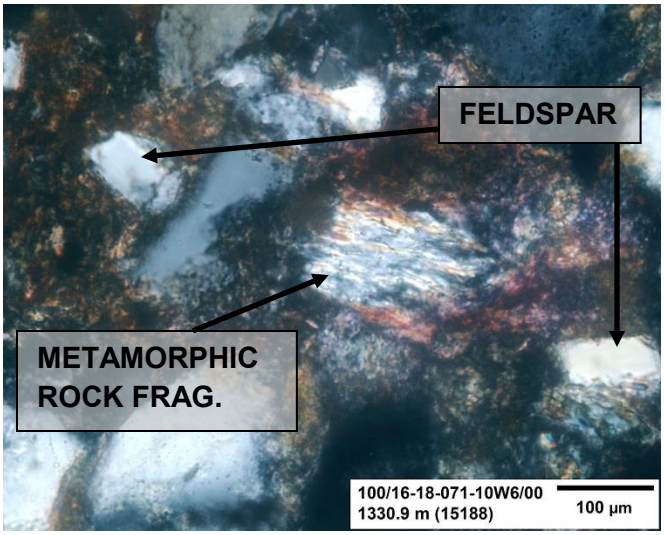

Figure 106: This figure is a low magnification image of the sample under cross-polarized light. The metamorphic rock fragment in this image is identified as a micaceous schist. Feldspar grains are also present in the sample.

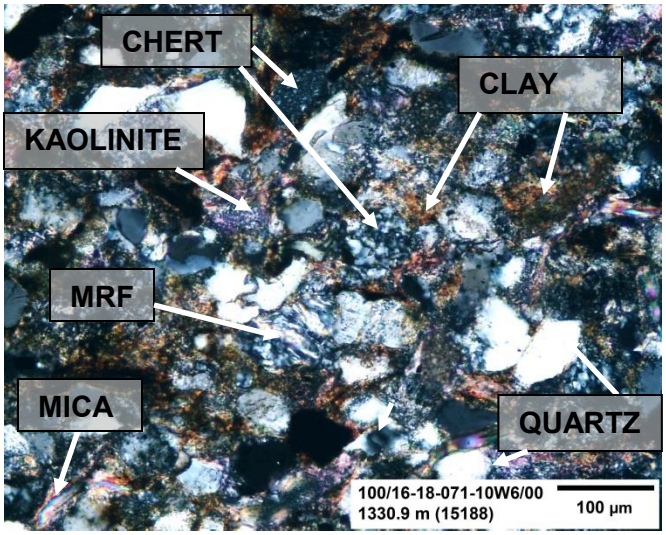

Figure 107: This figure is a high magnification image of the sample under cross-polarized light. Quartz, chert and some metamorphic rock fragment (MRF) grains are composed of silica and cannot be differentiated using XRD analysis. Under cross-polarized light these grains can be discriminated from one another. Clay and mica are also annotated in the image.

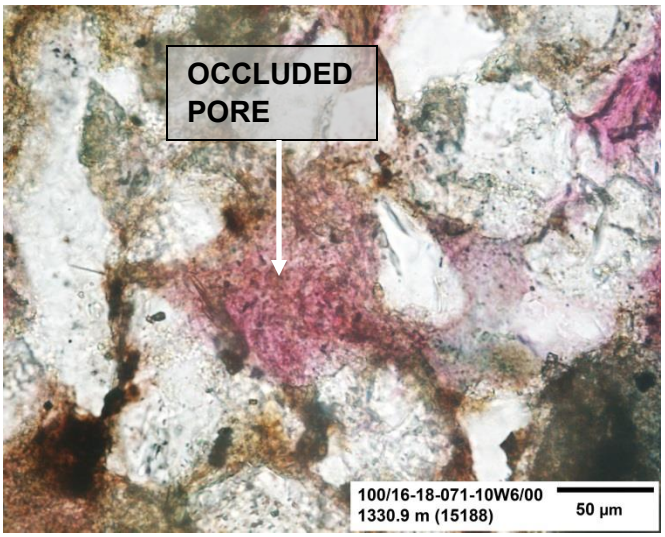

Figure 108: This figure is a high magnification image of the sample under plane-polarized light. Note the pore that has been replaced by clays/fines which changes the porosity type from intergranular to microporosity.

Sample ID	**15191**	**UWI**	**100/16-18-071-10W6/00**
Map ID	**n/a**	**Depth**	**1339.7 m**
Strat. Unit	**n/a**		

Grain Size	**%**	**Variety (%)**	**Variety (%)**	**Variety (%)**	**Variety (%)**	**Variety (%)**
sand	3	mica (100)				
upper silt	70	quartz (70)	rock frag. (20)	mica (5)	feldspar (5)	glauconite (<1)
lower silt	15	quartz (72)	rock frag. (20)	mica (5)	feldspar (3)	
clay	5	detrital (100)				
Cement	1	quartz (100)				
Allochems						
Organics	5	amorphous (100)				
Opaques	1	pyrite (100)				
	100					

Roundness	subangular to subround
Sphericity	moderate to high
Sorting	well-sorted

Sedimentary Structures

Primary	weakly laminated beds with lenses
Biogenic	none

Fractures	2 to 3 micro-fractures
Porosity	intraparticle and secondary porosity observed

Description

The rock sample is characterized as a siltstone. Throughout the sample beds/lenses of clay-rich/quartz-rich lithologies are observed forming a weakly laminated structure. Quartz and rock fragments are the main detrital grains observed in the sample. Rock fragments are identified as metamorphic rock fragments, chert and clay clasts. Clays are mainly classified as detrital. Organics are commonly observed compacted/oriented parallel to bedding.

Thin section Quality

Thickness of the section is consistent with minor pluck out of clays. Average quality. ½ stained for carbonates.

Rock Classification

siltstone (Folk, 1974)

Sample ID 15191, 100/16-18-071-10W6/00, 1339.7 m

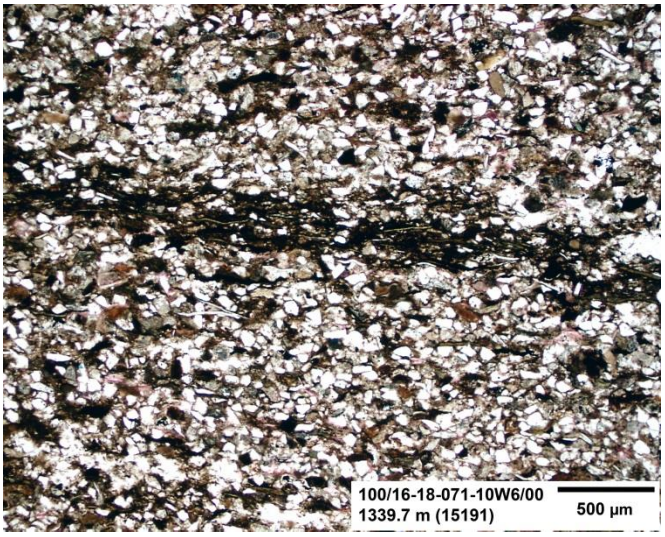

Figure 109: This figure is a low magnification image of the sample under plane-polarized light. This sample is composed of silt-sized, subangular to subround, well sorted grains. Clay-rich lenses are observed throughout this sample.

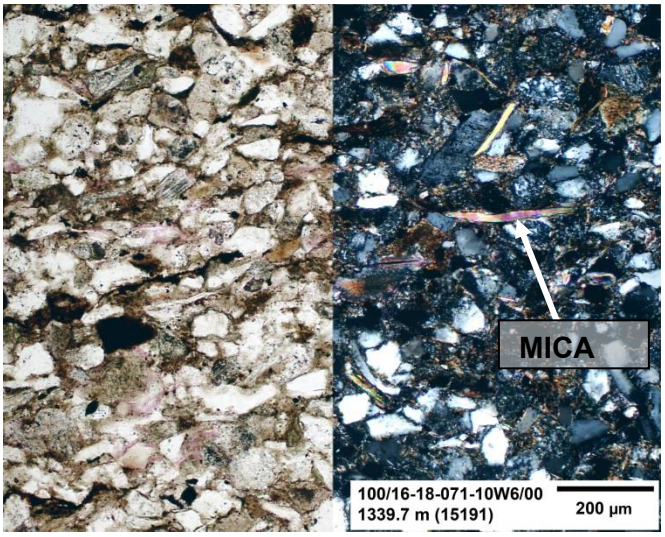

Figure 110: This figure is a medium magnification image of the sample under plane-polarized light (left) and cross-polarized light (right). Note the mica grains in the image where some are in excess of 200 microns (fine sand-sized). Comparing these mica grains to the harder framework grains, the micas are found fewer in number but coarser-grained.

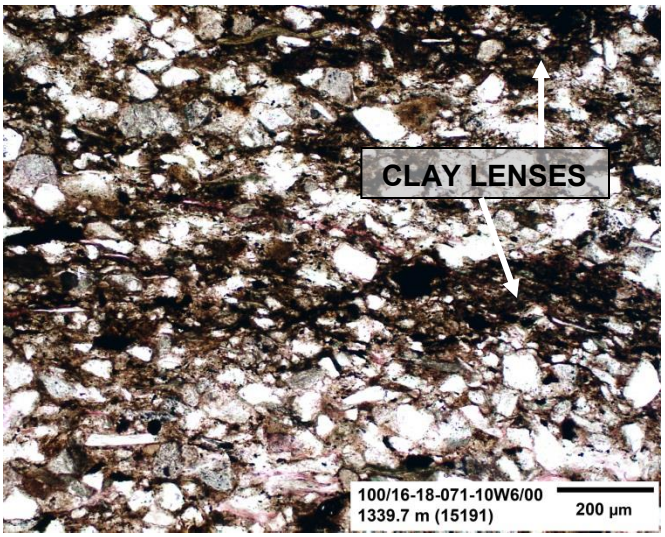

Figure 111: This figure is a medium magnification image of the sample under plane-polarized light. Isolated clay lenses are observed throughout the sample contrasting the lighter colored framework grains. Organics are often associated with the clay-rich lenses.

Sample ID 15191, 100/16-18-071-10W6/00, 1339.7 m

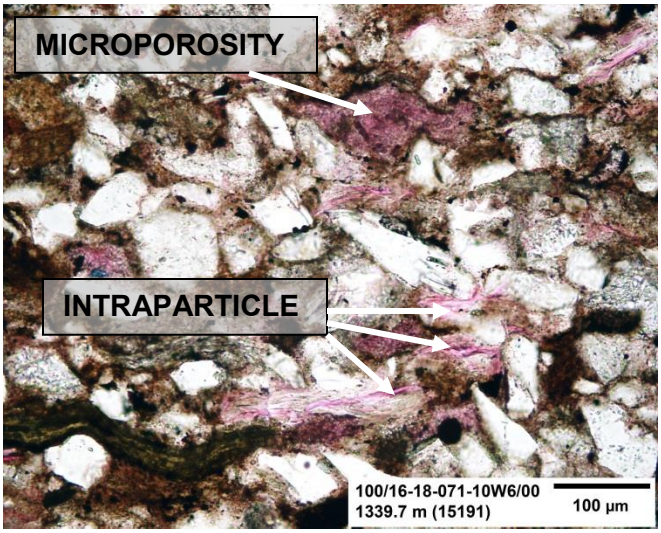

Figure 112: This figure is a high magnification image of the sample under plane-polarized light. The two main porosity types are identified in this image. Intraparticle porosity is mainly associated within mica grains. Microporosity is mainly attributed to clays that have replaced secondary porosity.

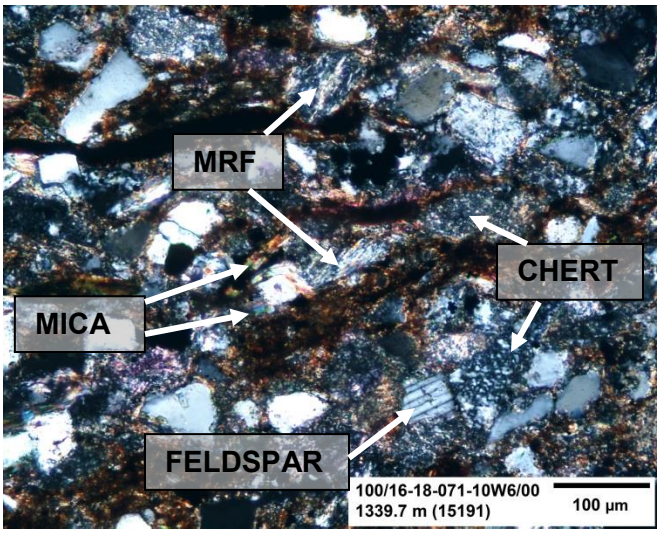

Figure 113: This figure is a high magnification image of the sample under cross-polarized light. This image shows the texture commonly associated with beds containing well-sorted, silt-rich grains. There is a large variety of grains observed in this image and are identified as metamorphic rock fragments (MRF), chert, mica and feldspar.

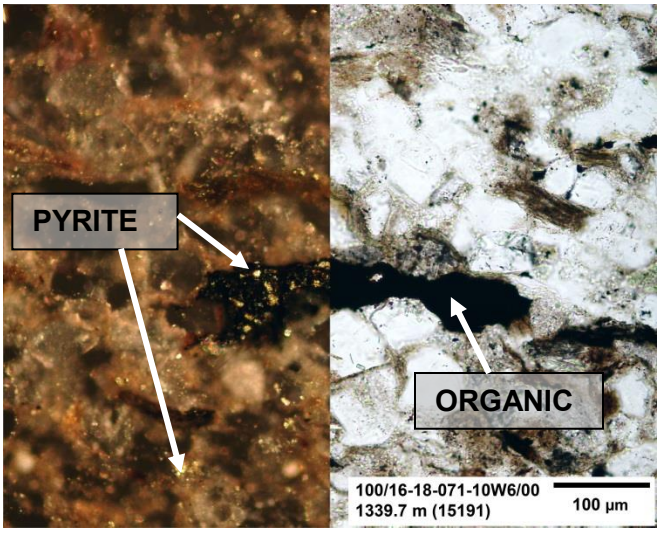

Figure 114: This figure is a high magnification image of the sample under both plane-polarized light (right) and reflected light (left). This picture focuses on an organic fragment in the center of the image. Under plane-polarized light the pyrite remains opaque and "hidden" within the organic. Under reflected light pyrite is revealed and can be discriminated from the organic.

Sample ID	**15223**	**UWI**	**100/14-36-078-11W6/00**
Map ID	**n/a**	**Depth**	**352.8 m**
Strat. Unit	**n/a**		

Grain Size	**%**	**Variety (%)**	**Variety (%)**	**Variety (%)**	**Variety (%)**	**Variety (%)**
sand	1	mica (100)				
upper silt	70	quartz (69)	rock frag. (20)	mica (5)	feldspar (5)	glauconite (1)
lower silt	20	quartz (82)	rock frag. (15)	mica (3)		
clay	5	detrital (100)				
Cement	1	quartz (100)				
Allochems						
Organics	1	amorphous (100)				
Opaques	2	pyrite (100)				
	100					

Roundness	subangular
Sphericity	moderate to high
Sorting	well-sorted

Sedimentary Structures

Primary	wavy bed-forms with clay-rich lenses
Biogenic	none

Fractures	minor amount of fractures
Porosity	minor localized portions of intergranular porosity

Description

The rock sample is characterized as a siltstone. Throughout the sample, beds/lenses of clay-rich/quartz-rich lithologies are observed forming wavy bedforms. Quartz and rock fragments are the main detrital grains observed in the sample. Rock fragments are identified as metamorphic rock fragments, chert and clay clasts. Clays are mainly classified as detrital. Organics are commonly observed compacted/oriented parallel to bedding.

Thin section Quality

Thickness of the section is consistent with minor pluck out of clays. Average quality.

Rock Classification

siltstone (Folk, 1974)

Sample ID 15223, 100/14-36-078-11W6/00, 352.8 m

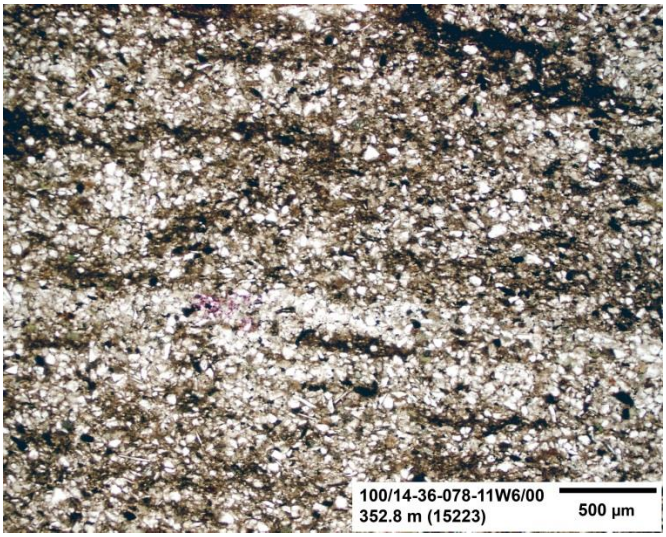

Figure 115: This figure is a low magnification image of the sample under plane-polarized light. This sample is composed of silt-sized, subangular to subrounded, well-sorted grains. Clay-rich lenses are observed throughout this sample.

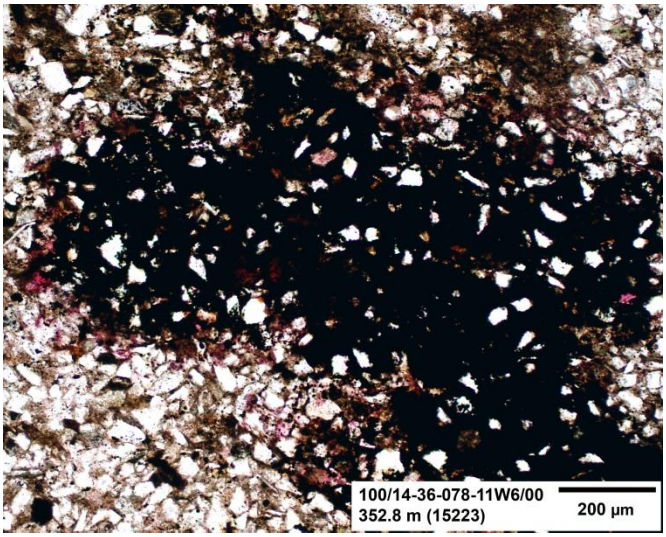

Figure 116: This figure is a medium magnification image of the sample under plane-polarized light. Pyrite is observed in concentrated "patches" throughout the sample.

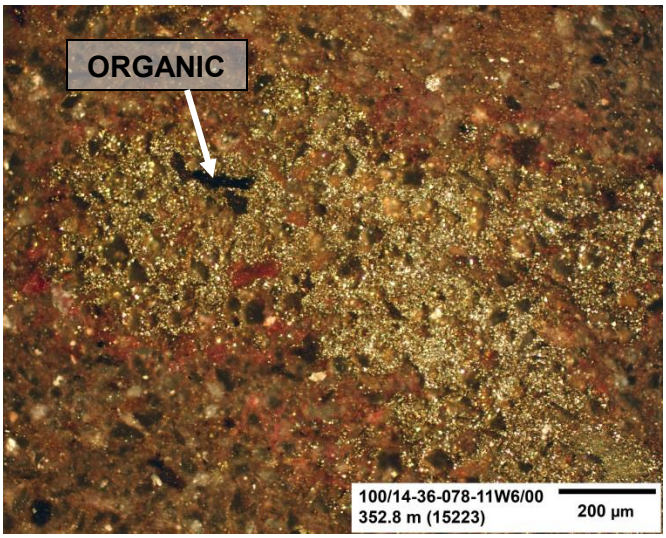

Figure 117: This figure is a medium magnification image of the sample, as in Figure 116, under reflect-polarized light. Note the organic fragment associated with the pyrite. Pyrite is highly lustrous and is primarily identified using reflected light.

Sample ID 15223, 100/14-36-078-11W6/00, 352.8 m

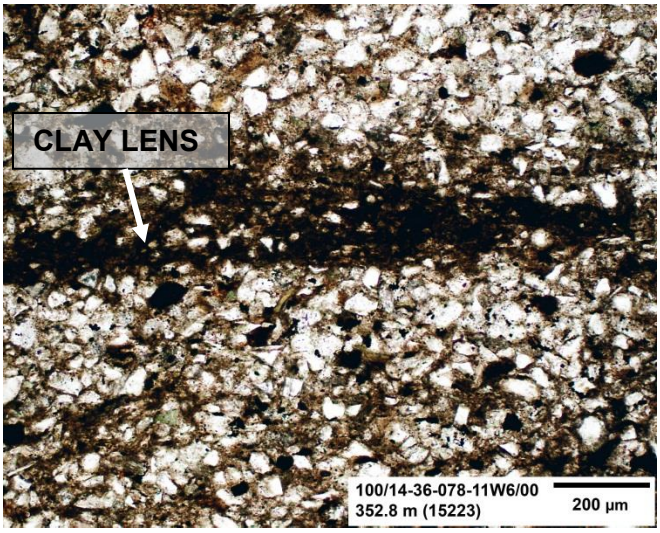

Figure 118: This figure is a medium magnification image of the sample under plane-polarized light. Thin clay lenses are observed throughout this sample.

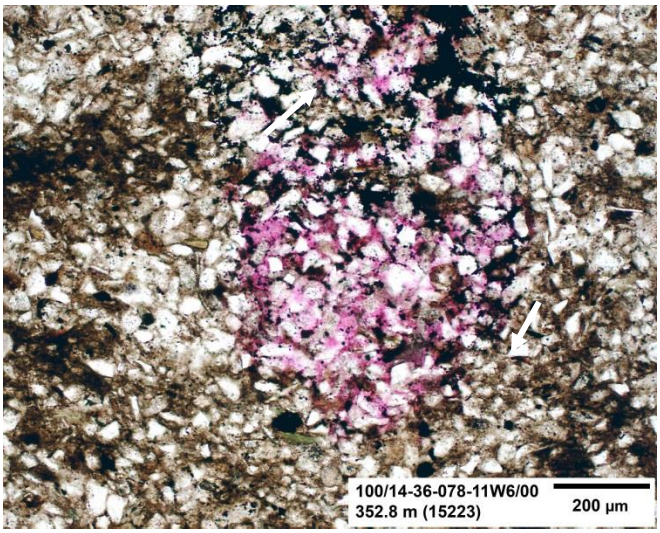

Figure 119: This figure is a medium magnification image of the sample under plane-polarized light. This image shows the localized intergranular porosity observed throughout the sample. These localized high porosity zones may lack interconnectivity.

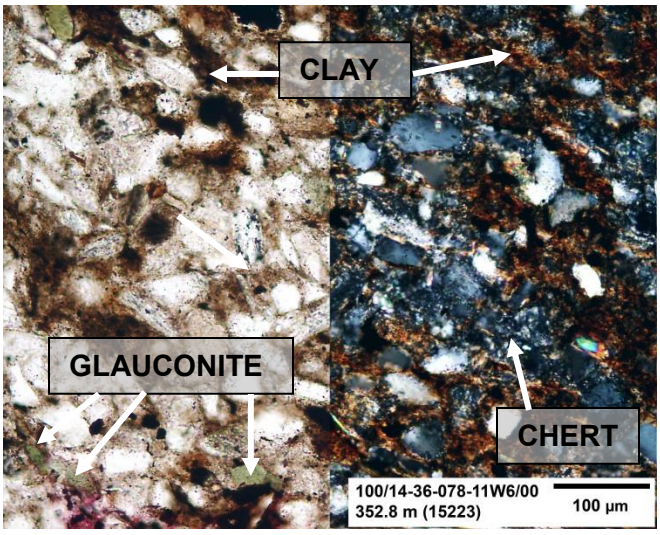

Figure 120: This figure is a high magnification image of the sample under both plane-polarized light (left) and cross-polarized light (right). This image shows some of the minerals observed in this sample and are identified as glauconite, chert and clay.

3.0 Recommendations

X-ray diffraction analysis is highly recommended for the samples to refine petrographic estimations, identify microcrystalline minerals (clays), identify possible swelling clays and differentiate optically similar minerals. Without additional aid it is difficult to determine petrographically with accuracy the overall mineral content of the rock.