AER/AGS Open File Report 2013-06

Alberta Energy Regulator

Thin Section Analysis of Core Samples from the Duvernay and Muskwa Formations and the Majeau Lake Member in Alberta

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Thin Section Analysis of Core Samples from the Duvernay and Muskwa Formations and the Majeau Lake Member in Alberta

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Abstract

This report is a release of thin section descriptions from the Duvernay and Muskwa formations and the Majeau Lake Member of the Western Canada Sedimentary Basin. These were generated for the ongoing Energy Resources Conservation Board (now Alberta Energy Regulator) project on shale- and siltstone-hosted hydrocarbon resources in Alberta.

Thin sections were created by laboratories to our specifications for very fine grained, transmitted-light microscopy. The analysis of each thin section included visual estimations (in per cent) of grain-size distribution, mineralogy, cement, allochems, opaque material, and organic material. Physical and biogenic 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

The Energy Resource Appraisal (ERA) Group of the Alberta Energy Regulator (AER), formerly the Energy Resource Conservation Board (ERCB), initiated a project in 2007 to evaluate shale gas resources in Alberta to determine the quantity and spatial extent of these resources. Since then, this project has expanded to include shale- and siltstone-hosted hydrocarbons (oil, gas, and natural gas liquids) in the province. The ERA is releasing reports and digital data to disseminate knowledge from the project. These data and reports can be accessed from the Alberta Geological Survey (AGS) website (http://www.ags.gov.ab.ca/publications). Table 1 lists the Open File Reports and datasets for this continuing project.

This report disseminates results from the analysis of thin sections from the Duvernay and Muskwa formations and the Majeau Lake Member. The data generated from the project have been combined with additional data to map and estimate shale- and siltstone-hosted hydrocarbon resources in Alberta (Rokosh et al., 2012).

Table 1. ERCB publications related to shale- and siltstone-hosted hydrocarbon resource assessment in Alberta.

Report Code	Title
DIG 2013-0003	Rock Eval and Total Organic Carbon of Sedimentary Rocks in Alberta
OFR 2012-06	Summary of Alberta's Shale- and Siltstone-Hosted Hydrocarbon Resource Potential
OFR 2010-07	Organic Petrography of the Montney Formation in Alberta: Shale Gas Data Release
OFR 2010-06	Organic Petrography of the Duvernay and Muskwa Formations in Alberta: Shale Gas Data Release
OFR 2010-05	Rock Eval, Total Organic Carbon and Adsorption Isotherms of the Montney Formation in Alberta: Shale Gas Data Release
OFR 2010-04	Rock Eval, Total Organic Carbon and Adsorption Isotherms of the Duvernay and Muskwa Formations in Alberta: Shale Gas Data Release
OFR 2010-03	Mineralogy, Permeametry, Mercury Porosimetry, Pycnometry and Scanning Electron Microscope Imaging of the Montney Formation: Shale Gas Data Release
OFR 2010-02	Mineralogy, Permeametry, Mercury Porosimetry, Pycnometry and Scanning Electron Microscope Imaging of Duvernay and Muskwa Formations: Shale Gas Data Release
OFR 2008-14	Mineralogy, Permeametry, Mercury Porosimetry and Scanning Electron Microscope Imaging of the Colorado Group: Shale Gas Data Release
OFR 2008-13	Mineralogy, Permeametry, Mercury Porosimetry and Scanning Electron Microscope Imaging of the Banff and Exshaw Formations: Shale Gas Data Release
OFR 2008-12	Rock-Eval, Total Organic Carbon, Adsorption Isotherms and Organic Petrography of the Banff and Exshaw Formations: Shale Gas Data Release
OFR 2008-11	Rock Eval, Total Organic Carbon, Adsorption Isotherms and Organic Petrography of the Colorado Group: Shale Gas Data Release
OFR 2008-10	Geochemical and Sedimentological Investigation of Banff and Exshaw Formations for Shale Gas Potential: Initial Results
OFR 2008-09	Geochemical and Sedimentological Investigation of the Colorado Group for Shale Gas Potential: Initial Results
OFR 2008-08	What is Shale Gas? An Introduction to Shale-Gas Geology in Alberta

2 Sample Locations and Descriptions

Table 2 lists the thin section sample sites. Figure 1 displays sample sites associated with the Duvernay and Muskwa formations and the Majeau Lake Member thin sections. Appendices 1 and 2 provide detailed sample location and description information.

Table 2. Thin section sample sites.

Site No.	Location – UWI	Stratigraphic Unit	Depth (m)	Lithology	No. of Thin Sections
D01	100/06-14-037-07W5/00	Duvernay	3649.7	shale	1
D06	100/02-06-047-04W5/00	Duvernay	2639.6	calcareous shale	1
D07	100/14-29-048-06W5/00	Duvernay	2655.7	calcareous shale	1
D10	100/09-06-052-11W5/00	Duvernay	3020.1	calcareous shale	1
D11	100/10-30-053-14W5/00	Majeau Lake	3172.8	shale	1
D15	100/10-09-059-11W4/00	Duvernay	797.7	lime mudstone	1
D21	100/10-13-063-12W5/00	Majeau Lake	2625.5	calcareous shale	1
D22	100/10-05-065-15W5/00	Duvernay	2752.0	shale	1
D23	100/04-33-068-22W4/00	Duvernay	1054.6	lime mudstone	1
D30	100/11-17-088-03W6/00	Muskwa	2319.3	shale	1
D31	100/02-30-088-04W6/00	Muskwa	2401.2	shale	1
D34	100/02-04-126-11W6/00	Muskwa	1517.4	shale	1
D50	100/12-12-057-22W5/00	Duvernay	3881.7–3902.1	shale	4

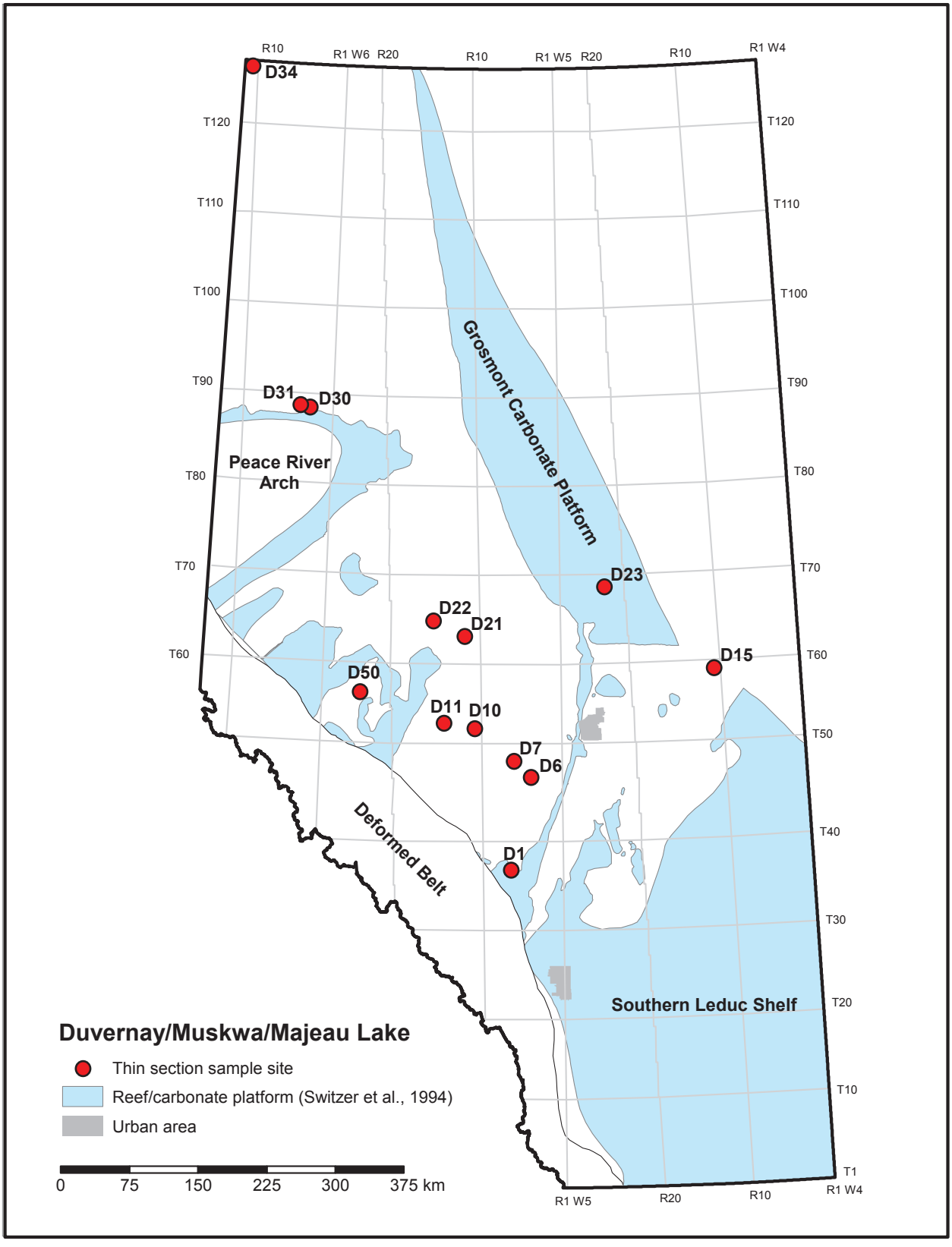

Figure 1. Thin section sites sampled for the Duvernay and Muskwa formations and the Majeau Lake Member.

3 Analytical Methods and Results

This report contains thin section descriptions from core samples of the Duvernay and Muskwa formations and the Majeau Lake Member. We selected 16 samples from 13 sites for thin section analysis. Of these samples, 11 are from the Duvernay Formation, 3 are from the Muskwa Formation, and 2 are from the Majeau Lake Member. We initially analyzed the thin sections to determine the desired reporting method and to create a template for descriptions. Using this template, initial descriptions, images, and interpretations were done by J. Bladek of Calgary Petrographics Ltd. Final technical revisions were done by ERA staff.

3.1 Thin Section Preparation

Thin section preparation for laboratory analysis underwent a series of modifications to maximize viewable shale details. Traditional thin sections are typically ground to ~30 microns thick, which is good for examining silt or sand laminations but poor for observing details in the clay-sized particle range. Our initial investigations in grinding sections to ~20 microns thick revealed concerns about grains being plucked during grinding and polishing. For the second round, sections were first ground to ~30 microns, and then one-half of the section was wedged to just a few microns thick. The wedge successfully created an observation area for the clay-sized particles, but this area was still less then one third of the thin section surface, and images were poor due to the wedge effect. On the third round, an independent lab was contracted to test-grind the thin sections to an even thickness of ~20 microns to maximize the observable area of the slide and minimize the destruction of features due to plucking or smearing. In the end, the following steps were taken for thin section preparation:

1) The sample was coated and impregnated (if impregnation was possible) with epoxy to maintain the sample's integrity.
2) Sections were ground to ~18–20 microns thick and polished to a low polish.
3) One-half of the thin section was stained with alizarin red and potassium ferricyanide to identify carbonate minerals.

Thin sections that were previously prepared to ~30 microns thick were sent to Calgary Rockworks Inc. to be repolished to ~20 microns and wedged, if possible. These thin sections were not as well prepared as newer versions because they were not coated and impregnated with epoxy before the sample was mounted on the slide, creating slides of reduced quality. The quality of each thin section is documented in the sample descriptions.

3.2 Thin Section Analysis

Thin sections were analyzed for the following elements:

- grain-size distribution,
- mineralogy,
- organic-matter distribution,
- primary and secondary structure,
- porosity (if visible), and
- any other notable characteristics.

3.2.1 Grain-Size Distribution, Mineralogy, and Organic Matter

A visual estimate of the percentage of sand-, silt-, and clay-sized grains; the mineralogy of these grains; and the percentage of organic matter are based on thin section and hand-sample observation. Estimates

of the percentage of clay-sized particles are aided by examining results from energy-dispersive X-ray or X-ray diffraction data for the samples. For carbonate rocks, micritic textures were recorded as a visually estimate per cent under clay-sized grains. Some factors that affect the error in visual estimates include the thickness of the thin section compared to the average grain size of the sample and the overall quality of the thin section. Where the thin sections are excessively thick, constituents may be overestimated. Where thin section quality is poor from excessive etching of sample material during staining, underestimation of constituents is likely.

For thin sections that contain at least 10% silt- and sand-sized grains combined; the roundness, sphericity and sorting were observed and recorded. Figure 2 is an illustration of the sphericity and roundness chart used in this analysis.

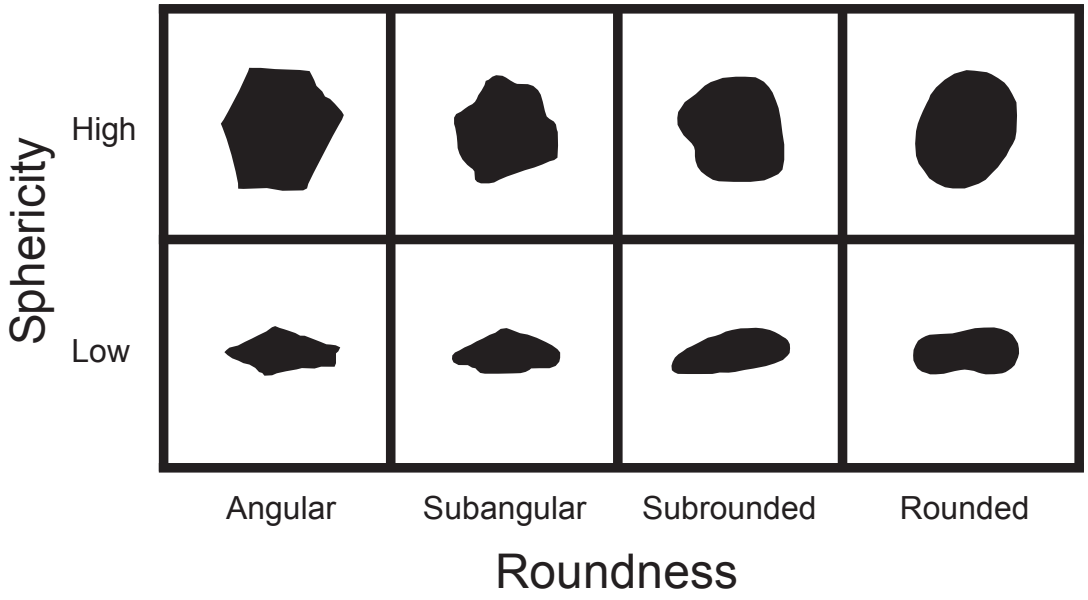

Figure 2. Illustrative chart showing the range of sphericity and roundness for silt- and sand-sized grains. Chart is modified from Krumbein and Sloss (1963).

3.2.2 Primary Sedimentary Structures, Secondary Structures, and Porosity

When making observations about structures and porosity, the main goal is to record bedding, laminations, and fractures. Although the presence of porosity was also noted for each sample, it is dependent on impregnation of epoxy into the sample, which was extremely difficult due to the low permeability of these rocks.

3.2.3 Sample Descriptions

Appendix 2 contains thin section photographs and descriptions. A description of each sample includes the type of shale lamination present (as described by O'Brien and Slatt, 1990), the presence of any trace fossils, and any other notable characteristics. Images of some of the more interesting features are included. In addition, one or more rock names are given to each sample based on a variety of naming conventions (Folk, 1974; Dunham, 1962 cited in Embry and Klovan, 1972) and the type of sample observed. The naming convention for the sample is listed in the description table.

3.2.4 Errors and Assumptions

Thin section analyses for very fine grained rocks are problematic because it is very difficult to see the optical characteristics of very fine grained components under the transmitted light microscope. For this reason, data from other analyses we conducted—such as X-ray diffraction, X-ray fluorescence, scanning electron microscope imaging, inorganic geochemistry, and organic geochemistry—were examined for each formation to aid in thin section descriptions. Each component or mineral was visually estimated to give a general comparison to the other components. Point counting was not used to accomplish this.

Several problems were encountered during thin section creation. These included the following:

- plucking of larger grains from the finer grained matrix when polishing,
- scratching of the sample when polishing,
- dragging of grains when polishing to a wedge,
- erosion of large amounts of material when staining, and
- removal of stain when repolished.

4 Summary

As part of the ERCB project on shale- and siltstone-hosted hydrocarbon resources in Alberta, thin section analyses were conducted on 16 samples consisting of shale, wackestone, and carbonate mudstone samples from the Duvernay and Muskwa formations, and the Majeau Lake Member. We visually estimated grain-size distribution, mineralogy, cement, allochems, opaque material, and organic material. The analyses included information on sedimentary structures, fractures, rock classification, and included photomicrographs of each sample. These descriptions are provided as a resource for geological research on these units in the Western Canada Sedimentary Basin in Alberta.

5 References

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Switzer, S.B., Holland, W.G., Graf, G.C., Hedinger, A.S., McAuley, R.J., Wierzbicki, R.A. and Packard, J.J. (1994): Devonian Woodbend-Winterburn strata of the Western Canada Sedimentary Basin; *in* Geological atlas of the Western Canada Sedimentary Basin, G.D. Mossop and I. Shetsen (comp.), Canadian Society of Petroleum Geologists and Alberta Research Council, p. 165–202.

Appendix 1 Sample Locations and Descriptions

Column Label	Label Description
Map ID	ERA* ID assigned for plotting sites on a map
Site ID	AGS** ID used to uniquely identify oil and gas wells in Alberta
Location - UWI	Unique well identifier
Well Name	Name assigned to well when drilling began
Latitude NAD83	Well location - degrees latitude, North American Datum 1983
Longitude NAD83	Well location - degrees longitude, North American Datum 1983
Year Drilled	Year well was drilled
No. of Samples	Number of samples taken from core

Map ID	Site ID	Location - UWI	Well Name	Latitude NAD 83	Longitude NAD 83	Year Drilled
D01	149532	100/06-14-037-07W5/00	CANHUNTER CHEDDARVILLE 6-14-37-7	52.178681	-114.895395	2009
D06	66452	100/02-06-047-04W5/00	IMP CDN-SUP NORBUCK 2-6-47-4	53.020332	-114.571521	2008
D07	70231	100/14-29-048-06W5/00	IMP CDN-SUP PEMBINA 14-29 BR- 48-6	53.176390	-114.845842	2008
D10	82469	100/09-06-052-11W5/00	IMPERIAL CYNTHIA NO. 9-6-52-11	53.463004	-115.601615	2009
D11	83772	100/10-30-053-14W5/00	HOME MOBIL PEERS 10-30-53-14	53.608763	-116.049330	2009
D15	92284	100/10-09-059-11W4/00	SUN IOE LOTTIE 10-9-59-11	54.087511	-111.587683	2008
D21	96975	100/10-13-063-12W5/00	IMP VIRGINIA HILLS 10-13-63-12	54.452329	-115.674185	2008
D22	100906	100/10-05-065-15W5/00	MARATHON VIRGINIA HILLS 10-5-65-15	54.599662	-116.225665	2009
D23	103988	100/04-33-068-22W4/00	IMPERIAL DEEP CREEK NO. 4-33-68-22	54.923841	-113.307416	2008
D30	117592	100/11-17-088-03W6/00	PEX ET AL EUREKA 11-17-88-3	56.634242	-118.443537	2008
D31	117603	100/02-30-088-04W6/00	TOTAL ATAPCO WORSLEY 2-30-88-4	56.656887	-118.620914	2009
D34	184283	100/02-04-126-11W6/00	ESSO KAKISA 2-4-126-11	59.913369	-119.842205	2008
D50	293507	100/12-12-057-22W5/02	TALISMAN 02 CECILIA 12-12-57-22	53.913120	-117.144736	2010

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Column Label	Label Description
Sample ID	AGS* sample number
Map ID	ERA** ID assigned for plotting sites on a map
Location UWI	Well location - unique well identifier
Sample Depth (Metres)	Depth of core sample in metres (measured from core)
Lithology	Brief lithological description of sample
Stratigraphic Unit	Name of stratigraphic unit at depth of sample

Sample ID	Map ID	Location UWI	Sample Depth (Metres)	Lithology	Stratigraphic Unit
8128	D30	100/11-17-088-03W6/00	2319.3	shale	Muskwa
8454	D23	100/04-33-068-22W4/00	1054.6	lime mudstone	Duvernay
8461	D15	100/10-09-059-11W4/00	797.7	lime mudstone	Duvernay
8481	D21	100/10-13-063-12W5/00	2625.5	calcareous shale	Majeau Lake
8492	D07	100/14-29-048-06W5/00	2655.7	calcareous shale	Duvernay
8995	D31	100/02-30-088-04W6/00	2401.2	shale	Muskwa
9210	D10	100/09-06-052-11W5/00	3020.1	calcareous shale	Duvernay
9226	D22	100/10-05-065-15W5/00	2752.0	shale	Duvernay
9238	D01	100/06-14-037-07W5/00	3649.7	shale	Duvernay
9362	D06	100/02-06-047-04W5/00	2639.6	calcareous shale	Duvernay
9367	D34	100/02-04-126-11W6/00	1517.4	shale	Muskwa
9392	D11	100/10-30-053-14W5/00	3172.8	shale	Majeau Lake
9645	D50	100/12-12-057-22W5/00	3881.7	shale	Duvernay
9651	D50	100/12-12-057-22W5/00	3884.7	shale	Duvernay
9658	D50	100/12-12-057-22W5/00	3894.8	shale	Duvernay
9663	D50	100/12-12-057-22W5/00	3902.1	shale	Duvernay

* Alberta Geological Survey

** Energy Resource Appraisal Group

Appendix 2 Thin Section Descriptions

Legend

Column Label	Label Description
Sample ID	AGS* sample identification number
Map ID	ERA** ID assigned for plotting sites on a map
UWI	Well location - unique well identifier
Strat. Unit	Name of stratigraphic unit at depth of sample
Depth	Depth of core sample in metres (measured from core, uncorrected)
Grain Size	Size of the clastic grains
Sand	Grain size ≥ 62 µm
Upper Silt	Grain size 16-62 µm - including very coarse and coarse silt
Lower Silt	Grain size 4-16 µm - including medium and fine silt
Clay	Grain size ≤ 4 µm
Cement	Secondary component that holds the grains together and/or occludes porosity
Allochems	Carbonate grains including lithoclasts, coated grains, peloids, aggregate grains, and skeletal grains
Organics	Constituents containing carbon
Opaques	Elements of the thin section that do not transmit light
%	The per cent of the constituent in the thin section.
Variety (%)	Type of constituent with its visually estimated per cent in brackets
Roundness	Grain morphology - degree to which the grains have been smoothed
Sphericity	Grain morphology - degree to which the grains have formed a spherical shape
Sorting	Measure of the spread of the grain-size distribution
Sedimentary Structures	Spatial arrangement of the rock constituents
Primary	Sedimentary structures including erosional, depositional, and post-depositional structures
Biogenic	Sedimentary structures including microbial mats and trace fossils
Fractures	Information about the fractures in the sample
Porosity	The visual estimation of space available to be occupied by liquids or gases in the sample
Description	Overall description of sample
Thin Section Quality	The physical quality of the thin section, including staining if it is present.
Rock Classification	Name of rock based on thin section using a variety of classification schemes

* Alberta Geological Survey

** Energy Resource Appraisal Group

Sample ID	***8128***		
Map ID	***D30***	**UWI**	***100/11-17-088-03W6/00***
Strat. Unit	***Muskwa Formation***	**Depth**	***2319.3 m***

Grain Size	**%**	**Variety (%)**	**Variety (%)**	**Variety (%)**	**Variety (%)**	**Variety (%)**
sand	0					
upper silt	5	rock frag. (40)	calcite (30)	quartz (20)	mica (10)	plant matter?
lower silt	30	quartz (50)	calcite (20)	mica (20)	rock frag. (10)	
clay	52	clay/mud (60)	quartz (20)	mica (15)	dolomite (5)	
Cement	5	dolomite (100)				
Allochems	2	calcispheres (100)				
Organics	3	amorphous (100)	plant matter?			
Opaques	3	pyrite (100)				
	100					

Roundness	subangular to subrounded
Sphericity	medium
Sorting	moderately sorted

Sedimentary Structures

Primary	lenticular laminated, local clay lenses with disseminated pyrite
Biogenic	none observed

Fractures	three prominent open horizontal fractures are a product of thin-section creation
Porosity	no porosity or microporosity observed

Description

Lenticular laminated silty mudstone. The sample has a low amount of silt-sized grains that are mainly quartz, but some are calcite and some are rounded calcispheres. Thin horizontal lenses of clay-sized material are common and locally associated with increased pyrite. This thin section was re-polished; therefore, staining may have been polished away, leaving only faint staining in places. However, high relief and birefringence suggests more carbonate minerals. Minor amounts of organics are present as thin interlaminations and trace amounts of plant matter.

Thin Section Quality

Some of the thin section is slightly too thick, but overall it is of fair quality; 1/2 stained for carbonates.

Rock Classification

mudstone (Folk, 1974)

Sample # 8128, 100/11-17-088-03W6/00, 2319.3 m - Muskwa Formation

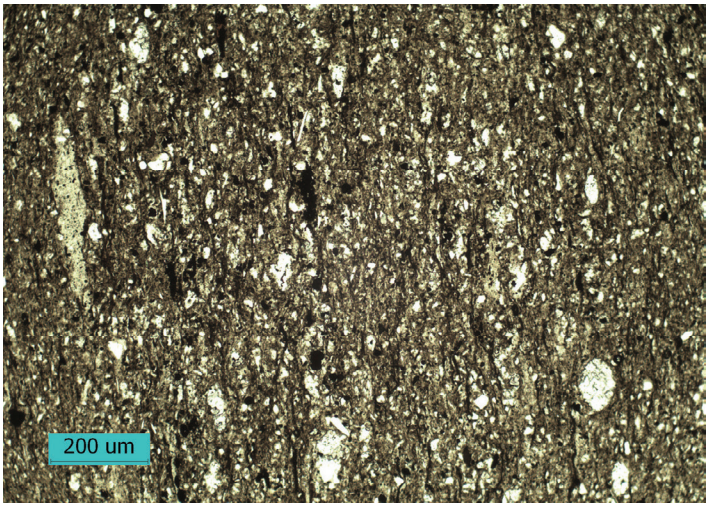

Plate 1: plane-polarized light. A low- to medium-magnification view showing lenticular laminated mudstone. Bedding orientation is displayed vertically in the image.

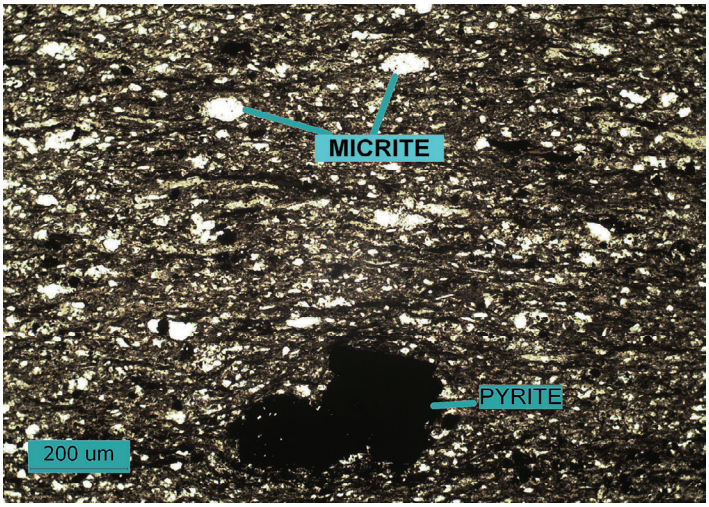

Plate 2: plane-polarized light. A medium-magnification view showing mudstone with local pyrite and round carbonate grains which may be micritic burrows. Bedding orientation is displayed horizontally in the image.

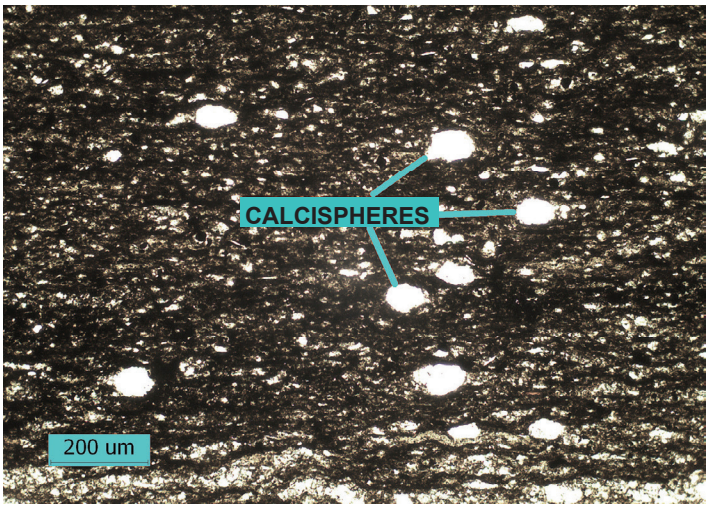

Plate 3: plane-polarized light. A low- to medium-magnification view of a thicker portion of the slide showing rounded calcispheres. Bedding orientation is displayed horizontally in the image.

Sample # 8128, 100/11-17-088-03W6/00, 2319.3 m - Muskwa Formation

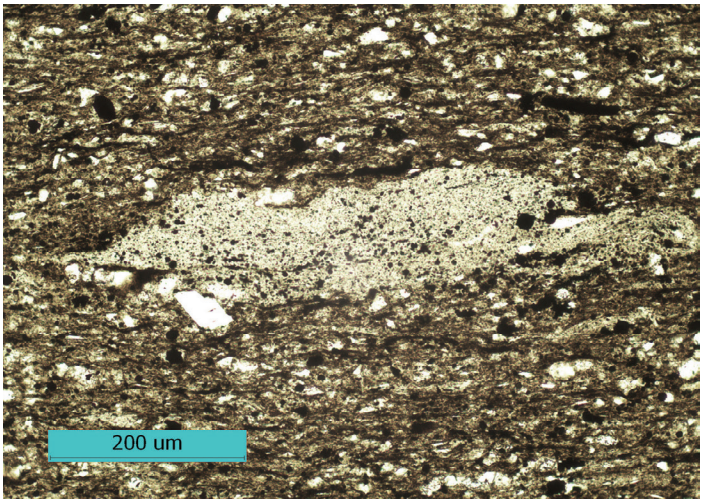

Plate 4: plane-polarized light. A medium- to high-magnification view showing a lens of clay-sized minerals. These lenses are fairly common in the slide and sometimes are associated with an increase in disseminated pyrite. The clay-sized minerals are too fine grained for positive identification. Bedding orientation is displayed horizontally in the image.

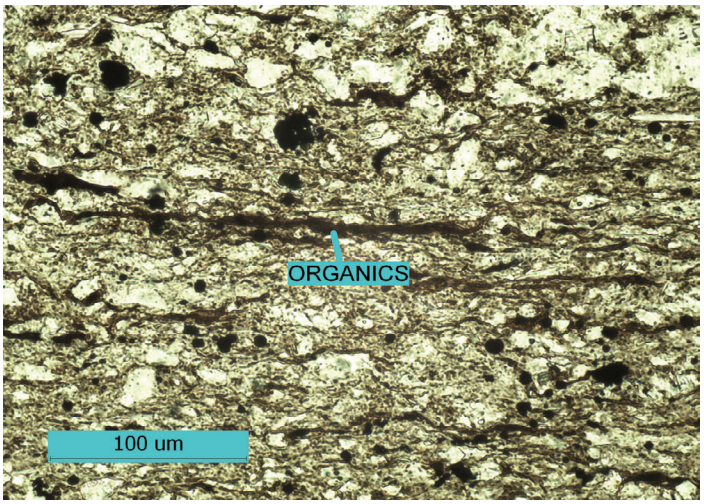

Plate 5: plane-polarized light. A high-magnification view showing mudstone with organic material present as very thin, wispy laminations. Bedding orientation is displayed horizontally in the image.

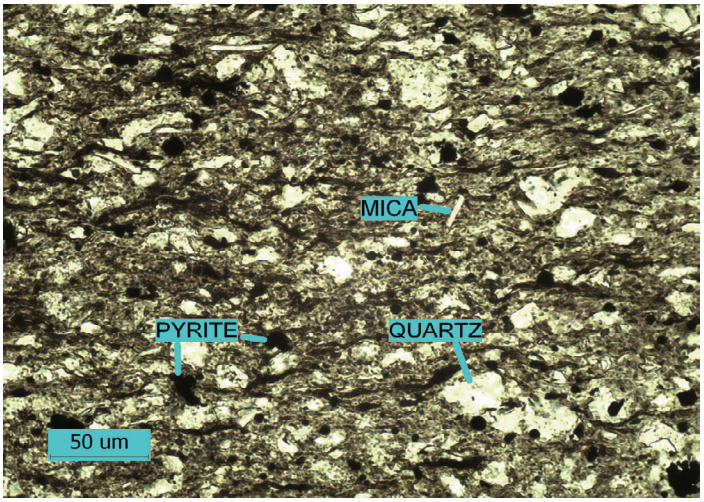

Plate 6: plane-polarized light. A high-magnification view showing mudstone with minor disseminated pyrite. Most of the light coloured grains are quartz but some are dolomite. Bedding orientation is displayed horizontally in the image.

Sample ID	***8454***			
Map ID	***D23***	**UWI**	***100/04-33-068-22W4/00***	
Strat. Unit	***Duvernay Formation***	**Depth**	***1054.6 m***	

Grain Size	**%**	**Variety (%)**	**Variety (%)**	**Variety (%)**	**Variety (%)**	**Variety (%)**
sand	0					
upper silt	0					
lower silt	0					
clay	64	calcite (70)	clay/mud (20)	dolomite (10)		
Cement	5	calcite (100)				
Allochems	25	peloids (80)	bioclasts (20)			
Organics	5	algae spores (60)	amorphous (40)			
Opaques	1	pyrite (100)				
	100					

Sedimentary Structures

Primary	wackestone is massive, mudstone is finely laminated to wavy laminated
Biogenic	none observed

Fractures	several carbonate-cemented vertical microfractures and two carbonate-filled discontinuous horizontal microfractures
Porosity	no porosity or microporosity observed

Description

Peloidal wackestone and finely to wavy laminated carbonate mudstone. Approximately 50% of the slide is a very tight peloidal wackestone with scattered bioclasts and trace fossils. This wackestone is bordered on either side by a dark, thinly laminated carbonate mudstone with amorphous organic material, compressed marine algae spore cases, scattered thin lenses of coarser bioclastic debris, and sparry cement.

Thin Section Quality

The slide has uneven thickness throughout, slightly too thick in places; 1/2 stained for carbonates.

Rock Classification

peloidal wackestone and mudstone (Dunham, 1962 cited in Embry and Klovan, 1972)

fossiliferous micrite and micrite (Folk, 1974)

Sample # 8454, UWI 100/04-33-068-22W4/00, 1054.6 m - Duvernay Formation

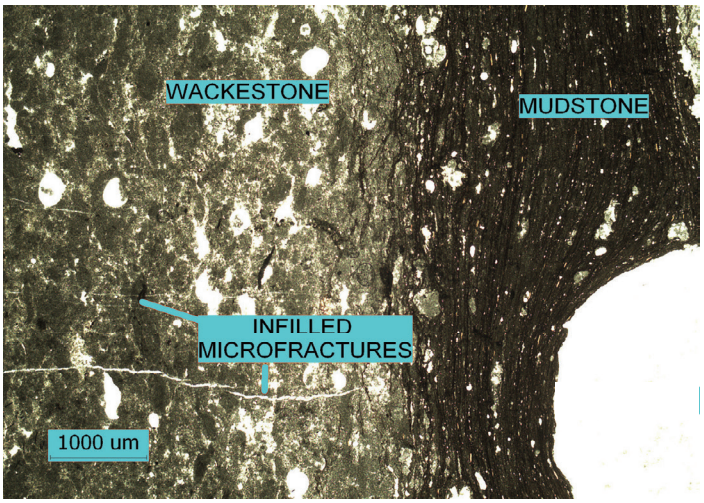

Plate 1: plane-polarized light. A low-magnification view shows a sharp contact between very thinly laminated mudstone (right) and peloidal wackestone (left). Part of a bioclast (overexposed) is at lower right corner of image. Another thin bed of mudstone borders the wackestone to the left of the field of view. Bedding orientation is displayed vertically in the image.

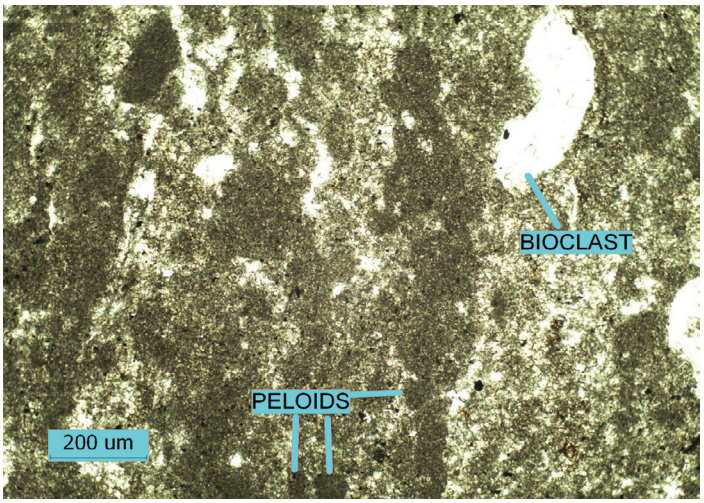

Plate 2: plane-polarized light. A low- to medium-magnification view of an unstained, thicker portion of the wackestone showing groups of peloids. Bedding orientation is displayed vertically in the image.

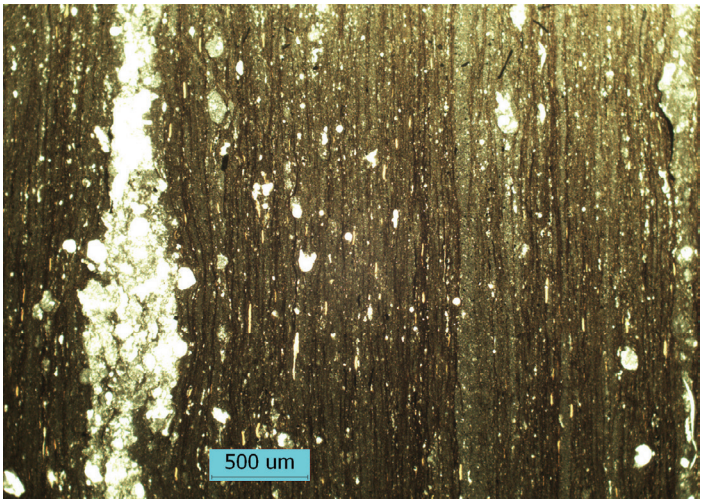

Plate 3: plane-polarized light. A low- to medium-magnification view of an unstained portion of mudstone showing fine laminations and a lense of coarser material, predominantly bioclastic debris. Bedding orientation is displayed vertically in the image.

Sample # 8454, UWI 100/04-33-068-22W4/00, 1054.6 m - Duvernay Formation

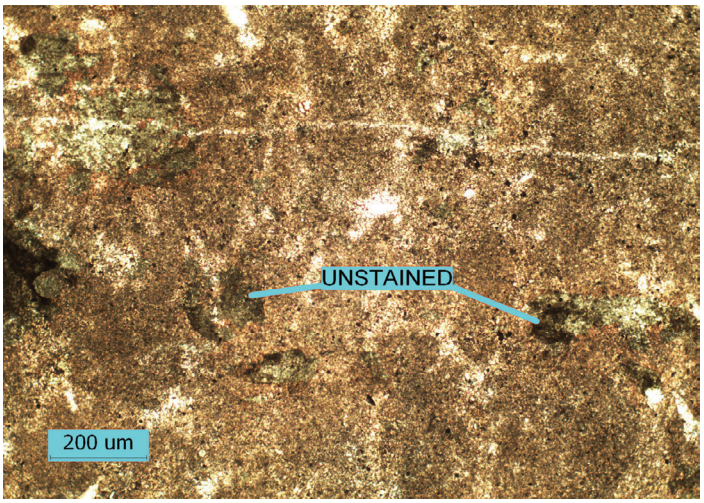

Plate 4: plane-polarized light. A low- to medium-magnification view of a stained portion of wackestone, with an extremely fine vertical fracture with calcite cement. Similar fractures are in the unstained portion of the slide. Small patches of the slide did not stain. This could be a staining issue rather than selective dolomitization. A few of the unstained patches are associated with increased organics. Bedding orientation is displayed vertically in the image.

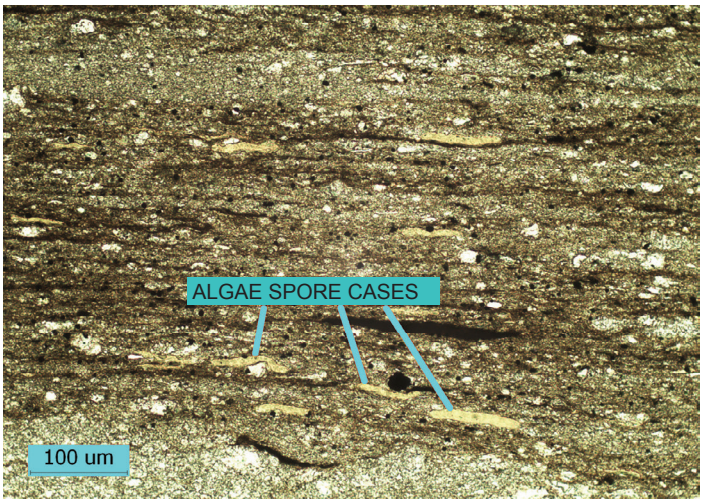

Plate 5: plane-polarized light. A medium- to high-magnification view of unstained mudstone shows organic matter, possibly compressed marine algae spore cases (light yellow). They appear throughout the mudstone sections of the slide but not in the wackestone. Bedding orientation is displayed horizontally in the image.

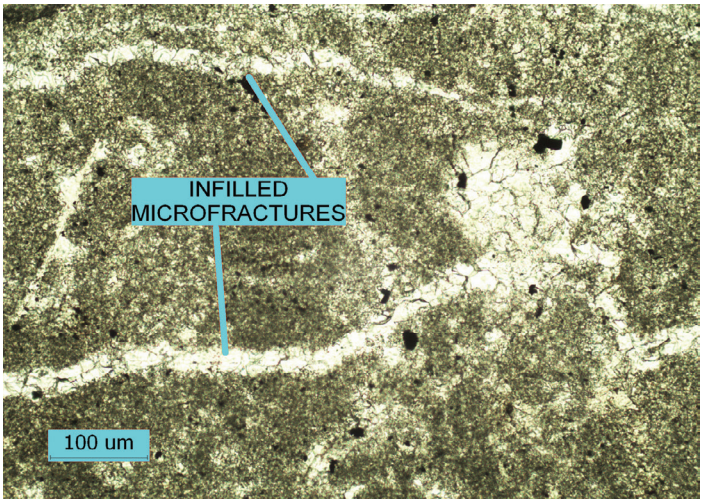

Plate 6: plane-polarized light. A medium- to high-magnification view shows cemented vertical microfractures. This portion of the slide is unstained but the cement appears to be calcite. Bedding orientation is displayed vertically in the image.

Sample ID	***8461***		
Map ID	***D15***	**UWI**	***100/10-09-059-11W4/00***
Strat. Unit	***Duvernay Formation***	**Depth**	***797.7 m***

Grain Size	**%**	**Variety (%)**	**Variety (%)**	**Variety (%)**	**Variety (%)**	**Variety (%)**
sand	0					
upper silt	0					
lower silt	0					
clay	64	calcite (100)				
Cement	25	bioclasts (90)	fractures (10)			
Allochems	5	peloids (100)				
Organics	5	amorphous (90)	algae spores (10)			
Opaques	1	pyrite (100)				
	100					

Sedimentary Structures

Primary	wavy laminated
Biogenic	minor bioturbation

Fractures	one very fine vertical fracture that is filled with calcite cement
Porosity	no porosity or microporosity observed

Description

Wavy laminated wackestone. The sample is wavy laminated and contains bioclastic debris, trace amounts of amorphous organics, algae spore cases, and peloids. Coarser laminations contain increased amorphous organic material (thin and wispy) and trace amounts of plant matter. Staining indicates that the majority of the mineral content is calcite.There are minor amounts of bioturbation.

Thin Section Quality

The slide is of fair quality; 1/2 stained for carbonates

Rock Classification

wackestone (Dunham, 1962 cited in Embry and Klovan, 1972)

sparse biomicrite (Folk, 1974)

Sample # 8461 - 100/10-09-059-11W4/00, 797.7 m - Duvernay Formation

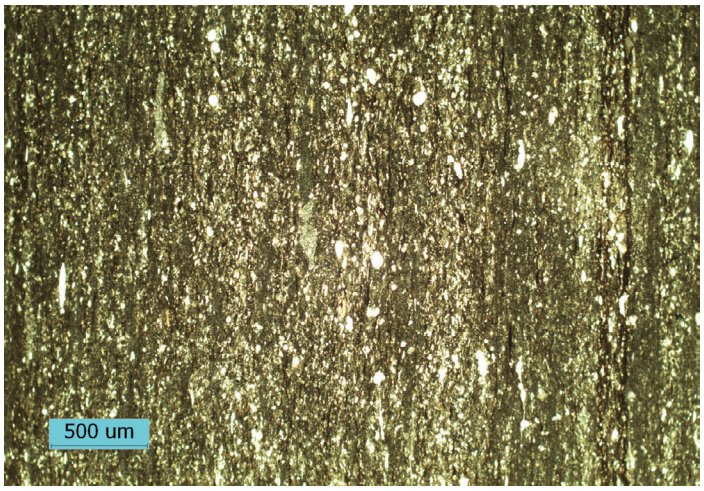

Plate 1: plane-polarized light. A low-magnification overview of an unstained portion of the thin section with thinly laminated wackestone. Bedding orientation is displayed vertically in the image.

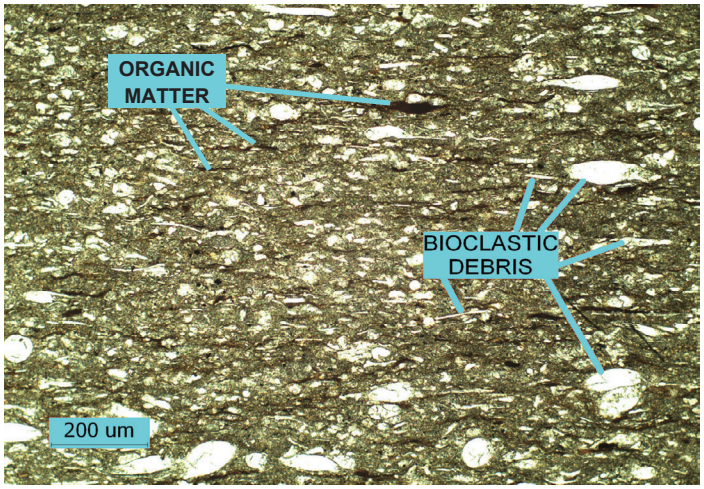

Plate 2: plane-polarized light. A medium-magnification view of an unstained portion of the slide shows a slightly coarser section of the slide. All of the white grains in the image are calcite, some are bioclastic others, are uncertain. Small lenses of organic matter can be seen scattered throughout the sample. Bedding orientation is displayed horizontally in the image.

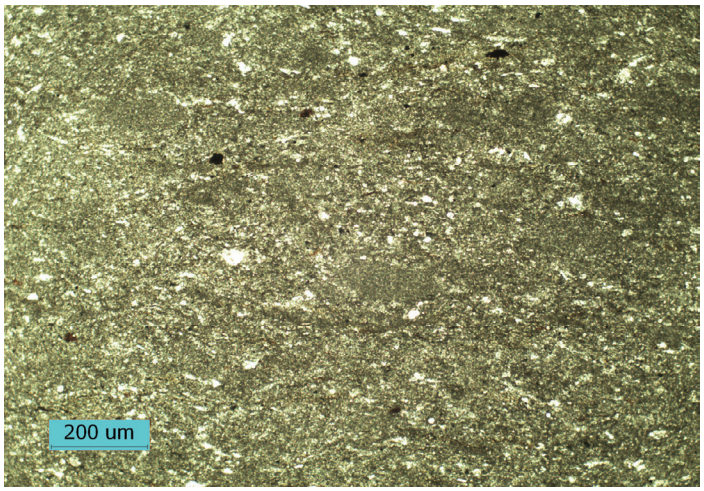

Plate 3: plane-polarized light. A medium-magnification view of an unstained portion of the slide exhibiting a much finer grained limestone compared to the two previous Plates. This is classified as mudstone (lime mudstone) with minor bioturbation and very little organic matter. Bedding orientation is displayed horizontally in the image.

Sample # 8461 - 100/10-09-059-11W4/00, 797.7 m - Duvernay Formation

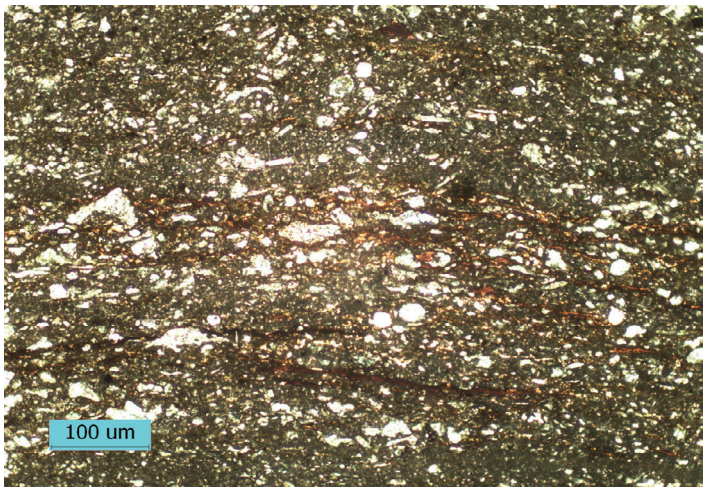

Plate 4: plane-polarized light. A medium- to high-magnification view of an unstained portion of the slide showing a very fine bioclastic wackestone. The reddish-brown in this image is organics mixed with possibly clays. Bedding orientation is displayed horizontally in the image.

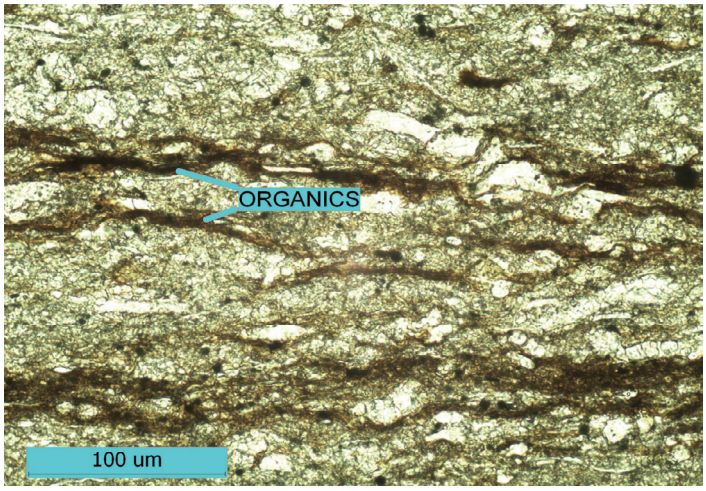

Plate 5: plane-polarized light. A high-magnification view showing very thin laminations of organic-rich material. Most of the organics in the slide are in wispy, discontinuous laminations within the coarser material, but some laminations, such as these, are continous over the length of the slide. Bedding orientation is displayed horizontally in the image.

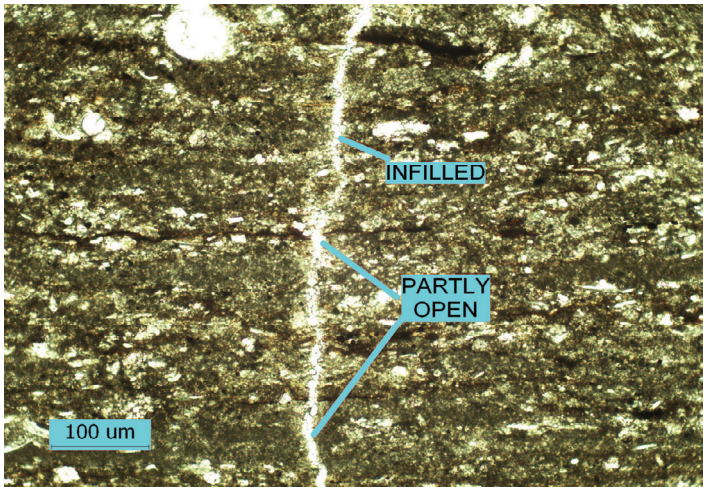

Plate 6: plane-polarized light. A medium- to high-magnification view of a vertical fracture in the unstained portion of the slide. The fracture is predominantly cemented, possibly with calcite. Areas of the fracture that are not infilled could be original uncemented areas or may be the result of thin-section creation. Bedding orientation is displayed horizontally in the image.

Sample ID	***8481***		
Map ID	***D21***	**UWI**	***100/10-13-063-12W5/00***
Strat. Unit	***Majeau Lake Member***	**Depth**	***2625.5 m***

Grain Size	**%**	**Variety (%)**	**Variety (%)**	**Variety (%)**	**Variety (%)**	**Variety (%)**
sand	0					
upper silt	0					
lower silt	3	quartz (60)	calcite (30)	mica (10)	feldspar (trace)	
clay	89	clay/mud (60)	quartz (30)	mica (5)	carbonate (5)	
Cement	0					
Allochems	0					
Organics	3	amorphous (90)	plant (10)			
Opaques	5	pyrite (100)				
	100					

Sedimentary Structures

Primary	massive to lenticular laminated
Biogenic	none observed

Fractures	multiple very fine, open, horizontal microfractures, likely created during thin-section creation, indicates some natural fissility
Porosity	no porosity or microporosity observed

Description

Lenticular laminated claystone. The parallel orientation of organics and microfractures is a faint indication of bedding orientation. There is only a very small amount of lower silt-sized grains. Cement is ferroan calcite. Lack of staining of the clay-sized fraction suggests noncarbonate minerals. There is approximately 5% disseminated pyrite, minor amorphous organic material (as thin, wispy discontinous laminations and partings), and trace plant debris.

Thin Section Quality

There are two thin-sections, neither are of very good quality; one was 1/2 stained for carbonates

Rock Classification

claystone (Folk, 1974)

Sample # 8481 - 100/10-13-063-12W5/00, 2625.5 m - Majeau Lake Member

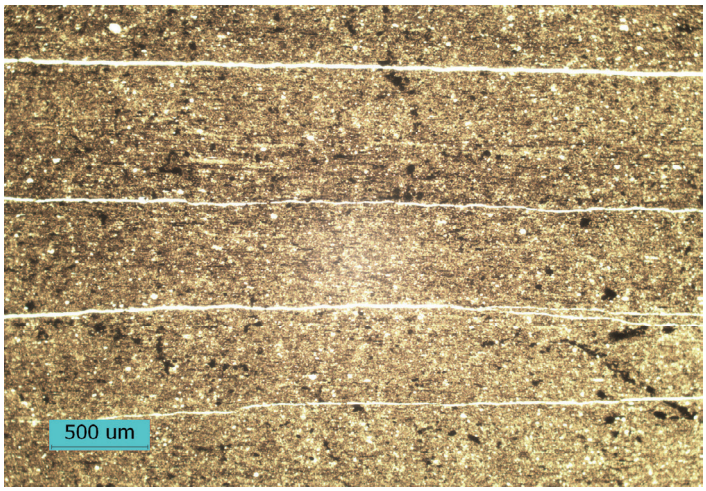

Plate 1: plane-polarized light. A low- to medium-magnification shows extremely fine grained claystone with parallel, open, horizontal microfractures (created during thin-section creation). Bedding orientation is displayed horizontally in the image.

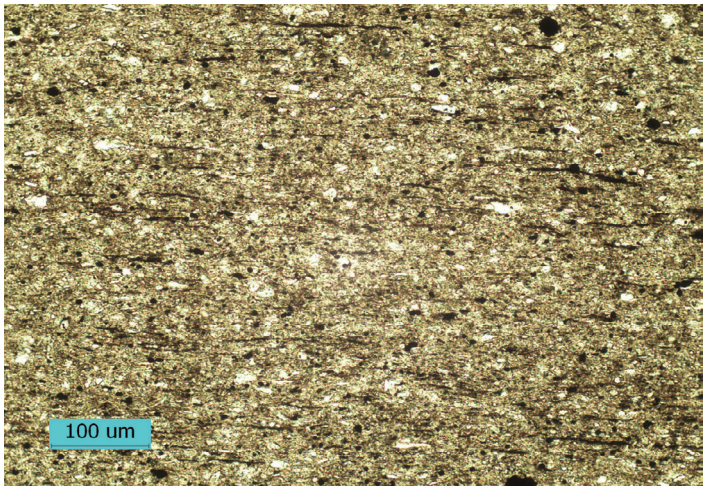

Plate 2: plane-polarized light. A medium-magnification view shows slightly silty claystone. Bedding orientation is displayed horizontally in the image.

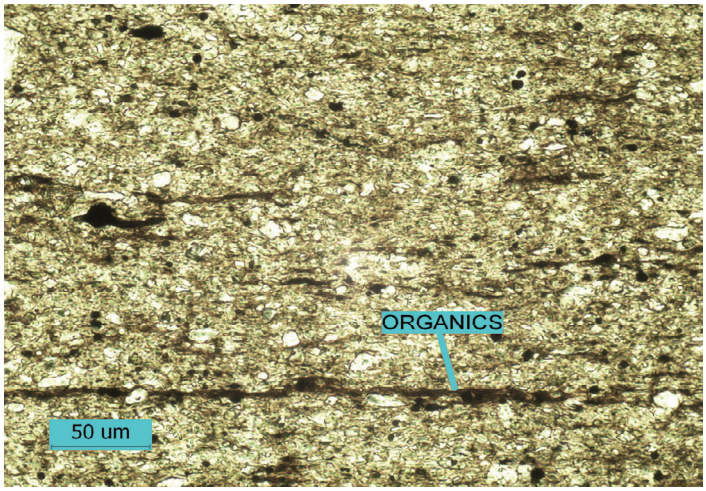

Plate 3: plane-polarized light. A high-magnification view shows slightly silty claystone with minor organic material present as thin, wispy, discontinuous laminations. Bedding orientation is displayed horizontally in the image.

Sample # 8481 - 100/10-13-063-12W5/00, 2625.5 m - Majeau Lake Member

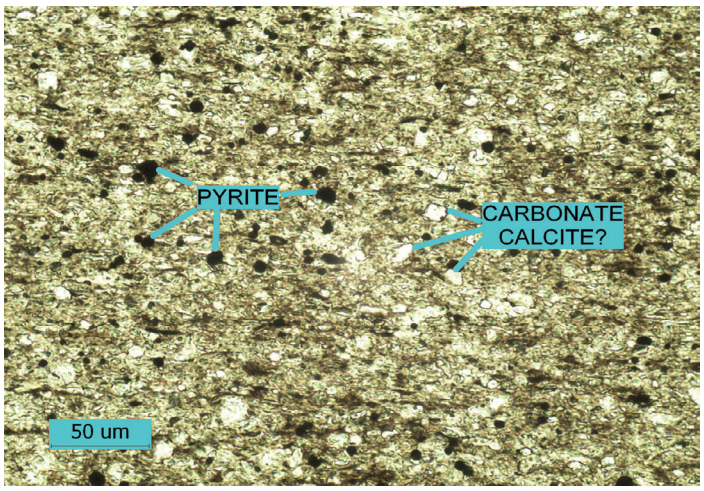

Plate 4: plane-polarized light. A high-magnification view of a representative portion of the thin section. There is a relatively high pyrite content as well as the presence of clay- and silt-sized carbonate cement (see description of Plate 5 below). Bedding orientation is displayed horizontally in the image.

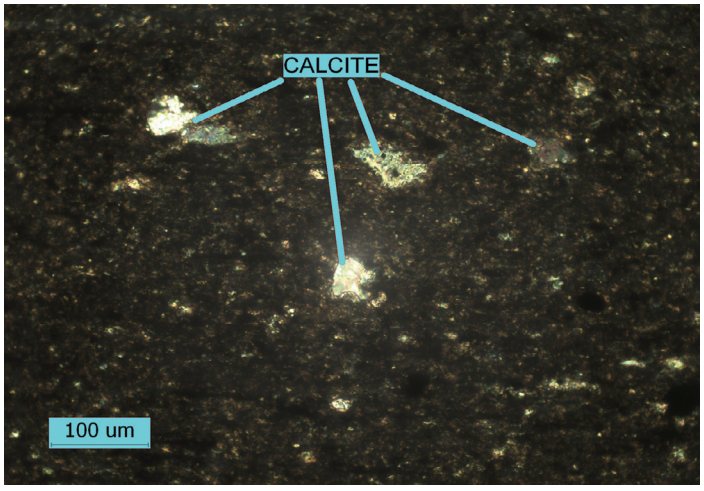

Plate 5: cross-polarized light. A high-magnification view shows the presence of a carbonate mineral, possibly calcite. There is also a small percentage of clay-sized carbonate grains in the matrix, such as those seen in Plate 4. Bedding orientation is displayed horizontally in the image.

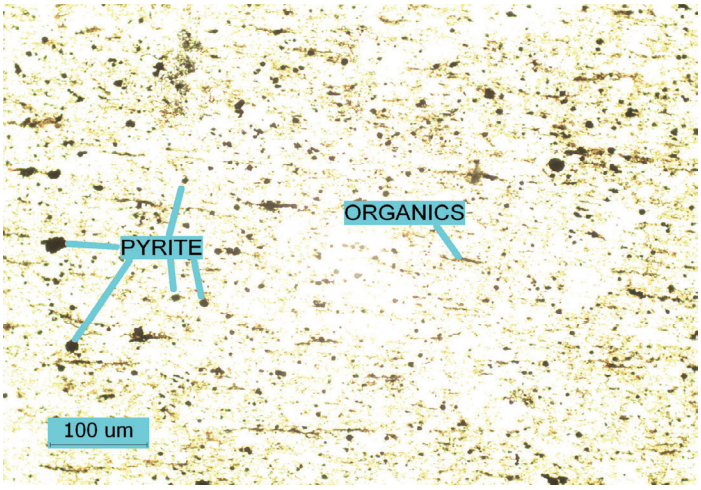

Plate 6: plane-polarized light. A medium- to high-magnification view, purposely overexposed to highlight the presence of opaques, mainly pyrite, which are disseminated throughout the thin section as small nodules. Some organic material is opaque in this image (thin, wispy laminae). Bedding orientation is displayed horizontally in the image.

Sample ID	***8492***				
Map ID	***D07***		**UWI**	***100/14-29-048-06W5/00***	
Strat. Unit	***Duvernay Formation***		**Depth**	***2655.7 m***	

Grain Size	**%**	**Variety (%)**	**Variety (%)**	**Variety (%)**	**Variety (%)**	**Variety (%)**
sand	0					
upper silt	5	quartz (60)	calcite (35)	mica (5)	feldspar (trace)	
lower silt	15	quartz (60)	calcite (35)	mica (5)	feldspar (trace)	
clay	70	clay/mud (80)	quartz (15)	mica (5)		
Cement	4	dolomite (100)				
Allochems	<1	bioclasts (100)				
Organics	3	amorphous (100)				
Opaques	2	pyrite (100)				
	99					

Roundness	subangular to subrounded
Sphericity	medium to high
Sorting	moderately sorted

Sedimentary Structures

Primary	finely laminated
Biogenic	none observed

Fractures	trace amounts of irregular, open microfractures, likely created during thin-section creation
Porosity	no porosity or microporosity observed

Description

Finely laminated silty claystone. Silt-sized grains are predominantly quartz and ferroan calcite with some mica (muscovite). The matrix did not stain for carbonates. Organic material is also present throughout the sample in small amounts, mixed with other fine material. The sample has only trace microfractures that were likely created during thin-section creation. Trace bioclasts are present and include tentaculitids and brachiopod shell fragments.

Thin Section Quality

The thin section is of fair quality; 1/2 stained for carbonates.

Rock Classification

silty claystone (Folk, 1974)

Sample # 8492 - 100/14-29-048-06W5/0, 2655.7 m - Duvernay Formation

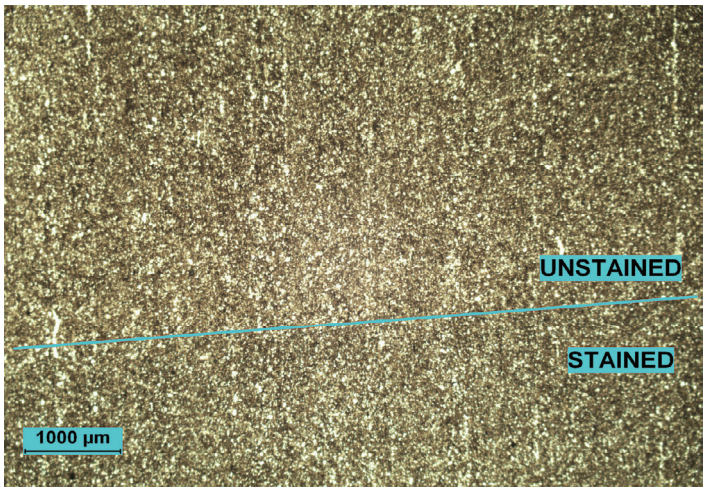

Plate 1: plane-polarized light. A low-magnification view shows finely laminated silty claystone. Lighter coloured laminations are composed of slightly coarser silt-sized grains with a decreased clay-sized content. The stained portions of the slide are slightly darker due to the presence of ferroan calcite (stained blue). Bedding orientation is displayed vertically in the image.

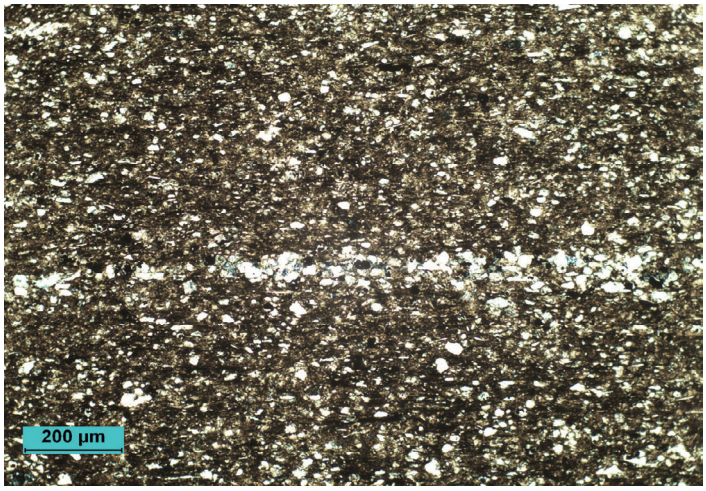

Plate 2: plane-polarized light. A medium-magnification view shows silty claystone with a lamination of slightly coarser silt. The lamination contains ferroan calcite cement (stained blue). Bedding orientation is displayed horizontally in the image.

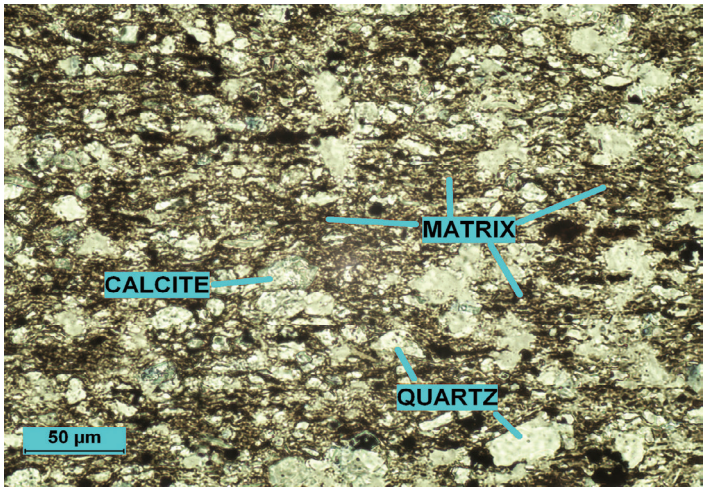

Plate 3: plane-polarized light. A high-magnification view shows silty claystone with quartz grains, calcite and dolomite cements. Organic material is extremely fine, predominantly intermixed within the matrix. Bedding orientation is displayed horizontally in the image.

Sample # 8492 - 100/14-29-048-06W5/0, 2655.7 m - Duvernay Formation

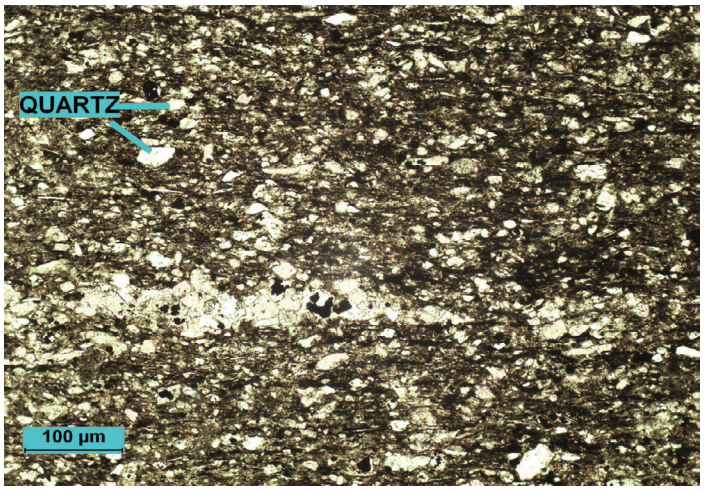

Plate 4: plane-polarized light. A medium- to high-magnification view shows silty claystone with a discontinuous silt lamination. Bedding orientation is displayed horizontally in the image.

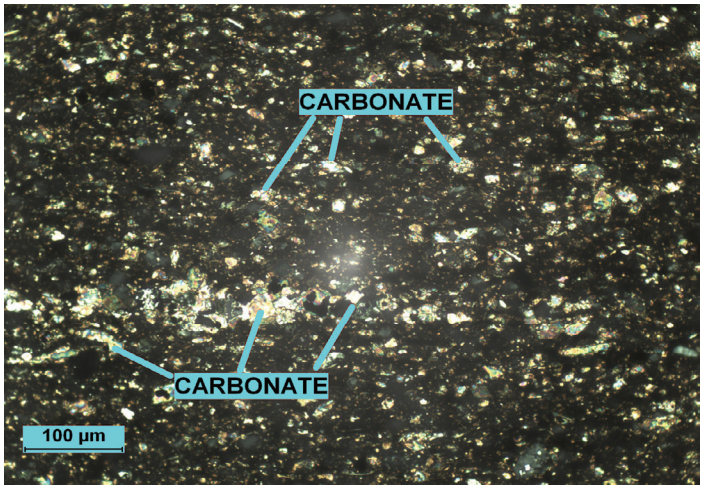

Plate 5: cross-polarized light. The same view as Plate 4 under cross-polarized light shows carbonate cement within the sample. Staining indicates that much is ferroan calcite, but there could be dolomite as well. Bedding orientation is displayed horizontally in the image.

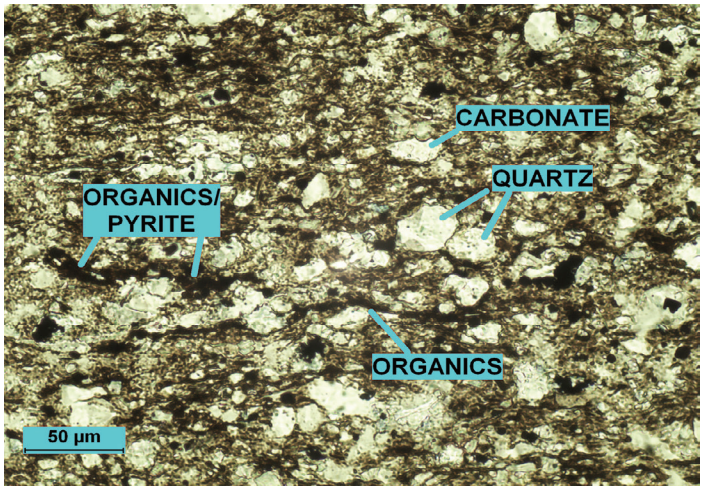

Plate 6: plane-polarized light. A high-magnification view shows organics as thin wispy plates: most of the organic material in the sample is extremely fine and intermixed within the clay-sized material. Bedding orientation is displayed horizontally in the image.

Sample ID	***8995***		
Map ID	***D31***	**UWI**	***100/02-30-088-04W6/00***
Strat. Unit	***Muskwa Formation***	**Depth**	***2401.2 m***

Grain Size	**%**	**Variety (%)**	**Variety (%)**	**Variety (%)**	**Variety (%)**	**Variety (%)**
sand	trace	quartz (100)				
upper silt	2	quartz (100)				
lower silt	5	quartz (80)	mica (20)			
clay	79	clay/mud (65)	calcite (20)	quartz (10)	mica (5)	dolomite (trace)
Cement	2	dolomite (100)				
Allochems	0					
Organics	4	amorphous (100)	plant (trace)			
Opaques	8	pyrite (100)				
	100					

Roundness	subrounded
Sphericity	medium
Sorting	well sorted

Sedimentary Structures

Primary	wavy laminated
Biogenic	none observed

Fractures	abundant open microfractures, most are horizontal and parallel, some are sub-horizontal and discontinuous, all were likely created during thin-section creation
Porosity	no porosity or microporosity observed

Description

Wavy laminated claystone. The sample is a claystone with minor detrital quartz and mica. A few quartz grains are very fine grained sand, but most are lower silt. Most of the sample is noncarbonate clay-sized minerals based on birefringence, habit, and lack of carbonate staining. The sample has abundant, open, parallel microfractures, likely created during thin-section creation. Trace amounts of organic material and relatively high pyrite content are distributed throughout the slide. There are also trace amounts of plant matter and a possible trace fossil. Organic-rich, discontinuous laminations have a parallel orientation, which is indicative of bedding orientation.

Thin Section Quality

The original slide broke and was remounted, very poor quality; 1/2 stained for carbonates.

Rock Classification

claystone (Folk, 1974)

Sample # 8995 - 100/02-30-088-04W6/0, 2401.2 m - Muskwa Formation

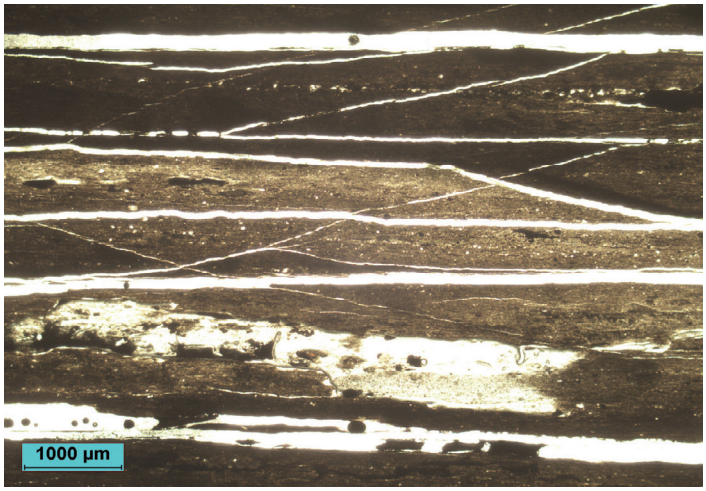

Plate 1: plane-polarized light. A low-magnification overview shows the poor quality of the thin section. The area in the middle of the image represents the most useable portion of the slide. There are abundant fractures created during thin-section creation. The bright white patch in the lower half of the slide is where material has been plucked or washed out. The condition of the slide suggests the presence of some water-sensitive clay minerals. Bedding orientation is displayed horizontally in the image.

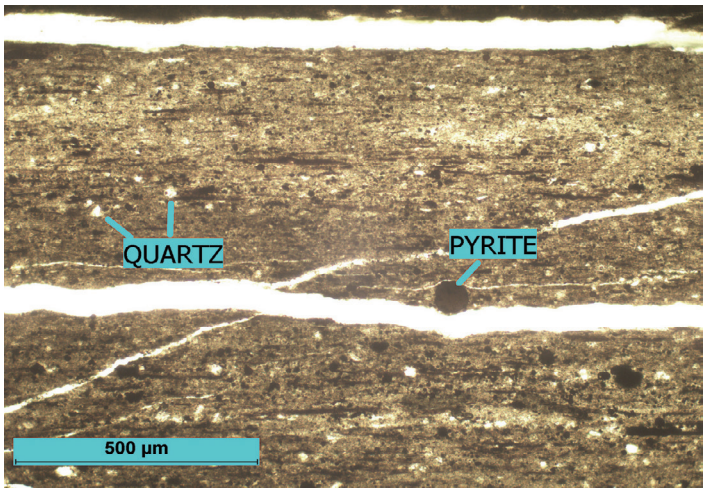

Plate 2: plane-polarized light. A low- to medium-magnification view shows claystone with small amounts of detrital quartz. Most pyrite in the sample is much smaller than indicated in this view. Bedding orientation is displayed horizontally in the image.

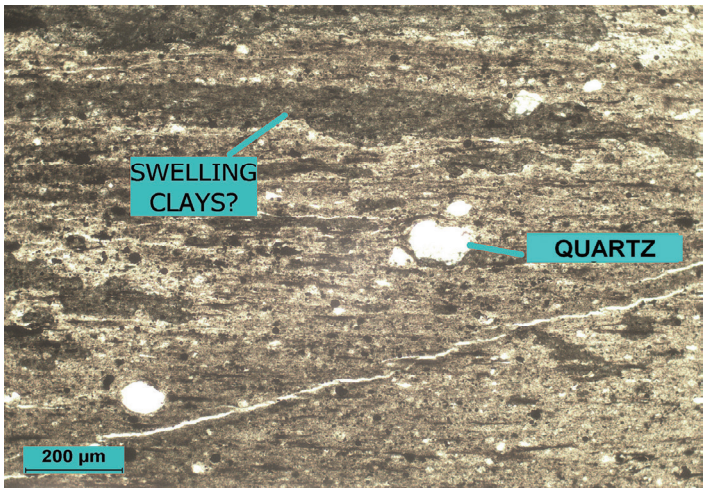

Plate 3: plane-polarized light. A medium-magnification view shows trace amounts of detrital quartz within the claystone, predominantly silt sized, but a few sand-sized grains are present. There is separation between the sample and the glass slide, which could indicate that clay minerals retained water after thin-section creation. The dark patch of clay-sized material could be abundant in swelling clay minerals. Bedding orientation is displayed horizontally in the image.

Sample # 8995 - 100/02-30-088-04W6/0, 2401.2 m - Muskwa Formation

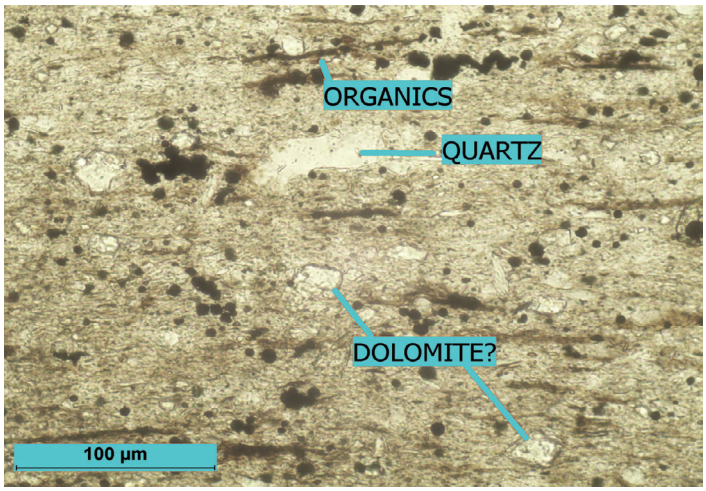

Plate 4: plane-polarized light. A high-magnification view shows a fairly representative portion of the slide. There is no evidence of carbonate staining. A sand-sized quartz grain is present. Euhedral crystals appear to be authigenic dolomite. There are minor amounts of organic material present as thin, wispy, discontinuous laminations and also trace amounts of plant matter. Bedding orientation is displayed horizontally in the image.

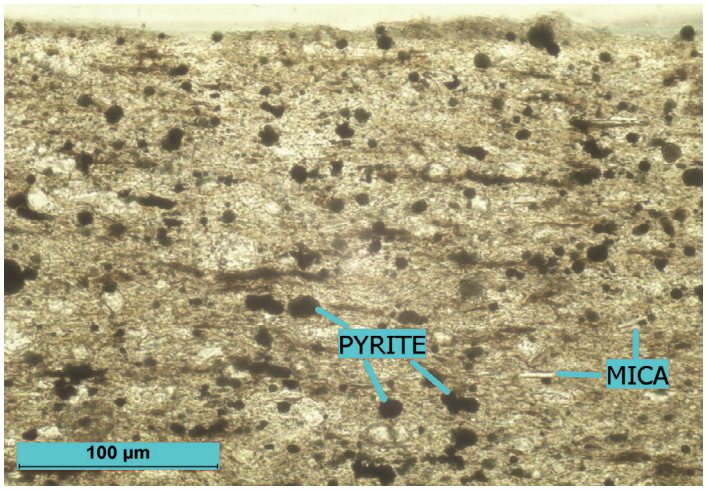

Plate 5: plane-polarized light. A high-magnification view shows disseminated pyrite. Bedding orientation is displayed horizontally in the image.

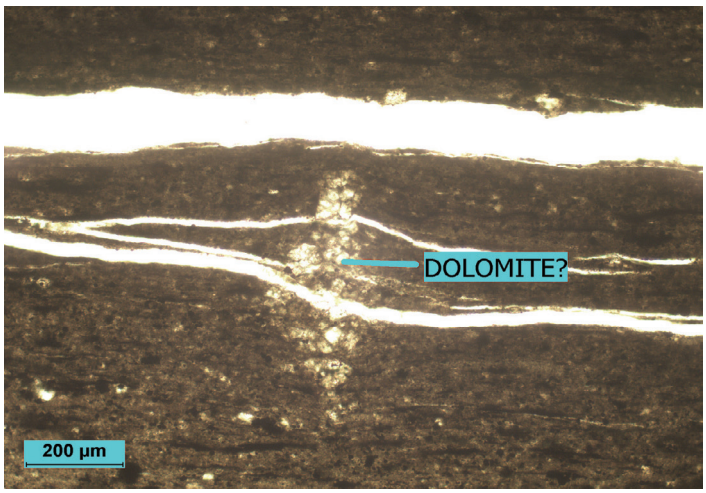

Plate 6: plane-polarized light. A medium-magnification view of a structure in a thick portion of the slide may be an infilled burrow. This section of the slide is unstained and too thick, but the mineral appears to be crystalline dolomite. Bedding orientation is displayed horizontally in the image.

Sample ID	***9210***		
Map ID	***D10***	**UWI**	***100/09-06-052-11 W5/00***
Strat. Unit	***Duvernay***	**Depth**	***3020.1 m***

Grain Size	**%**	**Variety (%)**	**Variety (%)**	**Variety (%)**	**Variety (%)**	**Variety (%)**
sand	0					
upper silt	0					
lower silt	2	quartz (100)				
clay	50	clay/mud (70)	calcite (15)	dolomite (15)		
Cement	20	dolomite (60)	calcite (40)			
Allochems	25	tentaculitids (70)	bioclasts (30)			
Organics	2	amorphous (100)				
Opaques	1	pyrite (100)				
	100					

Sedimentary Structures

Primary	very faint evidence of bedding
Biogenic	none observed

Fractures	no fractures seen
Porosity	no porosity or microporosity observed

Description

Wackestone. There is a significant amount of dark brown groupings of clay-sized grains, which does not seem to have stained; therefore, it is likely noncarbonate. Tentaculitid fragments up to 1 mm in longitudinal section and approximately 150 microns in cross-section are present along with other bioclastic material. Minor amounts of crystalline dolomite and calcite cement are present.

Thin Section Quality

There are 2 thin sections, both are too thick; one is 1/2 stained for carbonates.

Rock Classification

wackestone (Dunham, 1962 cited in Embry and Klovan, 1972)

sparse biomicrite (Folk, 1974)

Sample # 9210 - 100/09-06-052-11W5/00, 3020.1 m - Duvernay Formation

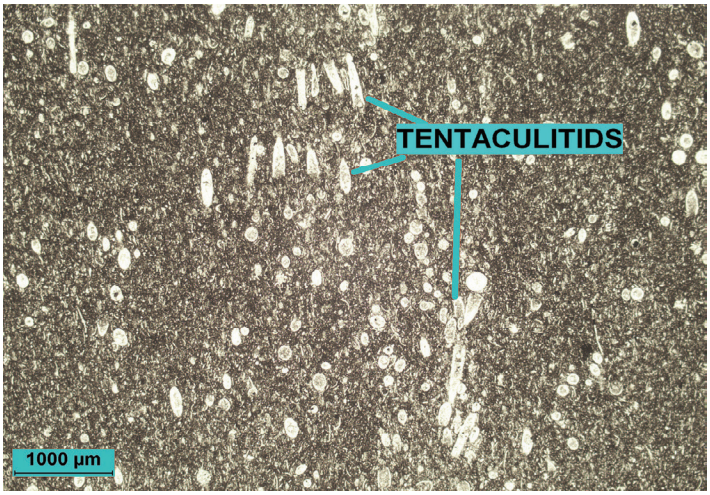

Plate 1: plane-polarized light. A low-magnification overview of an unstained portion of the slide shows wackestone. The most common fossils are tentaculitids. Also present are ostracod shell fragments. Bedding orientation is displayed vertically in the image.

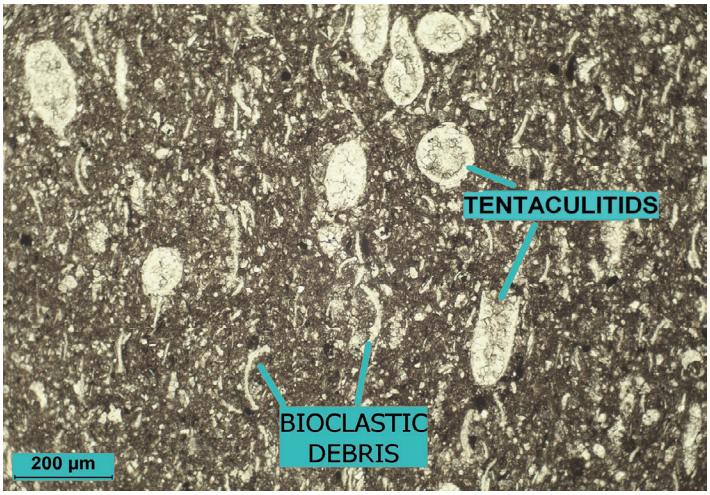

Plate 2: plane-polarized light. A low- to medium-magnification view of an unstained portion of the slide shows tentaculitids and bioclastic debris (tentaculitid and ostracod fragments) within a clay-sized matrix with calcite and dolomite cements. Bedding orientation is displayed vertically in the image.

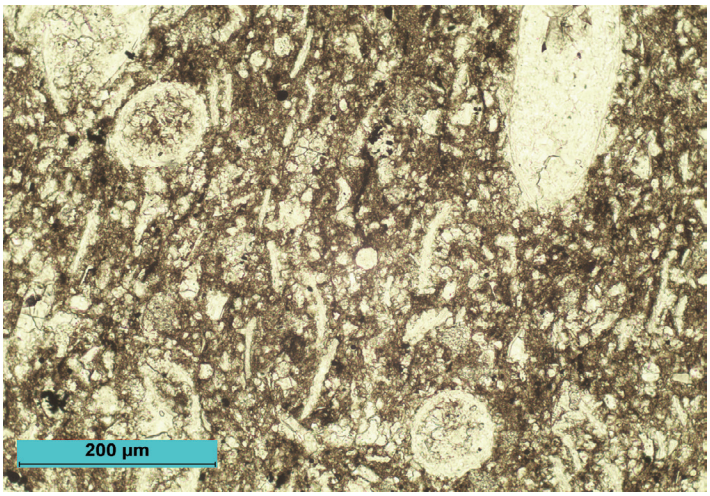

Plate 3: plane-polarized light. A medium- to high-magnification view of an unstained portion of the slide shows tentaculitids and other bioclastic debris within a clay-sized matrix, with calcite and dolomite cements. Bedding orientation is displayed vertically in the image.

Sample # 9210 - 100/09-06-052-11W5/00, 3020.1 m - Duvernay Formation

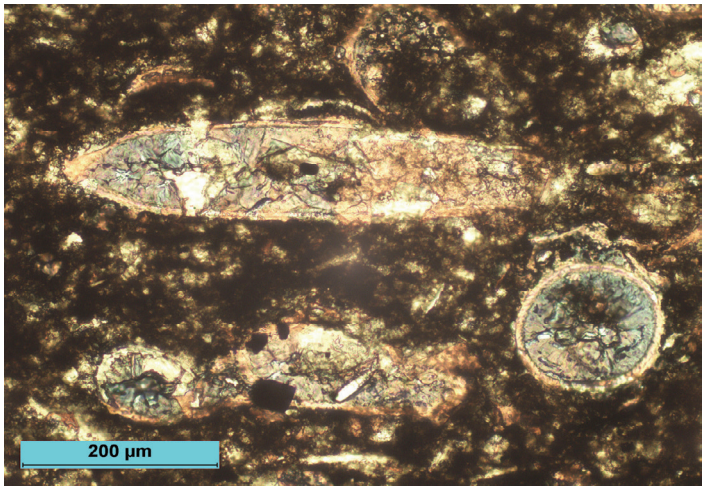

Plate 4: plane-polarized light. A medium- to high-magnification view of tentaculitids in the stained portion of the slide. The stained portion of the slide is over-thick. Ferroan calcite stains blue, non-ferroan calcite stains red. Some fossils also have minor dolomite replacement, locally ferroan. Bedding orientation is displayed horizontally in the image.

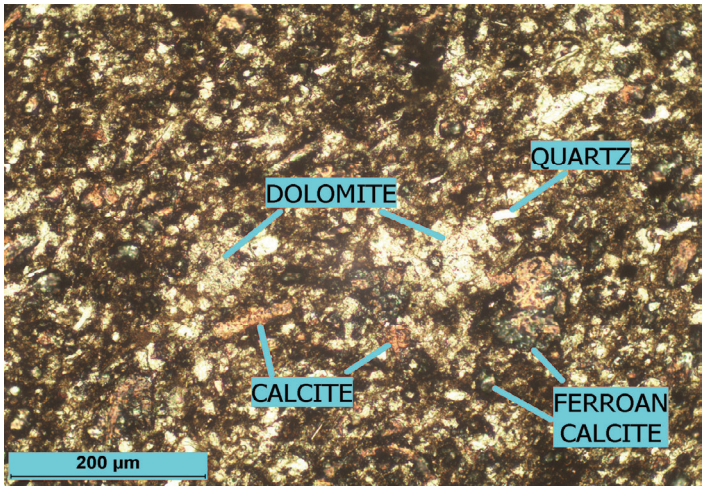

Plate 5: plane-polarized light. A medium- to high-magnification view of a stained portion of the slide shows a variety of cements. Most of the non-ferroan calcite is bioclastic debris while the ferroan calcite and dolomite appears to be a secondary cement. The stained portion of the slide is over-thick. Bedding orientation is displayed horizontally in the image.

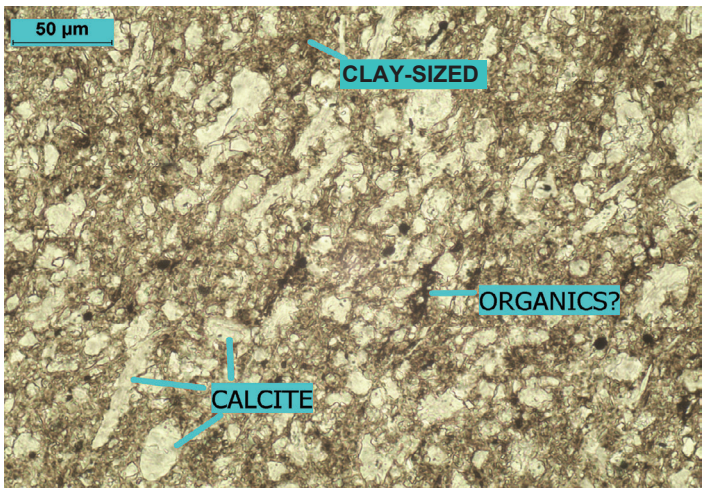

Plate 6, plane-polarized light. A high-magnification view shows that the thin section has high clay-sized content. Only trace amounts of organics are present, some visible and intermixed with clay-sized material. Bedding orientation is displayed vertically in the image.

Sample ID	***9226***				
Map ID	***D22***		**UWI**	***100/10-05-065-15W5/00***	
Strat. Unit	***Duvernay***		**Depth**	***2752.0 m***	

Grain Size	**%**	**Variety (%)**	**Variety (%)**	**Variety (%)**	**Variety (%)**	**Variety (%)**
sand	0					
upper silt	0					
lower silt	4	quartz (60)	mica (40)			
clay	82	clay/mud (55)	calcite (30)	mica (10)	quartz (5)	
Cement	5	calcite (100)				
Allochems	2	tentaculitids (80)	bioclasts (20)			
Organics	5	amorphous (100)				
Opaques	2	pyrite (100)				
	100					

Sedimentary Structures

Primary	massive with parallel orientation of organics
Biogenic	none observed

Fractures	common parallel open microfractures assumed to be horizontal, a few are sub-horizontal and/or discontinuous; all are likely created during thin-section creation
Porosity	no porosity or microporosity observed

Other Notes

Calcareous claystone. The sample is extremely fine grained with only trace amounts of lower silt-sized grains (quartz and mica). A small amount of tentaculitid fossils are present. There is a ferroan calcite component, predominantly as silt-sized grains, some recognizable as bioclastic debris, and the rest probably a cement.

Thin Section Quality

Very poor quality, original slide broke and was remounted on a second; 1/2 stained for carbonates.

Rock Classification

calcareous claystone (Folk, 1994)

Sample # 9226 - 100/10-05-065-15W5/00, 2752.0 m - Duvernay Formation

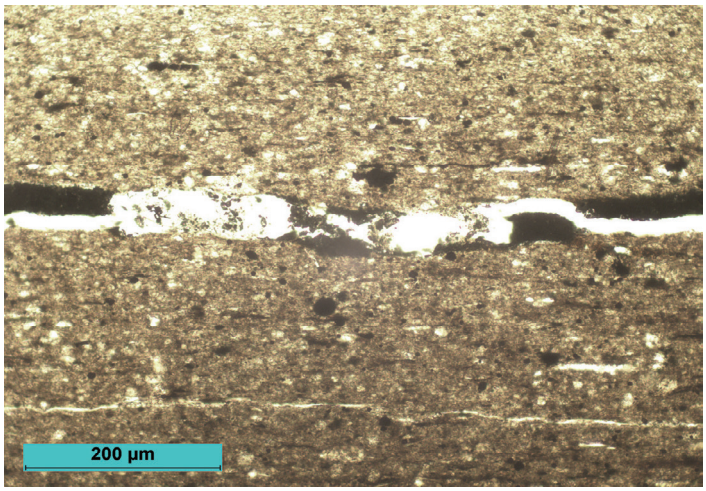

Plate 1: plane-polarized light. A low- to medium-magnification overview shows calcareous claystone with a large open fracture near the middle, partly infilled with rock flour. It is difficult to get good images because of the poor quality of the slide. Bedding orientation is displayed horizontally in the image.

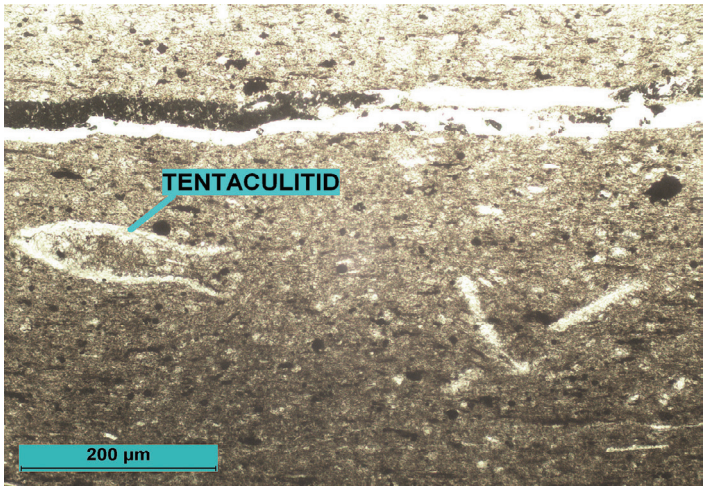

Plate 2: plane-polarized light. A low- to medium-magnification view of the unstained portion of the slide shows a tentaculitid fossil and other bioclastic debris. Bedding orientation is displayed horizontally in the image.

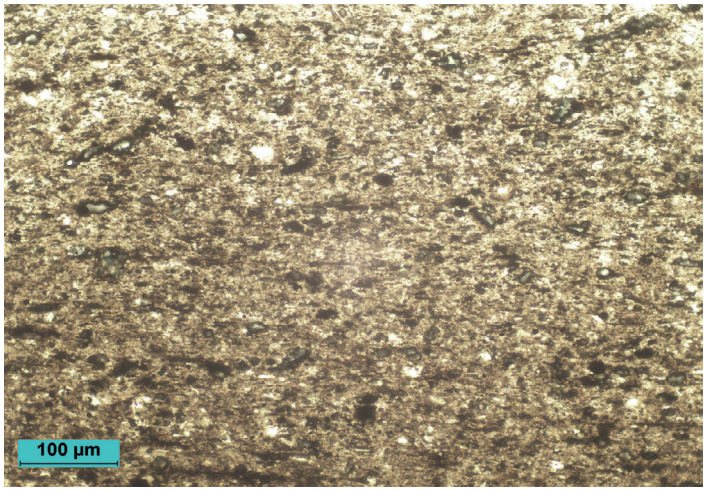

Plate 3: plane-polarized light. A medium- to high-magnification view of a stained portion of the slide shows claystone with a moderate ferroan calcite component (stained blue). Some calcite is bioclastic debris and some is cement. Bedding orientation is displayed horizontally in the image.

Sample # 9226 - 100/10-05-065-15W5/00, 2752.0 m - Duvernay Formation

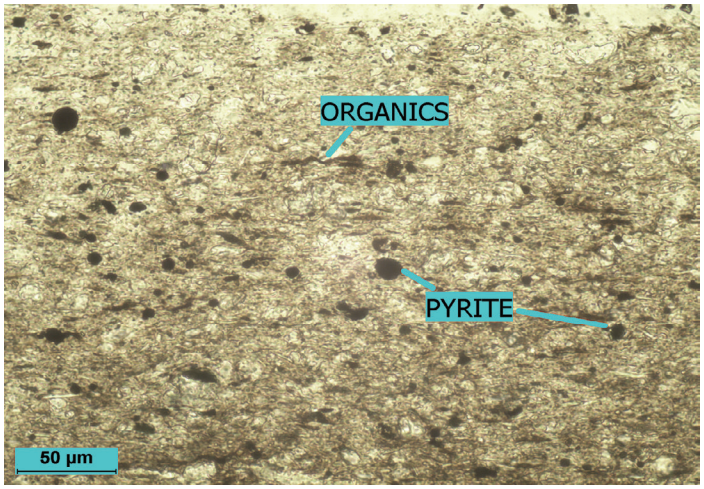

Plate 4: plane-polarized light. A high-magnification view of the unstained portion of the slide. The bulk of the sample is either dolomitic or noncarbonate with trace amounts of silt-sized quartz and mica, minor disseminated pyrite, and trace amounts of organic material. Bedding orientation is displayed horizontally in the image.

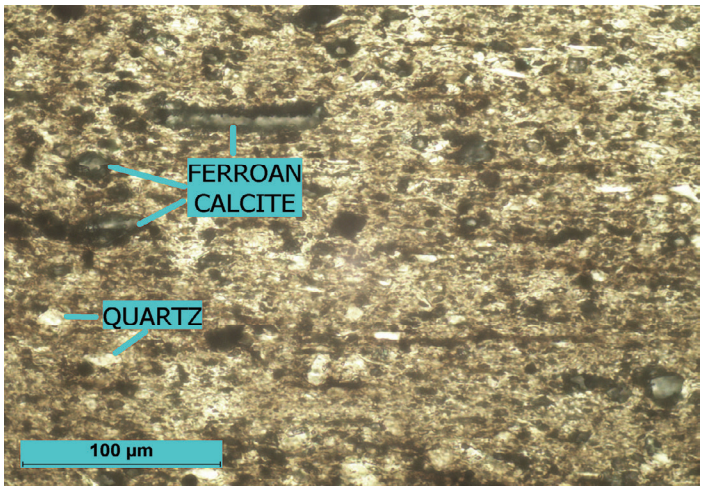

Plate 5: plane-polarized light. A medium- to high-magnification view of the stained portion of the slide shows the presence of ferroan calcite (faintly blue staining). Some larger grains can be identified as bioclastic debris, some may be cement. The hand sample has a strong reaction with HCl. Bedding orientation is displayed horizontally in the image.

Sample ID	***9238***		
Map ID	***D01***	**UWI**	***100/06-14-037-07W5/00***
Strat. Unit	***Duvernay***	**Depth**	***3649.7 m***

Grain Size	**%**	**Variety (%)**	**Variety (%)**	**Variety (%)**	**Variety (%)**	**Variety (%)**
sand	0					
upper silt	0					
lower silt	2	quartz (100)				
clay	35	clay/mud (60)	carbonate (40)			
Cement	23	calcite (90)	dolomite (10)			
Allochems	36	calcispheres (80)	tentaculitids (10)	brachiopods (5)	ostracods (5)	
Organics	<1	amorphous				
Opaques	4	pyrite				
	100					

Sedimentary Structures

Primary	lenticular laminated
Biogenic	minor bioturbation

Fractures	trace amounts of open horizontal microfractures, likely created during thin-section creation
Porosity	no porosity or microporosity observed

Description

Lenticular laminated wackestone. Sample has bioclastic debris (thin-shelled brachiopods, tentaculitids, and ostracods) and burrows, as well as trace amounts of amorphous organic matter. There are minor amounts of other silt-sized grains (quartz and possibly mica).

Thin Section Quality

Two thin sections: one is of fair quality and 1/2 stained for carbonates; the other is too thick.

Rock Classification

wackestone (Dunham, 1962 cited in Embry and Klovan, 1972)

sparse biomicrite (Folk, 1974)

Sample # 9238 - 100/06-14-037-07W5/00, 3649.7 m - Duvernay Formation

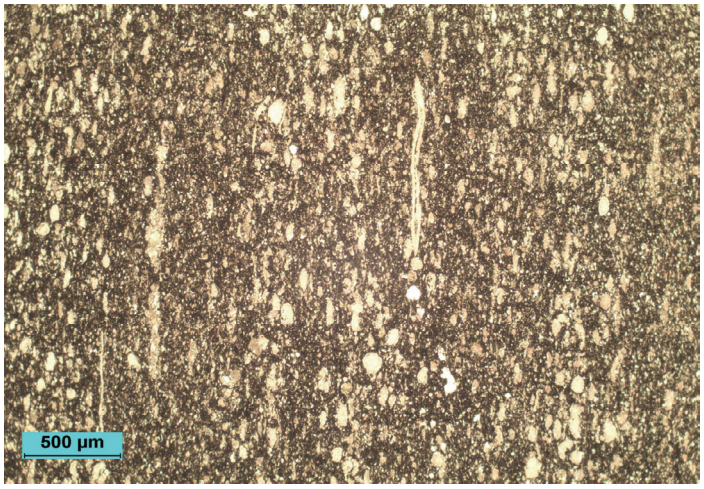

Plate 1: plane-polarized light. A low-magnification view of a stained portion of the slide is a wackestone, showing fossils possibly including tenticulitids, calcispheres, thin-shelled brachiopod fragments, and ostracods. Bedding orientation is displayed vertically in the image.

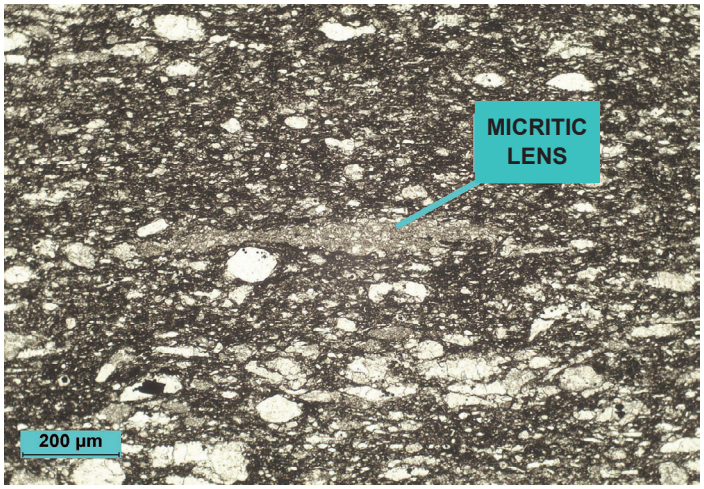

Plate 2: plane-polarized light. A medium-magnification view shows a micritic lens. This portion of the slide is unstained, but similar features in the stained portion of the slide confirm the burrows are infilled with micrite. Bedding orientation is displayed horizontally in the image.

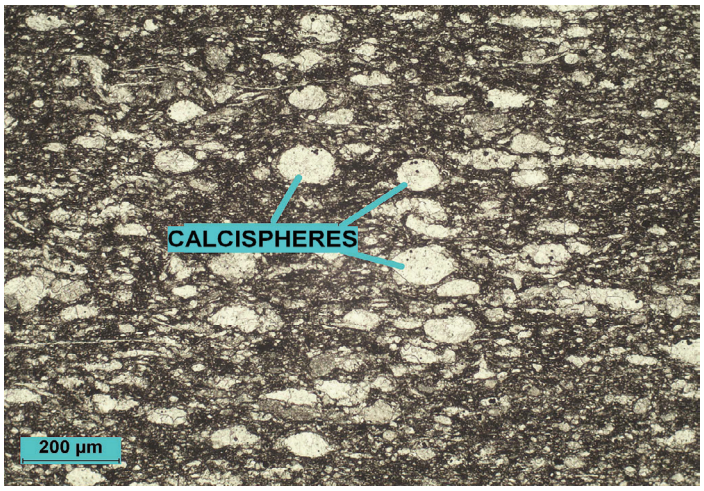

Plate 3: plane-polarized light. A medium-magnification view of an unstained portion of the slide showing fossils including tentaculitids and calcispheres. Bedding orientation is displayed horizontally in the image.

Sample # 9238 - 100/06-14-037-07W5/00, 3649.7 m - Duvernay Formation

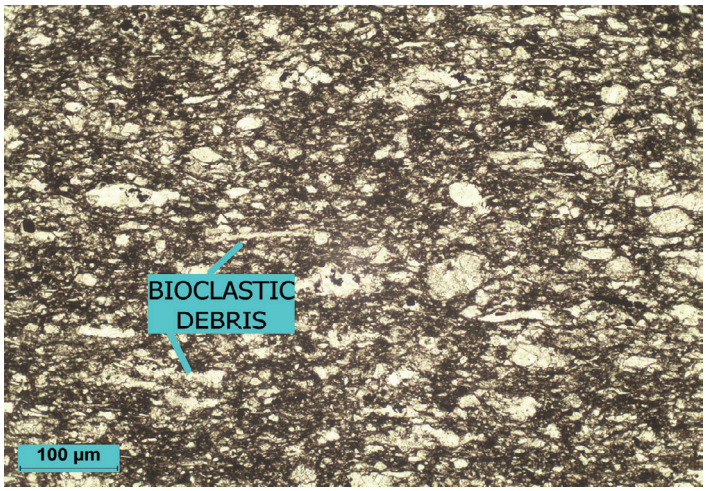

Plate 4: plane-polarized light. A medium- to high-magnification view of an unstained portion of the slide showing abundant grains, mostly calcareous. Almost all light-coloured grains are calcite, some are identifiable as bioclastic debris, and some of the smaller grains may be secondary cement. Bedding orientation is displayed horizontally in the image.

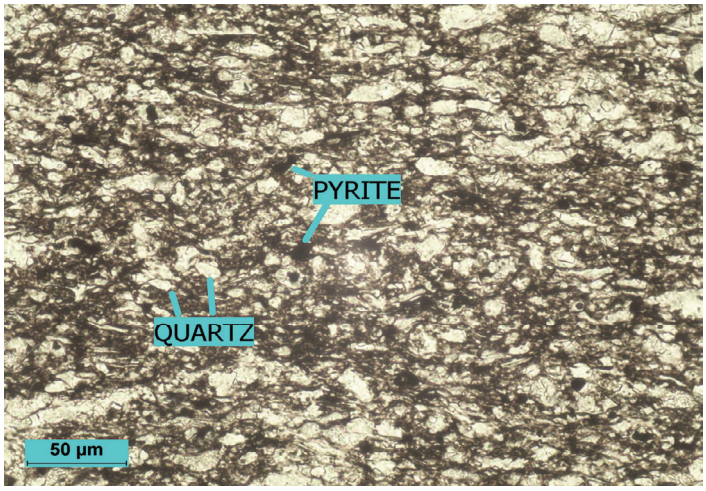

Plate 5: plane-polarized light. A high-magnification view of an unstained portion of the slide showing abundant grains, mostly calcareous. The dark, clay-sized material did not appear to stain; therefore, it is likely a mixture of noncarbonate minerals. Bedding orientation is displayed horizontally in the image.

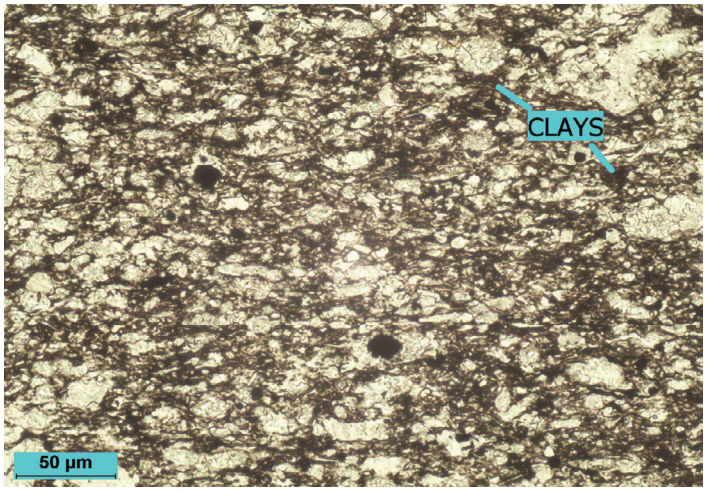

Plate 6: plane-polarized light. A high-magnification view shows abundant calcareous grains. Almost all of the light-coloured grains are calcite; only a trace amount of quartz and dolomite are present. Bedding orientation is displayed horizontally in the image.

Sample ID	***9362***			
Map ID	***D06***	**UWI**	***100/02-06-047-04W5/00***	
Strat. Unit	***Duvernay***	**Depth**	***2639.6 m***	

Grain Size	**%**	**Variety (%)**	**Variety (%)**	**Variety (%)**	**Variety (%)**	**Variety (%)**
sand	0					
upper silt	0					
lower silt	2	quartz (100)				
clay	61	calcite (60)	clay/mud (35)	quartz (5)	dolomite (trace)	
Cement	5	dolomite (90)	calcite (10)			
Allochems	23	tentaculitids	bioclasts			
Organics	5	amorphous (100)				
Opaques	4	pyrite (100)				
	100					

Sedimentary Structures

Primary	thinly bedded, lenticular laminated
Biogenic	none observed

Fractures	trace irregular, horizontal open microfractures likely created during thin-section creation
Porosity	no porosity or microporosity observed

Description

Thinly bedded, lenticular laminated wackestone. The thin section is very thin, and the carbonate staining is difficult to interpret, but it appears that some of the dark clay-sized matrix did stain as calcite. Allochems include calcareous fossils of tentaculitids, brachiopod shells, and other bioclastic debris. Smaller calcareous grains may be bioclastic debris as well; some may be cement. There are trace amounts of silt-sized quartz, as well as minor amounts of crystalline dolomite. Evidence of parallel bedding with increased allochems in coarser laminations.

Thin Section Quality

Thin section is of fair quality, too thin in places; 1/2 stained for carbonates.

Rock Classification

wackestone (Dunham, 1962 cited in Embry and Klovan, 1972)

sparse biomicrite (Folk, 1974)

Sample # 9362 - 100/02-06-047-04W5/00, 2639.6 m - Duvernay Formation

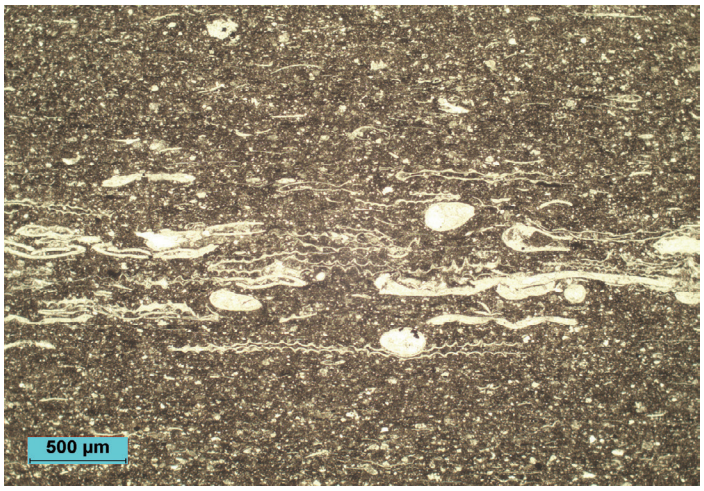

Plate 1: plane-polarized light. A low-magnification overview of the unstained portion of the slide shows a lamination with increased fossils within a wackestone matrix. Bedding orientation is displayed horizontally in the image.

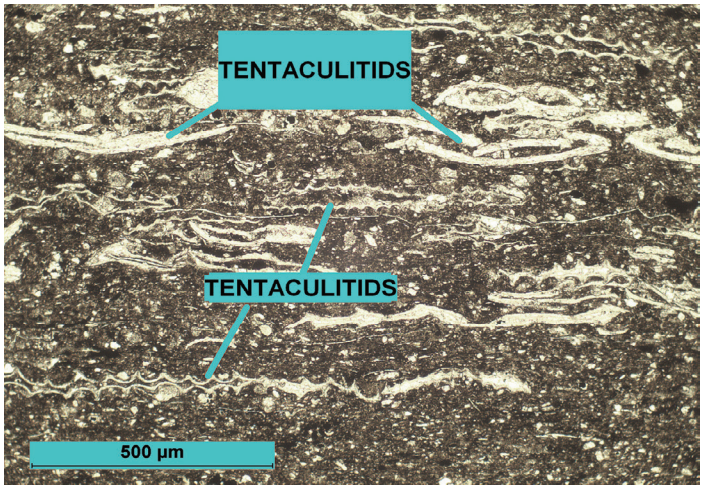

Plate 2: plane-polarized light. A medium-magnification view shows the two major fossils present in the slide, both tentaculitids. This portion of the slide is unstained. Bedding orientation is displayed horizontally in the image.

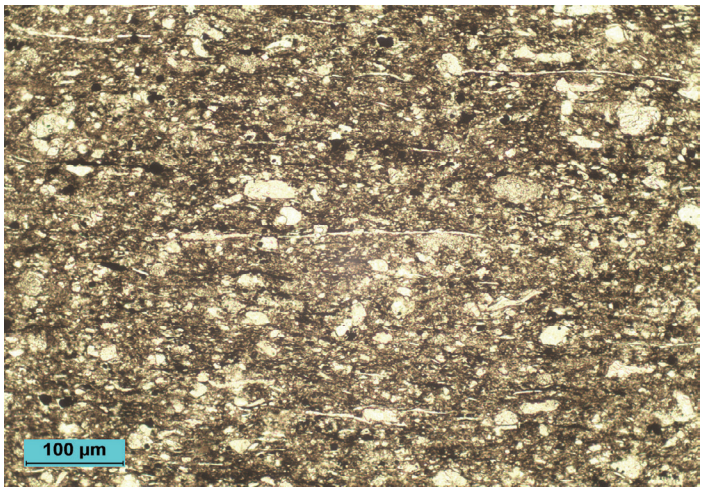

Plate 3: plane-polarized light. A medium- to high-magnification view of an unstained portion of the slide, which is representative of most of the slide: a bioclastic wackestone. Bedding orientation is displayed horizontally in the image.

Sample # 9362 - 100/02-06-047-04W5/00, 2639.6 m - Duvernay Formation

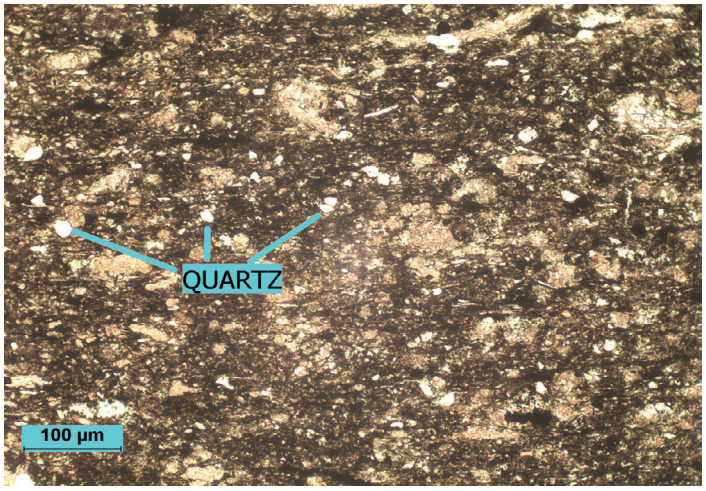

Plate 4: plane-polarized light. A medium- to high-magnification view of a stained portion of the slide showing a bioclastic wackestone with trace amounts of silt-sized quartz. This stained portion of the slide is very thin and some components were dissolved by the staining agents. Bedding orientation is displayed horizontally in the image.

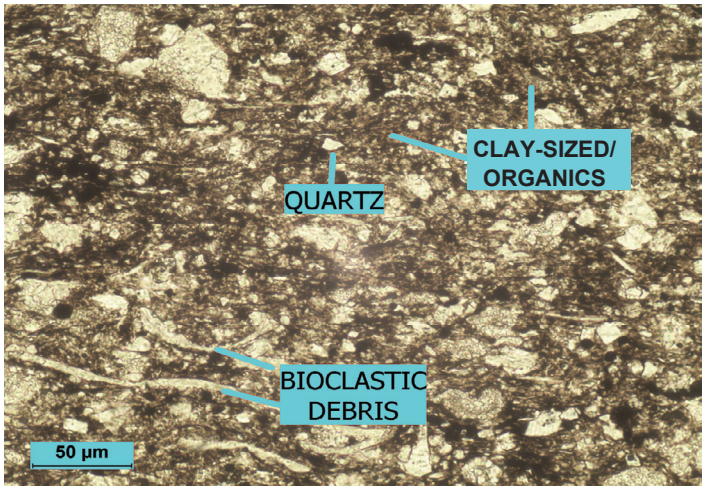

Plate 5: plane-polarized light. A high-magnification view of an unstained portion of the slide. Representative of much of the slide, it shows abundant calcareous grains, trace amounts of silt-sized quartz within a matrix of a mixture of clay-sized carbonate minerals, clays, organics, and possibly other minerals. Bedding orientation is displayed horizontally in the image.

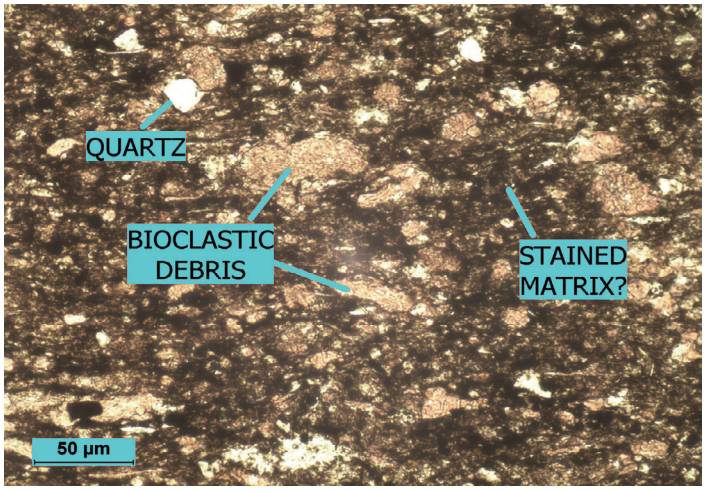

Plate 6: plane-polarized light. A high-magnification image of a stained portion of the slide shows bioclastic debris, calcareous grains, and trace amounts of silt-sized quartz within a clay-sized matrix. The matrix is difficult to identify, but it is stained red (indicating calcite), and there are also organics and clays intermixed. Bedding orientation is displayed horizontally in the image.

Sample ID	***9367***			
Map ID	***D34***	**UWI**	***100/02-04-126-11W6/00***	
Strat. Unit	***Muskwa***	**Depth**	***1517.4 m***	

Grain Size	**%**	**Variety (%)**	**Variety (%)**	**Variety (%)**	**Variety (%)**	**Variety (%)**
sand	0					
upper silt	0					
lower silt	8	quartz (70)	mica (30)			
clay	80	clay/mud (85)	mica (10)	quartz (5)		
Cement	6	dolomite (100)				
Allochems	0					
Organics	1	amorphous (100)				
Opaques	5	pyrite (100)				
	100					

Sedimentary Structures

Primary	lenticular laminated to massive, some evidence of soft sediment deformation
Biogenic	none observed

Fractures	several irregular horizontal and subhorizontal, open microfractures, likely created during thin-section creation
Porosity	no porosity or microporosity observed

Description

Lenticular laminated to massive silty claystone. The detrital grains are quartz and mica. There are also minor amounts of dolomite, probably a secondary cement. Pyrite is distributed throughout the sample, with large nodules in some areas. Minor amounts of organic material are present as thin, wispy interlaminations. There are several open microfractures that are approximately parallel to lamination orientation. The sample is moderately to well consolidated.

Thin Section Quality

Thin section is of fair quality; 1/2 stained for carbonates.

Rock Classification

claystone (Folk, 1974)

Sample # 9367 - 100/02-04-126-11W6/00, 1517.4 m - Muskwa Formation

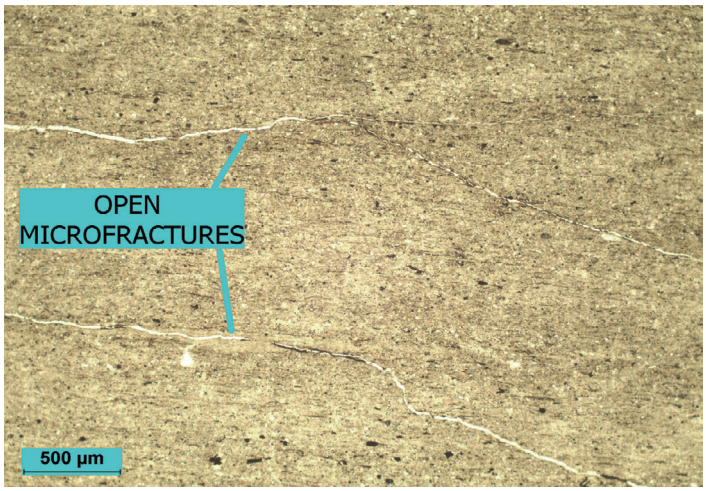

Plate 1: plane-polarized light. A low-magnification view shows claystone with irregular, open microfractures. They are close to parallel with lamination orientation. The microfractures were likely a product of thin-section creation. The near-vertical lines in the image are scratch marks on the underside of the sample. Bedding orientation is displayed horizontally in the image.

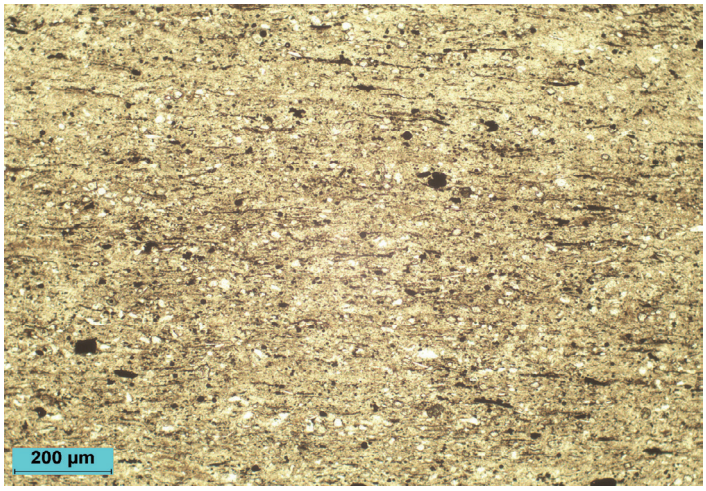

Plate 2: plane-polarized light. A low- to medium-magnification view shows slightly silty claystone. The light-coloured grains are either quartz, authigenic dolomite, or mica. Bedding orientation is displayed horizontally in the image.

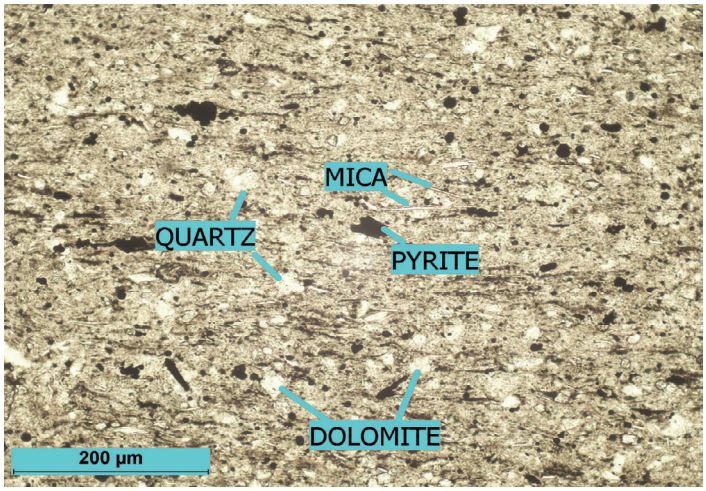

Plate 3: plane-polarized light. A medium- to high-magnification view shows slightly silty claystone. The matrix is too fine to identify individual minerals. Bedding orientation is displayed horizontally in the image.

Sample # 9367 - 100/02-04-126-11W6/00, 1517.4 m - Muskwa Formation

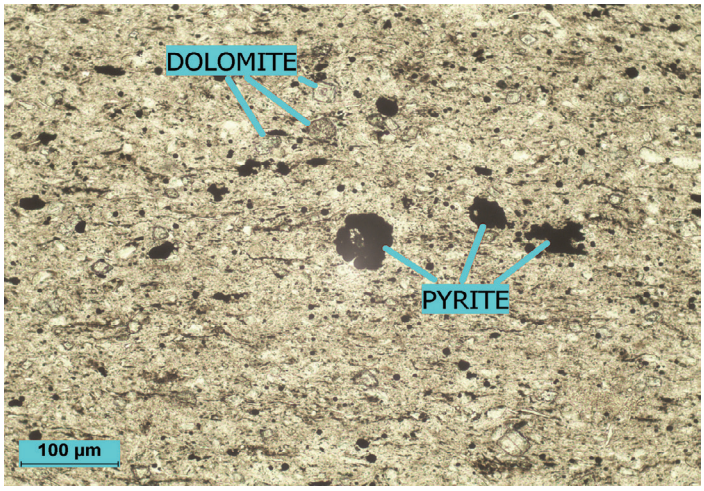

Plate 4: plane-polarized light. A medium- to high-magnification view shows pyrite nodules, which are distributed throughout the slide. A few nodules in the slide are close to 0.5 mm in length. Bedding orientation is displayed horizontally in the image.

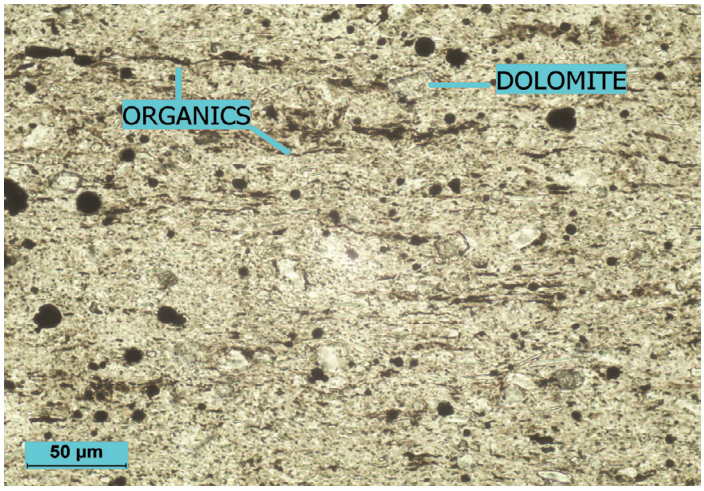

Plate 5: plane-polarized light. A high-magnification view shows slightly silty claystone with trace organics as thin, wispy interlaminations. Bedding orientation is displayed horizontally in the image.

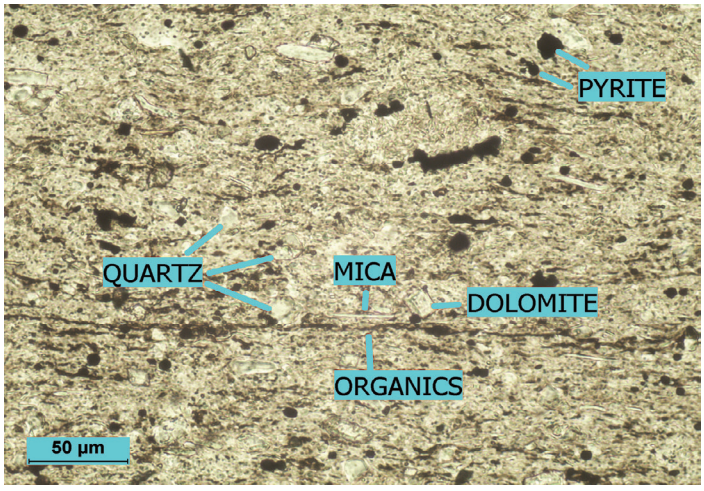

Plate 6: plane-polarized light. A high-magnification view shows a claystone. The matrix, which is the bulk of the sample, is a mixture of clay-sized minerals. Bedding orientation is displayed horizontally in the image.

Sample ID	***9392***		
Map ID	***D11***	**UWI**	***100/10-30-053-14W5/00***
Strat. Unit	***Majeau Lake Member***	**Depth**	***3172.8 m***

Grain Size	**%**	**Variety (%)**	**Variety (%)**	**Variety (%)**	**Variety (%)**	**Variety (%)**
sand	0					
upper silt	0					
lower silt	1	quartz (trace)	mica (trace)			
clay	77	clay/mud (60)	calcite (35)	mica (5)	pyrite (trace)	
Cement	15	calcite (100)				
Allochems	4	calcispheres (60)	bioclasts (40)			
Organics	<1	amorphous (100)				
Opaques	3	pyrite (100)				
	100					

Sedimentary Structures

Primary	massive
Biogenic	none observed

Fractures	horizontal, open microfractures; irregular, branching, discontinuous in sections, likely a result of thin-section creation
Porosity	no porosity or microporosity observed

Description

Massive calcareous claystone. The sample has moderate amounts of ferroan calcite in the form of cement and bioclastic debris. The clay-sized matrix does not stain for carbonates. There are scattered microfossils, which are predominantly calcispheres. Pyrite frambroids distributed throughout the sample, and in some areas they have a higher concentration in coarser-grained lenses. There are trace amounts of amorphous organic material.

Thin Section Quality

This thin section is fair quality; 1/2 stained for carbonates.

Rock Classification

calcareous claystone (Folk, 1974)

Sample # 9392 - 100/10-30-053-14W5/00, 3172.8 m - Majeau Lake Member

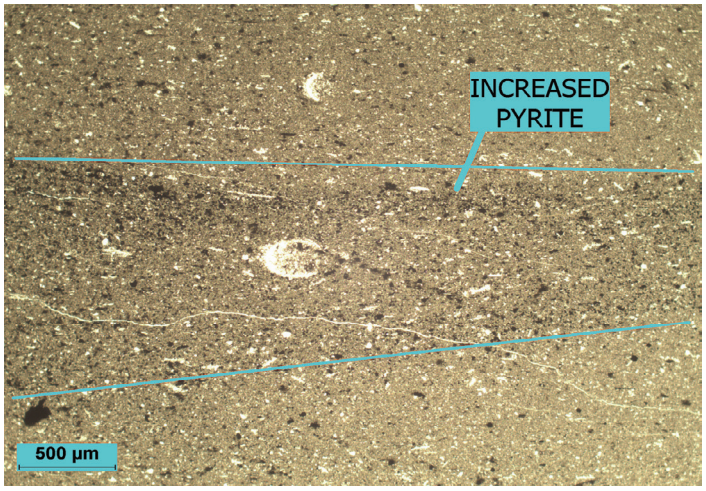

Plate 1: plane-polarized light. A low-magnification view of an unstained portion of the slide shows massive claystone with calcisphere microfossils. The area between the annotated lines is part of a lens that has increased pyrite. Bedding orientation is displayed horizontally in the image.

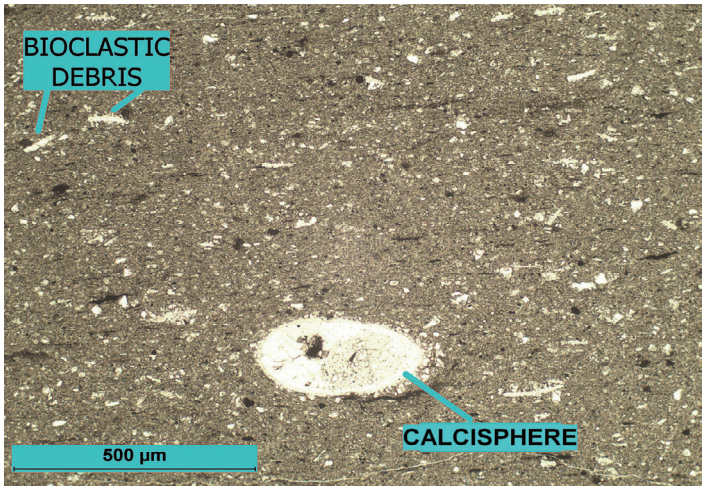

Plate 2: plane-polarized light. A low- to medium-magnification view shows a claystone with a calcite-filled calcisphere and other bioclastic debris. Nearly all of the light-coloured grains in the image are calcite. Bedding orientation is displayed horizontally in the image.

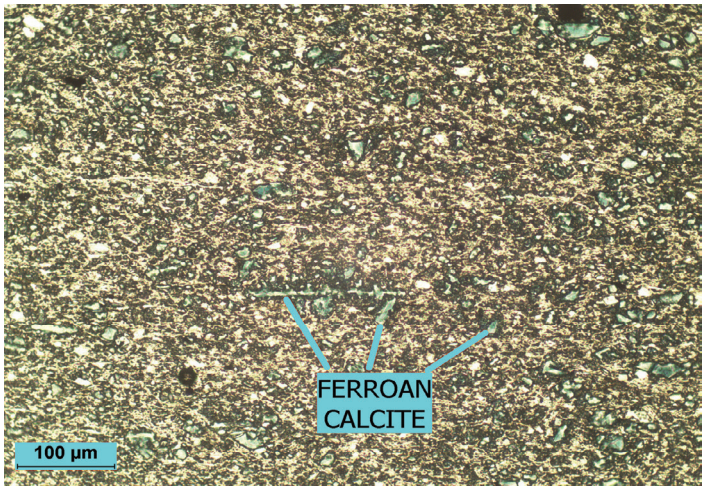

Plate 3: plane-polarized light. A medium- to high-magnification view of a stained portion of the slide shows ferroan calcite within a clay-sized matrix. Both detrital and authigenic calcite grains are present. Bedding orientation is displayed horizontally in the image.

Sample # 9392 - 100/10-30-053-14W5/00, 3172.8 m - Majeau Lake Member

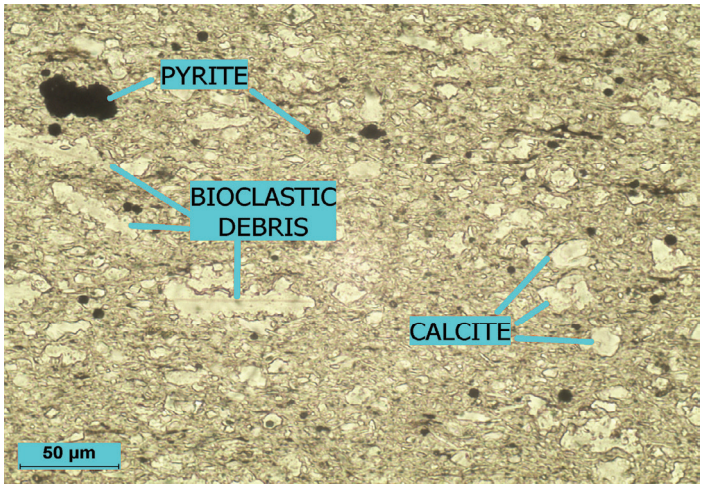

Plate 4: plane-polarized light. A high-magnification view of an unstained portion of the slide shows calcite in the form of bioclastic debris and cement. Bedding orientation is displayed horizontally in the image.

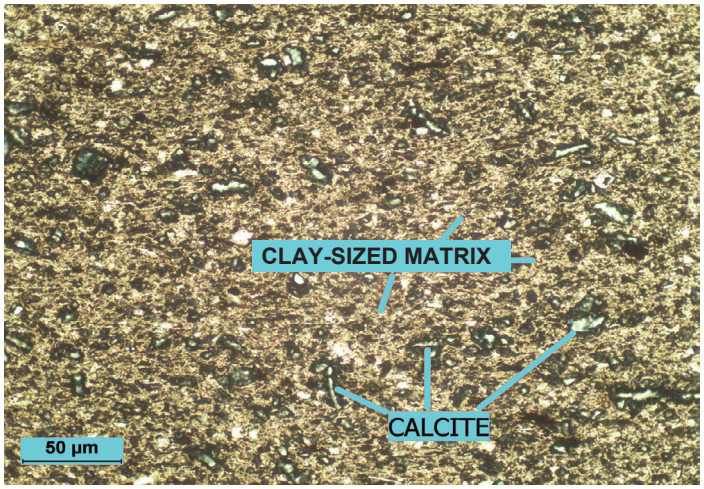

Plate 5: plane-polarized light. A high-magnification view of a stained portion of the slide shows ferroan calcite (stained blue) within an unstained clay-sized matrix. Bedding orientation is displayed horizontally in the image.

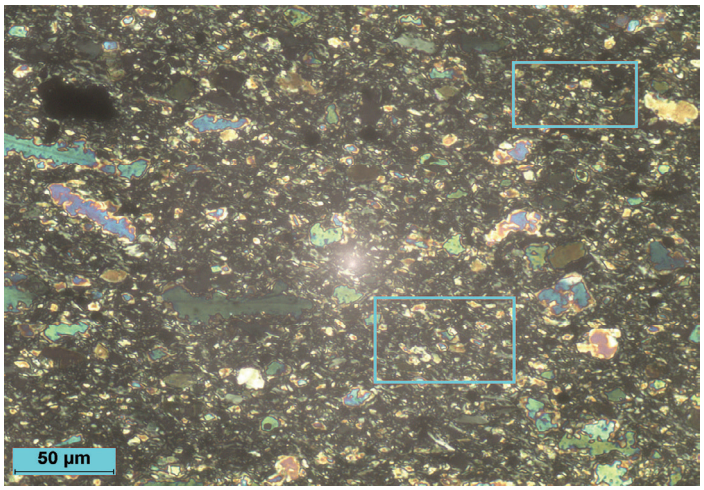

Plate 6: cross-polarized light. A high-magnification view shows that many minerals in the matrix have a high birefringence. It appears that this is the ferroan calcite component: the bulk of the clay-sized fraction remains unidentifiable. Bedding orientation is displayed horizontally in the image.

Sample ID	***9645***			
Map ID	***D50***	**UWI**	***100/12-12-057-22W5/00***	
Strat. Unit	***Duvernay Formation***	**Depth**	***3881.7 m***	

Grain Size	**%**	**Variety (%)**	**Variety (%)**	**Variety (%)**	**Variety (%)**	**Variety (%)**
sand	0					
upper silt	0					
lower silt	6	quartz (40)	mica (40)	calcite (20)		
clay	71	clay/mud (50)	calcite (20)	quartz (20)	mica (10)	
Cement	20	calcite (95)	dolomite (5)			
Allochems	<1	tentaculitids	bioclasts			
Organics	2	amorphous (100)				
Opaques	1	pyrite (100)				
	100					

Sedimentary Structures

Primary	massive with vague laminations
Biogenic	none observed

Fractures	open microfractures, branching and apparently parallel to bedding, likely created during thin-section creation
Porosity	no porosity or microporosity observed

Description

Massive calcareous claystone. Carbonate staining indicates that most of the carbonate minerals are ferroan calcite. The sample is dominantly comprised of microcrystalline and clay-sized grains. There is a small amount of silt-sized quartz and mica present, as well as bioclastic debris including tentaculitids and other shell fragments. The clay-sized portion of the sample is composed of clay minerals, quartz, minor amounts of mica, and minor amounts of intermixed organics and clays. There are several open horizontal microfractures, likely created during thin-section creation.

Thin Section Quality

Thin section is of fair quality, slightly thick in the middle; 1/2 stained for carbonates.

Rock Classification

calcareous claystone (Folk, 1974)

Sample # 9645 -100/12-12-057-22W5/00, 3881.7 m - Duvernay Formation

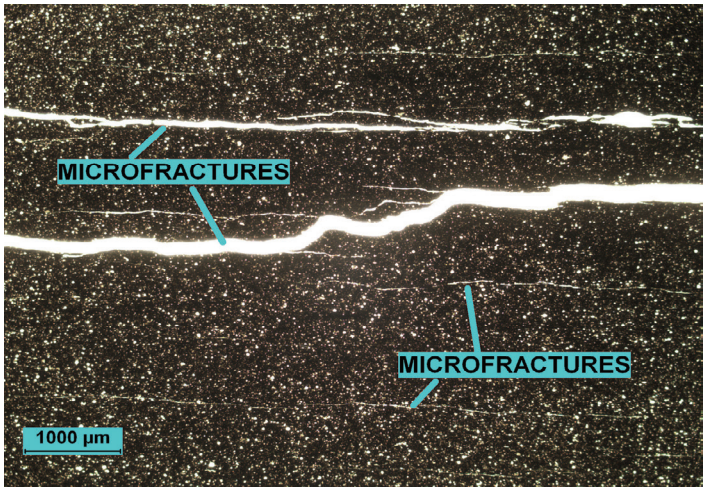

Plate 1: plane-polarized light. A low-magnification overview shows predominantly massive claystone with open microfractures. The majority of them are parallel to bedding (horizontal). Fractures are from thin-section creation. Bedding orientation is displayed horizontally in the image.

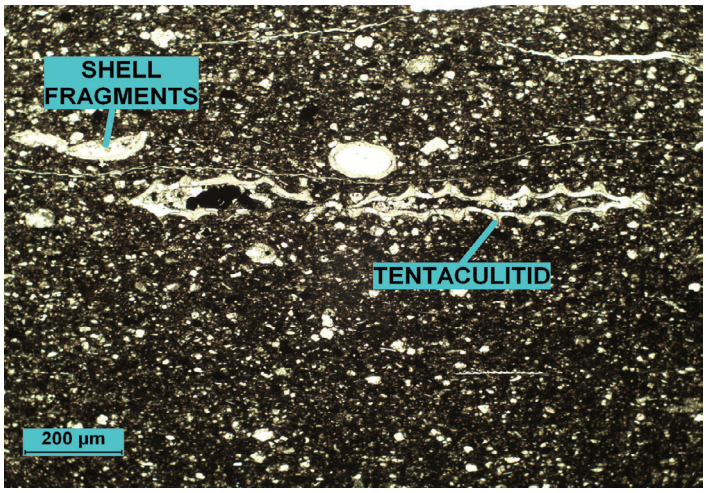

Plate 2: plane-polarized light. A medium-magnification view shows claystone with bioclasts, including tentaculitids. Bedding orientation is displayed horizontally in the image.

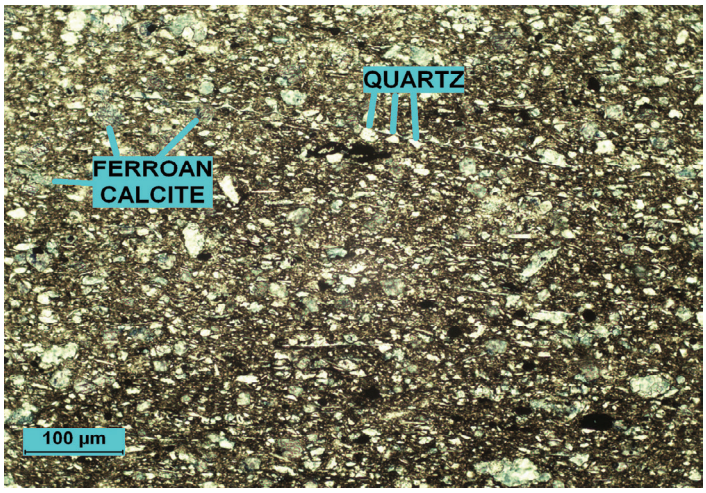

Plate 3: plane-polarized light. A medium- to high-magnification view of a stained portion of the slide shows common presence of ferroan calcite, much of which is in the clay-sized fraction. Most of the light-coloured grains are calcite (stained blue), with only minor amounts of quartz grains. Bedding orientation is displayed horizontally in the image.

Sample # 9645 -100/12-12-057-22W5/00, 3881.7 m - Duvernay Formation

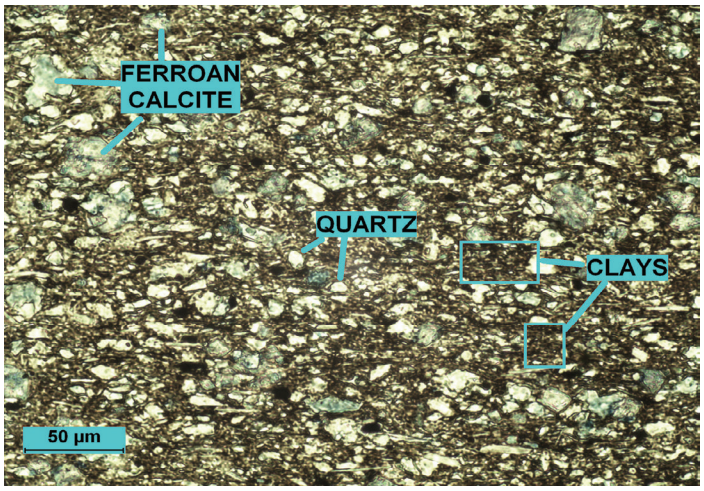

Plate 4: plane-polarized light. A high-magnification view of a stained portion of the slide shows ferroan calcite (stained blue) and minor amounts of quartz, within a predominantly clay-sized matrix. There appears to be minor amounts of organic material within the clay-sized matrix. Bedding orientation is displayed horizontally in the image.

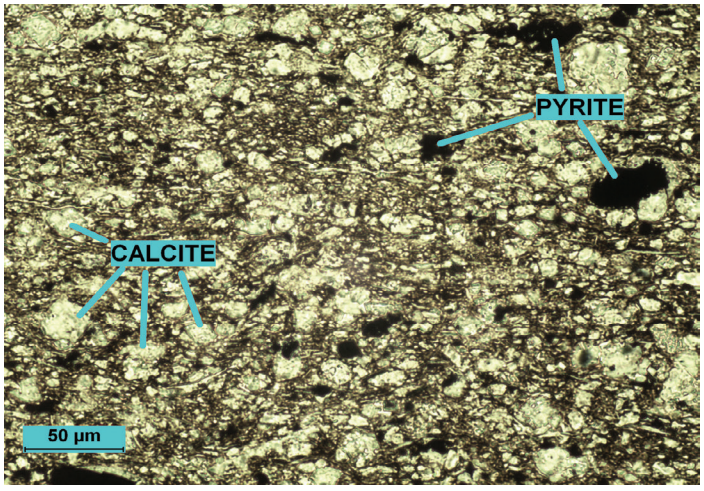

Plate 5: plane-polarized light. A high-magnification view shows claystone with calcite cement. Bedding orientation is displayed horizontally in the image.

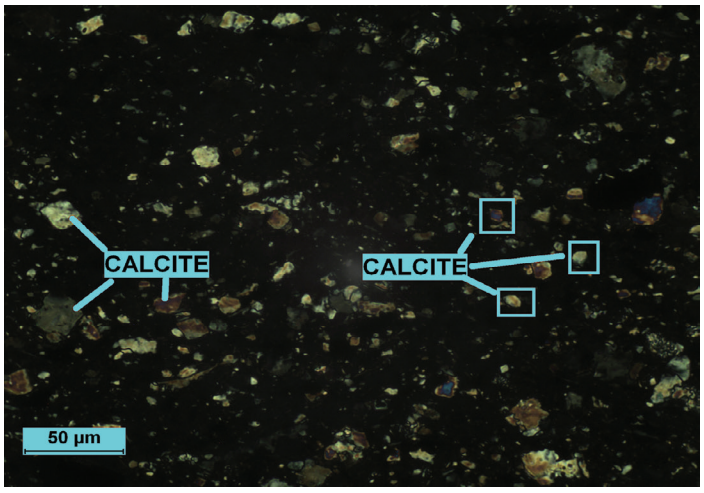

Plate 6: cross-polarized light. A high-magnification view shows some calcite as light-coloured grains. Based on the stain, most of the carbonate content is ferroan calcite. Bedding orientation is displayed horizontally in the image.

Sample ID	***9656***			
Map ID	***D50***	**UWI**	***100/12-12-057-22W5/00***	
Strat. Unit	***Duvernay Formation***	**Depth**	***3891.9 m***	

Grain Size	**%**	**Variety (%)**	**Variety (%)**	**Variety (%)**	**Variety (%)**	**Variety (%)**
sand	0					
upper silt	4	calcite (60)	quartz (30)	mica (10)		
lower silt	10	calcite (60)	quartz (30)	mica (10)		
clay	76	clay/mud (40)	calcite (35)	quartz (20)	mica (5)	
Cement	7	calcite (95)	dolomite (5)			
Allochems	1	bioclasts (100)				
Organics	1	amorphous (100)				
Opaques	1	pyrite (100)				
	100					

Roundness	subrounded
Sphericity	medium
Sorting	moderately sorted

Sedimentary Structures

Primary	massive with faint bedding
Biogenic	none observed

Fractures	two calcite-infilled fractures (assumed vertical) are natural; several open fractures (assumed horizontal) are likely created during thin-section creation
Porosity	no porosity or microporosity observed

Description

Massive calcareous silty claystone. The stain for carbonates is somewhat ambiguous, but it appears that most of the carbonate minerals are ferroan calcite with minor amounts of dolomite. There are only trace amounts of silt-sized grains. There are clay-sized quartz grains present. Two calcite-cemented fractures are observed, both are vertical based on faint indications of bedding in the sample. There are only trace amounts of silt- and sand-sized bioclastic debris as well as amorphous organics intermixed with clay-sized material.

Thin Section Quality

Thin section is of fair quality, uneven thickness, sample size is small; 1/2 stained for carbonates.

Rock Classification

calcareous silty claystone (Folk, 1974)

Sample # 9656 - 100/12-12-057-22W5/0, 3891.9 m - Duvernay Formation

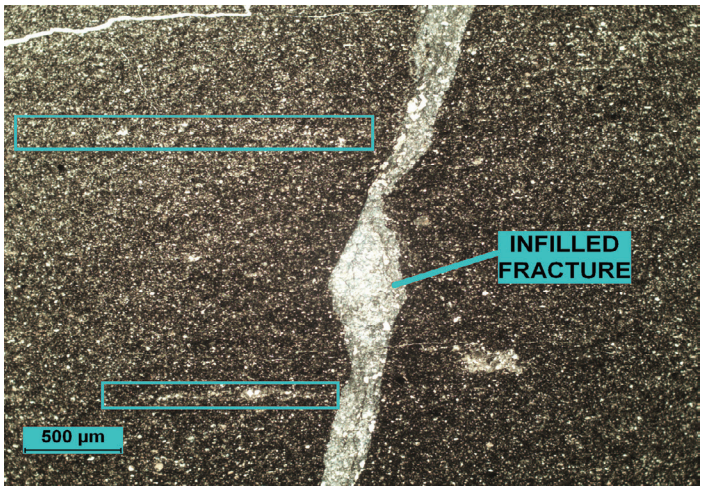

Plate 1: plane-polarized light. A low- to medium-magnification overview shows a massive calcareous silty claystone and a calcite-infilled fracture. Areas within the annotated rectangles are alignments of grains that may indicate the horizontal plane, which would suggest that the fracture is almost vertical. The thin section is slightly too thick in this image. Bedding orientation is displayed horizontally in the image.

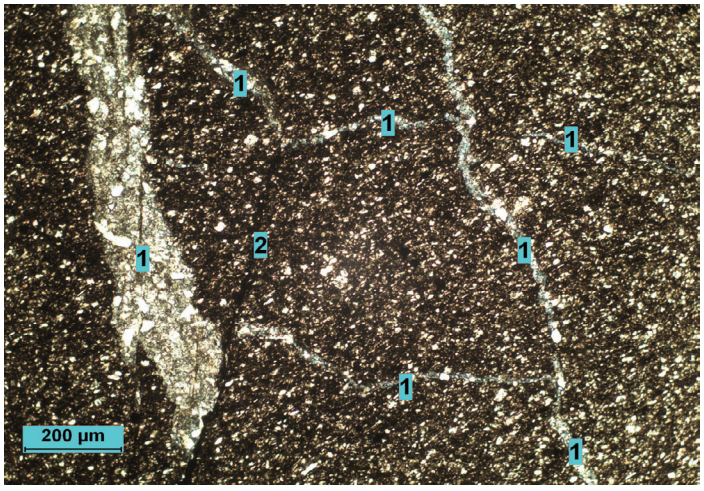

Plate 2: plane-polarized light. A medium-magnification view shows a network of infilled fractures, the most prominent (on the left) is present through the length of the slide. Infilled fractures annotated as "1" are infilled with what appears to be ferroan calcite, with trace amounts of quartz crystals within the calcite. The area annotated as "2" is a microfault. The thin section is slightly too thick in this image. Bedding orientation is displayed horizontally in the image.

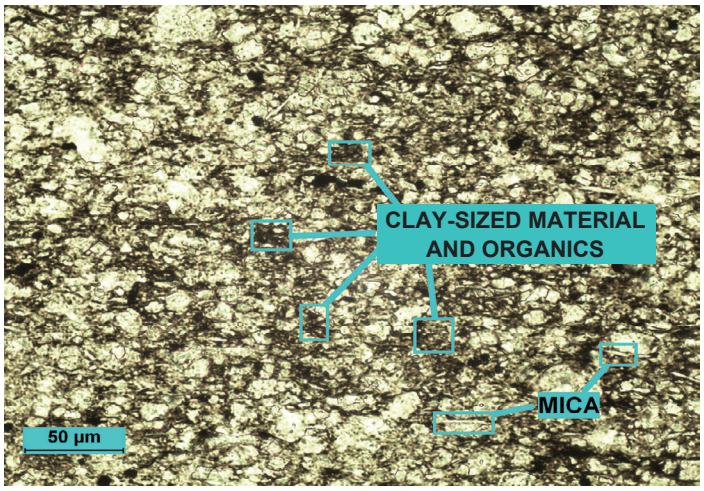

Plate 3: plane-polarized light. A high-magnification view shows claystone with trace amounts of mica. Almost all of the light-coloured grains are calcite but, there are clay-sized quartz grains present as well. It appears that there are minor amounts of amorphous organics intermixed with the clay-sized material. Bedding orientation is displayed horizontally in the image.

Sample # 9656 - 100/12-12-057-22W5/0, 3891.9 m - Duvernay Formation

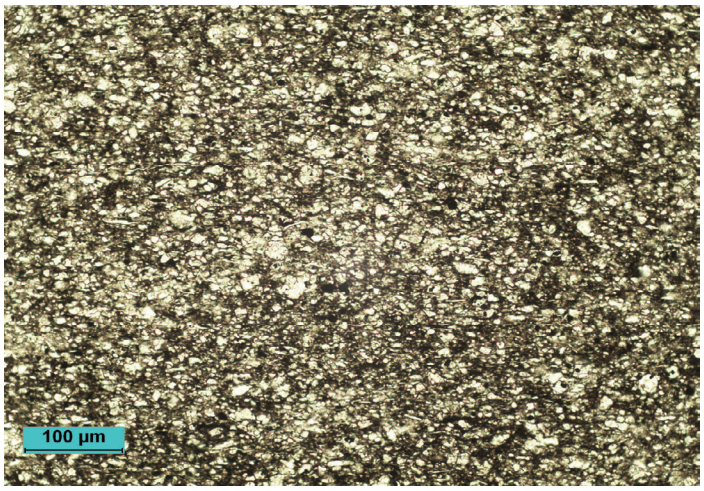

Plate 4: plane-polarized light. A medium- to high-magnification view shows calcareous claystone. This is an unstained portion of the slide.

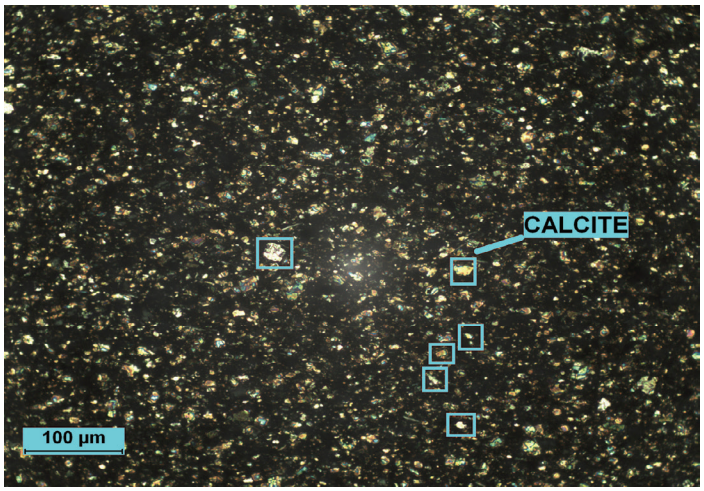

Plate 5: cross-polarized light. The same view as Plate 4 under cross-polarized light shows most of the carbonate content as light-coloured grains. Staining indicates that most of the carbonate content is ferroan calcite. Bedding orientation is displayed horizontally in the image.

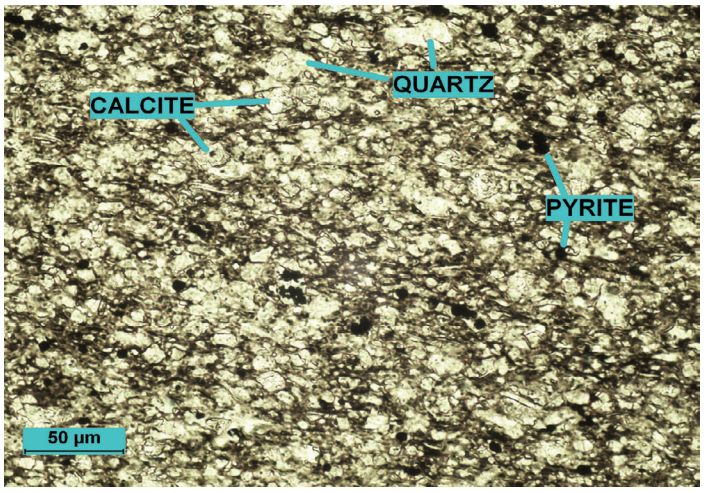

Plate 6, plane-polarized light. A high-magnification view shows an unstained portion of the slide. Most of the light-coloured grains in the image are calcite. There are also trace amounts of silt-sized quartz and minor amounts of clay-sized quartz. Bedding orientation is displayed horizontally in the image.

Sample ID	***9658***			
Map ID	***D50***	**UWI**	***100/12-12-057-22W5/00***	
Strat. Unit	***Duvernay Formation***	**Depth**	***3894.84 m***	

Grain Size	**%**	**Variety (%)**	**Variety (%)**	**Variety (%)**	**Variety (%)**	**Variety (%)**
sand	0					
upper silt	<1	mica (100)	quartz (trace)			
lower silt	12	calcite (70)	quartz (20)	mica (10)		
clay	80	clay/mud (40)	calcite (40)	quartz (15)	mica (5)	
Cement	5	calcite (95)	dolomite (5)			
Allochems	trace	bioclasts (100)				
Organics	2	amorphous (100)				
Opaques	1	pyrite (100)				
	100					

Roundness	subrounded
Sphericity	medium
Sorting	well sorted

Sedimentary Structures

Primary	massive, but the sample is highly fragmented
Biogenic	none observed

Fractures	natural extremely fine microfractures filled with ferroan calcite cement; sample is badly fractured/fragmented from thin-section creation
Porosity	no porosity or microporosity observed

Description

Massive calcareous silty claystone. The sample has minor amounts of lower-silt-sized quartz and mica. Staining indicates that most of the carbonate minerals are ferroan calcite, but minor amounts of dolomite are also observed. Trace amounts of bioclastic debris are present, as well as trace amounts of amorphous organics intermixed with clays. Although most of the extensive fracturing is attributed to thin section preparation, there are at least two extremely fine natural microfractures filled with ferroan calcite cement.

Thin Section Quality

Thin section is of poor quality, sample is badly fragmented; 1/2 stained for carbonates.

Rock Classification

calcareous silty claystone (Folk, 1974)

Sample # 9658 - 100/12-12-057-22W5/0, 3894.84 m - Duvernay Formation

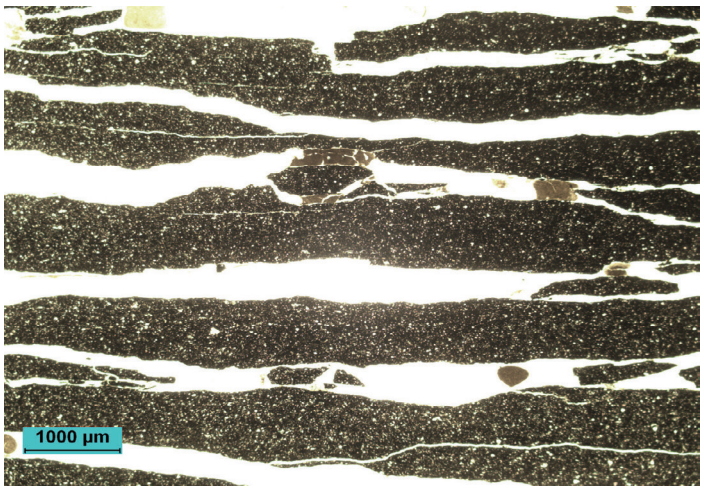

Plate 1: plane-polarized light. A low-magnification overview shows the fragmented condition of the slide. The large fractures are a result of thin-section creation. Bedding orientation is displayed horizontally in the image.

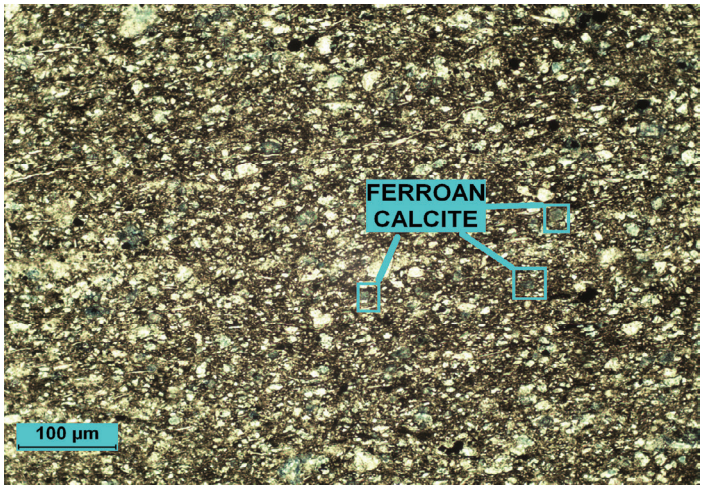

Plate 2: plane-polarized light. A medium- to high-magnification view of the stained portion of the slide shows calcareous silty claystone. Staining indicates that most of the carbonate minerals are ferroan calcite. There does appear to be a minor dolomite content as well. Many of the calcite grains are clay-sized. Bedding orientation is displayed horizontally in the image.

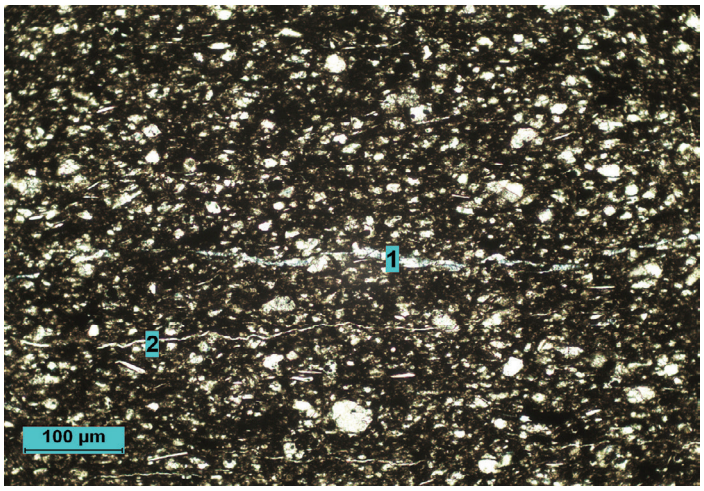

Plate 3: plane-polarized light. A medium- to high-magnification view shows a very fine microfracture assumed to be horizontally oriented and filled with ferroan calcite cement (annotated as "1"). Another parallel fracture is open (annotated as "2"). The slide is over-thick where this image was taken. Bedding orientation is displayed horizontally in the image.

Sample # 9658 - 100/12-12-057-22W5/0, 3894.84 m - Duvernay Formation

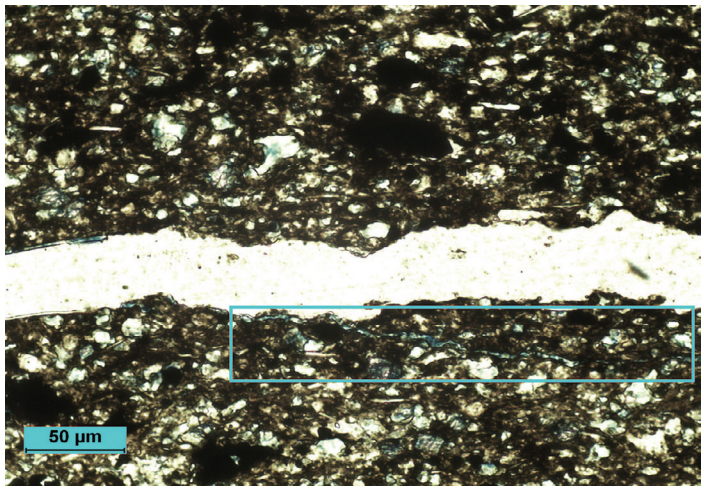

Plate 4: plane-polarized light. A high-magnification view shows a prominent, open, horizontal microfracture in the centre. This fracture was created during thin-section creation. Within the annotated rectangle there is a microfracture filled with ferroan calcite cement. This fracture is extremely fine and difficult to see, even at the highest magnification. Some of the fractures in the sample, which result from thin-section creation, formed along these extremely fine, infilled fractures. Bedding orientation is displayed horizontally in the image.

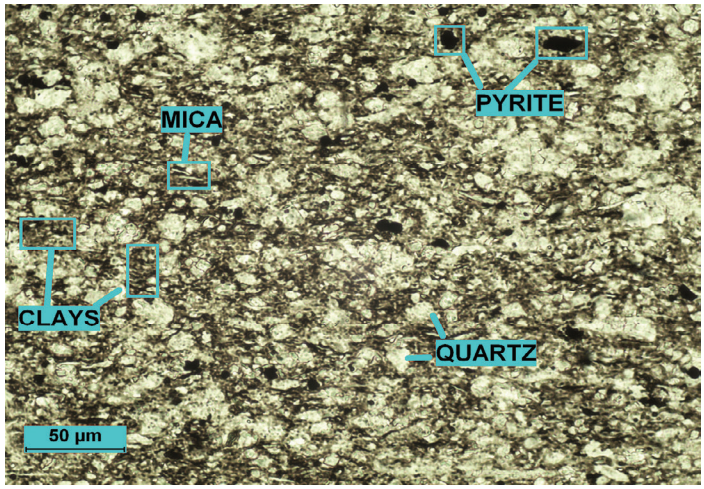

Plate 5: plane-polarized light. A high-magnification view shows slightly silty claystone. The dark brown matrix is predominantly clay minerals with trace amounts of organic material intermixed. Bedding orientation is displayed horizontally in the image.

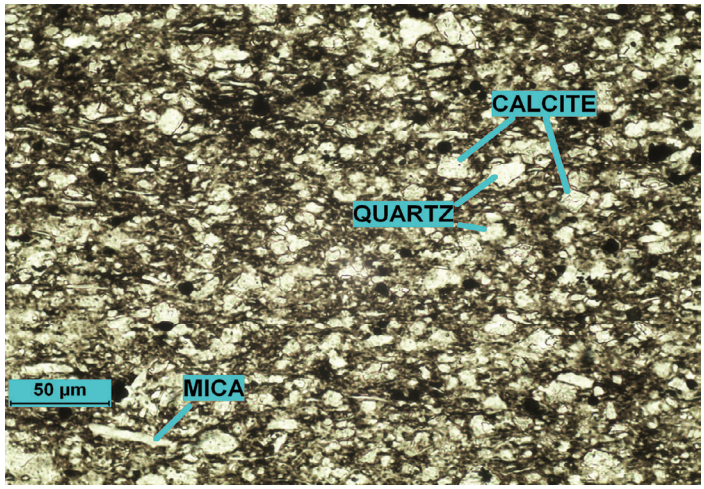

Plate 6: plane-polarized light. A high-magnification view of an unstained portion of the slide shows slightly silty claystone. Silt-sized quartz is present, but most of the quartz grains in the sample are clay-sized. Bedding orientation is displayed horizontally in the image.

Sample ID	***9663***		
Map ID	***D50***	**UWI**	***100/12-12-057-22W5/00***
Strat. Unit	***Duvernay Formation***	**Depth**	***3902.1 m***

Grain Size	**%**	**Variety (%)**	**Variety (%)**	**Variety (%)**	**Variety (%)**	**Variety (%)**
sand	0					
upper silt	trace	calcite (55)	quartz (45)	mica (trace)		
lower silt	10	calcite (50)	quartz (40)	mica (10)		
clay	81	calcite (40)	clay/mud (40)	quartz (15)	mica (5)	
Cement	5	calcite (100)	dolomite (trace)			
Allochems	trace	tentaculitids	bioclasts			
Organics	2	amorphous (100)				
Opaques	2	pyrite (100)				
	100					

Roundness	subrounded
Sphericity	medium
Sorting	well sorted

Sedimentary Structures

Primary	faintly lenticular laminated
Biogenic	none observed

Fractures	open microfractures (assumed horizontal), trace amounts of vertical microfractures
Porosity	no porosity or microporosity observed

Description

Lenticular laminated calcareous claystone. Grains are predominantly silt- and clay-sized calcite, quartz, and mica. Staining indicates that most of the carbonate minerals are ferroan calcite. Open microfractures parallel to laminations are common, and some have an opaque lining (possibly organic material). It is difficult to determine if this is a fracture lining or part of the pre-existing rock fabric. Only trace amounts of bioclastic debris are present, including tentaculitids and shell fragments. There are trace amounts of organics in the form of thin, wispy plates intermixed with clays. The sample fractured along planes of weakness during thin-section creation.

Thin Section Quality

Thin section is fair quality; 1/2 stained for carbonates.

Rock Classification

calcareous claystone (Folk, 1974)

Sample # 9663 - 100/12-12-057-22W5/0, 3902.05 m - Duvernay Formation

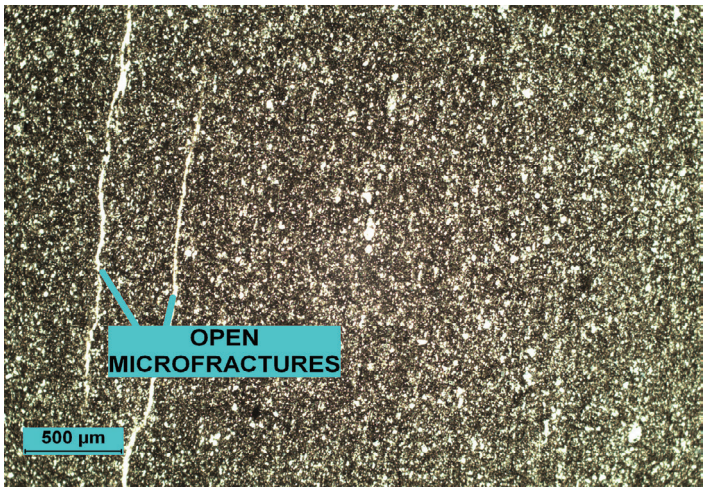

Plate 1: plane-polarized light. A low- to medium-magnification view shows calcareous claystone with minor amounts of open microfractures. There are faint indications of bedding, and most of the microfractures are parallel to bedding. Bedding orientation is displayed vertically in the image.

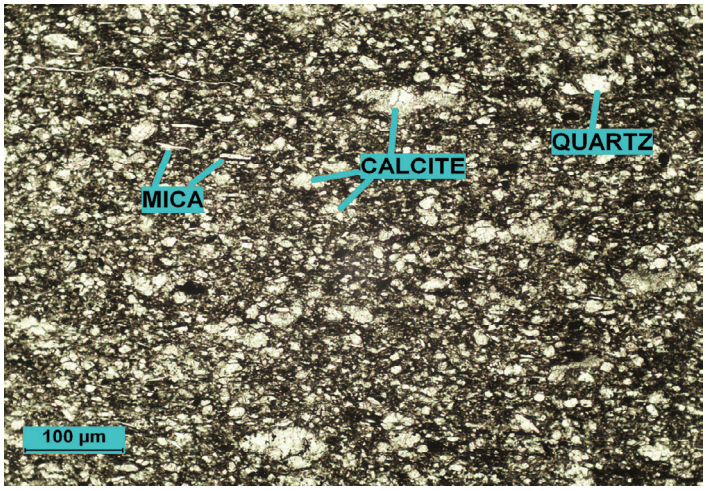

Plate 2: plane-polarized light. A medium- to high-magnification view of claystone shows light-coloured calcite and quartz grains. Staining indicates that most of the carbonate minerals are ferroan calcite. Quartz is present as silt- and clay-sized grains. Bedding orientation is displayed horizontally in the image.

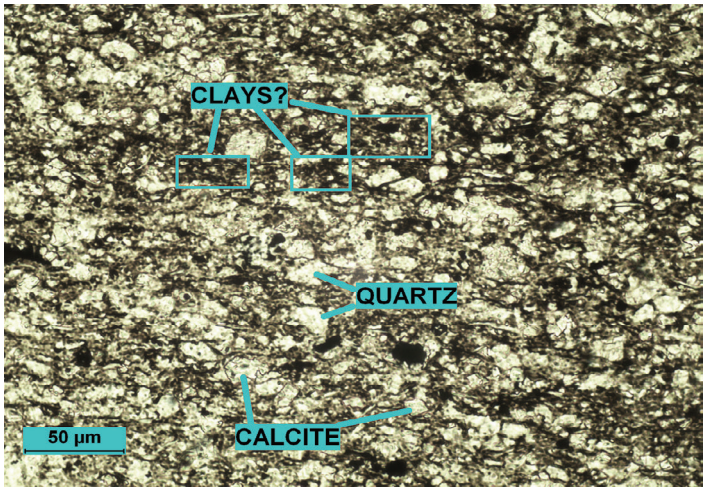

Plate 3: plane-polarized light. A high-magnification view shows slightly silty calcareous claystone. The dark brown matrix may be clays intermixed with organic material. Bedding orientation is displayed horizontally in the image.

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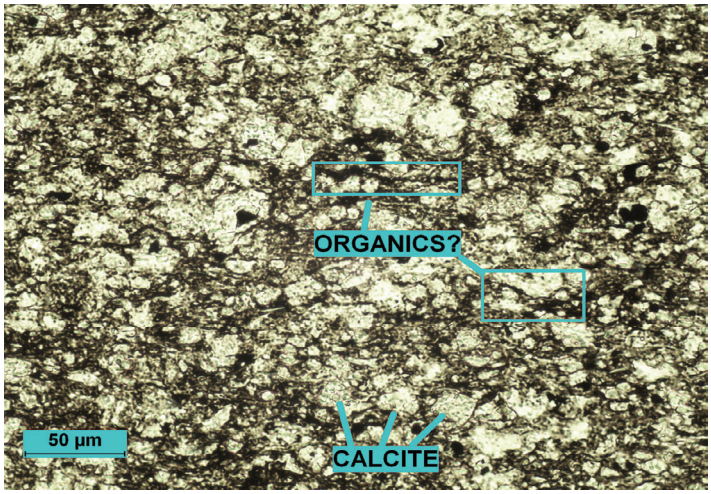

Plate 4: plane-polarized light. A high-magnification view shows what appears to be organic material present in the form of wispy plates, although they are too fine to positively identify with a standard petrographic microscope. Bedding orientation is displayed horizontally in the image.

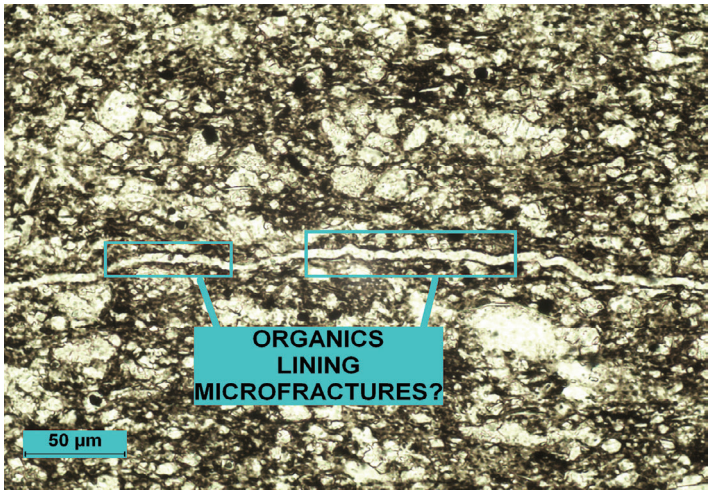

Plate 5: plane-polarized light. A high-magnification view shows a very fine, open microfracture that appears to be lined with organic material. The organic matter would have presented a plane of weakness for fracturing durring thin-section creation. Bedding orientation is displayed horizontally in the image.

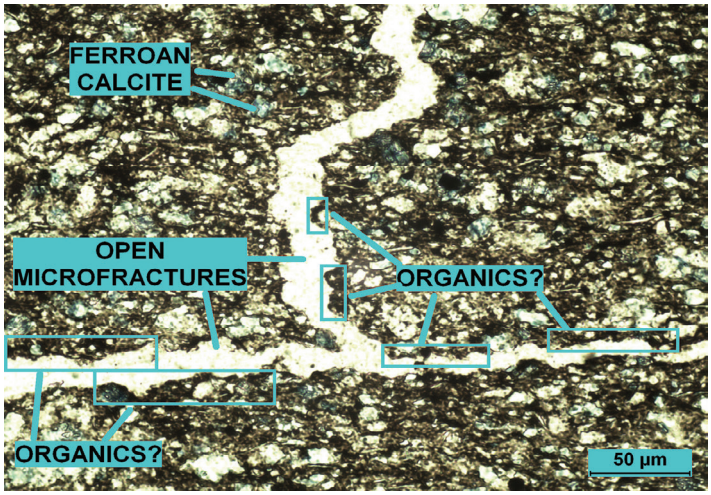

Plate 6: plane-polarized light. A high-magnification view shows intersecting open microfractures. As discussed in the description of Plate 5, there appears to be a relationship between the presence of organics and the open microfractures. This image was taken over a stained portion of the slide; ferroan calcite is stained blue. Bedding orientation is displayed horizontally in the image.