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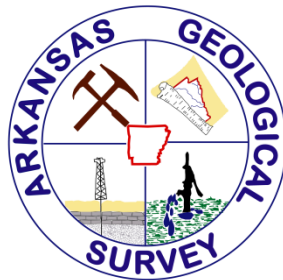
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OPEN-FILE REPORT 2013-1000

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PETROGRAPHIC AND GEOCHEMICAL ANALYSES OF THE LOWER  
SMACKOVER FORMATION, DOW CHEMICAL SMITH #1, COLUMBIA COUNTY  
AND MURPHY CHESTER #1 WELLS, UNION COUNTY, ARKANSAS

Peng Li and Michael Ed Ratchford



This publication is a preliminary compilation of selected industry reports that were provided to the Arkansas Geological Survey. These reports are compiled in their entirety in this Open-File Report with the express purpose to disseminate scientific information to the general public. Sample materials used for the analyses in the industry reports were acquired from the Norman F. Williams Well Log Library in Little Rock, Arkansas. The Arkansas Geological Survey does not endorse any company listed in this publication and does not provide a technical opinion regarding the nature and quality of the test results. Service company logos are retained in the original industry reports so that the reader can determine the name and location of the testing laboratories.

December 2013

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# **Petrographic and Geochemical Analyses of the Lower Smackover Formation, Dow Chemical Smith #1, Columbia County and Murphy Chester #1 Wells, Union County, Arkansas**

Peng Li and Michael Ed Ratchford

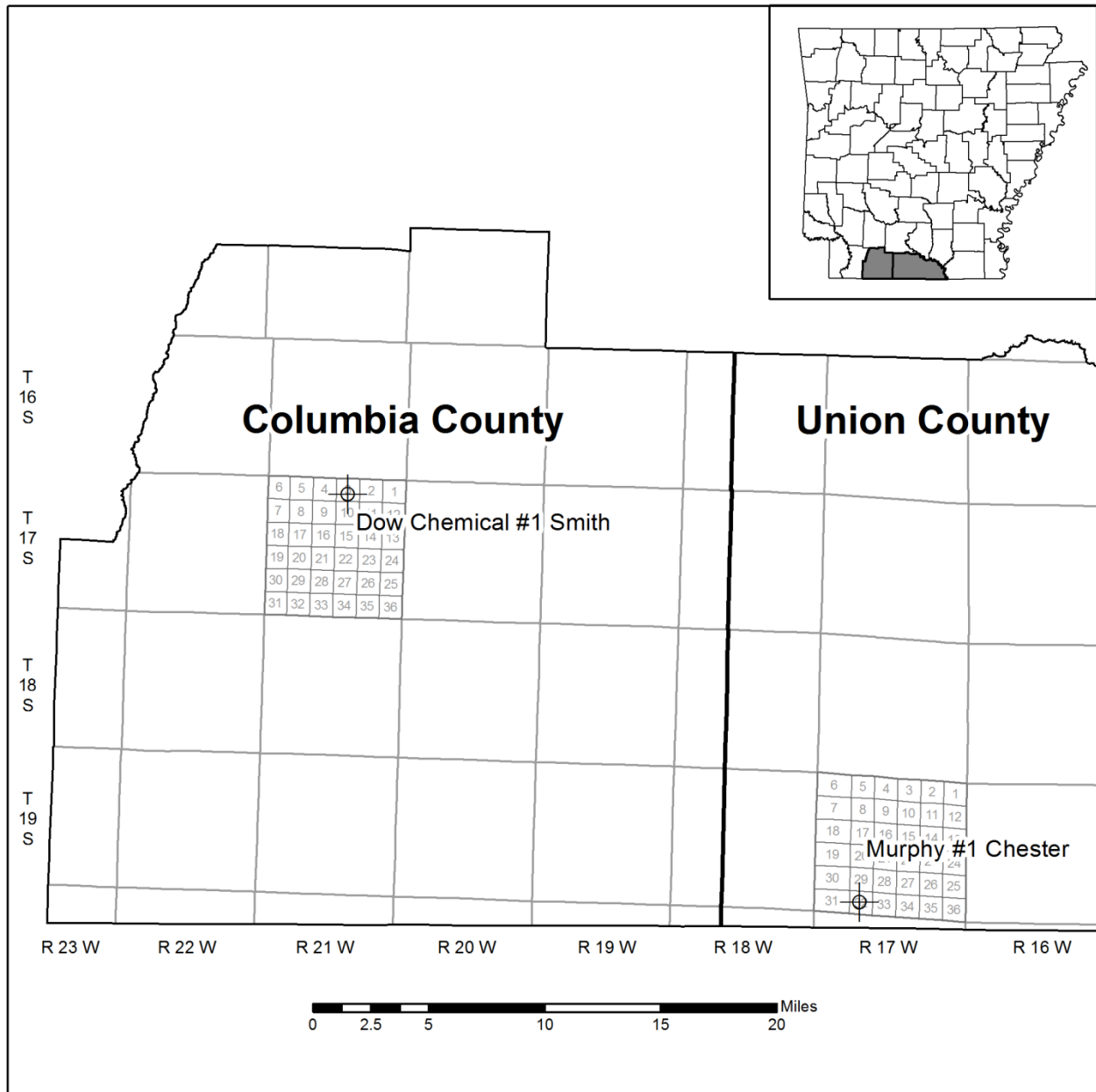
## **Introduction**

This report includes the petrographic and geochemical analyses conducted by industry on two wells drilled in south Arkansas: Dow Chemical Smith #1 (Sec. 3-T17S-R21W) located in Columbia County and Murphy Chester #1 (Sec. 32-T19S-R17W) in Union County (Figure 1). The purpose of the well study is to determine the source rock quality and petrographic nature of the lower Smackover Formation, referred to informally as the Brown Dense zone. The Brown Dense zone is the current focus of an unconventional oil mudstone resource play in southern Arkansas and northern Louisiana. Well information for these two wells, including well name, API number, legal location, and county name, is not revealed in the original Weatherford report. However, Table 1 correlates sample numbers with the missing well identification information.

Three (3) conventional core samples from Dow Chemical Smith #1 and two (2) cutting samples from Murphy Chester #1 were collected for petrographic analyses that consists of thin section preparation, photomicrography, and qualitative petrography. Three (3) conventional core chips from Dow Chemical Smith #1 and four (4) well cutting samples from Murphy Chester #1 were submitted for geochemical analyses that includes measurements of total organic carbon (TOC) content and Rock-Eval pyrolysis.

All samples analyzed from the two wells lie within the lower member of the Upper Jurassic (Oxfordian) Smackover Formation. The Smackover Formation in Arkansas is divided into two informal units: an upper member generally called the Reynolds Oolite Zone (Vestal,

1950) that is often a productive oil and gas reservoir and a lower member referred to as the Brown Dense Zone that consists primarily of organic-rich carbonate mudstone and was first described by Weeks (1938). The Brown Dense Zone is commonly considered as a regional source rock for all oil and gas accumulations in south Arkansas.



**Figure 1. Well Location Map for the Dow Chemical Smith #1, Columbia County and Murphy Chester #1, Union County, Arkansas.**

Core and well cutting samples for these two wells were collected at the Norman F. Williams Well Sample Library which is managed by the Arkansas Geological Survey in Little Rock, Arkansas. The samples were shipped to Weatherford Laboratories in Houston, Texas for analysis and interpretation. During the compilation of this publication, the original Weatherford report underwent minor redaction to ensure privacy for the clients that processed the samples.

## **References**

Vestal, J.H., 1950, Petroleum geology of the Smackover Formation of southern Arkansas:

Arkansas Geological Commission Information Circular 14, 19p.

Weeks, W.B., 1938, South Arkansas stratigraphy with emphasis on the older coastal plain beds:

American Association of Petroleum Geologists Bulletin, v. 22, no.8, p. 953-983.

Table 1. Sample List and Well Information.

Well Name	Sample ID	Sample Depth (ft)	Formation	Operator	API	Section	Township	Range	County	Sample Type	Analysis Type
Smith #1	1-A	8530.5-8530.7	Lower Smackover	Dow Chemical USA	03-027-11156-00-00	3	17S	21W	Columbia	Core Chip	TOC/Rock-Eval
Smith #1	1-B	8536.0-8536.2	Lower Smackover	Dow Chemical USA	03-027-11156-00-00	3	17S	21W	Columbia	Core Chip	TOC/Rock-Eval
Smith #1	1-C	8538.7-8538.9	Lower Smackover	Dow Chemical USA	03-027-11156-00-00	3	17S	21W	Columbia	Core Chip	TOC/Rock-Eval
Smith #1	1-D	8530.5-8530.7	Lower Smackover	Dow Chemical USA	03-027-11156-00-00	3	17S	21W	Columbia	Core Chip	Thin Section
Smith #1	1-E	8536.0-8536.2	Lower Smackover	Dow Chemical USA	03-027-11156-00-00	3	17S	21W	Columbia	Core Chip	Thin Section
Smith #1	1-F	8538.7-8538.9	Lower Smackover	Dow Chemical USA	03-027-11156-00-00	3	17S	21W	Columbia	Core Chip	Thin Section
Chester #1	2-A	9400-9410	Lower Smackover	Murphy Corporation	03-139-04393-00-00	32	19S	17W	Union	Cutting	TOC/Rock-Eval
Chester #1	2-B	9500-9510	Lower Smackover	Murphy Corporation	03-139-04393-00-00	32	19S	17W	Union	Cutting	TOC/Rock-Eval
Chester #1	2-C	9600-9610	Lower Smackover	Murphy Corporation	03-139-04393-00-00	32	19S	17W	Union	Cutting	TOC/Rock-Eval
Chester #1	2-D	9700-9710	Lower Smackover	Murphy Corporation	03-139-04393-00-00	32	19S	17W	Union	Cutting	TOC/Rock-Eval
Chester #1	2-E	9404-9408	Lower Smackover	Murphy Corporation	03-139-04393-00-00	32	19S	17W	Union	Cutting	Thin Section
Chester #1	2-F	9706-9710	Lower Smackover	Murphy Corporation	03-139-04393-00-00	32	19S	17W	Union	Cutting	Thin Section

**-DATA ONLY REPORT-  
PETROGRAPHIC DATA  
OF  
CONVENTIONAL CORE SAMPLES  
AND  
CUTTINGS SAMPLES  
FOR  
ARKANSAS GEOLOGICAL SURVEY WELLS NO. 1 & 2  
LOWER SMACKOVER FORMATION**

**WEATHERFORD FILE NO.: HH-48699**





## PETROGRAPHIC ANALYSIS

Three (3) conventional core samples and two (2) cuttings samples from the Arkansas Geological Survey Wells No. 1 & 2 were submitted for thin section preparation, photography, and qualitative (general) petrographic analysis. The samples represent the Lower Smackover Formation and range in depth from 8530.00'-8538.90' for the conventional core samples while the cuttings range from 9404' to 9710'.

**TABLE 2**

### **SAMPLE DEPTHS AND ANALYSES PERFORMED ON CONVENTIONAL CORE SAMPLES**

<b>Sample Depth (ft)</b>	<b>Sample Number</b>	<b>Thin Section Prep. &amp; Photo.</b>	<b>Qualitative Petrographic Analysis</b>
8530.50-8530.70	1-D	X	X
8536.00-8536.20	1-E	X	X
8538.70-8538.90	1-F	X	X

**TABLE 3**

### **SAMPLE DEPTHS AND ANALYSES PERFORMED ON CUTTINGS SAMPLES**

<b>Sample Depth (ft)</b>	<b>Sample Number</b>	<b>Thin Section Prep. &amp; Photo.</b>	<b>Qualitative Petrographic Analysis</b>
9404-9408	2-E	X	X
9706-9710	2-F	X	X

## APPENDIX A

### PETROGRAPHIC ANALYTICAL PROCEDURES

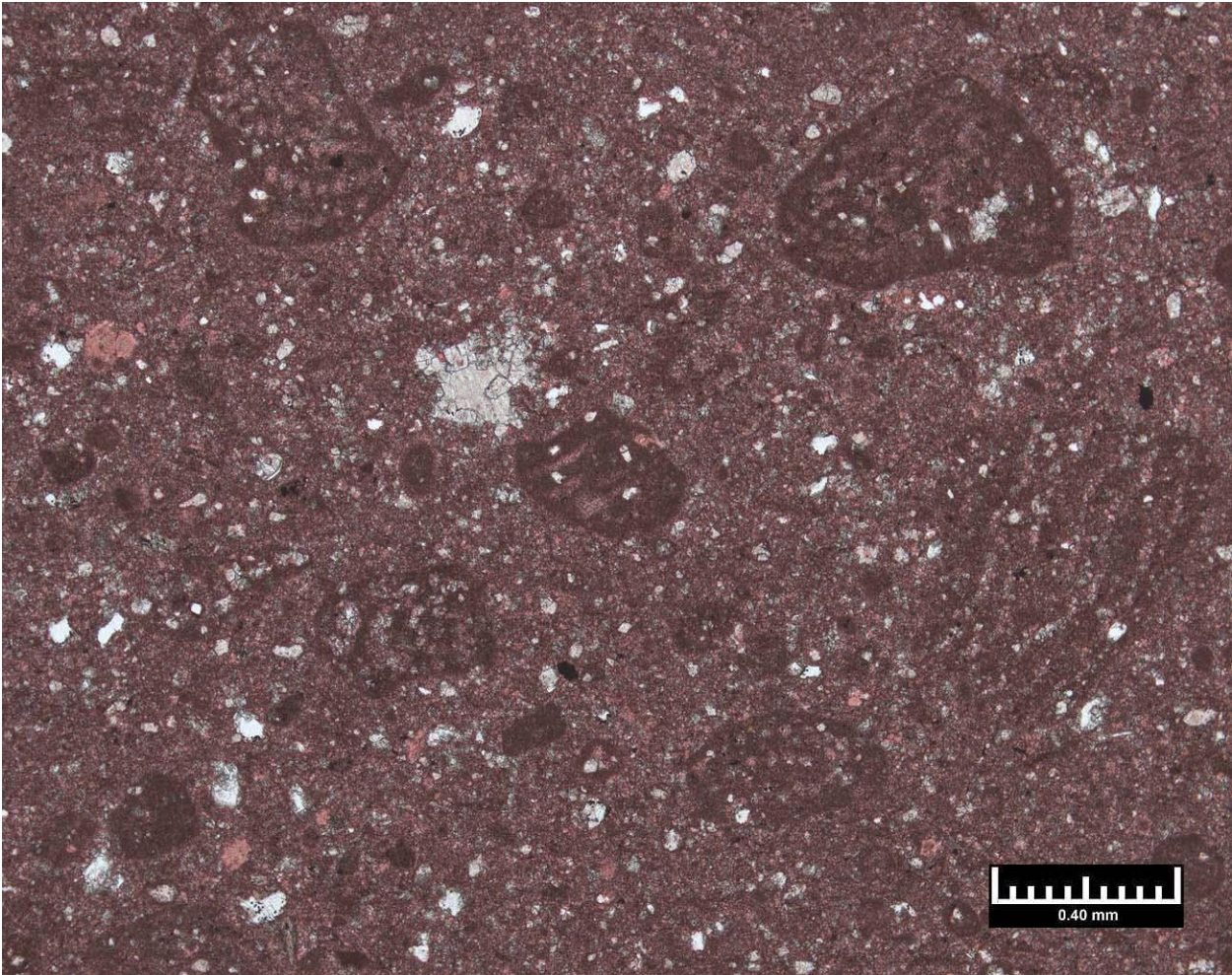
#### Thin Section Petrographic Analysis

Samples selected for thin section analysis were prepared by vacuum impregnation with blue-dyed epoxy. The samples were then mounted on an optical glass slide and cut and lapped in mineral oil to a thickness of 0.03 mm (30 microns). The sections were stained using Alizarin Red S for calcite and potassium ferricyanide for ferroan dolomite/calcite. This dual carbonate staining technique stains calcite pink or red, ferroan calcite purple or mauve, and ferroan dolomite sky blue. Non-ferroan dolomite remains unstained. The prepared sections were then covered with index oil and temporary cover slips, and photographed using a polarizing microscope.

**APPENDIX B**

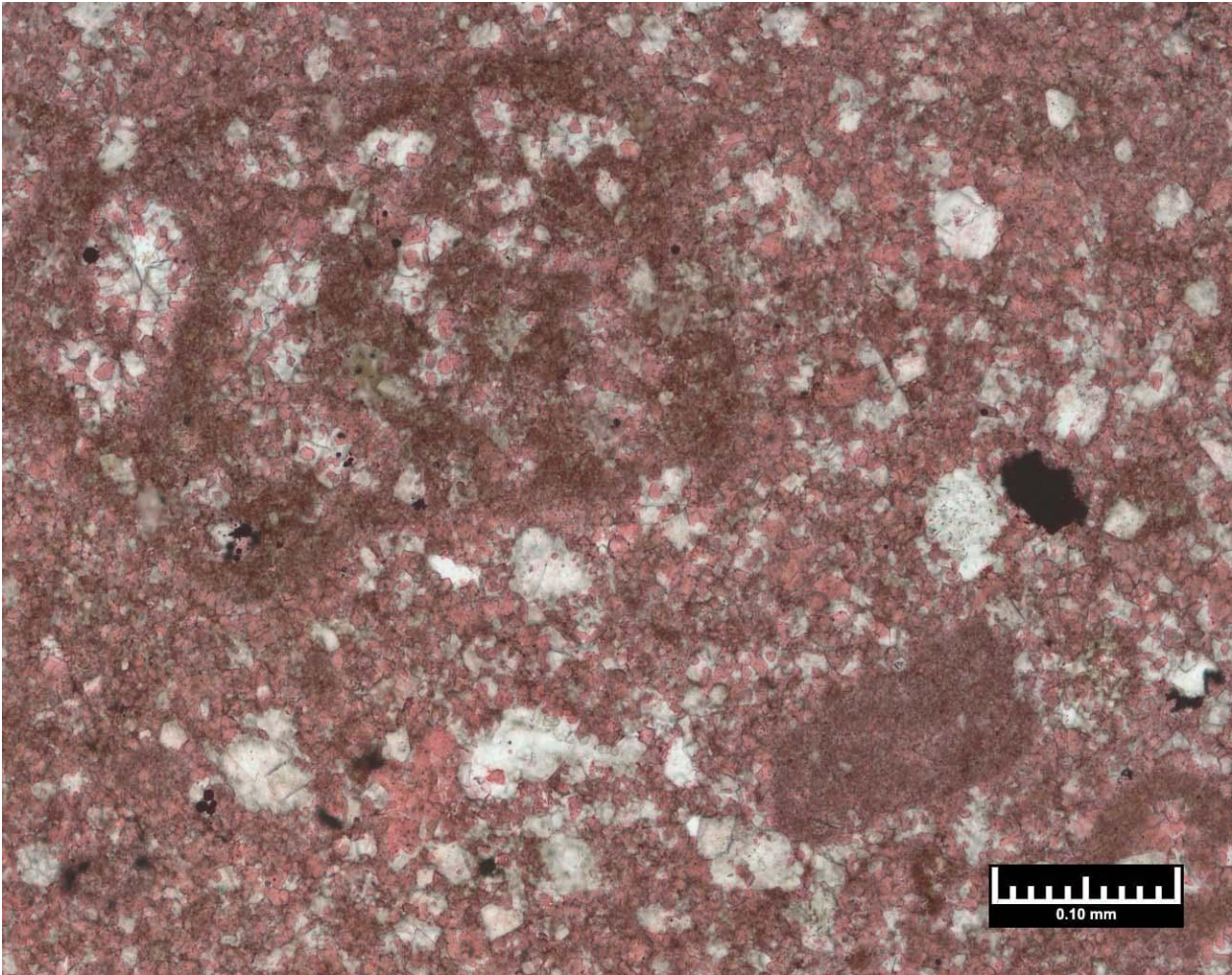
**THIN SECTION PHOTOMICROGRAPHS  
AND QUALITATIVE DESCRIPTIONS  
OF CONVENTIONAL CORE SAMPLES**

Smith #1; Sample 1-D; 8530.5-8530.7'; Magnification = 50X

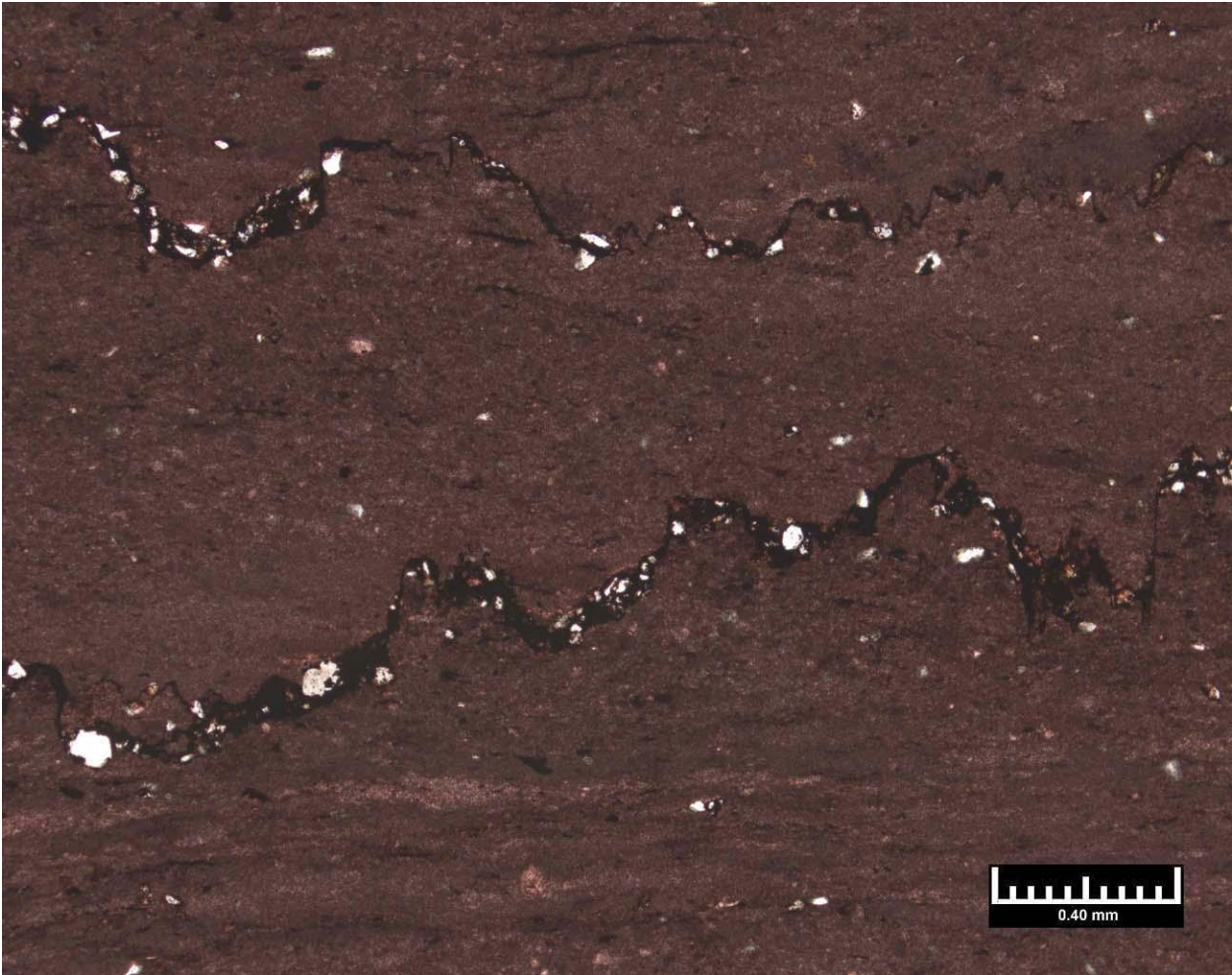




Smith #1; Sample 1-D; 8530.5-8530.7'; Magnification = 200X

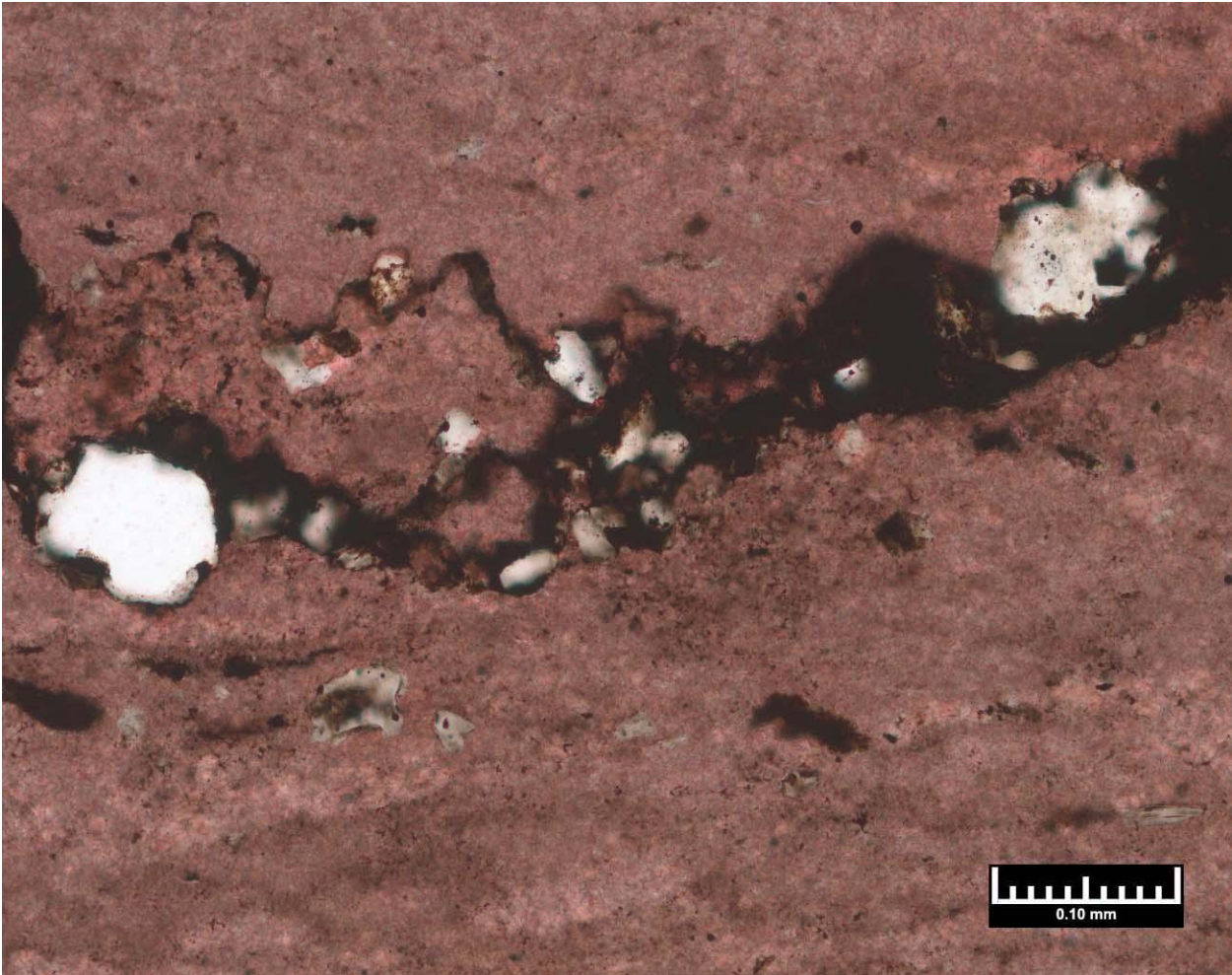


Smith #1; Sample 1-E; 8536.0-8536.2'; Magnification = 50X

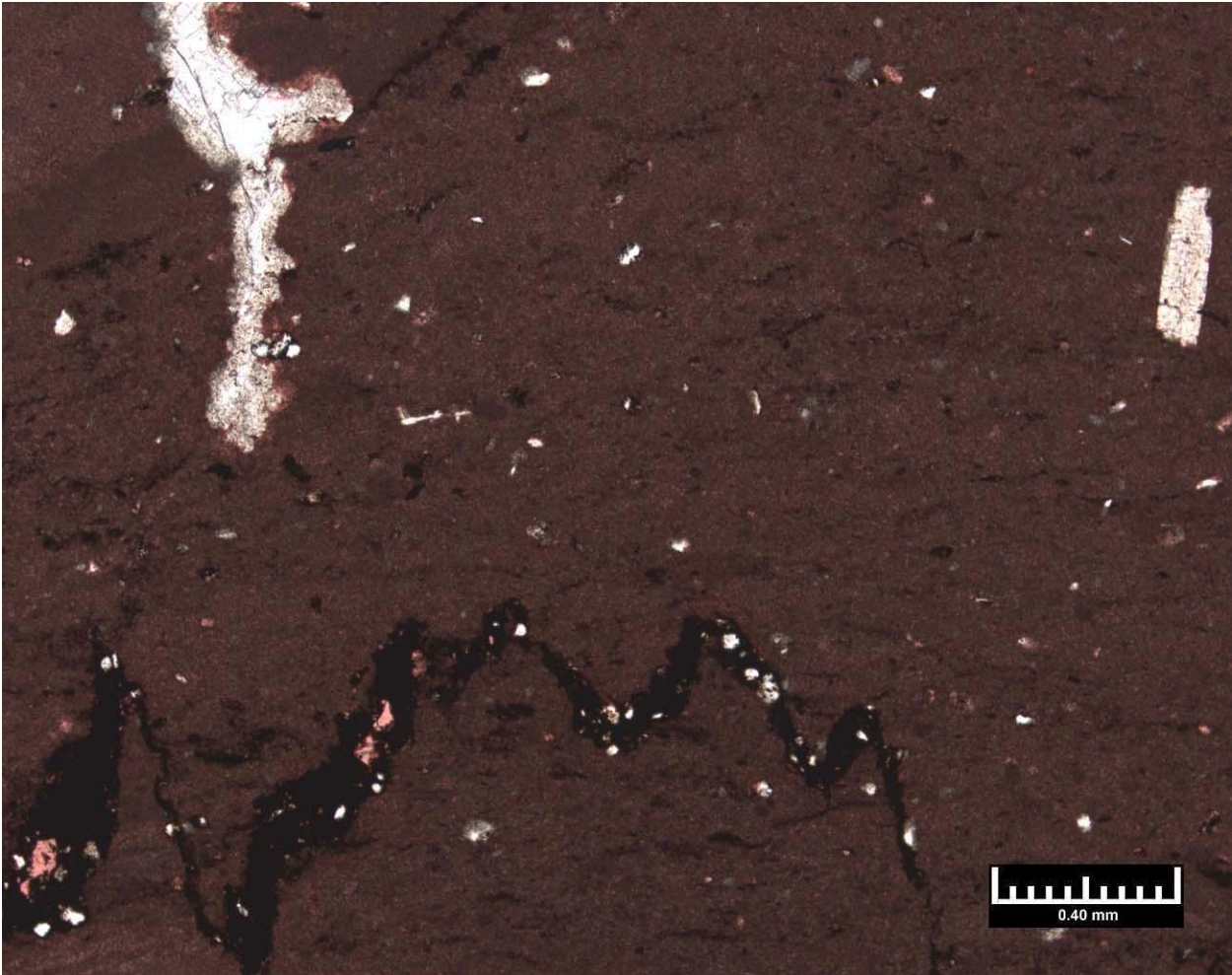




Smith #1; Sample 1-E; 8536.0-8536.2'; Magnification = 200X

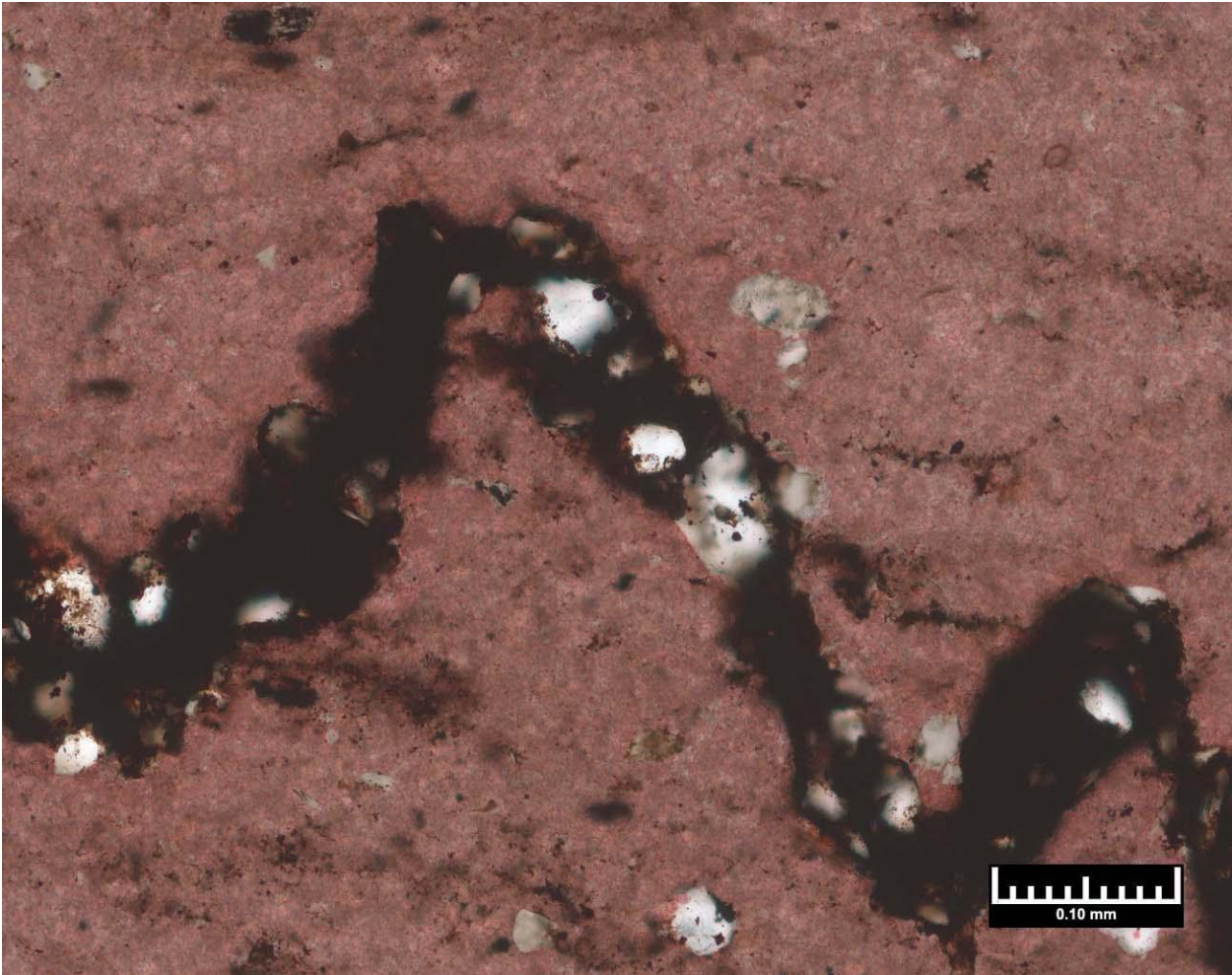


Smith #1; Sample 1-F; 8538.7-8538.9'; Magnification = 50X





Smith #1; Sample 1-F; 8538.7-8538.9'; Magnification = 200X



**Weatherford File No: HH-48699**  
**Arkansas Geological Survey Smith #1**  
**Lower Smackover Formation**  
**Conventional Core**

**THIN SECTION DESCRIPTION - GENERAL**

**SAMPLE DEPTH: 8530.50-8530.70 FEET**

**SAMPLE NUMBER: 1D**

**LECO TOC:** 0.34% (wt.)      **Tmax:** 429°C

**Lithology:** Limestone

**Texture:** Slightly silty, argillaceous, peloidal/skeletal lime wackestone; laminated; slightly bioturbated; contains induced fractures; poorly sorted allochems up to 2.13mm in length

**Detrital Grains/Allochems:** Common silt-sized detrital grains consisting of monocrystalline and polycrystalline quartz (photo A; B6,G1.5,K9); common peloidal grains; minor to rare foraminifera, gastropods, red algae fragments (photo A; B4,B-C12,H-J10), bivalves, and undifferentiated calcareous fragments; rare argillaceous fragments, chert, muscovite, metamorphic schistose fragments, and tourmaline heavy mineral fragments; rare carbonaceous material

**Matrix:** Very abundant depositional carbonate mud matrix; minor to rare amounts of detrital clay; carbonate mud commonly occurs within the chambers of some skeletal fragments and along the concave edges of bivalves

**Cements and Replacement Minerals:** Common allochem-/grain-replacing finely crystalline calcite; minor to rare sparry calcite occurring within or replacing skeletal fragments; minor amount of fine crystalline pyrite occurring as replacement of unstable detrital grains and allochems, within burrows, and as scattered framboids within the matrix (photo B; E-F13.5,H-J3); minor to rare hydrocarbon material intermixed with the calcareous/detrital matrix; rare replacement of skeletal fragments by dolomite (photo B; B-C12,H-J4); rare quartz overgrowths on host quartz silt grains; rare replacement of the matrix by anhydrite

**Pore System:** No visible porosity is present

**Magnification:**      A: 50X      B: 200X

**Weatherford File No: HH-48699  
Arkansas Geological Survey Smith #1  
Lower Smackover Formation  
Conventional Core**

**THIN SECTION DESCRIPTION - GENERAL**

**SAMPLE DEPTH: 8536.00-8536.20 FEET**

**SAMPLE NUMBER: 1E**

**LECO TOC:** 0.77% (wt.)      **Tmax:** 444°C

**Lithology:** Limestone

**Texture:** Slightly silty, organic-rich, lime mudstone/wackestone; cross-laminated; contains microstylolites (photo A; B1-14,G1-F15 / photo B; F1-B15); micrite-filled burrows; partially bioturbated; induced fractures

**Detrital Grains/Allochems:** Common silt-sized detrital grains consisting of monocrystalline and polycrystalline quartz (photo B; F2); minor amorphous carbonaceous material, pyrite, and siliciclastic sand- and silt-sized grains are concentrated along stylolites; rare foraminifera, peloids, bivalves, and undifferentiated calcareous fragments; rare siltstone fragments, muscovite, metamorphic schistose fragments, chert, and argillaceous grains

**Matrix:** Very abundant depositional carbonate mud matrix; minor amounts of detrital clay; carbonate mud commonly occurs within the chambers of some skeletal fragments and along the concave edges of bivalves

**Cements and Replacement Minerals:** Common allochem-/grain-replacing finely crystalline calcite; rare sparry calcite occurring within or replacing skeletal fragments; minor amount of fine crystalline pyrite occurring as replacement of unstable detrital grains and allochems, within burrows, and as scattered framboids within the matrix; minor to rare hydrocarbon material intermixed with the calcareous/detrital matrix (photo B; C-D3,F-G8,G-H13); minor to rare replacement of matrix by dolomite; rare quartz overgrowths on host quartz silt grains; rare replacement of the matrix by anhydrite

**Pore System:** No visible porosity is present

**Magnification:**      A: 50X      B: 200X

**Weatherford File No: HH-48699**  
**Arkansas Geological Survey Smith #1**  
**Lower Smackover Formation**  
**Conventional Core**

**THIN SECTION DESCRIPTION - GENERAL**

**SAMPLE DEPTH: 8538.70-8538.90 FEET**

**SAMPLE NUMBER: 1-F**

**LECO TOC:** 0.28% (wt.)      **Tmax:** 443°C

**Lithology:** Limestone

**Texture:** Slightly silty, lime mudstone; laminated; contains microstylolites (photo A; K1-K13) plus thin, wispy organic-rich laminations; partially bioturbated; gypsum- and anhydrite-filled fractures

**Detrital Grains/Allochems:** Common silt-sized detrital grains consisting of monocrystalline and polycrystalline quartz; minor amorphous carbonaceous material is concentrated along stylolites; rare peloids and undifferentiated calcareous fragments; rare plagioclase feldspar, muscovite, chert

**Matrix:** Very abundant depositional carbonate mud matrix; minor amounts of detrital clay; carbonate mud commonly occurs within the chambers of some skeletal fragments

**Cements and Replacement Minerals:** Common allochem-/grain-replacing finely crystalline calcite; rare sparry calcite occurring within or replacing skeletal fragments; minor amount of fine crystalline pyrite occurring as replacement of unstable detrital grains and allochems, within burrows, and as scattered framboids within the matrix; minor to rare hydrocarbon material intermixed with the calcareous/detrital matrix; minor to rare anhydrite and gypsum occurring as fracture fill (photo A; A3-E3.5); rare quartz overgrowths on host quartz silt grains (photo B; F9.5)

**Pore System:** No visible porosity is present

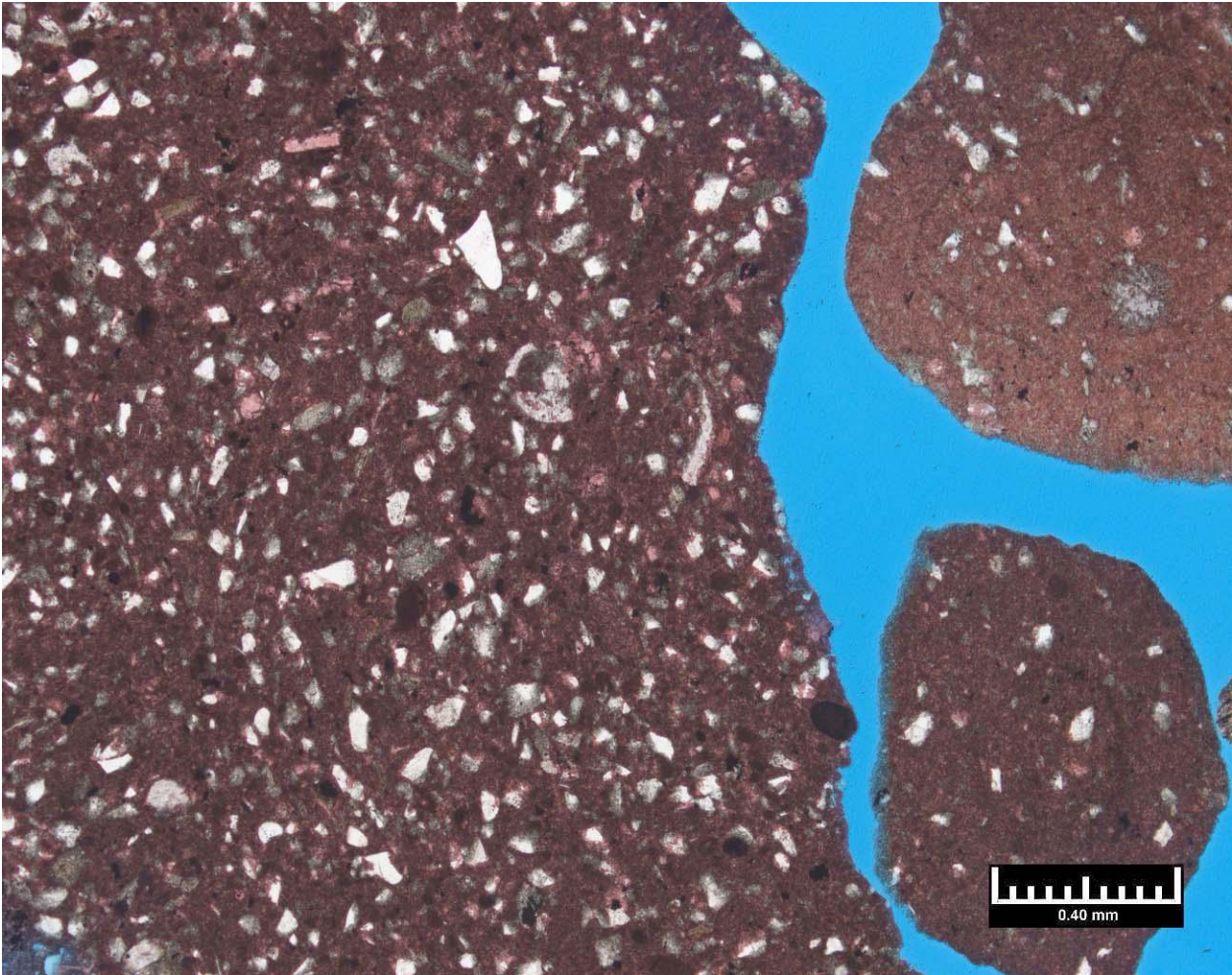
**Magnification:**      A: 50X      B: 200X

**APPENDIX C**

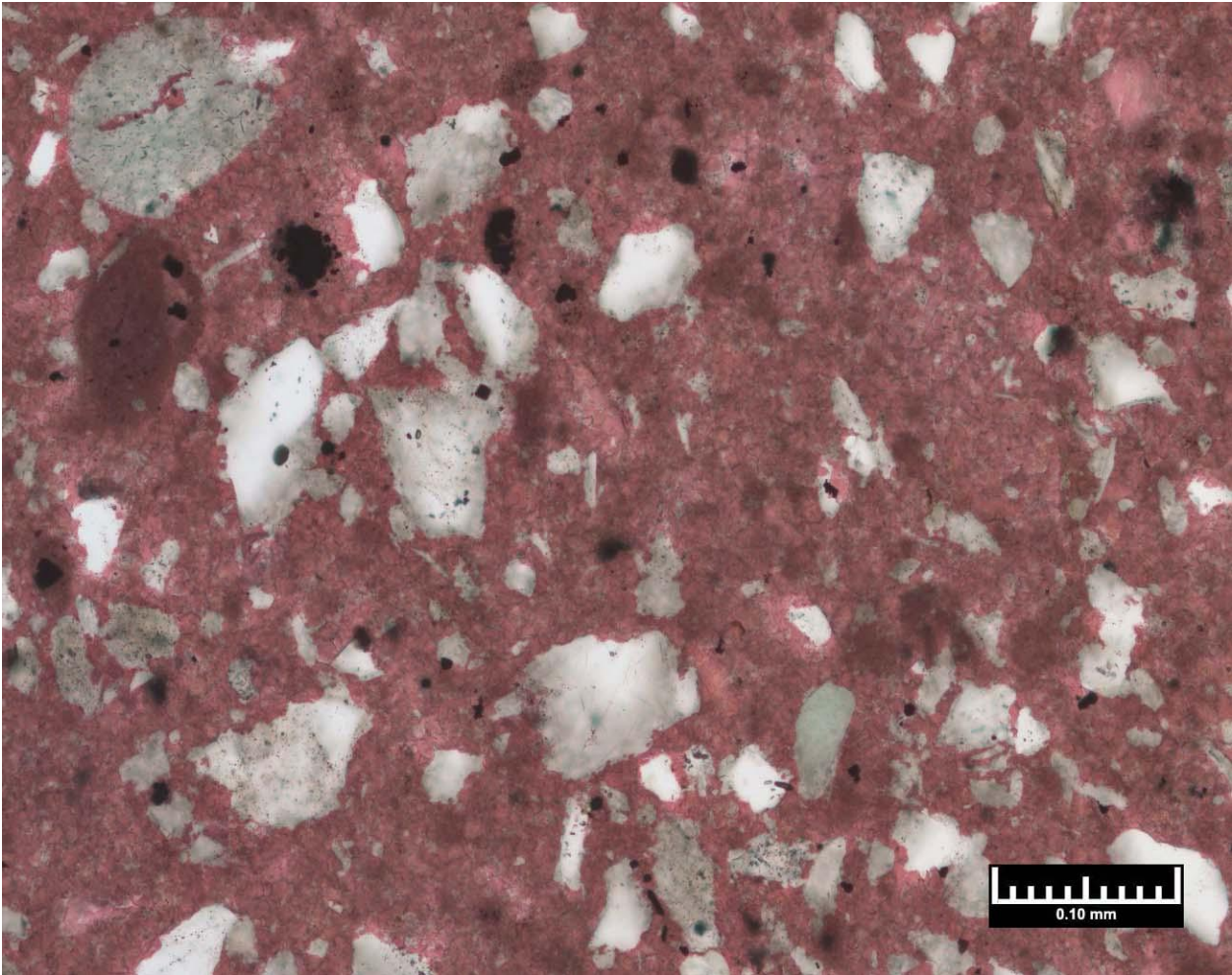
**THIN SECTION PHOTOMICROGRAPHS  
AND QUALITATIVE DESCRIPTIONS  
OF CUTTINGS**



Chester #1; Sample 2-E; 9404-9408'; Magnification = 50X

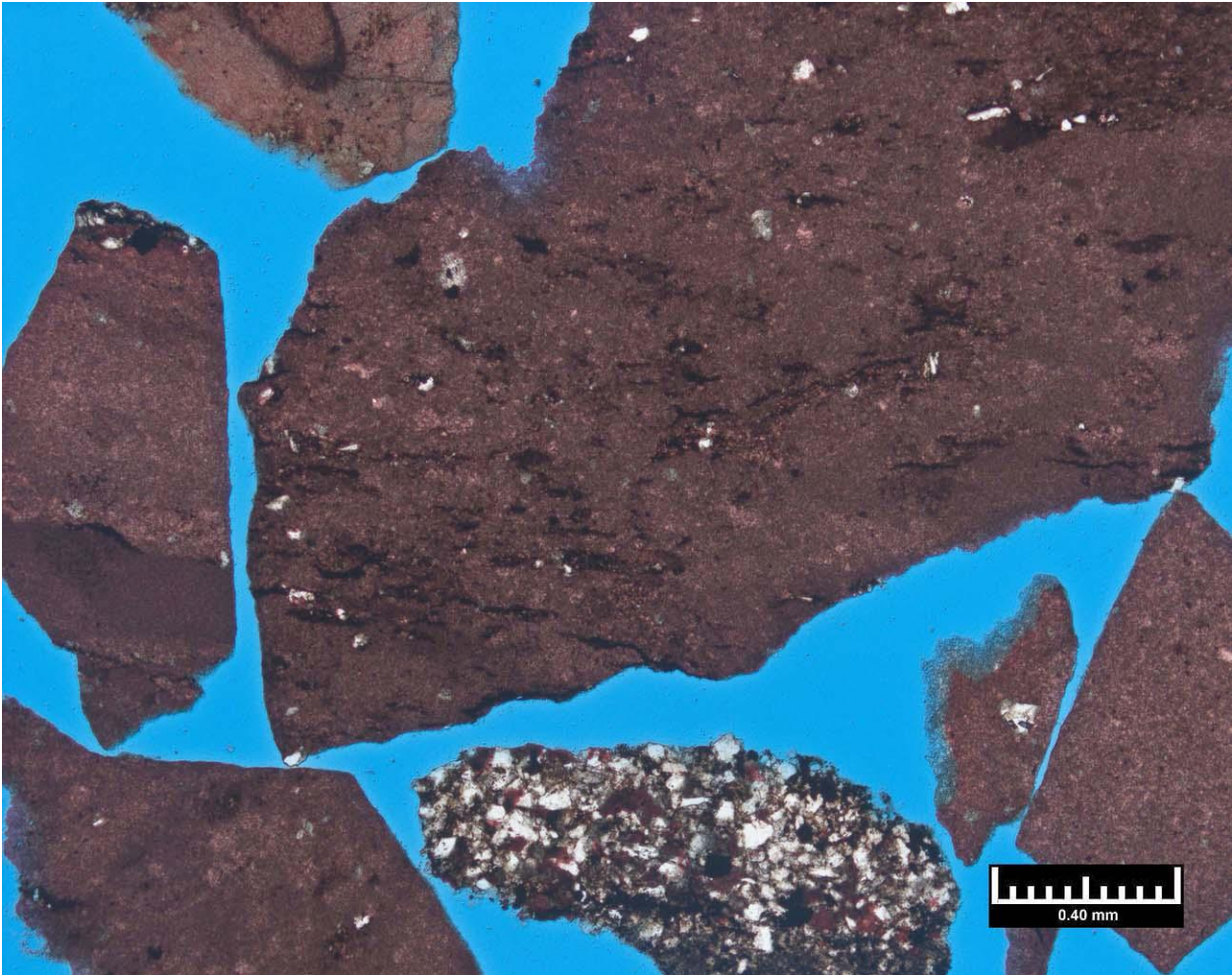


Chester #1; Sample 2-E; 9404-9408'; Magnification = 200X



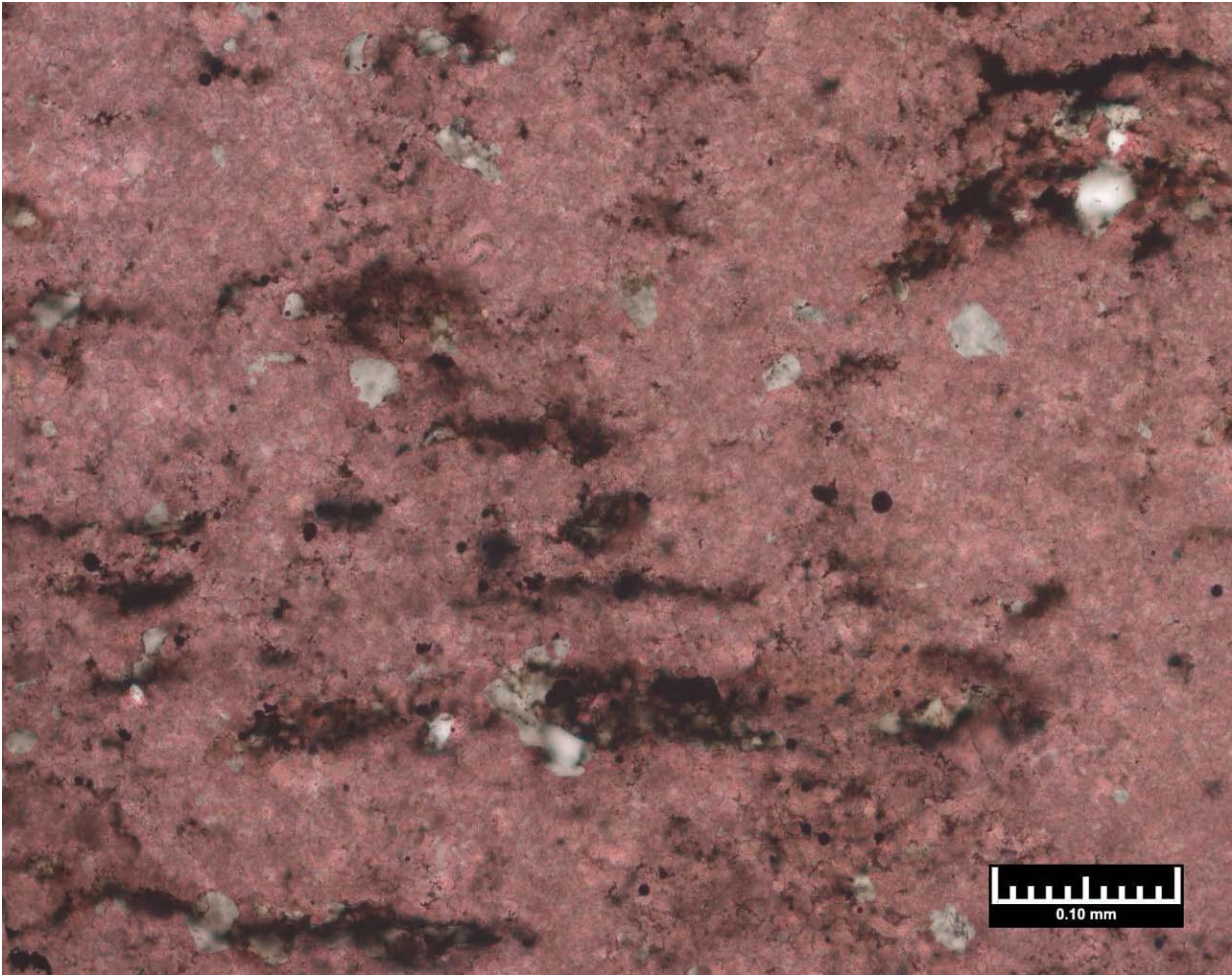


Chester #1; Sample 2-F; 9706-9710'; Magnification = 50X





Chester #1; Sample 2-F; 9706-9710'; Magnification = 200X



**Weatherford File No: HH-48699  
Arkansas Geological Survey Chester #1  
Lower Smackover Formation  
Cuttings**

**THIN SECTION DESCRIPTION - GENERAL**

**SAMPLE DEPTH: 9404-9408 FEET**

**SAMPLE NUMBER: 2-E**

**LECO TOC:** 0.24% (wt.)      **Tmax:** 441°C

**Lithology:** Limestone and siltstones

**Texture:** Slightly sandy, silty, lime mudstone to wackestone, calcareous siltstone (grain size average 0.06mm), and slightly sandy, argillaceous siltstone (grain size average 0.04mm); massive to laminated lithologies; siltstones are well sorted

**Detrital Grains/Allochems:** Common silt- and sand-sized detrital grains consisting of monocrystalline and polycrystalline quartz (photo A; C6.5,H5); minor carbonaceous material; rare uniserial foraminifera, peloids (photo B; C-D2), brachiopod fragments, and undifferentiated calcareous fragments; rare plagioclase feldspar, muscovite, biotite, chert, argillaceous fragments, metamorphic schistose fragments, and tourmaline and epidote heavy minerals

**Matrix:** Very abundant depositional carbonate mud matrix; minor amounts of detrital clay; carbonate mud commonly occurs within the chambers of some skeletal fragments

**Cements and Replacement Minerals:** Common allochem-/grain-replacing finely crystalline calcite; rare sparry calcite occurring within or replacing skeletal fragments; minor amount of fine crystalline pyrite occurring as replacement of unstable detrital grains and allochems and as scattered framboids within the matrix; minor to rare replacement of matrix material and skeletal fragments by dolomite (photo B; B2.5,B-C6,C-D15); rare hydrocarbon material intermixed with the calcareous/detrital matrix; rare quartz overgrowths on host quartz silt grains; rare siderite occurring as a replacement of argillaceous grains

**Pore System:** Micropores associated with detrital matrix clays in the siltstone lithologies represent the only form of porosity present

**Magnification:**            A: 50X            B: 200X

**Weatherford File No: HH-48699**  
**Arkansas Geological Survey Chester #1**  
**Lower Smackover Formation**  
**Cuttings**

**THIN SECTION DESCRIPTION - GENERAL**

**SAMPLE DEPTH: 9706-9710 FEET**

**SAMPLE NUMBER: 2F**

**LECO TOC:** 0.31% (wt.)      **Tmax:** 449°C

**Lithology:** Limestone and siltstone

**Texture:** Slightly sandy, slightly silty to silty, lime mudstone to wackestone and slightly sandy, argillaceous siltstone (grain size average 0.03mm); massive to laminated lithologies; siltstone is well sorted; thin, wispy laminations of detrital clay; microstylolites occur within some chips with organics, silt, pyrite, and mica grains

**Detrital Grains/Allochems:** Common silt- and sand-sized detrital grains consisting of monocrystalline and polycrystalline quartz (photo A; A-B10.5,J7.5); rare carbonaceous material; rare uniserial foraminifera, peloids, brachiopod fragments, and undifferentiated calcareous fragments; rare plagioclase feldspar, muscovite, and chert

**Matrix:** Very abundant depositional carbonate mud matrix; minor amounts of detrital clay; carbonate mud commonly occurs within the chambers of some skeletal fragments

**Cements and Replacement Minerals:** Common allochem-/grain-replacing finely crystalline calcite; rare sparry calcite occurring within or replacing skeletal fragments; minor amount of fine crystalline pyrite occurring as replacement of unstable detrital grains and allochems and as scattered framboids within the matrix; minor to rare replacement of matrix material and skeletal fragments by dolomite (photo B; B6,D12.5); minor replacement of material by gypsum and anhydrite; rare hydrocarbon material intermixed with the calcareous/detrital matrix (photo B; B-C12.5,H5); rare quartz overgrowths on host quartz silt grains

**Pore System:** Micropores associated with detrital matrix clays in the siltstone lithologies represent the only form of porosity present

**Magnification:**            A: 50X            B: 200X

**APPENDIX D**

**GEOCHEMISTRY DATA**



**TOTAL ORGANIC CARBON, PROGRAMMED PYROLYSIS DATA**

<b>Well Name : Arkansas Geological Survey Well No. 1 &amp; 2</b>	<b>Operator :</b> API # :	<b>State :</b> <b>County :</b>	<b>Project No. :</b> HH-48699 / HH-48699
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Client ID	Depth (1-a)			Formation	Sample Type	Sample Prep	*	Leco TOC	RE			Tmax (°C)	**	Ro, %	HI	OI	S2/S3	S1/TOC	PI	Notes		Lab ID
	Top	Bottom	Median						S1	S2	S3									Checks	Pyrogram	
	8530.5	8530.7	8530.6	Lower Smackover	Core Chip	NOPR		0.34	0.21	0.35	0.63	429	**		103	185	0.6	63	0.38	TOC RE	f	100012419
	8536	8536.2	8536.1	Lower Smackover	Core Chip	NOPR		0.77	0.25	0.55	0.60	444			72	78	0.9	32	0.31	TOC	n:Its2sh:hts2sh	100012421
	8538.7	8538.9	8538.8	Lower Smackover	Core Chip	NOPR		0.28	0.09	0.22	0.74	443	**		79	264	0.3	32	0.29	TOC	n:Its2sh:hts2sh	100012423
	9400	9410	9405	Lower Smackover	Cutting	NOPR		0.24	0.13	0.26	0.48	441	**		107	198	0.5	54	0.33	TOC	n:Its2sh:hts2sh	100012427
	9500	9510	9505	Lower Smackover	Cutting	NOPR		0.45	0.20	0.47	1.94	441	**		104	427	0.2	45	0.30	TOC RE	f	100012429
	9600	9610	9605	Lower Smackover	Cutting	NOPR		0.47	0.39	0.66	0.37	444			141	79	1.8	84	0.37	TOC RE	n:Its2sh:hts2sh	100012431
	9700	9710	9705	Lower Smackover	Cutting	NOPR		0.31	0.12	0.20	1.04	449	**		65	340	0.2	39	0.37	TOC RE	f	100012433

<b>Notes:</b>		
"-1" - not measured or invalid value for T <sub>max</sub> TOC - Total Organic Carbon, wt. % S1 - volatile hydrocarbon (HC) content, mg HC/ g rock S2 - remaining HC generative potential, mg HC/ g rock S3 - carbon dioxide content, mg CO <sub>2</sub> / g rock	* - comments regarding contamination ** - low S2, Tmax is unreliable Meas. %Ro - measured vitrinite reflectance HI - Hydrogen index = S2 x 100 / TOC, mg HC/ g TOC OI - Oxygen Index = S3 x 100 / TOC, mg CO <sub>2</sub> / g TOC PI - Production Index = S1 / (S1+S2)	<b>Pyrogram:</b> f - flat S2 peak n - normal ltS2sh - low temperature S2 shoulder htS2sh - high temperature S2 shoulder ltS2p - low temperature S2 peak htS2p - high temperature S2 peak LECO - TOC on Leco Instrument RE - Programmed pyrolysis or TOC on Rock-Eval instrument SRA - Programmed pyrolysis by SRA Instrument EXT - Extracted Rock NOPR - Normal Preparation