A GEOLOGIC STUDY TO DETERMINE THE POTENTIAL TO CREATE AN APPALACHIAN STORAGE HUB FOR NATURAL GAS LIQUIDS



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APPENDIX A – ANNOTATED BIBLIOGRAPHY

ANNOTATED BIBLIOGRAPHY

Matchen, David L., and Kammer, Thomas W., 1994, Sequence Stratigraphy of the Lower Mississippian Price and Borden Formations in Southern West Virginia and Eastern Kentucky: Southeastern Geology, V. 34 No. 1, pp. 25-41.

[Document Link: <u>http://pages.geo.wvu.edu/~kammer/reprints/Matchen&Kammer1994.pdf</u> (PDF, 1.28 MB)]

Keywords: sequence stratigraphy, West Virginia, Kentucky, Mississippian, outcrops, gamma-ray, logs, allo-units

This sequence stratigraphic study details the progradational wedge formed by the Lower Mississippian in the Appalachian basin. The Lower Mississippian rocks, which can be divided into four separate units, are units of major consideration in other manuscripts detailing prospects for geological sequestration. The researchers used three sets of outcrops and subsurface data, including 340 gamma-ray well logs, to correlate the units within the Lower Mississippian. The evidence presented in this manuscript can be used to further evaluate porosity and permeability of each of the four allo-units, further provided more detailed insight into which of the specific allo-units could be used as prospects for sequestration in West Virginia and Kentucky.

Martens, James H.C., 1943, Rock Salt Deposits of West Virginia: West Virginia Geological Survey, Bulletin No. 7, 67p.

[Document Information Link: http://www.wvgs.wvnet.edu/wvges2/publications/PubCat_Details.aspx?PubCatID=B-7]

Keywords: West Virginia, Salina, Salt, Cross-sections

In 1943, the West Virginia Geological Survey authored a Bulletin on the Rock Salt Deposits of West Virginia. Even at that time, the implications of these salt deposits were being explored. This publication illustrated that through the use of "deep" well cuttings, the Salina Rock Salt beds were present in West Virginia, covering almost the entirety of the state. At the time of publication, interest in the salt were high as it represented a commercial economic resource. Today, these same salt beds present the opportunity for carbon capture utilization and storage. The 1943 Bulletin described the stratigraphy of Post-Silurian rocks above the salt and produced a detailed geologic column of the Northwestern Panhandle of West Virginia from the Dunkard Group through the Albion Sandstone for the Gribble well in Harrison County. Two simplified cross sections of the salt position were created: the first, between four wells spanning Washington County, Ohio, and the Gribble Well in Harrison County, West Virginia; and the second, spanning five wells between Wayne County, Ohio, and Harrison County, West Virginia. While these cross sections lack much detail, the show approximate positions and variations of thickness. Table 1 of the Bulletin provides a handy visual showing the maximum and minimum thicknesses between the top of the Onondaga Limestone and top of salt, as well as the number of wells (at the time) penetrating the formation in Ohio, West Virginia, Pennsylvania and New York. Formations associated with the salt were correlated between West Virginia, Maryland and western New York. Individual condensed well records were included in the Bulletin to further identify the position and thickness of the salt at specific localities.

Fergusson, William B. and Prather, Bruce A., 1968, Salt Deposits in the Salina Group in Pennsylvania: Pennsylvania Geological Survey Bulletin, M 58, 37p.

[Document Link: http://dcnr.state.pa.us/cs/groups/public/documents/document/dcnr_016635.zip]

Key Words: salt, Salina Group, basins, Silurian, reefs, Lockport Dolomite, Bloomsburg Formation, Michigan, West Virginia, New York, Pennsylvania

In 1968, the Pennsylvania Geological Survey produced a Bulletin describing the thickness and geography of the Salina in formation across Pennsylvania. While at the time, the formation was studied for its economically viable deposits of salt, it was the drilling of oil and gas wells that provided the information about the rock layers. The division of the salt was based on correlations developed by Michigan and Ohio to draw a regional picture of the deposit. In Pennsylvania, the Salina Group units were named Unit A through Unit G. The manuscript details the depositional environment of Upper Silurian evaporates across Michigan, Ohio, West Virginia, New York and Pennsylvania. An extensive description of each of the Salina Group units are described throughout the manuscript including the thickness, pseudonyms and correlation to neighboring states, and isopach and the lithofacies of each.

Sminchak, Joel R. and Gupta, Dr. Neeraj, eds., 2015, Development of Subsurface Brine Disposal Framework in the Northern Appalachian Basin: Research Partnership to Secure Energy for America (RPSEA), 411 p.

[Project Link: <u>http://www.rpsea.org/projects/11122-73/</u>]

[Document Link: <u>http://www.rpsea.org/media/files/project/185d70b8/11122-73-FR-</u> <u>Development_Subsurface_Brine_Disposal_Framework_Northern_Appalachian_Basin-10-06-15_P.pdf</u> (PDF, 18.7 MB]

Key Words: brine, disposal, subsurface, injection, Battelle, pore

In 2015, Battelle Memorial Institute sponsored the Development of Subsurface Brine Disposal Framework in the Northern Appalachian Basin. The purpose of the two-and-a-half-year consortium was to develop a geologic framework for disposal of the produced fluids from onshore drilling. While the purpose of this study is different from that of the Appalachian Storage Hub project, the brine disposal study investigates many of the same formations and their characteristics of interest in great detail. Geophysical well logs (690 in all) were utilized to analyze the formations. The injection rates derived from the study provide a clue into the porosity, permeability, and storage capacities of the formations. The most prolific formations used for brine disposal included Cambrian basal sandstone, the Cambrian Copper Ridge Dolomite and Rose Run Sandstone, the Silurian Medina Group/'Clinton'' Sandstone, the Silurian Lockport-"Newburg" dolomite, the Devonian Oriskany Sandstone and Mississippian sandstone units. Based on historical gas production in Kentucky, Ohio, West Virginia and Pennsylvania it's estimated that 47 billion barrels of brine void pore space exist in these depleted reservoirs.

Nelson, Paul E., Mathews, Noah H., Flores, Cecilia P., Patel, Pradeep K., Roth, Thomas P., Farnsworth, Lori K., Reichwein, M.C. (Tim)., 2001, Geological Prefeasibility Study of Ethane Storage Opportunities within Salt, Hard Rock, and Oil and Gas Reservoirs in West Virginia: PB Energy Storage Services, Inc., Topical Report PB-0326, 92 p.

[Company Link: <u>https://www.pbenergy.com/</u>]

Key Words: ethane, storage, feasibility, salt, volume, Marcellus, caverns, oil and gas, infrastructure, logistics, Greenbrier Limestone

In 2011, West Virginia explored subsurface ethane storage opportunities across the state from the logistics of moving ethane from sources to storage facilities to the screening criteria to be used for geologic prospects for ethane storage. The studied formations included salt caverns, mined-rock caverns and oil and gas reservoirs. The manuscript describes, by county, which formations are present and hold the most potential for ethane storage capacity. The prospects are ranked in order by geological characteristics, geological uncertainty, logistics, environmental impacts, parametric capital costs and estimated development schedules. To summarize the extensive study, a table listing each storage option and the advantages and disadvantages of each is provided at the end of the manuscript discussion. During the study, the total required storage volume was estimated between 2 and 10 million barrels with maximum withdrawal and injections for each facility type at 80,000 barrels per day. The study found that salt caverns are desirable for ethane storage at depth ranges from 1,500-3,000 feet, which is generally shallower than cavern depths in West Virginia. In mined-rock, the Greenbrier Limestone, in intervals at least 40 feet thick and at depths 1,800 feet or greater, presents the most suitable option for storage in the state due to its high strength, stability and low porosity. The study found that due to the prolific oil and gas production in the state, oil and gas reservoirs provide the greatest potential for ethane storage opportunities in terms of existing infrastructure. While the volume is great enough for storage, more wells would need to be drilled to cycle viable amounts of ethane through the reservoir. Each type of storage option provides certain advantages in different situations. The desired location of a storage facility may determine which kind of formation is best utilized for the operation.

Greb, Stephen F., and Chestnut, Donald R. Jr., 2009, Carboniferous Geology and Biostratigraphy of the Appalachian Basin, Special Publication 10: Lexington, Kentucky, Kentucky Geological Survey.

[Document Link: <u>http://www.uky.edu/OtherOrgs/KPS/books/grebchesnut2009/grebchesnut2009.pdf</u> (PDF, 8.0 MB)]

Key Words: Carboniferous, biostratigraphy, Appalachian, Black Warrior basins

This work, put together by the Kentucky Geological Survey, is segregated into 12 smaller, specialized manuscripts highlighting various areas of expertise. The introduction, written by editors Donald R. Chestnut Jr. and Stephen F. Greb, provides a brief description of the Mississippian and Pennsylvanian systems including regional correlations and general geology. Other chapters detailing specific fossil types found in the Carboniferous provide detailed insight into the deposition and environmental conditions associated with each formation.

Patchen, Douglas G., and others, 2006, A Geologic Playbook for Trenton-Black River Appalachian Basin Exploration: United States Department of Energy, 582 p.

[Project Link: <u>http://www.wvgs.wvnet.edu/www/tbr/</u>]

[Document Link: http://www.wvgs.wvnet.edu/www/tbr/docs/41856R06.pdf]

[Document Link: <u>https://www.netl.doe.gov/research/oil-and-gas/project-summaries/completed-ep-tech/de-fc26-03nt41856-</u> (PDF, 113 MB)]

Key Words: Ordovician, Appalachian, gas, oil, exploration, Trenton, Black River, reserves, dolomite, hydrothermal, geothermal, porosity, pores, geochemistry, petrology

In the early 2000s, interest in the oil and natural gas potential of Ordovician-age formations skyrocketed. Northwestern Ohio oil and gas production on the edge of the Ordovician-age margin warranted further exploration into the interbedded limestone, calcareous shale and black shale of the Trenton-Black River sequence. The manuscript is highlighted by detailed petrographic data, used to determine types and locations of seals, extent of hydrothermal fluid influence and pore shapes and sizes that contribute to viable reservoir space. Geochemical and fluid inclusion analyses on limestones and dolomites as well as natural gas geochemical analyses add to the plethora of technical data used to identify key fields, estimate resources and reserves and point to future trends in production and development.

Roen, John B. and Walker, Brian J., eds., 1996, The Atlas of Major Appalachian Gas Plays: West Virginia Geological and Economic Survey, V. 25, 201 p.

[Document Information Link: http://www.wvgs.wvnet.edu/wvges2/publications/PubCat_Details.aspx?PubCatID=V-25]

Key Words: gas, shale, Appalachian, structure, stratigraphy, trends, wells,

This major volume provides a detailed overview of Appalachian basin structure, stratigraphy and background of major oil and gas development in the region. Each section of the Atlas details individual formations from the Middle Pennsylvanian to Cambrian Pre-Knox Group. Within each formation section of the playbook can be found detailed structural, stratigraphic descriptions as well as reservoir characteristics, future trends in oil and gas development and a map of production wells in the play. The Atlas acts as a compact, yet detailed and informative

"one-stop-shop" for any and all information related to oil and gas development in the Appalachian basin through the late 1990s.

Seni, S. J., Mullican, W.F. III, and Hamlin, H. S., 1984, Texas Salt Domes – Aspects Affecting Disposal of Toxic-Chemical Waste in Solution-Mined Caverns: Austin, Texas, Bureau of Economic Geology, the University of Texas at Austin, 34 p.

[Document: Out-of-Print, Limited availability]

Key Words: salt, disposal, waste, caverns, Texas, salt domes, salt caverns

The study investigates the mechanical properties of salt caverns used in the disposal of chemical waste. Heavily focused on creep behavior and deformation mechanics of salts, the study reveal how site specific the behavior of salt can be. Even when using empirical models, there is no consensus on how various factors can affect salt creep. The study stresses the need to further refine salt models and identify factors affecting injection into salt storage prospects.

Wickstrom, Lawrence H. and others, 2005, Characterization of Geologic Sequestration Opportunities in the MRCSP Region: Columbus, Ohio, Battelle Memorial Institute, 152 p.

[Document Link: https://geosurvey.ohiodnr.gov/portals/geosurvey/PDFs/OpenFileReports/OFR_2005-1.pdf (PDF, 21.96MB)]

Key Words: carbon sequestration, oil and gas, subsurface, regional geology, stratigraphy, MRCSP, Battelle, reservoir, seal, porosity, permeability, Appalachian basin, Michigan basin, Arches province, Atlantic Coastal Plain

The Phase I report of the Midwest Regional Carbon Sequestration Partnership (MRCSP) outlines a preliminary assessment of carbon dioxide (CO_2) sequestration opportunities across New York, Pennsylvania, Ohio, Michigan, Maryland, West Virginia and Kentucky in the Appalachian and Michigan basins, Arches province and Atlantic Coastal Plain. The study identifies nine potential reservoirs and five caprocks within the Middle Devonian-Middle Silurian (MDMS) interval using geological and logistical characteristics. The study identified numerous formation types as potential reservoirs and seals, all with varying characteristics and storage capabilities. The study includes detailed descriptions and evaluations of these numerous siliciclastic and carbonate units present throughout the region. In the Appalachian basin, it was concluded that the Oriskany Sandstone presents the most promising target for sequestration, while in the Michigan basin, the Bass Islands Dolomite and the Dundee Formation present the most promising targets. The study utilized a vast amount of geological information including oil and gas production, drilling records, geophysical logs, laboratory-derived evaluations of core, rock cuttings and outcrop samples. A smaller part of the larger MRCSP report to the U.S. Department of Energy, this Phase I evaluation includes some of the most detailed research on individual sequestration prospects ever compiled.

Patchen, D.G. and Carter, K.M., eds., 2015, A geologic play book for Utica Shale Appalachian basin exploration, Final report of the Utica Shale Appalachian basin exploration consortium, 187 p.

Available from: <u>http://www.wvgs.wvnet.edu/utica</u>.

Key Words: Utica, Marcellus, shale, natural gas, porosity, permeability, thermal maturity, subsurface, regional geology, stratigraphy, porosity, permeability, Appalachian basin

The Study represents the efforts of five different states and fifteen oil and gas industry partners to research all aspects of the Utica Shale Play in the Appalachian basin from basin-scale stratigraphy to nano-porosity textures. The study assessed the lithology, geochemistry, stratigraphy and depositional environment of the reservoir as well as defined the oil and gas fairways and production capabilities in production-based and volumetric resource assessments. The combination of various data-types, analyses, and detailed research including core studies, tracking drilling activities, mineralogy and carbonate analyses, TOC data, thermal maturity evaluations, stratigraphic correlations, SEM analyses and resource assessment provides an extremely detailed account of the Utica Shale Play across the Appalachian basin.

APPENDIX B – REGIONAL GEOLOGIC CROSS SECTION PLATES









Appalachian NGL Storage Hub



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SW

Appalachian NGL Storage Hub

NW

Appalachian NGL Storage Hub

CAMBRIAN-ORDOVICIAN ROSE RUN SANDSTONE





SW C

Appalachian NGL Storage Hub CAMBRIAN-ORDOVICIAN ROSE RUN SANDSTONE

34141200090000 34129200240000 34045205810000 34119270760000 34031263790000 <21.37MI> <21.47MI> <21.67MI> <44.19MI> <14.64MI> TD : 3,863 TD : 4,446 TD : 3,973 TD : 7,381 TD : 7,166 _PHID_SS [V/V CALI [IN] DPHI [PCN] CALI [IN] GR [GAPI] GR [GAPI] -500 -BKRV 33 -400 --300 --200 --100 -WLCK 0 -Datum Thot my hundred MANA A. BKMN . 100 -2 200 -humber -300 and the manus and the H Z 400 -



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APPENDIX C – PPG INDUSTRIES CORE ANALYSES, MARSHALL COUNTY, WEST VIRGINIA

PPG INDUSTRIES SALT CORE DATA, MARSHALL COUNTY, WEST VIRGINIA

Thirty-four core samples from the PPG36 well were analyzed for 51 different major and trace elements. Major element concentrations were reported in weight percentages (%), and trace element concentrations were reported in parts per million (ppm) or parts per billion (ppb). The samples were grouped into six different groups by the predominant lithology reported in the core description. For example, black shaley siltstone with euhedral halite crystals was grouped into the dark gray to black shaley siltstone category. Tables C-1 and C-2 show the major element and trace element concentrations by lithology, respectively. Elements were not included in these tables if concentrations were reported to be below laboratory detection limits. An additional four elements (barium, cobalt, hafnium and europium) were not included in the trace element table because these were only detected in a single siltstone sample. Detection limits for the various major and trace elements are included in Tables C-3 and C-4, respectively.

Major Element Lithology Table Summary

The halite samples had no iron, while the shaley siltstone and dolomicrite samples had a small amount. As expected, the halite samples had far more sodium than the siltstone or dolomicrite samples. In addition, the siltstone and dolomicrite reported more calcium and magnesium than the predominately halite samples. Titanium, aluminum and potassium concentrations increased in the darker halite samples, which likely get their dark color from dark anhydrite particles. Siltstone samples had the highest concentrations of these three elements. The siltstone and dolomicrite had almost twice as much sulfur as the halite samples.

Trace Element Lithology Table Summary

Halite samples had approximately twice as much bromine than either the siltstone or dolomicrite samples. Scandium concentrations increased in the darker halite samples, which likely get their dark color from dark anhydrite particles. Siltstone samples had the highest concentrations of this element. Lithium concentrations also increased in the darker halite samples, and dolomicrite and siltstone samples had the highest concentrations of lithium. The halite samples contained no molybdenum, thorium or uranium, and the siltstone samples reported higher concentrations of these three elements than the dolomicrite samples. The highest concentrations of the rare-earth elements - lanthanum, cerium, neodymium, samarium and ytterbium - were found in the siltstone samples. These elements were generally reported below detection limits in most of the halite samples, with the exception of detectable levels of lanthanum, neodymium and samarium in the black halite samples and some neodymium in one clear halite sample. Copper was detected in most of the lithologies (gray halite excepted), and dolomicrite samples had the highest concentrations of copper. Lead levels ranged from below detection limits to a few ppm for most lithologies, with the siltstone having the greatest concentration of lead and concentrations remaining below detection limits for the clear halite samples. Zinc and nickel were detected in all six lithologies, with siltstone and dolomicrite lithologies having the highest concentrations of these metals. Manganese and strontium were

also present in all six lithologies, but in much greater concentrations than zinc and nickel. Again, siltstone samples had the highest concentrations of these two elements. Yttrium and vanadium were mostly found to be below detection limits, with the exception of a couple ppm in the black halite and dolomicrite samples and 10 to 30 ppm in the siltstone samples.

In conclusion, the shaley siltstone samples have the highest concentrations of most of the elements analyzed for these core samples. Concentrations of several elements increase in the predominantly halite samples as the samples get darker. This probably results from increasing concentrations of non-salt particles such as anhydrite in these core samples. The gray to dark gray, coarsely crystalline halite lithology is shown in Figures 1A, 2 and 3. The dark gray to black, shaley siltstone lithology is illustrated in Figures 1C and 3.



Figure 1. a: Coarse halite crystals with evenly disseminated black anhydrite pieces that give the section a dark gray color; b: post-lithification fracture includes some salt crystals along the fracture zone; c: brown-gray calcareous shale, thinly laminated, sometimes wavy, partially replaced by salt and pepper carbonate(?)-anhydrite mixture. The shale is interbedded with the carbonate-anhydrite beds.



Figure 2. Uniformly coarse (0.25-0.5 inch) halite crystals with evenly disseminated black anhydrite pieces, which give the section a dark gray color.



Figure 3. Mix of gray coarse crystalline halite as above and disoriented large (up to 0.8 ft) clasts of thin bedded anhydrite-carbonate plus calcareous shale. Core base is 6,648 ft.

		RANGE	Low	High	Low	High	Low	High	Low	High	Low	High
		Element		FE		NA		SN	С	A2		P
		Units	c	%		%		%		%		%
	Number	Element										
	of	Detection										
Lithology	samples	Limit	0.	01	0.	01	0.	01	0.	.01	0.0	001
Clear coarsely crystalline halite	4		ND	ND	16.90	21.10	ND	ND	0.08	0.31	ND	ND
Gray, coarsely crystalline halite	4		ND	ND	16.70	21.40	ND	0.08	0.40	5.94	ND	0.001
Dark gray, coarsely crystalline halite	8		ND	ND	13.30	22.70	ND	ND	0.11	4.43	ND	0.003
Black coarsely crystalline halite	6		ND	ND	17.60	22.90	ND	0.10	0.55	6.29	ND	0.005
Dark gray to black, shaley siltstone	4		ND	1.45	0.55	9.45	ND	ND	9.68	15.90	0.002	0.025
Light and dark gray dolomricite	8		ND	0.38	0.82	10.40	ND	ND	9.08	14.80	0.001	0.010

*ND = Not Detected/Below detection limits

		Low	High	Low	High	Low	High	Low	High	Low	High
		Ν	ЛG		TI	ļ	AL.		К		S
			%		%		%		%		%
	Number										
Lithology	of		01	0	01	0	01	0	01		1 10
Lithology	samples	0.		0.		0.		0	1	0.0	
Clear coarsely crystalline halite	4	ND	0.03	ND	ND	ND	0.02	0.03	0.04	0.030	0.230
Gray, coarsely crystalline halite	4	0.02	0.57	ND	ND	ND	0.08	0.03	0.05	0.300	4.490
Dark gray, coarsely crystalline halite	8	ND	0.44	ND	ND	0.01	0.27	0.02	0.11	0.080	3.670
Black coarsely crystalline halite	6	0.03	1.60	ND	0.02	0.01	0.39	0.03	0.29	0.350	3.520
Dark gray to black, shaley siltstone	4	1.41	9.61	ND	0.14	0.06	2.38	0.11	1.95	0.640	8.000
Light and dark gray dolomricite	8	2.20	6.35	ND	0.03	0.08	0.60	0.09	0.51	2.920	6.070

*ND = Not Detected/Below detection limits

		RANGE	Low	High	Low	High	Low	High	Low	High	Low	High
		Element		AS		BR		CR		CS		RB
		Units	P	PM	P	PM	P	PM	P	PM	Р	PM
	Number	Element										
	of	Detection										
Lithology	samples	Limit	0	.5	0	.5	5	.0	1	.0	1	5.0
Clear coarsely crystalline halite	4		ND	ND	54.8	138.0	ND	19.0	ND	ND	ND	ND
Gray, coarsely crystalline halite	4		ND	2.4	58.7	97.7	ND	15.0	ND	ND	ND	33.0
Dark gray, coarsely crystalline halite	8		ND	ND	62.4	135.0	ND	10.0	ND	ND	ND	ND
Black coarsely crystalline halite	6		ND	1.0	83.7	116.0	ND	ND	ND	3.0	ND	ND
Dark gray to black, shaley siltstone	4		ND	15.8	20.7	61.5	ND	36.0	ND	3.0	ND	115.0
Light and dark gray dolomricite	8		ND	6.4	22.6	56.5	ND	18.0	ND	ND	ND	ND

*ND = Not Detected/Below detection limits

** The following elements have been removed from the table because sample PPG36-1-17 was the only sample

registering any detection: BA, CO, HF, and EU.

		Low	High										
			SB		SC		ТН		U		LA		CE
		P	PM	F	PM	Р	PM	F	PM	F	PM	F	PM
	Number												
Lithology	or samples	o).1	C).1	o	.2	C).5	C).5	3	8.0
Clear coarsely crystalline halite	4	ND	ND										
Gray, coarsely crystalline halite	4	ND	ND	ND	1.0	ND	ND	ND	ND	ND	ND	ND	ND
Dark gray, coarsely crystalline halite	8	ND	0.2	ND	0.6	ND	ND	ND	ND	ND	ND	ND	ND
Black coarsely crystalline halite	6	ND	ND	ND	1.2	ND	ND	ND	ND	ND	0.6	ND	ND
Dark gray to black, shaley siltstone	4	ND	0.9	0.9	4.3	ND	4.5	ND	4.9	ND	18.3	ND	39.0
Light and dark gray dolomricite	8	ND	0.3	0.3	3.5	ND	1.4	ND	2.5	ND	3.8	ND	6.0

*ND = Not Detected/Below detection limits

** The following elements have been removed from the

table because sample PPG36-1-17 was the only sample registering any detection: BA, CO, HF, and EU.

		Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
			ND		SM		YB	М	02	(CU	F	РВ
		Р	PM	F	PM	P	PM	F	PM	F	PM	F	PM
	Number												
Lithology	of	5	0		1		12	2	00	1	00	1	00
Littiology	samples	5	1). I	0	1.2	2	.00	1	.00	4	.00
Clear coarsely crystalline halite	4	ND	10.0	ND	ND	ND	ND	ND	ND	ND	3.00	ND	ND
Gray, coarsely crystalline halite	4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	4.00
Dark gray, coarsely crystalline halite	8	ND	ND	ND	ND	ND	ND	ND	ND	ND	2.00	ND	6.00
Black coarsely crystalline halite	6	ND	11.0	ND	0.2	ND	ND	ND	ND	ND	4.00	ND	6.00
Dark gray to black, shaley siltstone	4	ND	17.0	ND	3.0	ND	1.1	ND	7.00	ND	11.00	ND	16.00
Light and dark gray dolomricite	8	ND	8.0	ND	0.5	ND	0.2	ND	3.00	2.00	21.00	ND	4.00

*ND = Not Detected/Below detection limits

** The following elements have been removed from the

table because sample PPG36-1-17 was the only sample registering any detection: BA, CO, HF, and EU.

		Low	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
		z	N2	Ν	112	N	1N	S	R2		V		Y	l	_1
		Р	PM	F	PM	Р	PM	Р	PM	Р	PM	P	PM	PI	PM
Lithology	Number of samples	1.	00	1	.00	1.	00	1.	00	2.	00	2.	.00	1.	00
Clear coarsely crystalline halite	4	ND	2.00	ND	ND	9.00	16.00	4.00	23.00	ND	ND	ND	ND	ND	ND
Gray, coarsely crystalline halite	4	ND	17.00	ND	1.00	9.00	19.00	27.00	356.00	ND	ND	ND	ND	ND	20.00
Dark gray, coarsely crystalline halite	8	ND	3.00	ND	1.00	7.00	26.00	6.00	799.00	ND	ND	ND	ND	ND	52.00
Black coarsely crystalline halite	6	ND	5.00	ND	3.00	8.00	33.00	26.00	280.00	ND	4.00	ND	2.00	1.00	44.00
Dark gray to black, shaley siltstone	4	2.00	14.00	ND	19.00	19.00	214.00	618.00	5830.00	ND	27.00	ND	10.00	60.00	147.00
Light and dark gray dolomricite	8	3.00	12.00	1.00	6.00	16.00	58.00	502.00	2400.00	ND	9.00	ND	2.00	21.00	159.00

*ND = Not Detected/Below detection limits

** The following elements have been removed from the

table because sample PPG36-1-17 was the only sample registering any detection: BA, CO, HF, and EU.

Major Element Detection Limits

Element	Units	Detection Limit
CA	%	0.01
FE	%	0.01
K	%	0.01
NA	%	0.01
Р	%	0.001
S	%	0.010
SN	%	0.01
AL	%	0.01
MG	%	0.01
TI	%	0.01

Trace Element Detection Limits

Element	Units	Detection Limit
AG	PPM	0.40
AS	PPM	0.5
AU	PPB	2.0
BA	PPM	50.0
BR	PPM	0.5
CE	PPM	3.0
CO	PPM	1.0
CR	PPM	5.0
CS	PPM	1.0
EU	PPM	0.2
HF	PPM	1.0
HG	PPM	1.0
IR	PPB	5.0
LA	PPM	0.5
LU	PPM	0.05
ND	PPM	5.0
NI	PPM	20.0
RB	PPM	15.0
SB	PPM	0.1
SC	PPM	0.1
SE	PPM	3.0
SM	PPM	0.1
TA	PPM	0.5
TB	PPM	0.5
TH	PPM	0.2
U	PPM	0.5
V	PPM	2.00
W	PPM	1.0
Y	PPM	2.00
YB	PPM	0.2
BE	PPM	2.00
BI	PPM	5.00
CD	PPM	0.5
CU	PPM	1.00
MN	PPM	1.00
PB	PPM	4.00
LI	PPM	1.00
MO	PPM	2.00
NI2	PPM	1.00
SR2	PPM	1.00
ZN2	PPM	1.00

Thin Section Analysis Report

Sample ID:	C-01	
Sample ID.	C-01 Rose Run	
Lithologic Classification:	Sandstone	
Donth /Donth Bongo:	1529.9 ft	
Depth/Depth Kange.	4528.8 IL	
Analysis:	6/1/2017	
Analyzed by:	L. Ditzier	
Т	exture	Comments
Grain Siz	ze medium-grained, 350-500μ	
Roundir	ng well rounded to subrounded	
Sortir	ng well sorted	
Composition	/Detrital Minerals	Comments
(Quartz	
Polycrystallir	ne <<1%	
Monocrystallir	ne 79%	grains sometimes with undulose
		extinction, some quartz overgrowths
Microcrystallir	ne	
F	eldspar	
Plagioclas	se	
Orthoclas	Se	1% total microcline & plag
Microclir	ne	
Ca	rbonate	
Calci	te 20%	interstitial cement
Dolomi	te	
Aragoni	te	
	Clay	
Illi	te	
Smecti	te	
Kaolini	te	
Muscovi	te	
Chlori	te	
Glauconi	te	
Rock	Fragments	
Sedimenta	ry	
Volcan	ic	
Metamorph	ic	
Other (Acc	essory Minerals)	
Cement	ing Materials	Comments
Quar	tz minor	
Feldsp	ar	
Carbona	te most abundant cement. interstitial to	
	guartz grains	
CI	av	
Iron Oxide Hydoxide and/or Sulfic	-, e	
	ar	
Sth	51	
Visual Po	rosity Estimate	Comments

10%

pores between quartz grains

25x magnification, 5mm field of view



Thin Section Analysis Report

Sample ID:	C-02	
Formation/Member Name:	Rose Run	
Lithologic Classification:	Sandstone	
Depth/Depth Range:	4204 ft	
Date of Analysis:	6/1/2017	
Analyzed by:	L. Ditzler	
	Texture	Comments
Grain	Size medium-grained, 350-500µ	
Round	ling rounded to subrounded	
Sort	ting well sorted	
Compo	osition/Detrital Minerals	Comments
	Quartz	
Polycrystal	line <1%	
Monocrystal	line 98%	grains sometimes with undulose
		extinction, quartz overgrowths
Microcrystal	line	
	Feldspar	
Plagiocl	ase	
Orthocl	ase	1% total microcline & plag
Microc	line	
	Carbonate	
Cal	cite	
Dolon	nite	
Aragoi	nite	
	Clay	
	llite	
Smec	tite	< 1% total clays
Kaolii	nite	
Musco	vite	
Chlo	rite	
Glaucor	nite	
	Rock Fragments	
Sediment	tary	
Volca	anic	
Metamorp	phic	
	or (Accorrory Minorale)	
Ce	ementing Materials	Comments
Qua	artz overgowths on grains	well cemented
Felds	par	
Carbon	ate absent	
(Clay	
Iron Oxide, Hydoxide and/or Sulf	fide	
Ot	her	
	ual Parasity Estimato	Commonto
Vis	15%	nores hetween quartz grains
	10/0	pores between quartz Brains

25x magnification, 5mm field of view

Thin Section Analysis Report

Sample ID:	C-03	
Formation/Member Name:	Rose Run	
Lithologic Classification:	Breccia	
Depth/Depth Range:	6511 ft	
Date of Analysis:	6/1/2017	
Analyzed by:	L. Ditzler/S. Shank	
	Texture	Comments
	Grain Size fragments of silicified oolites in	scattered quartz grains in carbonate - fine to medium
	carbonate	grained, well rounded to subrounded
	Rounding	
	Sorting	
Compo	osition/Detrital Minerals	Comments
	Quartz	
Po	lycrystalline	
Mon	ocrystalline 1%	scattered grains in carbonate
Micr	ocrystalline	
	Feldspar	
	Plagioclase	
	Orthoclase	
	Microcline	
	Carbonate	
	Calcite	
	Dolomite 70%	fine-grained (<125 μ), recrystallized (dolomite?) with
		relic very fine-grained rounded oolites
	Aragonite	
	Clay	
	Illite	
	Smectite	
	Kaolinite	
	Muscovite	
	Chlorite <<1%	trace green in silicified oolites
	Glauconite	
	Rock Fragments	
S	edimentary 29%	silicified oolites in microcrytalline quartz matrix
	Volcanic	
Μ	etamorphic	
Oth	er (Accessory Minerals)	
C	ementing Materials	Comments
	Quartz	
	Feldspar	
	Carbonate	
	Clay	
Iron Oxide, Hydoxide an	d/or Sulfide	
	Other	
Vis	sual Porosity Estimate	Comments
	1%	thin partially open fracture and voids along silicified
		oolite/carbonate contact, no blue epoxy



25x magnification, 5mm field of view
Sample ID:	C-06	
Formation/Member Name:	Rose Run	
Lithologic Classification:	Breccia	
Depth/Depth Range:	4191 ft	
Date of Analysis:	6/27/2017	
Analyzed by:	S. Shank	
	Texture	Comments
G	rain Size	silicified oolites in microcrystalline quartz matrix,
		numerous veins of carbonate, quartz and pyrite
R	ounding	
	Sorting	
Compositio	n/Detrital Minerals	Comments
POIVE	ystalline	
Monoci	ystalline	
WIELOCI	ystaillie	
	Feldspar	
Pla	gioclase	
Or	thoclase	
Mi	icrocline	
С	arbonate	
	Calcite	
D	olomite	
A	ragonite	
	<u>Clay</u>	
	Illite	
	omectite	
1	kaolinite	
M	uscovite Chlasita	
	Chlorite	
Gla	auconite	
Roc	k Fragments	
Sedir	mentary	
	Volcanic	
Meta	morphic	
Other (Ac	cessory Minerals)	
Comor	ting Matariala	Commonto
Cemen		Comments
	Foldenar	
	rbanata	
Ca		
Iron Ovido Undovido and/a	Cidy r Sulfido 19	purite in fractures
Iron Oxide, Hydoxide and/o	Other	pyrite in fractures
	other	
Visual P	orosity Estimate	Comments
	<1%	most voids appear to be due to plucking

Sample D. Correction Correction Correction Control of Carbonate Control	rbonate
Identification: Sandy Carbonate Depth/Depth Range: 6500.2 ft Date of Analysis: 6/27/2017 Analyzed by: S. Shank	rbonate
Laboration of the second	rbonate
bete of Analysis: 6/27/2017 Analyzed by: S. Shank Texture Comments Grain Size fine to medium scattered quartz grains in recrystallized ca matrix, quartz grains locally abundant Rounding well-rounded to subangular Sorting well sorted Composition/Detrital Minerals Comments Quartz Polycrystalline <1% Monocrystalline 10% Microcrystalline 10% Microcrystalline 20% Carbonate Calcite Dolomite 90% Aragonite Clay Ilite Smeetite Kaolinite Muscovite Chlorite Glauconite	rbonate
Analyzed by: S. Shank Texture Comments Grain Size fine to medium scattered quartz grains in recrystallized ca matrix, quartz grains locally abundant Rounding well-rounded to subangular Sorting well sorted Composition/Detrital Minerals Comments Quartz Polycrystalline <136 Monocrystalline 10% Microcrystalline 10% Microcrystalline Feldspar Plagioclase Orthoclase Microcline Carbonate Calcite Dolomite 90% Aragonite Clay Illite Smectite Kaolinite Muscovite Chiorite Glauconite	rbonate
Texture Comments Grain Size fine to medium scattered quartz grains in recrystallized camatrix, quartz grains locally abundant Rounding well-rounded to subangular Sorting well sorted Composition/Detrital Minerals Comments Quartz Polycrystalline <1% Monocrystalline Noncrystalline 10% Microcrystalline Feldspar Plagioclase Orthoclase Microcline Calcite Dolomite 90% <125µ, equant recrystallized carbonate, d Aragonite Smeetite Kaolinite Muscovite Chlorite Glauconite	rbonate
Texture Comments Grain Size fine to medium scattered quartz grains in recrystallized camatrix, quartz grains locally abundant Rounding well-rounded to subangular Sorting well sorted Composition/Detrital Minerals Comments Quartz Polycrystalline <<1% Monocrystalline 10% Microcrystalline Pilagioclase Orthoclase Microcline Microcline Calcitle Dolomite 90% Calcitle Somette Mille Smeettle Kaolinite Muscovite Chlorite Glauconite	rbonate
Grain Size Time to medium cattered quartz grains in recrystallized ca matrix, quartz grains locally abundant Sorting well sorted Composition/Detrital Minerals Comments Quartz Polycrystalline <1% Monocrystalline 10% Microcrystalline Plagioclase Orthoclase Microcline Carbonate Calcite Dolomite 90% Aragonite Clay Illite Smectite Kaolinite Muscovite Chlorite Glauconite	
Rounding well-rounded to subangular Sorting well sorted Composition/Detrital Minerals Comments Quartz Polycrystalline <1% Monocrystalline 10% Microcrystalline Polycrystalline 10% Microcrystalline Feldspar Plagioclase Orthoclase Microcline Carbonate Calcite Dolomite 90% <125µ, equant recrystallized carbonate, d Aragonite Lilite Smectite Kaolinite Muscovite Chlorite Glauconite Ilite Smectite Kaolinite Muscovite Chlorite Rock Fragments Contentery	
Sorting well sorted Composition/Detrital Minerals Quartz Polycrystalline <<1% Monocrystalline 10% Microcrystalline Feldspar Plagioclase Orthoclase Microcline Calcite Dolomite 90% <125µ, equant recrystallized carbonate, d Aragonite Clay Illite Smectite Kaolinite Muscovite Chlorite Glauconite	
Composition/Detrital Minerals Comments Quartz Polycrystalline <<1% Monocrystalline 10% Microcrystalline Feldspar Plagioclase Orthoclase Microcline Carbonate Calcite Dolomite 90% <125µ, equant recrystallized carbonate, d Aragonite Illite Smectite Kaolinite Muscovite Chlorite Glauconite Stationate	
Quartz Polycrystalline <<1% Monocrystalline 10% Microcrystalline Feldspar Plagioclase Orthoclase Microcline Carbonate Calcite Dolomite 90% <125µ, equant recrystallized carbonate, d Aragonite Clay Illite Smectite Kaolinite Muscovite Chlorite Glauconite Rock Fragments Sections Sect	
Polycrystalline <1% Monocrystalline 10% Microcrystalline Plagioclase Orthoclase Microcline Calcite Dolomite 90% <125µ, equant recrystallized carbonate, d Aragonite Clay Illite Smectite Kaolinite Muscovite Chlorite Glauconite	
Monocrystalline 10% Microcrystalline	
Microcrystalline Feldspar Plagioclase Orthoclase Microcline Carbonate Calcite Dolomite 90% <125μ, equant recrystallized carbonate, d Aragonite Clay Illite Smectite Kaolinite Muscovite Chlorite Glauconite Rock Fragments Codimentant	
Feldspar Plagioclase Orthoclase Microcline Calcite Dolomite 90% Aragonite Clay Illite Smectite Kaolinite Muscovite Chlorite Glauconite	
Plagioclase Orthoclase Microcline Calcite Dolomite 90% <125µ, equant recrystallized carbonate, d Aragonite Clay Illite Smectite Kaolinite Muscovite Chlorite Glauconite	
Orthoclase Microcline Carbonate Calcite Dolomite 90% <125µ, equant recrystallized carbonate, d Aragonite Clay Illite Smectite Kaolinite Muscovite Chlorite Glauconite	
Microcline Carbonate Calcite Dolomite 90% <125µ, equant recrystallized carbonate, d Aragonite Clay Illite Smectite Kaolinite Muscovite Chlorite Glauconite Rock Fragments Sedimenteri	
Carbonate Calcite Dolomite 90% <125μ, equant recrystallized carbonate, d Aragonite Clay Illite Smectite Kaolinite Muscovite Chlorite Glauconite	
Calcite Dolomite 90% <125µ, equant recrystallized carbonate, d Aragonite Clay Illite Smectite Kaolinite Muscovite Chlorite Glauconite Rock Fragments	
Dolomite 90% <125μ, equant recrystallized carbonate, d Aragonite	
Aragonite Clay Illite Smectite Kaolinite Muscovite Chlorite Glauconite Rock Fragments	olomite?
Clay Illite Smectite Kaolinite Muscovite Chlorite Glauconite Rock Fragments	
Illite Smectite Kaolinite Muscovite Chlorite Glauconite Rock Fragments	
Smetite Kaolinite Muscovite Chlorite Glauconite Rock Fragments	
Rock Fragments	
Chlorite Glauconite Rock Fragments Sedimontary	
Glauconite Rock Fragments Sadimentary	
Rock Fragments	
Volcanic	
Metamorphic	
Other (Accessory Minerals)	
Cementing Materials Comments	
Quartz	
Feldspar	
Clau	
Uay Iron Ovida, Hudovida and /ar Sulfida	
Visual Porosity Estimate Comments	
<1% voids appear to be due to plucking, no blue	

<u>T-07 apr</u>

Samala ID:	C 08	
Sample ID:	C-08 Roce Burn	
Lithologic Classification:	Carbonate	
Donth /Donth Bongo:	6519 ft	
Depth/Depth Kange.	6/28/2017	
Date of Analysis:	6/28/2017	
Analyzeu by.	S. SHAIK	
	Texture	Comments
Gra	in Size	recrystallized carbonate with trace very fine-
		grained quartz
Rou	unding	
S	Sorting	
Compos	ition/Detrital Minerals	Comments
	Quartz	
Polycrys	talline	
Monocrys	talline <1%	trace very fine-grained quartz
Microcrys	talline	
	Feldspar	
Plagi	oclase	
Orth	oclase	
Micr	rocline	
	Carbonate	
(Calcite	
Do	lomite 100%	equant, recrystallized carbonate, <125μ, few larger rhombs, dolomite?
Ara	gonite	
	Clay	
	Illite	
Sm	nectite	
Ка	olinite	
Mus	scovite	
C	hlorite	
Glau	conite	
	Rock Fragments	
Sedim	entary	
Vo	blcanic	
Metam	orphic	
Other	(Accessory Minerals)	
Cer	menting Materials	Comments
(Quartz	
Fe	laspar	
Cark	oonate	
	Clay	
Iron Oxide, Hydoxide and/or S	Sulfide	
	Other	
Visu	al Porosity Estimate	Comments
	<<1%	voids appear to be due to plucking, no blue
		ероху

Sample ID:	C-11	
Formation/Member Name:	Rose Run	
Lithologic Classification:	Sandy Carbonate	
Denth/Denth Range:	A219 ft	
Date of Analysis:	6/28/2017	
Analyzed by:	S. Shank	
	Texture	Comments
		coarsely recrystallized carbonate with trace quartz
Grai	in Size	grains, really poor thin section - thin, wedged
Rou	Inding	
S	orting	
Compositi	on/Detrital Minerals	Comments
·	Quartz	
Polycrys	talline	
Monocrys	talline 1%	scattered, very fine-grained, few larger grains
Microcrys	talline	
	Feldspar	
Plagi	oclase	
Orth	oclase	
Micr	ocline	
	Carbonate	
0	Calcite	
Dol	lomite	<500μ, coarse, irregular to rhombic grains, very clouded, dolomite?
Ara	gonite	
	Clay	
	Illite	
Sm	lectite	
Ka	olinite	
Mus	covite	
Cł	nlorite	
Glau	conite	
Ro	ock Fragments	
Sedime	entary	
Vo	blcanic	
Metam	orphic	
Other (/	Accessory Minerals)	
Ceme	enting Materials	Comments
(Quartz	
Fe	ldspar	
Carb	onate	
	Clay	
Iron Oxide, Hydoxide and/or S	Sulfide	
	Other	
Visual	Porosity Estimate	Comments
	5%	angular vugs with carbonate rhombs growing into
		void

Samula ID:	C 12	
	0-13	
Formation/Member Name:	Rose Run	
Lithologic Classification:	Quartz Sandstone	
Depth/Depth Range:	6484 tt	
Date of Analysis:	6/28/2017	
Analyzed by:	S. Shank	
	Texture	Comments
Gr	ain Size very fine to medium	
-		some lamination based on grain size section riddled with grit
Be	unding well to poorly rounded	
	Sorting moderately well corted	
	Softing moderately well softed	
Composit	ion/Detrital Minerals	Comments
	Quartz	
Polycry	vstalline	
Monocry	vstalline 97%	some undulatory extinction
Microcry	vstalline	
	Feldspar	
Plag	gioclase	
Ort	hoclase	
Mi	crocline 2%	minor plagioclase
	Carbonate	
	Calcite	
D	olomite	
Ar	agonite	
	-	
	Clay	
	Illite	
S	mectite	
к	aolinite	
Mu	iscovite	
(Chlorite	thin, irregular laminae of very fine-grained brownish green
		unidentified clay
Gla	uconite	
R	ock Fragments	
Sedin	nentary	
N	/olcanic	
Metar	norphic	
Other (/	Accessory Minerals)	
Cem	enting Materials	Comments
Cent	Quartz overgrowths on quartz	well cemented
E	eldsnar	
1 (a)	eluspai	
Car	Clau	
	Clay	
Iron Oxide, Hydoxide and/or	Sulfide	
	Other	
Visual	Porosity Estimate	Comments
	3%	very irregular distribution - restricted to margins of slide, some
		may be plucked grains, tractures from coring?



Comula ID:	C 14	
Formation/Member Name	C-14 Bose Run	
Lithologic Classification:	Calcareous Sandstone	
Depth/Depth Range:	4246 ft	
Date of Analysis:	6/2/2017	
Analyzed by:	L. Ditzler	
	Texture	Comments
	Grain Size fine to very-fine grained, $88-125\mu$	well laminated based on grain size and mineralogy of coarser quartz layers, finer quartz layers with clay, clay laminae, and carbonate-rich layers
	Rounding poorly rounded	
	Sorting moderately well sorted	
Co	mposition/Detrital Minerals	Comments
	Quartz	connients
F	Polycrystalline	
Mo	onocrystalline 65%	
Mi	icrocrystalline	
	Foldenar	
	Plagioclase	
	Orthoclase	
	Microcline 2%	with minor plagioclase
	Carbonate	
	Delemite	
	Aragonite	
	<u> </u>	
	<u>Clay</u>	
	lilite Smostite	
	Smectite	
	Naomine	
	Chlorite	dull green very fine grained interstitial patches with quartz
	Glauconite	
	Rock Fragments	
	Sedimentary	
	Volcanic	
	Metamorphic	
	Other (Accessory Minerals)	
	very trace opaques	
	Cementing Materials	Comments
	Quartz	overgrowths on quartz
	Feldspar	
	Carbonate	
	Clay	some interstial material in quartz-rich layers
Iron Oxide. Hvdoxide a	and/or Sulfide	······································
	Other	
	Visual Porosity Estimate	Comments
	5%	right variable, in coarser quartz rich layers - open space in clay
		arained quartz and carbonate layers
		gramed quartz and carbonate layers

C-14



Sample ID:	C-15	
Formation/Member Name:	Rose Run	
Lithologic Classification:	Sandstone	
Depth/Depth Range:	4243.6 ft	
Date of Analysis:	6/2/2017	
Analyzed by:	L. Ditzler/S. Shank	
	·	
	Texture	Comments
	Grain Size very fine-grained	well layered, defined by brown clay rich laminae
	Rounding well rounded to subrounded	
	Sorting well sorted	
Co	mposition/Detrital Minerals	Comments
	Quartz	
P	olycrystalline	
Mc	onocrystalline 78%	
Mi	crocrystalline	
	Feldspar	
	Plagioclase 2.5	
	Orthoclase	fairly feldspar rich
	Microcline 2.5	
	Comb an anti-	
	Calche	
	Aragonito	
	Alagointe	
	Clay	
	Smectite	
	Kaolinite	
	Muscovite	
	Chlorite 17%	alternating layers of greenish interstitial clay and
		brownish red interstitial (some hematite?) - Liesegang
		bands?
	Glauconite	
	Rock Fragments	
	Sedimentary	
	Voicanic	
	vietanioi pilic	
	Other (Accessory Minerals)	
	Cementing Materials	Comments
	Quartz	quartz overgrowths, well cemented
	Feldspar	
	Carbonate	and a state to the state of the
	Clay 17%	greenish insterstitial patches and mm wide bands of
		prownish day and nematite? Liesegang bands?
Iron Ovida Hudavida a	nd /or Sulfido	
iron Oxide, Hydoxide a	Other	
	Uller	
	Visual Porosity Estimate	Comments
	10%	restricted to quartz rich lavers - renlacing green clay
	2070	but with patchy distribution, minimal porosity in red
		brown bands



Consulta ID	6.46	
Sample ID:	C-16	
Formation/Member Name:	Carbonato	
Denth /Denth Pango		
Date of Analysis:	4247 IL 6/28/2017	
Analyzed by:	S Shank	
Analyzeu by.	5. SHAIK	
Тех	ture	Comments
Grain Size	2	
Rounding	g	
Sorting	5	
Composition/D	etrital Minerals	Comments
Qu	artz	
Polycrystalline	2	
Monocrystalline	2	
Microcrystalline	2	
Felc	lspar	
Plagioclase	2	
Orthoclase	2	
Microcline	2	
Carb	onate	
Calcite	2	
Dolomite	2	62-250μ, recrystallized, equigranular to rhombic grains, very cloudy, dolomite?
Aragonite	2	
C	lay	
Illite	2	
Smectite	2	
Kaolinite	2	
Muscovite	2	
Chlorite	2	
Glauconite	2	
Rock Fr	agments	
Sedimentary	/	
Volcanio		
Metamorphic		
Other (Access	sory Minerals)	
Cementin	g Materials	Comments
Quartz	<u> </u>	
Feidspar	ſ	
Carbonate		
Clay	/	
Iron Uxide, Hydoxide and/or Sulfide	2	
Other	ſ	
Visual Poros	sity Estimate	Comments
	<<1%	very scattered, small angular voids, no blue

C16.jrg

Sample ID:	DN-29	
Formation/Member Name:	Gateshurg/Rose Run	
Lithologic Classification:	Carbonate	
Denth/Denth Bange:	N/A	
Date of Analysis:	6/12/2017	
Analyzed by:	S Shank	
Analyzed Sy.	5. Shank	
Тех	ture	Comments
Grain Siz	e	
Roundin	g	
Sortin	g	
Composition/D	etrital Minerals	Comments
Qu	artz	
Polycrystallin	e	
Monocrystallin	e	
Microcrystallin	e	
Feld	spar	
Plagioclas		
Orthoclas	e	
Microclin	e	
Carb	onate	
Calcit	e	
Dolomit	e 100%	125-2500 equigranular recrystallized very cloudy
Dolomit		common but discontinuous vugs with coarser
		carbonate rhombs and voids
Aragonit	e	
, "450"	c	
CI	ay	
Illit	e	
Smectit	e	
Kaolinit	e	
Muscovit	e	
Chlorit	e	
Glauconit	e	
Rock Fra	agments	
Sedimentar	у У	
Volcani	ic	
Metamorphi	ic	
Other (Access	sory Minerals)	
Cementing	g Materials	Comments
Quart	72	
Feldspa	ar	
Carbonat	e	
Cla	У	
Iron Oxide, Hydoxide and/or Sulfid	e	
Othe	er	
Visual Poros	sity Estimate	Comments
	1%	
		almost all in or near vugs, virtually no porosity in matrix



Page 2 of 19

Sample ID:	DN-32	
Formation/Member Name:	Gatesburg/Rose Run	
Lithologic Classification:	Carbonate	
Depth/Depth Range:	N/A	
Date of Analysis:	6/12/2017	
Analyzed by:	S. Shank	
	Texture	Comments
Gra	ain Size	
Rc	ounding	
	Sorting	
Composi	ition/Detrital Minerals	Comments
	Quartz	
Polycry	stalline	
Monocry	stalline	
Microcry	stalline	
	Feldspar	
Plag	jioclase	
Ortl	hoclase	
Mic	crocline	
	Carbonate	
	Calcite	
De	olomite 100%	very fine-grained, <125µ, equigranular, recrystallized matrix, dolomite, very cloudy, large common vugs with coarse carbonate rhombs, rounded, extremely fine-grained patches - relic peloids?. dolomite?
Ara	agonite	
	Clay	
	Illite	
Si	nectite	
K	aolinite	
Mu	scovite	
(Chlorite	
Gla	uconite	
I	Rock Fragments	
Sedin	nentary	
V	olcanic	
Metan	norphic	
Other	(Accessory Minerals)	
Cen	nenting Materials	Comments
	Quartz	
F	eldspar	
Car	bonate	
	Clay	
Iron Oxide, Hydoxide and/or	Sulfide	
	Other	
Visu	al Porosity Estimate	Comments
	2%	porosity in vugs and thin fractures, almost no porosity in
		matrix

Dr-32.jps

Samala ID:		
Sample ID.	Catosburg/Rose Rup	
Lithologic Classification	Carbonato	
Denth /Denth Bango:		
Depth / Depth Range.	6/12/2017	
Analyzed by:	0/15/2017 S. Shank	
Analyzeu by:	5. Slidlik	
	Texture	Comments
Gra	in Size	
Rou	unding	
S	Sorting	
Compositi	on/Detrital Minerals	Comments
	Quartz	
Polycrys	talline	
Monocrys	talline	
Microcrys	talline	
	Feldspar	
Plagi	oclase	
Orth	oclase	
Micr	rocline	
	Carbonate	
(Calcite	
Do	lomite 100%	very fine-grained, <125, equigranular, recrystallized, clouded, dolomite? No vugs but a few small patches of slighty coarser carbonate
Ara	gonite	
	Clay	
	Illite	
Sm	nectite	
Ка	olinite	
Mus	scovite	
Cl	hlorite	
Glau	conite	
Ro	ock Fragments	
Sedim	entary	
Vo	olcanic	
Metam	orphic	
Other (A	Accessory Minerals)	
Ceme	enting Materials	Comments
	Quartz	
Fe	ldspar	
Carb	oonate	
	Clay	
Iron Oxide, Hydoxide and/or	Sulfide	
	Other	
\/?1	Dorocity Ectimato	
visual		Comments
	۷/ ۲۵	common, smail intergrational, pateny distribution



Sample ID:	DN-37	
Formation/Member Name	Gatesburg/Rose Run	
Lithologic Classification:	Carbonate	
Donth /Donth Bango:	N/A	
Date of Analysis:	6/12/2027	
Analyzed by:	0/15/2027	
Analyzeu by.	5. Slidlik	
	Texture	Comments
Grai	n Size	
Rou	nding	
S	orting	
Compositi	on/Detrital Minerals	Comments
	Quartz	
Polycryst	alline	
Monocryst	alline	
Microcryst	alline	
	Feldspar	
Plagie	oclase	
Ortho	oclase	
Micr	ocline	
	Carbonate	
C	Calcite	
Dol	omite 100%	generally fine-grained with veins and
		patches of coarser carbonate,
		equigranular, recrystallized, clouded,
		dolomite?
Ara	gonite	
	Clay	
	Illite	
Sm	ectite	
Кас	olinite	
Mus	covite	
Ch	lorite	
Glaud	conite	
Rc	ck Fragments	
Sedime	entary	
Vo	lcanic	
Metamo	orphic	
Other (A	Accessory Minerals)	
Ceme		Comments
C al	dener	
Fel C	uspai	
Carb		
Iron Ovide Hudevide en 1/ - C	Clay	
iron Uxide, Hydoxide and/or S		
	Uther	
Visual	Porosity Estimate	Comments
	5%	common voids in vugs and common
		intergranular porosity



Sample ID:	DN-38	
Formation/Member Name:	Gatesburg/Rose Run	
Lithologic Classification:	Carbonate	
Depth/Depth Range:	N/A	
Date of Analysis:	6/13/2017	
Analyzed by:	S. Shank	
Grain	exture	Comments
Boun	ding	
So	rting	
Composition	/Detrital Minerals	Comments
	Quartz	
Polycrysta	illine	
Monocrysta	lline	
Microcrysta	lline	
F	eldspar	
Plagio	clase	
Ortho	clase	
Micro	cline	
Ca	arbonate	
Ca	lcite	
Dolo	mite 100%	generally very fine-grained, <125μ, clouded, dolomite?,
		scattered, discontinuous vugs and veins of coarser
		carbonate rhombs and voids.
Arago	onite	
	Clay	
	Illite	
Sme	ctite	
Kaol	inite	
Musco	ovite	
Chl	orite	
Glauce	onite	
Rock	Fragments	
Sedimer	ntary	
Vol	canic	
Metamor	phic	
Other (Acc	essory Minerals)	
Cemeni	ing Materials	Comments
Q	Jartz	connicitis
Feld	spar	
Carbo	nate	
	Clay	
Iron Oxide, Hydoxide and/or Su	lfide	
C	ther	
Viewal De	prosity Estimate	Comments
visual re	2%	virtually no intergranular porosity, almost all in vugs and
	<u>_/-</u>	veins

Sample ID:	DN 40	
Formation/Member Name:	Gatesburg/Rose Run	
Lithologic Classification:	Dolostone	
Denth/Denth Bange:	N/A	
Date of Analysis	6/13/2017	
Analyzed by:	S. Shank	
	Texture	Comments
Grain S	size	
Round	ing	
Sort	ing	
Compo	sition/Detrital Minerals	Comments
·	Quartz	
Polycrystall	ine	
Monocrystall	ine	
Microcrystall	ine	
	Feldspar	
Plagioch	ase	
Orthool	ase	
Microcl	ine	
	Carbonate	
Calo	cite	
		fine to medium grained, <350μ,
		equigranular to irregular,
		recrystallized, cloudy dolomite.
Dolom	nite	100% Dolomite confirmed by SEM.
Aragor	nite	
	Clay	
	lite	
Smec	tite	
Kaolir	nite	
Muscov	vite	
Chlor	rite	
Glaucor	iite	
	Rock Fragments	
Sediment	ary	
Volca	inic	
Metamorp	hic	
Othe	er (Accessory Minerals)	
Ce	ementing Materials	Comments
Qua 		
Felds	par	
Carbon	ate	
	lay .	
Iron Uxide, Hydoxide and/or Sulf	lae	
Ot	ner	
Vis	ual Porosity Estimate	Comments
		scattered vugs, extremely limited
		2% intergranular porosity

Sample ID:	DN-41	
Formation/Member Name:	Gatesburg/Rose Run	
Lithologic Classification:	Carbonate	
Depth/Depth Range:	N/A	
Date of Analysis:	6/13/2017	
Analyzed by:	S. Shank	
	Texture	Comments
Grai	in Size	
Rou	Inding	
S	orting	
Composi	tion/Detrital Minerals	Comments
	Quartz	
Polycrys	talline	
Monocrys	talline	
Microcrys	talline	
	Feldspar	
Plagi	oclase	
Orth	oclase	
Micr	ocline	
	Carbonate	
(Calcite	
Dol	lomite 100%	
		very fine to fine-grained matrix, cloudy, <125µ, with large vugs filled with coarse carbonate. Few thin veins.
Ara	gonite	
	Clay	
	Illite	
Sm	nectite	
Ka	olinite	
Mus	covite	
Cł	nlorite	
Glau	conite	
R	lock Fragments	
Sedime	entary	
Vo	olcanic	
Metamo	orphic	
Other	(Accessory Minerals)	
Cem	enting Materials	Comments
(Quartz	
Fe	ldspar	
Carb	onate	
	Clay	
Iron Oxide, Hydoxide and/or S	Sulfide	
	Other	
Visua	l Porosity Estimate	Comments
	1%	scattered voids in vugs and veins, minimal porosity in matrix

Dr41,gg

Sample ID: DN-42 Formation/Member Name: GateSburg/Rose Run Lithologic Classification: Carbonate Depti/Ogeth Range: N/A Date of Analysis: 6/15/2017 Analyzed by: S. Shank Texture Comments Grain Size Rounding Sorting Composition/Detrital Minerals Composition/Detrital Minerals Composition/Detrital Minerals Composition/Detrital Minerals Comments Rounding Sorting Composition/Detrital Minerals Comments Polycrystalline Microcrystalline Microcrystalline Calcite Dolomite 100% abundant allochems, clasts, relic oolds, peloids? In recrystallide cloudy very fine-grained, <125µ, matrix. Dolomite 100% Calcite Dolomite 100% Sedimentary Vicanic Miscovite Clay. Illite Smeetite Somettie Sedimentary Vicanic Metamorphic Cementing Materials Comments Commen			
Formation/Member Name: Gatesburg/Mose Ruin Libhologic Cashinate Depti/Depti Range: N/A Depti/Depti Range: Si Shank Testure Comments Grain Size Rounding Sorring Composition/Detrital Minerals Comments Quart Polycrystalline Microcrystalline Microcrystalline Microcrystalline Carbonate	Sample ID:	DN-42	
Linnoige Classification: Carbonate Depti/Oeph Mange: N/A Analyzed by: Shank Texture Comments Grain Size Rounding Sorting Composition/Detrital Minerals Comments Rounding Sorting Composition/Detrital Minerals Comments Rounding Sorting Polycrystalline Minocrystalline Minocrystalline Carbonate	Formation/Member Name:	Gatesburg/Rose Run	
Deprotycept Mange: N/A Dete of Analysis: 6/15/2017 Analyzed by: S Shank Texture Comments Grain Size Rounding Sorting Composition/Detrital Minerals Comments Composition/Detrital Minerals Composition/Detrital Minerals Composition/Detrital Minerals Composition/Detrital Minerals Composition/Detrital Minerals Composition/Detrital Minerals Comments Dologram Polycrystalline Microcrystalline Microcrystalline Testigger. Pregordsee Orthoclase Microcline Microcrystalline Calcine Dolomite 100% recrystallized cloudy very fine-grained, <125µ, matrix. Dolomite? Aragonite Calcine Simerite Simerite Kaolinite Muscovite Chorite Glauconite Cementing Materials Quartz Feldspar Carbonate Calcy Tron Oxide, Hydoxide and/or Suffice Other (Comments) Visual Porsity Estimate Comments Comment	Lithologic Classification:	Carbonate	
Date of Analysis: e/15/2017 Analyzed by: S. Shank Texture Comments Grain Size Rounding Sorting Composition/Detrital Minerals Comments Quart Delogray stilline Microcrystalline Microcrystalline Microcrystalline Microcrystalline Carbonate Carbonate Carbonate Carbonate Calcite Dolomite 100% abundant allochems, clasts, relic oolds, peloids? in recrystallized doudy very fine-grained, <125 µ, matrix. Dolomite? Aragonite Cay Illite Somette Kaolinite Muscovite Chorine Glauconite Cementing Materials Quartz Feldspar Carbonate Comments	Depth/Depth Range:	N/A	
Analyzed by: S. Shank Texture Comments Grain Size Rounding Sorting Comments Composition/Detrital Minerals Comments Quart Polycrystalline Moncorystalline Microcrystalline Pilagiochase Prilagiochase Orthockse Microcrystalline Calcite Dolomite 100% Calcite Dolomite 100% Calcite Dolomite 200% Calcite Sedimental Calcite Dolomite 200% Calcite Sedimental Calcite Sedimental Calcite Sedimental Dolomite 200% recrystallized cloudy very fine-grained, <125µ, matrix. Dolomite? Aragonite Curve Illite Sedimentary Volomite? Volcanic Metamorphic Cementing Materials Comments Quartz Feldspar Feldspar Calcite Calcite Comments Quartz Feldspar Calcite Comments <td< th=""><th>Date of Analysis:</th><th>6/15/2017</th><th></th></td<>	Date of Analysis:	6/15/2017	
Texture Comments Grain Size Reunding Sorting Composition/Detrital Minerals Comments Quartz Polycrystalline Monocrystalline Monocrystalline Microdrystalline Microdrystalline Polycrystalline Microdrystalline Microdrystalline Orthocase Orthocase Microdrystalline Orthocase Microdrystalline Scarbonate Calicite Dolomite 100% abundant allochems, clasts, relic ooids, peloids? In recrystallized cloudy very fine-grained, <125µ, matrix. Dolomite? Aragonite Clay Illite Structure Scareitte Kaolinite? Kaolinite Miscootite Glauconite? Other Sedimentary Volcanic Metamorphic Other (Accessory Minerals) Comments Capartz FeldSpar Comments Graintice Clay Illite Stadimentary Volcanic Metamorphic Other (Accessory Minerals) Comments Capartz FeldSpar Capartz FeldSpar <	Analyzed by:	S. Shank	
Grain Size Rounding Sorting Composition/Detrital Minerals Quartz Polycrystalline Monocrystalline Microcrystalline Microcrystalline Pilgiochase Orthoctase Microcrite Carbonate Carbonate Calcite Dolomite 100% recrystallized cloudy very fine-grained, <125µ, matrix. Dolomite? Aragonite Muscourie City illite Smeetite Kaolinite Glauconite Glauconite Chiorite Glauconite Cotex Metamorphic Cerementing Materials Comments Calay Iron Daide, Hydoxide and/Or Suffed Other Clay Iron Daide, Hydoxide and/Or Suffed Other		Texture	Comments
Bounding Sorting Composition/Detrial Minerals Comments Polycrystalline Monocrystalline Monocrystalline Microcrystalline Microcrystalline Orthockse Orthockse Microcrystalline Calebre Dolomite 100% abundant allochems, dasts, relic ooids, peloids? in recrystallized cloudy very fine-grained, <125µ, matrix.	Gra	ain Size	
Sorting Composition/Detrital Minerals Comments Quart Polycrystalline Monocrystalline Microcrystalline Microcrystalline Plagioclase Orthoclase Orthoclase Carbonate Calcite Dolomite 100% abundant allochems, clasts, relic ooids, peloids? In recrystallized cloudy very fine-grained, <125µ, matrix. Dolomite? Aragonite Clay Illite Smectite Kaolinite Muscovite Chiorite Glauconite Sedimentary Volcanic Metamorphic Cementing Materials Comments Cuartz Feldspar Carbonate Carbonate Carbonate Comments Cuartz Feldspar Carbonate Comments Cuartz Feldspar Carbonate Clay Iron Oxide, Hydoxide and/or Sulfide Other Visual Porosity Estimate Comments Comments Comments Carbonate Carb	Rc	ounding	
Composition/Detrital Minerals Comments Quartz Polycrystalline Monocrystalline Monocrystalline Monocrystalline Microcrystalline Microcrystalline Microcrystalline Prilipicase Orthoclase Orthoclase Microcrine Carbonate Carbonate Calcite Dolomite 100% abundant allochems, clasts, relic ooids, peloids? In recrystallized cloudy very fine-grained, <125µ, matrix.		Sorting	
Polycrystalline Monocrystalline Microcrystalline Microcrystalline Plagioclase Orthoclase Microcline Całconate Calcite Dolomite 100% abundant allochems, clasts, relic ooids, peloids? In recrystallized cloudy very fine-grained, <125 µ, matrix. Dolomite? Aragonite Clay Illite Smectite Kaolinite Muscovite Chorite Glauconite Rock Fragments Sedimentary Volcanic Metamorphic Other (Accessory Minerals) Cementing Materials Quartz Feldspar Carbonate Carbonate Ciay Iron Oxide, Hydoxide and/or Sulfide Other	Composit	ion/Detrital Minerals	Comments
Polycrystalline Monocrystalline Microcrystalline Piagloclase Orthoclase Microcline Carbonate Calcite Dolomite 100% abundant allochems, clasts, relic ooids, peloids? in recrystallized cloudy very fine-grained, <125µ, matrix. Dolomite? Aragonite Muscovite Clay Illite Smeetite Kaolinite Muscovite Chorite Glauconite Muscovite Chorite Glauconite Cementing Materials Comments Carbonate	•	Quartz	
Monocrystalline Microcrystalline Plagioclase Orthoclase Microcline Calcite Dolomite 100% abundant allochems, clasts, relic ooids, peloids? in recrystallized cloudy very fine-grained, <125µ, matrix. Dolomite? Aragonite Clay Illite Smectite Kaolinite Muscovite Chlorite Glauconite Bock Fragments Sedimentary Volcanic Metamorphic Cther (Accessory Minerals) Cementing Materials Quartz Feldspar Carbonate Clay Iron Oxide, Hydoxide and/or Suffice Other	Polycry	stalline	
Microcrystalline Feldspar Plagicalase Orthoclase Microcline Carbonate Calcite Dolomite 100% abundant allochems, clasts, relic coids, peloids? in recrystallized cloudy very fine-grained, <125 µ, matrix. Dolomite? Aragonite Clay Illite Smectite Kaolinite Muscovite Chorte Glauconite Rock Fragments Sedimentary Volcanic Metamorphic Cementing Materials Comments Cuart Feldspar Carbonate Clay Iron Oxide, Hydoxide and/or Suffide Other Visual Porosity Estimate Comments Comments Comments Carbonate Carbona	Monocry	stalline	
Feldspar Plagioclase Orthoclase Microcline Calotie Dolomite 100% abundant allochems, clasts, relic ooids, peloids? in recrystallized cloudy very fine-grained, <125µ, matrix. Dolomite? Aragonite Clay Illite Smectite Kaolinite Muscovite Chlorite Glauconite Volcanic Metamorphic Other (Accessory Minerals) Carbonate Carbonate Carbonate Cay Iron Oxide, Hydoxide and/or Sulfide Other Visual Porosity Estimate	Microcry	stalline	
Plagioclase Orthoclase Microcline Calcite Dolomite 100% abundant allochems, clasts, relic ooids, peloids? in recrystallized cloudy very fine-grained, <125µ, matrix. Dolomite? Aragonite Clay Illite Smectrite Kaolinite Muscovite Chlorite Glauconite Rock Fragments Sedimentary Volcanic Metamorphic Other (Accessory Minerals) Cementing Materials Quartz Feldspar Carbonate Clay Iron Oxide, Hydoxide and/or Suffide Other		Feldspar	
Orthoclase Microcline Calotte Dolomite 100% abundant allochems, clasts, relic ooids, peloids? in recrystallized cloudy very fine-grained, <125µ, matrix. Dolomite? Aragonite Clay Illite Smectite Kaolinite Muscovite Chlorite Glauconite Choirite Glauconite Sedimentary Volcanic Metamorphic Cterenting Materials Quartz Feldspar Carbonate Cay Iron Oxide, Hydoxide and/or Sulfide Other	Plag	gioclase	
Microcline Carbonate Calcite Dolomite 100% abundant allochems, clasts, relic ooids, peloids? in recrystallized cloudy very fine-grained, <125µ, matrix. Dolomite? Aragonite Clay Illite Smectite Kaolinite Muscovite Chlorite Glauconite Sedimentary Volcanic Metamorphic Other (Accessory Minerals) Cementing Materials Cuments Carbonate Carbo	Ort	hoclase	
Carbonate Calcite Dolomite 100% abundant allochems, clasts, relic ooids, peloids? in recrystallized cloudy very fine-grained, <125µ, matrix. Dolomite? Aragonite Clay Illite Smectite Kaolinite Muscovite Chlorite Glauconite Rock Fragments Sedimentary Volcanic Metamorphic Other (Accessory Minerals) Cementing Materials Quartz Feldspar Carbonate Clay Iron Oxide, Hydoxide and/or Sulfide Other	Mic	crocline	
Calcite Dolomite 100% abundant allochems, clasts, relic ooids, peloids? in recrystallized cloudy very fine-grained, <125µ, matrix. Dolomite? Aragonite Clay Illite Smectite Kaolinite Muscovite Chlorite Glauconite Sedimentary Volcanic Metamorphic Other (Accessory Minerals) Cementing Materials Quartz Feldspar Carbonate Calcy Iron Oxide, Hydoxide and/or Sulfide Other Visual Porosity Estimate Comments		Carbonate	
Dolomite 100% abundant allochems, clasts, relic ooids, peloids? in recrystallized cloudy very fine-grained, <125µ, matrix. Dolomite?		Calcite	
recrystallized cloudy very fine-grained, <125µ, matrix. Dolomite? Aragonite Clay Illite Smectite Kaolinite Muscovite Chlorite Glauconite Sedimentary Volcanic Metamorphic Other (Accessory Minerals) Cementing Materials Quartz Feldspar Carbonate Clay Iron Oxide, Hydoxide and/or Sulfide Other	Do	plomite 100%	abundant allochems, clasts, relic ooids, peloids? in
Dolomite? Aragonite Clay Illite Smectite Kaolinite Muscovite Chlorite Glauconite Rock Fragments Sedimentary Volcanic Metamorphic Other (Accessory Minerals) Cementing Materials Comments Carbonate Clay Iron Oxide, Hydoxide and/or Sulfide Other Visual Porosity Estimate Comments Comments Comments Comments Comments Comments Comments Carbonate Clay Iron Oxide, Hydoxide and/or Sulfide Other Visual Porosity Estimate Comments Comment			recrystallized cloudy very fine-grained, <125µ, matrix.
Aragonite Clay Illite Smectite Kaolinite Muscovite Chlorite Glauconite Sedimentary Volcanic Metamorphic Other (Accessory Minerals) Cementing Materials Quartz Feldspar Carbonate Clay Iron Oxide, Hydoxide and/or Sulfide Other Visual Porosity Estimate			Dolomite?
Clay Illite Smectite Kaolinite Muscovite Chlorite Glauconite Rock Fragments Sedimentary Volcanic Metamorphic Other (Accessory Minerals) Quartz Feldspar Carbonate Clay Iron Oxide, Hydoxide and/or Sulfide Other Visual Porosity Estimate	Ara	agonite	
Ilite Ilite Smettle Kaolinite Muscovite Chlorite Glauconite Sedimentary Volcanic Metamorphic Other (Accessory Minerals) Quartz Feldspar Carbonate Clay Iron Oxide, Hydoxide and/or Sulfide Other Visual Porosity Estimate			
Smectite Smectite Kaolinite Muscovite Chlorite Glauconite			
Kaolinite Muscovite Chlorite Glauconite Sedimentary Volcanic Metamorphic Other (Accessory Minerals) Cementing Materials Quartz Feldspar Carbonate Clay Iron Oxide, Hydoxide and/or Sulfide Other Visual Porosity Estimate	c,	mactita	
Muscovite Chlorite Glauconite Sedimentary Volcanic Metamorphic Other (Accessory Minerals) Cementing Materials Quartz Feldspar Carbonate Clay Iron Oxide, Hydoxide and/or Suffide Other	31		
Chlorite Glauconite Sedimentary Volcanic Metamorphic Cther (Accessory Minerals) Cementing Materials Quartz Feldspar Carbonate Clay Iron Oxide, Hydoxide and/or Sulfide Other Visual Porosity Estimate Comments Comments	No.	aomite	
Glauconite Rock Fragments Sedimentary Volcanic Metamorphic Other (Accessory Minerals) Cementing Materials Quartz Feldspar Carbonate Clay Iron Oxide, Hydoxide and/or Sulfide Other Visual Porosity Estimate	IVIU	Scovice	
Rock Fragments Sedimentary Volcanic Metamorphic Other (Accessory Minerals) Cementing Materials Quartz Feldspar Carbonate Clay Iron Oxide, Hydoxide and/or Sulfide Other Visual Porosity Estimate		Linorite	
Rock Fragments Sedimentary Volcanic Metamorphic Other (Accessory Minerals) Cementing Materials Quartz Feldspar Carbonate Clay Iron Oxide, Hydoxide and/or Sulfide Other Visual Porosity Estimate	Gla	uconite	
Sedimentary Volcanic Metamorphic Other (Accessory Minerals) Cementing Materials Quartz Feldspar Carbonate Clay Iron Oxide, Hydoxide and/or Sulfide Other Visual Porosity Estimate Comments	R	ock Fragments	
Volcanic Metamorphic Other (Accessory Minerals) Cementing Materials Quartz Feldspar Carbonate Clay Iron Oxide, Hydoxide and/or Sulfide Other Visual Porosity Estimate Comments	Sedin	nentary	
Metamorphic Other (Accessory Minerals) Cementing Materials Comments Quartz Guartz Feldspar Carbonate Clay Clay Iron Oxide, Hydoxide and/or Sulfide Other Visual Porosity Estimate Comments	v	olcanic	
Other (Accessory Minerals) Cementing Materials Comments Quartz Guartz Feldspar Carbonate Clay Iron Oxide, Hydoxide and/or Sulfide Other Visual Porosity Estimate	Metan	norphic	
Cementing Materials Comments Quartz Feldspar Feldspar Carbonate Clay Iron Oxide, Hydoxide and/or Sulfide Other Visual Porosity Estimate Visual Porosity Estimate Comments	Other (Accessory Minerals)	
Cementing Materials Comments Quartz Feldspar Carbonate Clay Iron Oxide, Hydoxide and/or Sulfide Other Visual Porosity Estimate Comments			
Quartz Feldspar Carbonate Clay Iron Oxide, Hydoxide and/or Sulfide Other Visual Porosity Estimate Comments	Cem	enting Materials	Comments
Feldspar Carbonate Clay Iron Oxide, Hydoxide and/or Sulfide Other Visual Porosity Estimate Comments	Cem	Quartz	Comments
Carbonate Clay Iron Oxide, Hydoxide and/or Sulfide Other Visual Porosity Estimate Comments	E	eldenar	
Clay Iron Oxide, Hydoxide and/or Sulfide Other Visual Porosity Estimate Comments		bonata	
Iron Oxide, Hydoxide and/or Sulfide Other Visual Porosity Estimate Comments	Car		
Visual Porosity Estimate Comments	Iron Ovide, Undevide and /or	Cidy	
Visual Porosity Estimate Comments	iron Uxide, Hydoxide and/or	Sumde	
Visual Porosity Estimate Comments		Other	
	Visua	l Porosity Estimate	Comments
<1% No porosity observed except for small discontinuous fracture		<<1%	No porosity observed except for small discontinuous fracture



Sample ID: Formation/Member Name:	DN-43 Gatesburg/Rose Run	
Lithologic Classification:	Carbonate	
Depth/Depth Range:	N/A	
Date of Analysis:	6/16/2017	
Analyzed by:	S. Shank	
16	exture	Comments
Grain	Size	
Rouh	aing	
50	rting	
Composition	Detrital Minerals	Comments
0	luartz	
Polycrysta	Illine	
Monocrysta	lline	
Microcrysta	lline	
	lidspar	
Plagiou		
Offilo	clino	
INICI O	ume	
Ca	bonate	
Ca	lcite	
Dolo	mite 100%	very fine-grained, <125µ, recrystallized, cloudy dolomite?, with scattered coarser patches and veins. Cut by thin stylolites and subparallel fracture
Arago	onite	
	Clay	
(ma	lilite	
Sille	inite	
Naul	nite	
Chi		
Glauce		
Gladee	Jinte	
Rock	Fragments	
Sedimer	ntary	
Volo	canic	
Metamor	phic	
Other (Acce	assory Minerals)	
	<1% opaques	scattered grains and in stylolites
Cementi	ng Materials	Comments
Qu	Jartz	
Feld	spar	
Carbo	nate	
	Clay	
Iron Oxide, Hydoxide and/or Su	lfide	
C	ther	
Visual Por	osity Estimate	Comments
	<1%	virtually no intergranular porosity in very fine-grained
		matrix, thin fracture along stylolite and scattered
		porosity in coarser grained patches
		· - ·



Sample ID:	DN-45	
Formation/Member Name:	Gatesburg/Rose Run	
Lithologic Classification:	Breccia	
Depth/Depth Range:	N/A	
Date of Analysis:	6/16/2017	
Analyzed by:	S. Shank	
	Texture	Comments
Gra	ain Size	matrix supported breccia with angular clasts (~1 cm) of chert and
		silicified oolites in carbonate
Ro	unding	
	Sorting	
Composit	ion/Detrital Minerals	Comments
	Quartz	
Polycry	stalline	
Monocry	stalline <1%	
		few scattered sand grains in silicified oolites and carbonate matrix
Microcry	stalline	
	Feldspar	
Plag	ioclase	
Orth	noclase	
Mic	rocline	
	Carbonate	
	Calcite	
Do	blomite	
Ara	agonite	
Sr	nite	
Mu	scovite	
lvia C	blorite	
Glau	iconite	
Giat	aconite	
R	ock Fragments	
Sedim	nentary 75%	chert and silicified oolites
V	olcanic	
Metam	norphic	
Other (Accessory Minerals)	
Cem	enting Materials	Comments
	Quartz	
Fe	eldspar	
Car	bonate 25%	very fine-grained, <125 μ , equigranular to rhombic cloudy
		carbonate, some rhombs of carbonate in silicified oolites
	Clay	
Iron Oxide, Hydoxide and/or	Sulfide	
	Other	
Viene	l Porosity Estimate	Comments
Visua	<1%	extremely limited porosity in very thin yeins fractures along clast
	21/0	margins and scattered voids
		margina and seattlered volual



Sample ID:	H 6 00	
Sample 10.	Gordon	
Lithologic Classification:	Sandstone	
Denth/Denth Bange:	2906 ft	
Date of Analysis:	7/14/2017	
Analyzed by:	l Ditzler	
, and year by:		
T	exture	Comments
Grain Size	fine-grained, 177-250µ	
Rounding	Sub-angular to sub-rounded	
Sorting	well sorted	
Composition,	/Detrital Minerals	Comments
	Quartz	
Polycrystalline	4%	
Monocrystalline	86%	
Microcrystalline	5%	
Fe	eldspar	
Plagioclase		2% total feldspar
Orthoclase		
Microcline		
Ca	rbonate	
Calcite		
Dolomite		
Aragonite		
	Clay	
Illite	<1%	total clay - skattered flakes and patches
Smectite		
Kaolinite		
Muscovite		
Chlorite	<<1%	
Glauconite		
Rock	Fragments	
Sedimentary		
Volcanic		
Metamorphic		
Other (Acce	essory Minerals)	
	Zircon	very minor amount
Cementi	ng Materials	Comments
Quartz		very poorly cemented
Feldspar		· · · ·
Carbonate		
Clay	3%	
Iron Oxide, Hydoxide and/or Sulfide		
Other		
Visual Por	osity Estimate	Comments
	25%	primarily intergranular - evenly dispersed


Sample ID:	H-4-99	
Formation/Member Name:	Gordon	
Lithologic Classification:	Sandstone	
Depth/Depth Range:	2894.9 ft	
Date of Analysis:	7/14/2017	
Analyzed by:	L. Ditzler	
	Texture	
	Texture Curring Circle Very-fine (88-125µ) to very-coarse (1410-	Comments
		some lamination based on grain size
	Bounding very-coarse grains are very well rounded	
	while very-fine grains are sub-rounded to	
	Sorting poor	
<u> </u>	mnosition/Detrital Minerals	Comments
	Ouartz	comments
Pc	lycrystalline 3%	
Mor	nocrystalline 90%	
Mic	rocrystalline 3%	
	Feldspar	
	Plagioclase 1%	total feldspar
	Orthoclase	
	Microcline	
	Carbonate	
	Calcite	
	Dolomite	
	Aragonite	
	Clay	
	Illite	scattered grains
	Smectite	
	Kaolinite	
	Muscovite <1%	
	Chlorite	
	Glauconite	
	Rock Fragments	
	Sedimentary	
	Volcanic	
Ν	1etamorphic	
	Other (Accessory Minerals)	
	Zircon	verv minor amount
	Cementing Materials	Comments
	Quartz	Poorly cemented
	Feldspar	
	Carbonate	
	Clay 3%	
Iron Oxide, Hydoxide ar	nd/or Sulfide	
	Other	
	Visual Porosity Estimate	Comments
	25%	primarily intergranular - evenly dispersed
		. , 5 ,



Sample ID:	H-2-99	
Formation/Member Name:	Gordon	
Lithologic Classification:	Quartz Comglomerate	
Depth/Depth Range:	2892.75 ft	
Date of Analysis:	7/14/2017	
Analyzed by:	l Ditzler	
Analyzeu by.		
Text	ure	Comments
Grain Size		
	very-fine (88-125u) to granular (2-6mm)	
Bounding	well rounded to subangular	
ite analig	very-coarse grains are very well	
	rounded while very-fine grains are sub-	
Sorting	rounded to sub angular	
Solung	Tourided to sub-angular	
Composition/De	etrital Minerals	Comments
Qua	irtz	
Polycrystalline	43%	
Monocrystalline	40%	
Microcrystalline	2%	
Felds	spar	
Plagioclase	2%	Total feldspar
Orthoclase		·
Microcline		
Carbo	nate	
Calcite		
Dolomite		
Aragonite		
_		
Cla	ν <u> </u>	
Illite		Scattered grains of muscovite and minor
Smectite		biotite (<<1%)
Kaolinite		
Muscovite	<1%	
Chlorite		
Glauconite		
Rock Fra	gments	
Sedimentary		
Volcanic		
Metamorphic		
Other (Access	ory Minerals)	
Cementing	Materials	Comments
Quartz	<1%	some quartz overgrowths
Feldspar		
Carbonate		
Clay	1%	minor, scattered
Iron Oxide, Hydoxide and/or Sulfide	7%	
Other		
· · · · · · · · · · · · · · · · · · ·		
Visual Porosi		Lomments
	470	are incompared and within fractures in
		grams



Thin	Section	Analys	is Re	nort
	Jechon	Allalvs	is ne	υυιι

Sample ID:		LH-1-02	
Formation/Member Name:		Gordon	
Lithologic Classification:		Sandstone	
Depth/Depth Range:		3130.75	
Date of Analysis:		//1//201/ Filen Davis	
Analyzed by:		Elieli Davis	observed at 10y
		Texture	Comments
	Grain Size	50-200 um. average grain size ~125 um	connenta
	Rounding	subangular, subrounded	
	Sorting	well sorted	
		Composition/Detrital Minerals	Comments
		Quartz	
	Polycrystalline	 some polycrystalline quartz present 	
			images LH-1-02_0002 - LH-1-02_0005, LH-1-02_0007
r i	Monocrystalline	~75% monocrystalline quartz ·smaller, subhedral grains ·not much overgrowth	
I	Microcrystalline	grains can be easily observed under petroscope	
		XN: black, white, gray PPL: light brown	
		Feldenar	
	Plagioclase	-albite twinning present	image H_1_02_0001
	Orthoclase	N/A	Inage 11-1-02_0001
	Microcline	N/A	
	in crochine		
		Carbonate	
	Calcite	~25% calcite ·subhedral grains ·mostly cementing grains	image LH-1-02_0006
		XN: brown, green, pink PPL: light brown	
	Dolomite	N/A	
	Aragonite	N/A	
		Clay	
	Illite	N/A	
	Smectite	N/A	
	Kaolinite	N/A	
	Muscovite	<5% muscovite ·small, subangular grains	images LH-1-02_0010, 0013, 0014, 0019
		XN: blue, purple, orange PPL: gray-green	
	Chlorite	N/A	
	Glauconite	N/A	
		Rock Fragments	
	Sedimentary	-sedimentary rock fragments present	image H-1-02 0020
	Volcanic	N/A	
	Metamorphic	N/A	
		Other (Accessory Minerals)	
		images LH-1-02_0009, LH-1-02_0012	
	Quartz	some intergrown quartz grains	Comments
	Feldenar	Some mergrown quartz grams	
	Carbonate	-some calcite cementing	
	Clav		
Iron Oxide, Hvdoxide	e and/or Sulfide		
, ,	Other		
		Visual Porosity Estimate	Comments
			images LH-1-02_0015 - LH-1-02_0018



This image shows subhedral, intergrown quartz grains. (10x, XN)



The subangular and subrounded quartz grains in this image. Some iron is shown here as well. (10x, XN)



This image shows a large calcite grain. (10x, XN)



The birefringent subhedral muscovite grains in this image are surrounded by quartz grains. (10x, XN)



This image shows the porosity of this sample. (10x, PPL)



The subhedral quartz grains in this image are cemented by calcite. Some grains of birefringent muscovite are also present. (10x, XN)



This image shows sedimentary rock fragments and subhedral quartz grains. (10x, XN)



The blue epoxy in this image shows the pore space in the sample. (10x, PPL)



This image shows polycrystalline quartz as well as subhedral, monocrystalline quartz grains.



This image shows several grains of birefringent muscovite in a matrix of intergrown quartz. (10x, XN)



This image shows a small, subangular grain of plagioclase feldspar with albite twinning in a matrix of quartz grains. (10x, XN)



The pore space in this image is filled with blue epoxy. (10x, PPL)

Sample ID:	LH-5-02	
Formation/Member Name:	Gordon	
Lithologic Classification:	Sandstone	
Depth/Depth Range:	3138.8	
Date of Analysis:	7/18/2017	
Analyzed by:	Ellen Davis	
		observed at 10x
	Texture	Comments
Grain	Size 50-600 μm, average grain size ~100 μm	
Rour	ding subangular, subrounded	
So	rting primarily well sorted	
	Composition/Detrital Minerals	Comments
	Quartz	
Polycrysta	Illine ·polycrystalline quartz present in larger grains	images LH-5-02_0003, 0009, 0010
Monocrysta	Iline ~90% monocrystalline quartz ·smaller, subhedral grains with not much overgrowth	
Microcrysta	Iline grains can be easily observed under petroscope	
	XN: black, white, gray PPL: light brown	
	Feldspar	
Plagio	clase ·albite twinning present	images LH-5-02_0002, 0004
Ortho	clase N/A	
Micro	cline N/A	
	Carbonate	
Ca	Icite ~<10% calcite -subhedral grains	images LH-5-02 0006, 0008
	XN: brown, green, pink PPL: light brown	• <u> </u>
Dolo	mite N/A	
Arag	onite N/A	
	<u>Clay</u>	
	Illite N/A	
Sme	ctite N/A	
Kao	inite N/A	
Musc	ovite <5% muscovite -small, subangular and subrounded grains	images LH-5-02_0005, 0007
	XN: blue, purple, orange PPL: gray-green	
Chl	orite N/A	
Glauce	onite N/A	
Codimo	Kock Fragments	imagos I H 5 02 0001 0014
Sedime	ranie N/A	Images Ln-5-02_0001, 0014
Metamo		
Wetanio		
	Other (Accessory Minerals)	
	Cementing Materials	Comments
Q	uartz -some intergrown quartz grains	
Felc	ispar	
Carbo	nate -some calcite cementing	
	Clay	
Iron Oxide, Hydoxide and/or Su	Itide	
C	ther	
	Visual Deresity Estimate	Commonte
	visual porosity estimate is ~30%	images LH-5-02 0011 - LH-5-02 0015
	House perconcy connuccio - 5070	11105C3 E1 5 02_0011 - E1 - 5-02_0015





The quartz in this image is cemented by grains of anhedral calcite. (10x, XN)



This image shows subrounded and subangular quartz grains with some intergrowth and some pore space visible. Colored muscovite can be seen in the top right corner as well. (10x, XN)



This image shows a grain of anhedral calcite surrounded by smaller, subhedral quartz grains. (10x, XN)



Plagioclase feldspar with albite twinning is shown in this image. Subrounded and subangular quartz grains surround the feldspar. (10x, XN)



This image shows the pore space in the sample. The blue is the epoxy filling the pore space and the brown is the grains. (10x, PPL)



The brightly colored grain in this image is muscovite. The muscovite is surrounded by subangular quartz and some pore space can be seen. (10x, XN)



The blue in this image shows the pore space in this sample. (10x, PPL)



Larger quartz grains with some intergrowth are shown in this image. (10x, XN)



This image shows plagioclase feldspar with albite twinning. Some larger quartz grains and sedimentary rock fragments are present as well. (10x, XN)



This image shows blue/green muscovite surrounded by subhedral quartz and pore space. (10x, XN)



Appalachian Storage Hub Project

Thin	Section	Analy	vsis	Rep	ort
	200000	7.1101		i top	

Sample ID:	LH-9-02	
Formation/Member Name:	Gordon	
Lithologic Classification:	Sandstone	
Depth/Depth Range:	3141.40	
Date of Analysis:	7/18/2017	
Analyzed by:	Ellen Davis	abconvod at 10v
	Toxturo	Observed at 10x
	Grain Size 50.150 um average grain size ~100 um	comments
	Bounding subangular subrounded grains	
	Sorting well sorted	
	Sorting Weir Sorted	
	Composition/Detrital Minerals	Comments
-	Quartz	
	Polycrystalline ·some polycrystalline quartz present	images LH-9-02_0009, 0010, 0012
	Monocrystalline ~90% monocrystalline quartz -smaller, subhedral grains	
	Microcrystalline grains can be easily observed under petroscope	
	XN: black, white, gray PPL: light brown	
	Feldspar	
	Plagioclase ·albite twinning present	images LH-9-02_0002, 0004
	Orthoclase N/A	
	Microcline N/A	
	Carbonate	
	Calcite ~10% calcite ·mostly subhedral grains	images LH-9-02, 0003, 0005
	XN: brown, green, pink PPL: light brown	······
	Dolomite N/A	
	Aragonite N/A	
	(In.	
	IIIILE N/A Smoothe N/A	
	Kaolinite N/A	
	Muscovite <5% muscovite ·small, subangular and subrounded grains	images LH-9-02 0001, 0008
	XN: blue, purple, orange PPL: gray-green	mages 211 5 02_0000
	Chlorite N/A	
	Glauconite N/A	
	Rock Fragments	
	Sedimentary -sedimentary rock fragments present	images LH-9-02_0006, 0011
	Volcanic N/A	
	Metamorphic N/A	
	Other (Accessory Minerals)	
	come iron present	image H-0-02, 0007
	some non present	indge En 5 02_0007
	Cementing Materials	Comments
	Quartz -intergrown quartz grains	
	Feldspar	
	Carbonate -some calcite cementing	
	Clay	
Iron Oxide, H	lydoxide and/or Sulfide	
	Other	
	Visual Porosity Estimate	Comments
	 visual porosity estimate is ~30% 	Images LH-9-02_0013 - LH-9-02_0016



This image shows subangular and subrounded quartz grains with some pore space present as well. (10x, XN)



The subangular and subrounded quartz grains in this image are cemented by calcite grains. (10x, XN)



The three brightly colored grains in this image are subhedral muscovite grains. The muscovite is surrounded by quartz grains. (10x, XN)



This image shows the pore space present in the sample. (10x, PPL)



Subhedral quartz grains are shown in this image along with some polycrystalline quartz grains and sedimentary rock fragments. (10x, XN)



This image shows plagioclase feldspar with albite twinning. Some quartz grains and pore space is shown as well.



This image shows a colorful grain of muscovite and subhedral quartz grains. (10x, XN)



The blue in this image is epoxy used to show pore space in a sample. (10x, PPL)



This image shows anhedral calcite and subhedral quartz grains. (10x, XN)



Plagioclase feldspar with albite twinning is surrounded by subhedral quartz grains in this image. (10x, XN)



This image shows a sedimentary rock fragment surrounded by quartz grains and pore space. (10x, XN)



This image shows the porosity of this sample. (10x, PPL)

	Thin Section Analysis Repor	t
Sample ID:	LH-11-02	
ormation/Member Name:	Gordon	
ithologic Classification:	Sandstone	
Depth/Depth Range:	3143.85	
Date of Analysis:	7/18/2017	
Analyzed by:	Ellen Davis	
	Territoria	observed at 10x
	Iexture	Comments
G	aram Size SU-150 μm, average gram Size "80 μm	
h	Conting Subangular, subrounded grains	
	Sorting wen sorted	
	Composition/Detrital Minerals	Comments
	Quartz	
Polyci	rystalline ·polycrystalline quartz present	images LH-11-02_0007, 0008, 0009
Monocr	rystalline ~90% monocrystalline guartz ·small, mostly subhedral grains	• <u> </u>
Microci	rystalline grains can be easily observed under petroscope	
	XN: black, white, gray PPL: light brown	
	Feldspar	
Pla	agioclase ·albite twinning present	images LH-11-02_0004, 0005
Or	rthoclase N/A	
M	licrocline N/A	
	Carbonate	
	Calcite ~10% calcite ·mostly subhedral, cementing grains	images LH-11-02_0002, 0006
	XN: brown, green, pink PPL: light brown	
[Dolomite N/A	
А	Aragonite N/A	
	Clav	
	Illite N/A	
	Smectite N/A	
	Kaolinite N/A	
M	1uscovite <5% muscovite small, subhedral grains	images LH-11-02, 0001, 0003
	XN: blue nurnle orange PPI: grav-green	
	Chlorite N/A	
G	auconite N/A	
	Rock Fragments	
Sedi	imentary -sedimentary rock fragments present	images LH-11-02_0003, 0011
	Volcanic N/A	
Meta	amorphic N/A	
	Other (Accessory Minerale)	
	possibly iron present	image LH-11-02 0010
	possibly non present	
	Cementing Materials	Comments
	Quartz ·intergrown quartz grains	
	Feldspar	
Ca	arbonate -some calcite cementing	
	Clay	
Iron Oxide, Hydoxide and/o	or Sulfide	
	Other	
	Visual Porosity Estimate	Comments
	visual polosity estimate is 50%	IIIIages Lu-11-02_0015 - Lu-11-02_0015



This image shows polycrystalline quartz. (10x, XN)



The subhedral quartz in this image is cemented by anhedral calcite. (10x, XN)



The elongated pink and orange grain in this image is muscovite. The muscovite is surrounded by subhedral quartz. (10x, XN)



This image shows plagioclase feldspar, a grain of muscovite, sedimentary rock fragments, and subhedral quartz grains. (10x, XN)



This image shows subangular and subrounded quartz grains with some pore space visible. (10x, XN)



This image shows subhedral calcite along with quartz grains and some pore space. (10x, XN)



This image shows a grain of subhedral muscovite along with quartz grains, pore space, and sedimentary rock fragments. (10x, XN)



The blue epoxy in this image shows the pore space in the sample. (10x, $\ensuremath{\mathsf{PPL}}\xspace)$



Subhedral quartz is shown in this image, some of which is intergrown.



This image shows iron cementing subhedral quartz grains. (10x, XN)



The albite twinning in this image shows the presence of plagioclase feldspar. The feldspar is surrounded by subhedral quartz grains and pore space.



This image shows the porosity of the sample. (10x, PPL)

Thin	Section	Analy	vsis	Report	
	Jection	Anan	313	inc poi t	

Sample ID: Formation/Member Name: Lithologic Classification:	LH-12-02 Gordon Sandstone	
Depth/Depth Range:	3145.25	
Date of Analysis:	7/18/2017	
Analyzed by:	Ellen Davis	
	Taxtura	observed at 10x
	Grain Size 50.100 um average grain size ~80 um	comments
	Rounding subangular, subrounded grains	
	Sorting well sorted	
	Composition/Detrital Minerals	Comments
	Quartz	images 12.02.0008.0010
	Polycrystalline ~90% monocrystalling guartz small, mostly subbedral grains and much intergrowth	Inages LH-12-02_0008, 0010
	Monocrystalline grains can be easily observed under netroscope	
	XN: black, white, gray PPL: light brown	
	Feldspar	
	Plagioclase -albite twinning present	images LH-12-02_0001, 0003
	Orthoclase N/A	
	Microcline N/A	
	Carbonate	
	Calcite ~10% calcite ·mostly subhedral, cementing quartz grains	images LH-12-02_0002, 0004, 0011
	XN: brown, green, pink PPL: light brown	
	Dolomite N/A	
	Aragonite N/A	
	Clav	
	Illite N/A	
	Smectite N/A	
	Kaolinite N/A	
	Muscovite <5% muscovite -small, subhedral grains	images LH-12-02_0005, 0007
	XN: blue, purple, orange PPL: gray-green	
	Chlorite N/A	
	Glauconite N/A	
	Rock Fragments	
	Sedimentary ·sedimentary rock fragments present	images LH-12-02_0006, 0009
	Volcanic N/A	
	Metamorphic N/A	
	Other (Accessory Minerale)	
	Cementing Materials	Comments
	Quartz ·some intergrown quartz is present	
	Feldspar	
	Carbonate isome calcite cementing	
Iron Ovide Hude	ciay hite and/or Sulfide	
non oxide, Hyde	Other	
	Visual Porosity Estimate	Comments
	 visual porosity estimate is ~25% 	images LH-12-02_0012 - LH-12-02_0015



This image shows subhedral quartz grains, some intergrown. Pore space is also shown by blue epoxy. (10x, XN)



This image shows calcite cementing smaller quartz grains and sedimentary rock fragments. (10x, XN)



The subhedral, birefringent grains in this image are muscovite, surrounded by pore space and quartz grains. (10x, XN)



This image shows the porosity of the sample. (10x, PPL)



Subangular and subrounded quartz grains are shown in this image. (10x, XN)



Subangular calcite cements quartz grains in this image. Blue epoxy shows pore space here as well. (10x, XN)



This image shows plagioclase feldspar with albite twinning. Subhedral quartz grains and sedimentary rock fragments surround the feldspar. (Jox, XN)



The blue epoxy shows the pore space in this sample. (10x, PPL)



The calcite in this image is surrounded by subhedral quartz grains. (10x, XN)



This image shows an elongated piece of birefringent muscovite along with some quartz grains and sedimentary rock fragments. (10x, XN)



Two grains of plagioclase feldspar, sedimentary rock fragments, and subhedral quartz grains are shown in this image. (10x, XN)



This image shows the porosity of the sample. The light-brown, subangular grains are surrounded by blue epoxy. (10x, PPL)

Appalachian Storage Hub Project

	Thin Section Analysis Report	
Sample ID:	LH-15-02	
Formation/Member Name:	Gordon	
Lithologic Classification:	Sandstone	
Depth/Depth Range:	3148.00	
Date of Analysis:	7/19/2017	
Analyzed by:	Ellen Davis	
· , · · · ,		observed at 10x
	Texture	Comments
Grain Size	50-200 μm, average grain size ~80 μm	
Rounding	subangular, subrounded grains	
Sorting	well sorted	
	Composition/Detrital Minerals	Comments
	Quartz	
Polycrystalline	wood and the second sec	images LH-15-02_0007, 0012
Monocrystalline	~90% monocrystalline quartz ·small, mostly subhedral grains	
Microcrystalline	grains can be easily observed under petroscope	
	XN: black, white, gray PPL: light brown	
	Feldspar	
Plagioclase	~3% feldspar -albite twinning present	images LH-15-02 0001, 0009, 0010
Orthoclase	N/A	mages 21 15 02_0001, 0005, 0010
Microcline	N/A	
	Carbonate	
Calcite	~10% calcite ·subhedral, cementing quartz	images LH-15-02_0002, 0003, 0005
	XN: brown, green, pink PPL: light brown	
Dolomite	N/A	
Aragonite	N/A	
	Clav	
Illite	N/A	
Smectite	N/A	
Kaolinite	N/A	
Muscovite	~3% muscovite -small elongated grains	images LH-15-02 0006 0008 0010
mascorric	XN: blue purple orange PPI: grav-green	mages 211 15 02_0000, 0000, 0010
Chlorita	N/A	
Clausenite	N/A	
Gladconte	N/A	
	Rock Fragments	
Sedimentary	·sedimentary rock fragments present	image LH-15-02_0004
Volcanic	N/A	
Metamorphic	N/A	
	Other (Accessory Minerals)	
	Cementing Materials	Comments
Quartz	 some intergrown quartz is present 	
Feldspar		
Carbonate	 some calcite cementing 	
Clay		
Iron Oxide, Hydoxide and/or Sulfide		
Other		
	Marcal Develop Fables de	
	visual Porosity Estimate	Comments images LH-15-02_0013 - LH-15-02_0016



This image shows subangular quartz grains and pore space. (10x, XN)



The calcite in this image cements quartz grains. (10x, XN)



This image shows a grain of birefringent muscovite, a grain of subhedral plagoicalse feldspar, and some sedimentary rock fragments. (10x, XN)







This image shows quartz grains of different sizes. Some sedimentary rock fragments are shown as well. (10x, XN)



This image shows an elongated grain of birefringent muscovite. (10x, XN)



The albite twinning in this image shows plagioclase feldspar surrounded by subhedral quartz grains. (10x, XN)



This image shows the porosity of the sample. (10x, PPL)



This image shows subangular calcite surrounded by subhedral quartz grains. (10x, XN)



The bright blue grains in this image are muscovite. These grains of muscovite are surrounded by quartz grains. (10x, XN)



This image shows quartz grains, plagioclase feldspar, sedimentary rock fragments, and birefringent muscovite. (10x, XN)



The subhedral grains in this image is shown with blue epoxy filling the pore space. (10x, PPL)

Appalachian Storage Hub Project

	Thin Section Analysis Report	
Sample ID:		
Sample ID.	En-17-02	
Lithologic Classification:	Sandstone	
Denth/Denth Bange:	3151 90	
Date of Analysis:	7/19/2017	
Analyzed by:	Fllen Davis	
/		observed at 10x
	Texture	Comments
	Grain Size 50-200 μm, average grain size ~100 μm	
	Rounding subangular, subrounded grains	
	Sorting well sorted	
	Composition/Detrital Minerals	Comments
	Quartz	comments
	Polycrystalline -some polycrystalline quartz present	images LH-17-02 0003, 0007
	Monocrystalline ~95% monocrystalline quartz small, mostly subhedral grains	о <u>г</u> ,
	Microcrystalline grains can be easily observed under petroscope	
	XN: black, white, gray PPL: light brown	
	Feldspar	
	Plagioclase albite twinning present	images LH-17-02_0001, 0005
	Orthoclase N/A	
	Microcline N/A	
	Carbonate	
	Dolomite N/A	
	Aragonite N/A	
	6 1	
	Sinectite N/A	
	Notifie N/A	images 111 17 02, 0002, 0004, 0006
	Muscovice <5% muscovice ismail, subneural grains	Images LH-17-02_0002, 0004, 0006
	XN: blue, purple, orange PPL: gray-green	
	Glauconite N/A	
	Rock Fragments	
	Sedimentary -sedimentary rock fragments present	images LH-17-02 0008.0013
	Volcanic N/A	
	Metamorphic N/A	
	Other (Accessory Minerals)	
	some iron present	
	Cementing Materials	Comments
	Quartz -cementing is primarily intergrown quartz	
	Feldspar	
	Carbonate	
	Clay	
Iron Oxide Hy	/doxide and/or Sulfide	
i on onde, ny	Other	
	Visual Porosity Estimate	Comments
	 visual porosity estimate is ~8% 	images LH-17-02_0009 - LH-17-02_0012



This image shows intergrown quartz grains. (10x, XN)



Sedimentary rock fragments are cemented in grains of intergrown quartz. (10x, XN)



Two grains of birefringent muscovite are embedded in a matrix of intergrown quartz. (10x, XN)



This image shows the porosity of the sample. (10x, PPL)



The subhedral quartz grains in this image are intergrown. Some sedimentary rock fragments are also shown. (10x, XN)



The colorful muscovite grains in this image are surrounded by subhedral intergrown quartz grains. (10x, XN)



This image shows plagioclase feldspar with albite twinning surrounded by intergrown quartz grains. (10x, XN)



Blue epoxy in this image shows the pore space in this sample. (10x, PPL)



This image shows a sedimentary rock fragment with iron present in the grain. Intergrown quartz grains surround the sedimentary rock fragment. (10x, XN)



This image shows two grains of birefringent muscovite: one elongated and one subrounded. (10x, XN)



Although slightly difficult to see, this image shows plagioclase feldspar. Intergrown quartz and sedimentary rock fragments are also present in this image. (LDx, XN)



The pore space in these subhedral grains is filled by blue epoxy. (10x, PPL)

Sample ID:	LH-20-02	
Formation/Member Name:	Gordon	
Lithologic Classification:	Sandstone	
Depth/Depth Range:	3158.30	
Date of Analysis:	7/19/2017	
Analyzed by:	Ellen Davis	
		observed at 10x
	Texture	Comments
	Grain Size 50-250 μm, average grain size ~150 μm	
	Rounding subangular, subrounded grains	
	Sorting well sorted	
	Composition/Detrital Minerals	Comments
	Quartz	
	Polycrystalline	images LH-20-02_0005, 0008, 0009
	Monocrystalline ~60% monocrystalline quartz ·subhedral grains ·abundant intergrowth	
	Microcrystalline grains can be easily observed under petroscope	
	XN: black, white, gray PPL: light brown	
	Feldspar	
	Plagioclase ·albite twinning present ·small, subhedral grains	images LH-20-02_0001, 0003, 0007
	Orthoclase N/A	
	Microcline N/A	
	Carbonate	
	Calcite ~40% calcite ·calcite mostly cementing smaller quartz grains	images LH-20-02_0004, 0009, 0010
	Dolomite N/A	
	Aragonite N/A	
	Class.	
	ilite N/A	
	Smectite N/A	
	kaolinite N/A	
	Muscovite <5% muscovite -small, subhedral grains	images LH-20-02_0002, 0006
	XN: blue, purple, orange PPL: gray-green	
	Chlorite N/A	
	Glauconite N/A	
	Rock Fragments	
	Sedimentary -sedimentary rock fragments present	
	Volcanic N/A	
	Metamorphic N/A	
	Other (Accessory Minerals)	
	Iron present	
	Comenting Materials	Commonts
	Quartz -some intergrown guartz comenting	comments
	Feldenar	
	Carbonate -primarily calcite cementing	
	Clay	
Iron Ovida Hud	ovide and /or Sulfide	
iron Oxide, Hyd	Other	
	otter	
	Visual Porocity Estimate	Comments
	visual porosity estimate is ~3%	images LH-20-02_0011 - LH-20-02_0014
	sada porosity estimate is 5%	mages in 20 02_0011 in 20 02_0014



This image shows intergrown, subhedral quartz grains. (10x, XN)





This elongated grain of birefringent muscovite is surrounded by sedimentary rock fragments and intergrown quartz. (10x, XN)



This image shows the porosity of the sample. (10x, PPL)



Intergrown quartz grains in this image are covered with iron. (10x, XN)



Calcite in this image surrounds intergrown quartz grains and sedimentary rock fragments. (10x, XN)



This image shows a subhedral grain of plagioclase feldspar. Sedimentary rock fragments, calcite grains, and intergrown quartz are also shown here. (10x, XN)



There is hardly any blue epoxy in this image but the blue epoxy that is visible shows the pore space in the sample. (10x, PPL)



Quartz grains in this image are cemented by calcite. Some polycrystalline quartz is present as well. (10x, XN)



This image shows a grain of subrounded muscovite in a matrix of intergrown quartz. (10x, XN)



The plagioclase feldspar in this image shows albite twinning surrounded by clacite and intergrown quartz. (10x, XN)



This image shows the porosity of this sample. (10x, PPL)

Sample ID:	LW-1	
Formation/Wember Name:	Oriskany Calaana Sandatana	
Lithologic Classification:		
Depth/Depth Range:	6963.1 ft	
Date of Analysis:	6/2//201/	
Analyzed by:	S. Shank	
	Texture	Comments
Gra	in Size very fine to fine-grained	scattered, uncommon rounded medium to
		coarse sand grains
Ro	unding rounded to angular	
9	Sorting moderate	
Compos	sition/Detrital Minerals	Comments
	Quartz	
Polycrys	stalline <1%	
Monocrys	stalline 65%	
Microcrys	stalline	
	Feldspar	
Plagi	ioclase	
Orth	loclase	
Mic	rocline 2%	total feldspar
	Carbonate	
	Calcite <1%	few fossil fragments - brachionods
Do	lomite	
Ara	igonite	
	Class	
So	nite	
Nd Mure		
Mus	blorito	
	monte	
Glau	iconite	
	Rock Fragments	
Sedim	entary	
Ve	olcanic	
Metam	orphic	
Othe	r (Accessory Minerals)	
·	tourmaline	······································
	opaques	
	5%	thin discontinuous laminae of unidentified red-
<u>(</u>	monting Matarials	brown clay/nematite mix?
Ce	Ouartz	Comments
Fe	eldspar	
Carl	nonate 28%	
Car	Clav	
Iron Ovida Hudavida and/ar	Sulfida	
iron Oxide, hydoxide and/or :	Other	
Vis	ual Porosity Estimate	Comments
	<1%	no intergranular porosity, few thin fractures -
		sometimes parallel to laminae



Sample ID:	I.W-2	
Formation/Member Name:	Oriskany	
Lithologic Classification:	Sandy Limestone	
Depth/Depth Range:	6985 ft	
Date of Analysis:	6/27/2017	
Analyzed by:	S. Shank	
	Texture	Comments
Gra	ain Size very fine to fine-grained	
КО	ounding rounded to angular	
	Sorting moderate to well sorted	
Composit	tion/Detrital Minerals	Comments
	Quartz	
Polycry	stalline <1%	
Monocry	stalline 15%	scattered, matrix supported
Microcry	stalline	
	Feldspar	
Plag	gioclase	
Ortl	hoclase	
Mic	crocline <1%	total feldspar
	Carbonate	
	Calcite 80%	highly variable, patchy distribution of fine-grained
		calcite and coarser=recrystallized calcite, scattered
		fossil brachiopod fragments
Do	olomite	
Ara	agonite	
	Clay	
	Illite	
Si	mectite	
Ka	aolinite	
Mu	scovite	
C	Chlorite	
Glau	uconite	
R	lock Fragments	
Sedim	nentary	
V	olcanic	
Metan	norphic	
Other	(Accessory Minerals)	
	5%	thin discontinuous laminae of unidentified red-
		brown clay/hematite mix?
Cem	enting Materials	Comments
	Quartz	
F	eldspar	
Car	bonate	
	Clay	
Iron Oxide, Hydoxide and/or	Sulfide 5%	secondary, thin discontinuous, wavy laminae of
		unidentified red-brown clay/hematite mix?
	Other	
Vieuz	I Porosity Estimate	Comments
VISUA	<1%	no intergranular porosity, few thin fractures -
		sometimes parallel to laminae



6 I.I.		
Sample ID:	LW-3	
Formation/Member Name:	Oriskany Colorization Sandstano	
Lithologic Classification:		
Depth/Depth Range:	6/37/2017	
Date of Analysis:	6/2//2017	
Analyzed by:	5. Shank	
	Texture	Comments
Gra	ain Size very fine to fine-grained	scattered, uncommon rounded medium sand
		grains
Ro	ounding rounded to angular	
	Sorting moderate	
Compos	ition/Detrital Minerals	Comments
	Quartz	
Polycry	stalline <1%	
Monocry	stalline 48%	
, Microcry	stalline	
	Feldspar	
Plag	gioclase	
Ort	hoclase	
Mic	crocline 2%	total feldspar
	Carbonate	
	Calcite 45%	fine-grained to coarse crystalline, few fossil
		fragments - brachiopods?
De	plomite	
Ar	agonite	
	agointe	
	Clay	
	Illite	
Si	nectite	
K	aolinite	
Mu	scovite	
0	Chlorite	
Gla	uconite	
	Rock Fragments	
Sedin	nentary	
V	'olcanic	
Metan	norphic	
Other	(Accessory Minerals)	
	tourmaline	
	opaques	
	5%	thin discontinuous laminae of unidentified red- brown clay/bematite mix?
Cer	menting Materials	Comments
	Quartz	
F	eldspar	
Car	bonate	
	Clay	
Iron Oxide, Hydoxide and/or	Sulfide	
	Other	
Visu	al Porosity Estimate	Comments
	<1%	no intergranular porosity, some porosity
		associated with laminae



	Thin Section Analysis Report	
Second ID:	WD 11	471070106
ample ID:	WD-11 Oriskapy Sandstone Wood County WV	471070126
ithologic Classification:	Sandstone	
enth/Denth Bange:	4225 ft	Observed @ 10x
ate of Analysis:	6/1/2017	
nalvzed by:	Fric Hirschfeld	
	2. Te finiserie la	
	Texture	Comments
Grain Size	avg size 250 microns	Clastic
Rounding	subangular-subrounded	Inequigranular
Sorting	moderate- well-sorted	
-		
Composit	ion/Detrital Minerals	Comments
	Quartz	
Polycrystalline	n/a	
	95% composition;predominantly undulose quartz;	Figure 11.1 through Figure 11.6
	high relief; intergrown and deformed quartz grains;	
	XN: black/white, PL: transparent	
Monocrystalline		
Microcrystalline	grains are easily observed via petroscope	
	Feldspar	
Plagioclase	<1% composition; albite twinning, subhedral-	Figure 11.1 and Figure 11.2
	anhedral; XN: black/white, PL: transparent;	
	subangular grains.	
Orthoclase	n/a	
Microcline	n/a	
	Carbonate	Figure 44.4 through Figure 44.6
Calcite	subangular fragments; 5% composition; some grains	Figure 11.1 through Figure 11.6
	elognated, some slightly globular; XPL: tan-pink, PPL:	
Delevite	transparent	
Dolomite	n/a	
Aragonite	ily a	
	Clay	
Illite	n/a	
Smectite	n/a	
Kaolinite	n/a	
Muscovite	small oblate grains; <1% composition; subhedral;	no figure
	high birefringence, <1% composition; XN: green,	
	pink, blue,orange, PL: transparent	
Chlorite	n/a	
Glauconite	n/a	
P	ock Erogmonte	
Sedimentary	Predominantly consisted of detrital sedimentary	
Seamentary	fragments	
Volcanic	nossible volcanic fragments present	
Metamorphic		
Wetanorphie		
Other (/	Accessory Minerals)	
Cemi	enting Materials	Comments
Quartz	quartz intergrowth apply cementing	Figure 11.1 through Figure 11.6
Feldspar	n/a	
Carbonate	Calcite present and fills in spacing between quartz	Figure 11.1 through Figure 11.6
	grains	
Clav	- n/a	
Iron Oxide, Hydoxide and/or Sulfide	n/a	
Other	n/a	
	-	
Visual	Porosity Estimate	Comments
isual Porosity Estimate of total thin	Porosity= 11%	Figure 11.7 through Figure 11.11



Figure 11.1 Observed at 10x magnification. In XN, intergrown, anhedral and deformed quartz and calcite grains. Also present is a small piece of plagioclase.



Figure 11.2 Observed at 10x magnification. In XN, anhedral quartz grain with intergrown calcite cementing material. Also present is a anhedral grain of plagioclase exhibiting albite twinning.



Figure 11.3 Observed at 10x magnification. In XN, anhedral to subhedral, quartz grains with subhedral calcite grains and intergrown calcareous cementing material





Figure 11.5 Observed at 10x magnification. In XN, interspersed, subhedral to anhedral unduloose quartz grains that are cement calcareous cementing material



Figure 11.6 Observed at 10x magnification. In XN, subhedral undulose quartz grains overgrown and cemented with calcareous material and calcite in between.



Figure 11.7 Observed at 10x magnification. In PL, the blue dye represents the open pore spaces in the thin section, estimating about 11% porous overall.



Figure 11.8 Observed at 10x magnification. In PL, the blue dye represents the open pore spaces in the thin section, estimating about 11% porous overall.



Figure 11.9 Observed at 10x magnification. In PL, the blue dye represents the open pore spaces in the thin section, estimating about 11% porous overall.



Figure 11.10 Observed at 10x magnification. In PL, the blue dye represents the open pore spaces in the thin section, estimating about 11% porous overall.



Figure 11.11 Observed at 10x magnification. In PL, the blue dye represents the open pore spaces in the thin section, estimating about 11% porous overall.

	Thin Section Analysis Report	
ample ID:	WD-10	471070126
ormation/Member Name:	Oriskany Sandstone Wood County, WV	
thologic Classification:	Sandstone	
epth/Depth Range:	4222.5 ft	Observed @ 10x
ate of Analysis:	6/2/2	017
nalyzed by:	Eric Hirschfeld	
	Texture	Comments
Gra	ain Size average grain size is approx 0.5 mm or less	non-homogeneous. Clastic.
ко	unding subangular- subrounded	
	Sorting moderately sorted	
Con	nposition/Detrital Minerals	Comments
	Quartz	
Polycry	stalline n/a	
Monocry	stalline 75% composition; deformed grains; subhedral;	Figure 10.1 through Figure 10.6
,	evidence of guartz overgrowth	0 0 0
Microcry	stalline grains are easily observed via petroscope	
	Feldspar	
Plag	ioclase 1% or less of composition; albite twinning;	no figure
	subangular; XN: black/white, PL: transparent	
Orth	noclase	
Mic	rocline	
	Carbonate	
	Calcite 24% composition; massive, globular grains; scatte	red Figure 10.2 through Figure 10.4,
	smaller subangular grains; some lamellar twinning	g is Figure 10.6
	present; XN: tan/pink, PL: transparent	
Do	olomite n/a	
Ara	agonite n/a	
	<u> </u>	
C -		
21		
No.	aunite 1% ar less composition, high hirofringence, round	ad Figure 10 F
IVIU:	scovice 1% of less composition; high birefringence, round	ed Figure 10.5
	oblate grains, XN: pink, blue, green, orange PL.	
	transparent	
Clas		
Glat	aconite nya	
	Rock Fragments	
Sedim	nentary Detrital sedimentary fragments is predominant	
V	olcanic miniscule amount of volcanic fragments	
Metam	norphic	
<u>c</u>	Other (Accessory Minerals)	
	Cementing Materials	Comments
	Quartz Quartz overgrowth acts as a cememnting materia	Figure 10.1, Figure 10.3. Figure 10.5
	for grains: well cemented	3,,,
Fe	eldspar n/a	
Carl	bonate Clcite fills in pores between grains as globular	Figure 10.4 and Figure 10.6
Car	cement: moderately cemented	
	Clav n/a	
Iron Oxide, Hydoxide and/or	Sulfide n/a	
	Other n/a	
	Visual Porosity Estimate	Comments



Figure 10.1 Observed at 10x magnification. In XN (unbalanced light), subhedral undulose quartz grains grown and cemented together.



Figure 10.2 Observed at 10x magnification. In XN, elongated and anhedral calcite grains. Grown together acting as cementing material.





Figure 10.3 Observed at 10x magnification. In XN, subhedral, undulose quartz grains grown and cemented together.



Figure 10.5 Observed at 10x magnification. In XN, subhedral and slightly intergrown quartz grains with a small grain of deformed





Figure 10.6 Observed at 10x magnification. In XN, globular calcite overgrown and interspersed with subhedral quartz.



Figure 10.7 Observed at 10x magnification. In PL, the blue dye represents the open pore spaces in the thin section, estimating



Figure 10.8 Observed at 10x magnification. In PL, the blue dye represents the open pore spaces in the thin section, estimating to about 10% porous overall.







Figure 10.10 Observed at 10x magnification. In PL, the blue dye represents the open pore spaces in the thin section, estimating to about 10% porous overall.



Figure 10.11 Observed at 10x magnification. In PL, the blue dye represents the open pore spaces in the thin section, estimating to about 10% porous overall.

Sample ID:	WD-9	4710701266
Formation/Member Name:	Oriskany Sandstone Wood County, WV	
Lithologic Classification:	Sandstone	
Depth/Depth Range:	4220.1 tt	Observed @ 10x
Analyzed by:	Eric Hirschfeld	
	Texture	Comments
Grain Size	average grain size 50 to 600 microns	inequigranular: subhedral: clastic
Rounding	subangularto subrounded	inequigranaiar, subinearar, classic
Sorting	moderately-well sorted	
Compositi	on/Detrital Minerals	Comments
	Quartz	
Polycrystalline	5% composition; Polycrystalline quartz is less	
	overgrowth	
Monocrystalline	70% composition: undulose quartz: XN: black/white.	Figure 9.1, Figure 9.4, Figure 9.6,
	PL: transparent	Figure 9.7
Microcrystalline	grains are easily observed via petroscope	0
	Feldspar	
Plagioclase	1% or less composition; subangular; albite twinning,	no figure
	subhedral	
Orthoclase	n/a	
Microcline	n/a	
	Carbonate	
Calcite	25% composition; elongated, fibrous, and globular	Figure 9.2 through 9.7
	texture; especially in areas of intergrowth; some	5 5
	massive cumulates of calcite; subangular grains; XN:	
	tan/pink, PL: Tan, transparent	
Dolomite	n/a	
Aragonite	n/a	
	Clau	
	n/a	
Smectite	n/a	
Kaolinite	n/a	
Muscovite	< 1% composition; olbate shape grains; <100 microns	no figure
	in size; XPL: pink, blue,green,orange, PPL:	
	transparent	
Chlorite	n/a	
Glauconite	n/a	
Ki Sodimontan	DCK Fragments	
Sedimentary	Fredominantiy detital sedimentary fock fragments	
Volcanic	n/a	
Metamorphic	n/a	
Other (/	Accessory Minerals)	
Biotite?	noticed a few grainsof biotite; deformed; subrounded	I no figure
	grain; 450 microns in size; XN: orange, PL: brown	
	anting Materials	Comments
Ceme	Ouartz intergrowth acts as a cementing material:	Figure 9.1 through Figure 9.7
Quartz	moderately cemented	
Feldspar	n/a	
Carbonate	Calcite filling in many of open pores spaces and in	Figure 9.1 through Figure 9.7
	between quartz grains; moderately cemented	
	· - · · · ·	
Clay	n/a	
Iron Oxide, Hydoxide and/or Sulfide	n/a	
Other	n/a	
Visual Denseits Estina i	Porosity Estimate	Comments



Figure 9.1 Observed at 10x magnification. In XN, subhedral undulose quartz that is also acting as cementing material from growth.



Figure 9.2 Observed at 10x magnification. In XN, deformed elongated grain of calcite grown in between subhedral quartz grains.



Figure 9.3 Observed at 10x magnification. In XN, large cumulate of deformed clacite, overgrown on quartz grains.



Figure 9.4 Observed at 10x magnification. In XN, grown calcite cementing together subhedral undulose quartz.



Figure 9.5 Observed at 10x magnification. In XN, interspersed calcite cementing together subhedral undulose quartz.



Figure 9.6 Observed at 10x magnification. In XN, intergrown calcite cementing together subhedral undulose quartz. Also quartz overgrowth, cementing grains together.



Figure 9.7 Observed at 10x magnification. In XN, interspersed subhedral quartz and calcite grains. Both acting as cementing material.



Figure 9.8 Observed at 10x magnification. In PL, blue dye represents the open pore spaces in the thin section, estimating about 10% porous overall



Figure 9.9 Observed at 10x magnification. In PL, blue dye represents the open pore spaces in the thin section, estimating about 10% porous overall



Figure 9.10 Observed at 10x magnification. In PL, blue dye represents the open pore spaces in the thin section, estimating about 10% porous overall



Figure 9.11 Observed at 10x magnification. In PL, blue dye represents the open pore spaces in the thin section, estimating about 10% porous overall



Figure 9.12 Observed at 10x magnification. In PL, blue dye represents the open pore spaces in the thin section, estimating about 10% porous overall
	Thin Section Analysis Report	
Sample ID:	WD-8	4710701266
Formation/Member Name:	Oriskany Sandstone Wood County, WV	
Lithologic Classification:	Sandstone	
Depth/Depth Range:	4218.7 ft	Observed @ 10x
Date of Analysis:	6/5/201	7
Analyzed by:	Eric Hirschfeld, Ellen Davis	
	Tautum	Commonte
Croir	lexture	Comments
Gian	TSIZE average grain size is approximately 100 microns	clastic
Bour	nding subangular- subrounded	Clastic
Sc	orting moderately to well sorted	
	in the model attery to men solited	
Comp	oosition/Detrital Minerals	Comments
	Quartz	
Polycryst	alline	
Monocryst	alline 70% composition; intergrown grains; subangular to	Figures 8.1 through 8.8
	subrounded; subhedral	
Microcryst	alline grains are easily observed via petroscope	
	_ ,	
	Feldspar	
Plagio	clase albite twinning; subangular grains; <1% composition;	no figures
	approx. 100 microns in size; subhedral	
Ortho	clase	
Micro	ocline Tartan twinning; subangular grains; <1% composition	; no figures
	approx. 100 microns in size; subhedral	
	Carbonate	Figures 0.2 through 0.7
Ci	alcite Intergrown and Interspersed grains; subangular;	Figures 8.3 through 8.7
	20% composition	
Dolo	so// composition	
Arag	onite	
,	onice	
	Clay	
	Illite	
Sme	ectite	
Као	linite	
Musc	ovite small oblated grains; approximately 50 microns in	no figures
	size; XN: green, orange, pink, blue, PL: transparent;	
	<0.5% composition	
Ch	lorite	
Glauc	onite	
	Deal Francisco	
Sedime	ntary Predominantly sedimentary detrital rock fragments	
Sedime	ntary rredominantly sedimentary detritar fock nagments	
Vol	canic n/a	
Metamo	rphic n/a	
Ot	her (Accessory Minerals)	
(Cementing Materials	Comments
Q	uartz Intergrown and cemented quartz grains that are	Figure 8.1 through 8.6
	evenly distributed	
Felo	uspar n/a	Figure 0.2 through 0.7
Carbo	bonate Deformed calcite acting as cementing material	Figure 8.3 through 8.7
	between subnedral calcite grains and quartz grains	
Iren Orida Historida and C. C.		
iron Uxide, Hydoxide and/or Si		
l	סנווכו וו/d	
V	isual Porosity Estimate	Comments
/isual Porosity Estimate	5% porosity	Figure 8.8 through 9.11
isual i orosity Estillate	576 por oarcy	inguic 0.0 through 0.11

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Figure 8.1 Observed at 10x magnification. In XPN subhedral and slightly deformed, undulose quartz. Slightly intergrown.



Figure 8.2 Observed at 10x magnification. In XN, large subhedral quartz grain surrounded by anhedral to subhedral quartz and small amounts of deformed calcite.



Figure 8.3 Observed at 10x magnification. In XN, deformed elongated calcite surrounded by subhedral quartz.



Figure 8.4 Observed at 10x magnification. In XN, deformed calcite grain grown between deformed and subhedral quartz grains.



Figure 8.5 Observed at 10x magnification. In XN, large, elongated, deformed calcite intergrown between subhedral quartz grains.



Figure 8.6 Observed at 10x magnification. In XN, subhedral undulose quartz with intergrown deformed calcite grains acting as cementing material.



Figure 8.7 Observed at 10x magnification. In XN, deformed calcite grains in between quartz, acting as cementing material. quartz appears to be anhedral to subhedral.



Figure 8.8 Observed at 10x magnification. In PL, blue dye represents the open pore spaces in the thin section, estimating 5% porosity overall.



Figure 8.9 Observed at 10x magnification. In PL, blue dye represents the open pore spaces in the thin section, estimating 5% porosity overall.



Figure 8.10 Observed at 10x magnification. In PL, blue dye represents the open pore spaces in the thin section, estimating 5% porosity overall.



Figure 8.11 Observed at 10x magnification In PL, blue dye represents the open pore spaces in the thin section, estimating 5%

Thin Section Analysis Report		
	4710701266	
WD-7	4/10/01266	
Sandstone		
4215.8 ft	Observed @ 10x	
6/5/2017		
Eric Hirschfeld		
Texture	Comments	
Average grain size is apporximately 300-400 microns	Inequigranular; Non-homogeneous;	
	Clastic;	
g subangular to subrounded		
g moderately sorted		
ion/Detrital Minerals	Comments	
Quartz		
e n/a		
e 70% composition; undulose quartz; subhedral;	Figures 7.1 through 7.7	
intergrown grains; deformed sub-grains but still		
monocrystalline; rew polycrystalline grains but are		
insignificant to total composition		
arains are easily observed via petrossene		
e grants are easily observed via petroscope		
Feldenar		
sunangular grain: albite twinning <1% composition:	no figures	
XN: black/white	ine ingeneer	
n/a		
e subangular grain: tartan twinning: <1% composition:	no figures	
XN: black/white		
,		
Carbonate		
29-30% composition; deformed grains; globular,	Figures 7.4 through 7.7	
elgongated, intergrown grains between quartz; XN:		
tan/pink, PL: transparent		
e n/a		
e n/a		
Clay		
e n/a		
2 II/d	no finunco	
e <1% composition; small, oblate grains; XN: green,	no ligures	
orange, blue, plink FL. transparent		
1// 0		
ock Fragments		
/ Predominantly sedimentary detrital fragments		
, ,		
c n/a		
c n/a		
Accessory Minerals)		
enting Materials	Comments	
z very well cemented intergrown quartz grains;	Figures 7.4 through 7.6	
r n/a		
e Calcite fills in some of the pores spaces and acts as a	Figures 7.4 through 7.6	
secondary cementing material		
,		
/ n/a		
y n/a e n/a		
y n/a 2 n/a r n/a		
y n/a 2 n/a r n/a I Porosity Estimate	Comments	
	WD-7 Oriskany Sandstone Wood County, WV Sandstone 4215.8 ft 6/5/2017 Eric Hirschfeld Texture 2 Average grain size is apporximately 300-400 microns 3 subangular to subrounded 3 moderately sorted ion/Detrital Minerals Quartz 9 n/a 7 0% composition; undulose quartz; subhedral; intergrown grains; deformed sub-grains but still monocrystalline; few polycrystalline grains but are insignificant to total composition e grains are easily observed via petroscope Feldspar 9 subangular grain; albite twinning; <1% composotion; XN: black/white 10 a 9 subangular grain; tartan twinning: <1% composition; XN: black/white 10 a 10 carbonate 2 29-30% composition; deformed grains; globular, elgongated, intergrown grains between quartz; XN: tan/pink, PL: transparent 9 n/a 10 clay 10	



Figure 7.1 Observed at 10x magnification. In XN, subhedral, intergrown undulose quartz grains. Quartz is acting as cementing material. Some deformed grains.



Figure 7.3 Observed at 10x magnification. In XN, anhedral to subhedral , undulose quartz grains. Quartz is the cementing



Figure 7.2 Observed at 10x magnification. In XN, subhedral , undulose quartz grains. Overgrown quartz grains. Also present, subhedral to euhedral calcite grains.



Figure 7.4 Observed at 10x magnification. In XN, Subhedral quartz and slightly globular calcite that is interspersed between quartz grains acting as a cementing material.



Figure 7.5 Observed at 10x magnification. In XN, globular, deformed calcite grain surrounded by subhedral grains of quartz.



Figure 7.6 Observed at 10x magnification. In XN, interspersed calcite in between quartz grains. Subhedral quartz grains with calcite cement.



Figure 7.7 Observed at 10x magnification. In XN, anhedral to subhedral quartz grains. some slight deformation from quartz growth.



Figure 7.8 Observed at 10x magnification. In PL, the blue dye represents the open spaces in the thin section, estimating to about 8% porosity overall.



Figure 7.9 Observed at 10x magnification. In PL, the blue dye represents the open spaces in the thin section, estimating to about 8% porosity overall.



Figure 7.10 Observed at 10x magnification. In PL, the blue dye represents the open spaces in the thin section, estimating to about 8% porosity overall.



Figure 7.11 Observed at 10x magnification. In PL, the blue dye represents the open spaces in the thin section, estimating to about 8% porosity overall.

Thin Section Analysis Report		
Samula ID:	WD C	4710701266
Comptend Member Name:	WD-0 Orickany Sandstone Wood County, WW	4/10/01286
ormation/Wember Name:	Conditione wood County, wv	
anth /Donth Bongo		Observed @ 10v
eptil/Deptil Kange.	4213:5 It 6/6/2017	Observed @ 10x
ale of Analysis.	0/0/2017	
naiyzeu by.	Lite misement	
	Texture	Comments
Grain Size	average grain size= approx $0.5 \text{ to } 0.75 \text{ mm}$	clastic: Homogeneous
Rounding	subangular to subrounded: mostly subrounded	
	,,,,,,,	
Sorting	moderately to well sorted	
Compositi	on/Detrital Minerals	Comments
Debum setelling	Quartz	
Polycrystalline	n/a	Figure C.4
wonocrystalline	80% composition; undulose quartz; subnedral;	Figure 6.1
	intergrown grains; some deformed grains; moderate	
	relief; most grains are large ranging from 0.5 to 1mm	
Microcrystalling	grains are easily observed via petroscope	
When our ystalline	grains are easily observed via perfoscope	
	Feldspar	
Plagioclase	n/a	
Orthoclase	n/a	
Microcline	<0.1% composition, tartan twinning, subrounded;	no figure
	subhedral	
	Carbonate	
Calcite	20% composition; globular texture; anhedral but	Figure 6.2 through Figure 6.5 and
	some grains appear to be subhedral; moderate	Figure 6.7
	birefringence; XN: tan/pink	
Dolomite	n/a	
Aragonite	n/a	
	Clay	
lilite Cura stite	n/a	
Smectite	n/a	
Kaolinite	n/a	c
Muscovite	<0.1% composition; approx <100 microns in size;	nofigure
	deformed grains; XPL: green, blue,ornage	
Chlorite	n/a	
Glauconite	n/a	
Cladeonite	.,	
<u>Rc</u>	ock Fragments	
Sedimentary	Predominantly sedimentary rock fragements	
Volcanic	n/a	
Metamorphic	n/a	
	Accessory (Minerela)	
Other (/		
Ceme	enting Materials	Comments
Quartz	Quartz intergrowth present are the cementing	
	material; moderate to well cemented	
Feldspar	n/a	
Carbonate	calcite deformed between grains also acts as	Figure 6.4, Figure 6.6, Figure 6.7
	cementing material in between quartz grains;	
	moderate to well cemented	
Clav	n/a	
Iron Oxide, Hydoxide and/or Sulfide	n/a	
Other	n/a	
Viewel	Devesity Estimate	Commente

	Visual Porosity Estimate	Comments
Visual Porosity Estimate	9% porosity	Figure 6.8 through Figure 6.12

Appalachian Storage Hub Project



Figure 6.1 Observed at 10x magnification. In XPN subhedral, intergrown, undulose quartz grains. Quartz is the acting cementing material.



Figure 6.2 Observed at 10x magnification. In XPL, subhedral undulose quartz grains and a subhedral calcitee grain.



Figure 6.3 Observed at 10x magnification. In XN, globular grain of calcite with subhedral, subrounded undulose quartz grains.



Figure 6.4 Observed at 10x magnification. In XN, globular calcite grain and calcite cementing material in between subhedral quartz grains.



Figure 6.5 Observed at 10x magnification. In XN, Deformed quartz grains with some globular calcite grains.



Figure 6.6 Observed at 10x magnification. In XN, quartz grains being cemented by both quartz growth and carbonate material calcite.



Figure 6.7 Observed at 10x magnification. In XN, massive globular calcite grain with some slightly deformed undulose quartz grains.



Figure 6.8 Observed at 10x magnification. In PL, the blue dye indicates the open pores spaces in the thin section. This thin section has an estimated 9% porosity overall.



Figure 6.9 Observed at 10x magnification. In PL, the blue dye indicates the open pores spaces in the thin section. This thin section has an estimated 9% porosity overall.



Figure 6.10 Observed at 10x magnification. In PL, the blue dye indicates the open pores spaces in the thin section. This thin section has an estimated 9% porosity overall.



Figure 6.11 Observed at 10x magnification. In PL, the blue dye indicates the open pores spaces in the thin section. This thin section has an estimated 9% porosity overall.



Figure 6.12 Observed at 10x magnification. In PL, the blue dye indicates the open pores spaces in the thin section. This thin section has an estimated 9% porosity overall

	Thin Section Analysis Report	
Sample ID: Formation/Member Name: Lithologic Classification:	WD-5 Oriskany Sandstone Wood County, WV Sandstone	4710701266
Depth/Depth Range:	4212.1 ft	Observed @ 10x
Date of Analysis:	6/8/2017	
Analyzed by:	Eric Hirschfeld	
	Toyturo	Comments
Grain Size	range of grain size = approx $0.01 \text{ mm to } 1\text{ mm}$	clastic
Rounding	subangular	
Sorting	moderately sorted	
Compositi	ion/Detrital Minerals	Comments
	Quartz	
Polycrystalline	n/a	
Monocrystalline	75% composition; undulose quartz; anhedral to	Figure 5.1 through Figure 5.6
	subhedral; interspersed grains; deformed grains	
Microcrystalline	grains are easily observed via petroscope	
	Feldspar	
Plagioclase	albite twinning; small; subhedral; <0.1% composition	no figure
Orthoclase	n/a	
Microcline	tartan twinning; small; subhedral; <0.1% composition	no figure
	Carbonata	
Calcite	25% composition: globular texture: fills in pores in	Figure 5.1 through Figure 5.6
Calcite	between quartz grains: some subangular grains: semi-	-
	elongated texutre on some grains: deformation	
	structures	
Dolomite	n/a	
Aragonite	n/a	
	Clay	
Smectite	n/a	
Kaolinite	n/a	
Muscovite	n/a	
Chlorite	n/a	
Glauconite	n/a	
	ock Fragments	
Sedimentary	Predominantly sedimentary rock fragments; detrital	Figure 5.1 through Figure 5.6
17-1	seuments of quartz	
Volcanic	n/a	
Metamorphic	n/a	
Other (/	Accessory Minerals)	
???	WD5_0036, WD5_0037	
Ceme	enting Materials	Comments
Quartz	Quartz normal Growth and intergrowth of grains act	
	as cementing material; moderately to well cemented	
Feldspar	n/a	
Carbonate	Calcite acts as carbonate cement material, fillin in	Figure 5.1 through Figure 5.6
	pore spaces between quartz grains; globular texture;	-
	irregularshaped, possibly from deformation	
	,	
Clay	n/a	
Iron Uxide, Hydoxide and/or Sulfide	n/a	
Other	n/a	
Visual	Porosity Estimate	Comments
Visual Porosity Estimate	11% porosity	Figure 5.7 through 5.12
· · · · · , - · · · · · ·	· · · · ·	J



Figure 5.1 Observed at 10x magnification. In XN, Slightly deformed undulose quartz grains with semi-elongated calcite grain



Figure 5.2 Observed at 10x magnification. In XN, anhedral and slightly deformed undulose quartz with a elongated calcite grain deformed from quartz growth, acting as cementing material.



Figure 5.3 Observed at 10x magnification. In XN, anhedral calcite grain with anhedral to subhedral undulose quartz grains. Quartz intergrowth is evident



Figure 5.4 Observed at 10x magnification. In XN, subhedral and slightly deformed undulose quartz. Some interspersed grains.



Figure 5.5 Observed at 10x magnification. In XN, subhedral undulose quartz grains cemented together by deformed calcite



Figure 5.6 Observed at 10x magnification. In XPL, subhedral and slightly deformed quartz grains with quartz cementing. Also a few deformed calcite grains.



Figure 5.7 Observed at 10x magnification. In PL, blue dye exhibts the open pore spaces in the thin section. the estimated porosity of the thin section is 11% overall



Figure 5.9 Observed at 10x magnification. In PL, blue dye exhibts the open pore spaces in the thin section. The estimated porosity of the thin section is 11% overall.



Figure 5.8 Observed at 10x magnification. In PL, blue dye exhibts the open pore spaces in the thin section. the estimated porosity of the thin section is 11% overall



Figure 5.10 Observed at 10x magnification. In PL, blue dye exhibts the open pore spaces in the thin section. The estimated porosity of the thin section is 11% overall.



Figure 5.11 Observed at 10x magnification. In PL, blue dye exhibts the open pore spaces in the thin section. The estimated porosity of the thin section is 11% overall



Figure 5.12 Observed at 10x magnification. In PL, blue dye exhibts the open pore spaces in the thin section. The estimated porosity of the thin section is 11% overall

Thin Section Analysis Report		
Sample ID:	WD-4	4710701266
Sample ID.	Oriskany Sandstone Wood County W/V	4/10/01200
Lithelesis Clessification	Candistano	
	Sandstone	0 0 0 0
Depth/Depth Range:	4209 ft	Observed @ 10x
Date of Analysis:	6/9/2017	
Analyzed by:	Eric Hirschfeld	
	Texture	Comments
Grain Size	average grain size= approx. 150 microns	clastic
Rounding	subangular to subrounded	
Sorting	moderately sorted	
Solung	moderately softed	
Compositi	on/Detrital Minorals	Commonts
compositi	Quartz	conments
Polycrystalling	n/a	
Polyciystallile		
Monocrystalline	80% composition; annedral to subhedral grains;	Figure 4.1 through Figure 4.8
	deformed grains from growth, undulose quartz	
Microcrystalline	grains are easily observed via petroscope	
	Feldspar	
Plagioclase	<1% composition; subhedral; subangular; albite	no Figure
	twinning	
Quite!	n/a	
Urthoclase	11/a	
Microcline	n/a	
	Carbonate	
Calcite	20% composition; anhedral, deformed grains; XPL;	Figure 4.3 through Figure 4.8
	pink/tan, PPL: transparent; moderate birfringence	
Dolomite	n/a	
Aragonite	n/a	
Alagonite	17.0	
	Clav	
	n/a	
Smertite	n/a	
Kaalinita		
Raomite		
IVIUSCOVITE	n/a	
Chlorite	n/a	
Glauconite	n/a	
KC	Detrital adimentary fragments are deminent in the	
Sedimentary	Detrital sedimentary fragements are dominant in the	
	thin section and is mostly quartz	
Volcanic	n/a	
Metamorphic	n/a	
Other (/	Accessory Minerals)	
·····	n/a	
Ceme	enting Materials	Comments
Quartz	Normal quartz growth, overgrowth, and intergrowth	Figure 4.3 through Figure 4.8
-	of the grains cement each other together:	
	moderately cemented	
Eoldenar	n/a	
reluspar	nyu	Figure 4.2 through Figure 4.0
Carbonate	calcite deformations and globular textured grains act	Figure 4.3 through Figure 4.8
	as cementing materials	
Clay	n/a	
Iron Oxide, Hydoxide and/or Sulfide	n/a	
Other	n/a	
Visual	Porosity Estimate	Comments
Visual Porosity Estimate	13% porosity	Figure 4.9 through Figure 4.12



Figure 4.1 Observed at 10x magnification. In XPL, subhedral, undulose quartz gains. Exhibits quartz growth that results in slight deformation.



Figure 4.2 Observed at 10x magnification. In XPL, anhedral to subhedral, undulose quartz. Exhibits quartz intergrowth. Also some deformed calcite grains.



Figure 4.3 Observed at 10x magnification. In XPL, Anhedral and subhedral undulose quartz . some deform grains from interspersion. Elongated and deformed calcite grains.



Figure 4.5 Observed at 10x magnification. In XPL, subhedral undulose quartz grains with some deformation growth with a few deformed calcite grains. Exhibits both quartz and carbonate



Figure 4.4 Observed at 10x magnification. Deformed undulose quartz grains with deformed calcite grains acting as cementing material. Calcite exhibits some lamellar twinning.



Figure 4.6 Observed at 10x magnification. In XPL, deformed, globular calcite grain cementing together subhedral, undulose quartz grains..



Figure 4.7 Observed at 10x magnification. In XPL, deformed calcite grain and calcareous cement with subrounded, subhedral, undulose quartz grains. Some grains are slightly deformed from growth.



Figure 4.8 Observed at 10x magnification. In XPL, Deformed, undulose quartz grains with calcareous cementing materials.



Figure 4.9 Observed at 10x magnification. In PPL, the blue dye exhibits the open pore spaces in the thin section. Visual estimate



Figure 4.10 Observed at 10x magnification. In PPL, the blue dye exhibits the open pore spaces in the thin section. Visual estimate of porosity is 13% porous.



Figure 4.11 Observed at 10x magnification. In PPL, the blue dye exhibits the open pore spaces in the thin section. Visual estimate of porosity is 13% porous.



Figure 4.12 Observed at 10x magnification. In PPL, the blue dye exhibits the open pore spaces in the thin section. Visual estimate of porosity is 13% porous.

Thin Section Analysis Report		
Comple ID:		471070126
Sample ID: Formation (Mombor Nome)	WD-3 Oriskapy Sandstone Weed County W/V	4/10/0126
Formation/ Member Name:	Sandstone	
Denth /Denth Bangar	ADDE ft	Observed @ 10v
Depth/Depth Range:	4206 IL 6/0/2011	Observed @ 10x
Analyzed by:	Fric Hirschfeld	
anaryzeu by.		
	Texture	Comments
Grain Size	average grain size ranges from 50 microns to 2 mm	clastic
Rounding	subangular to subrounded	
Sorting	g poorly sorted	
Composit	ion/Detrital Minerals	Comments
	Quartz	
Polycrystalline	n/a	
Monocrystalline	60% composition; anhedral to subhedral; undulose	Figure 3.1 and Figure 3.2
	quartz; quartz overgrowth and intergrowth;	
	deformed grains	
Microcrystalline	grains are easily observed via petroscope	
	Foldspar	
Diagioclass	n/a	
Orthoolse	n/a	
Microcline	n/a	
When Ochine	· · · / -	
	Carbonate	
Calcite	40% composition; deformed grains; semi-fibrous;	Figure 3.3 through Figure 3.9
	some subangular grains: anhedral to euhedral:	0 0 0
	texture in some locations appear to be lamellar	
	twinning: mostly deformed globular grains: one	
	massive deforemed grain of calcite. >3mm	
	hassive detotemed grain of calcice, somm	
Dolomite	n/a	
Aragonite	n/a	
, 1050110		
	Clay	
Illite	e n/a	
Smectite	e n/a	
Kaolinite	e n/a	
Muscovite	e n/a	
Chlorite	e n/a	
Glauconite	e n/a	
R	ock Fragments	5
Sedimentary	Predominantly sedimentary detrital minerals and	Figure 3.9
	rock tragments with a miniscule traces of volcanic	
	Tragments	
Volcanio		
Metamorphic	: n/a	
Othor (Accessory Minerals)	
	unidentifiable mineral	Images: WD3_0011 and WD3_0012
Cem	enting Materials	Comments
Quartz	comented	Figure 3.1 through Figure 3.8
Ealdena	· n/a	
Carbonate	Predominantly calcite, comenting material: calcite	Figure 3.1 through Figure 2.9
Carbonate	fills in nores between quarts grains, acting as resi-	ingule 3.1 through right 2.0
	cementing material: moderately to well cemented	
	concluding material, moderately to well temefiled	
Clay	r n/a	
Iron Oxide Hydoxide and/or Sulfide	n/a	
Other	· ., - · n/a	
Other		
Visua	Porosity Estimate	Comments



Figure 3.1 Observed at 10x magnification. In XN, subhedral undulose quartz grains cemented together by quartz growth



Figure 3.3 Observed at 10x magnification. In XN, Anhedral, undulose quartz grains grown with and cemented by anhedral, deformed calcite grains. Also quartz grains exhibit quartz intergrowth. Slight



Figure 3.5 Observed at 10x magnification. In XN, large andhedral, undulose quartz grains that are cemented together by quartz growth. Also an euhedral clacite grain.



Figure 3.2 Observed at 10x magnification. In XN, anhedral, undulose quartz grains that is calcareously cemented. Also quartz grains show example of overgrowth.



Figure 3.4 Observed at 10x magnification. In XN, anhedral, deformed undulose quartz grains cemented together by both quartz growth and deformed calcite or calcareous material.



Figure 3.6 Observed at 10x magnification. In XN, subrounded, anhedral quartz grains in a calcareous cement material.



Figure 3.7 Observed at 10x magnification. In XN, anhedral, slighlty deformed quartz grains that are cemented mostly by deformed calcite.



Figure 3.9 Observed at 10x magnification. In XN, portion of massive deformed calcite grain. Exhibits small sedimentary rock fragments and anhedral to subhedral calcite grains.



Figure 3.11 Observed at 10x magnification. In PL, blue dye represents the open pores spaces in the thin section, estimating of about 7% porous



Figure 3.8 Observed at 10x magnification. In XN, subhedral undulose monocrystalline quartz grains cemented together along with cemented of deformed calcite grains.



Figure 3.10 Observed at 10x magnification. In PL, blue dye represents the open pores spaces in the thin section,



Figure 3.12 Observed at 10x magnification. In PPL blue dye represents the open pores spaces in the thin section, estimating of about 7% porous

	Thin Section Analysis Report		
ample ID:		471070126	
ample ID.	WD-2 Oriskany Sandstone Weed County WV	4/10/0120	
thologic Classification:	Sandstone		
enth/Denth Bange:	4200.2 ft	Observed @ 10v	
ate of Analysis:	6/9/2017 6/9/2017		
nalyzed by:	Fric Hirschfeld		
nalyzeu by.			
	Texture	Comments	
Grain Size	grain size range = approx 50 microns to 500 microns	homogeneous; massive texture;	
Dounding	subangular	Clastic	
Sorting	subaliguiar		
501 ting	very wen sorted		
Compositi	on/Detrital Minerals	Comments	
	Quartz		
Polycrystalline	n/a		
Monocrystalline	1% composition; subrounded; subhedrai; undulose	Figure 2.1 through Figure 2.3 and	
Microcrystalling	quartz	Figure 28	
Microcrystalline	most grains are visible under the petroscope		
	Feldspar		
Plagioclase	n/a		
Orthoclase	n/a		
Microcline	n/a		
	Carbonate		
Calcite	97% composition; massively grained, some	Figure 2.6, Figure 2.7	
	elongated grains; deformation structures; Euhedral		
	to anhedral; grain size 500 microns to 500 microns;		
	dominant mineral in thin section		
Dolomite	n/a		
Aragonite	n/a		
	Clay		
Illite	n/a		
Smectite	n/a		
Kaolinite	n/a		
Muscovite	n/a		
Chlorite	n/a		
Glauconite	2% composition; small subangular; anhedral to		
	subhedral; XN: dark green, PL: light green/light olive		
R	ock Fragments		
Sedimentary	Predominantly sedimentary fragments of detrital	Figure 2.6, Figure 2.9 through Figure	
· · · ,	rocks	2.12	
Volcanic	some volcanic rock fragments dispersed		
Metamorphic			
·			
Other (/	Accessory Minerals)		
Cemo	enting Materials	Comments	
Quartz	n/a		
Feldspar	n/a		
Carbonate	completely carbonate cementing; entire smaple is deformed calcite with some residual grains		
Clay	n/a		
iron Uxide, Hydoxide and/or Sulfide	n/a n/a		
Other	ιı/α	_	
Visual	Porosity Estimate	Comments	
isual Porosity Estimate	U% Porosity		



Figure 2.1 Observed at 10x magnification. In XN (unbalanced lighting), subhedral, undulose quartz grain surrounded by deformed calcite grains and calcareous cement



Figure 2.3 Observed at 10x magnification. In XN (unbalanced lighting), anhedral, undulose quartz grain surrounded by anhedral and deformed calcite grains.



Figure 2.5 Observed at 10x magnification. In XN (balanced lighting), anhredal grains of greenish glauconite grown with deformed calcite grains and a few anhedral calcite grains all within a calcareous cement.



Figure 2.2 Observed at 10x magnification. In XN (unbalanced lighting), subhedral, undulose quartz grain surrounded by elongated, defromed calcite grains, subhedral calcite grains and calcareous cement



Figure 2.4 Observed at 10x magnification. In XN (balanced lighting), anhedral, greenish glauconite grains with deformed calcite growth and some euhedral calcite grains.



Figure 2.6 Observed at 10x magnification. In XN (balanced lighting), few euhedral calcite grains, deformed calcite growths and the black dots are detrital sedimentary rock fragments.



Figure 2.7 Observed at 10x magnification. In XN (balanced lighting) elongated, deformed calcite grains within a calcareous cement



Figure 2.9 Observed at 10x magnification. In XN (unbalanced light) deformed glauconite, black sedimnetary rock fragments, and euhedral and deformed calcite grains winth a calcareous cement.



Figure 2.11 Observed at 10x magnification. In XN (balanced lighting) subedral to eudhedral calcite grains, deformed, slightly elongated calcite grains and sedimentary rock fragments.



Figure 2.8 Observed at 10x magnification. In XN (unbalanced lighting), anhedral, undulose quartz grain surrounded by multiple euhedral to anhedral calcite grains, all within a calcareous cement.



Figure 2.10 Observed at 10x magnification. In XN (balanced lighting), anhedral grains of glauconite (green), sedimentary rock fragments (black) and calcite, all in a calcareous



Figure 2.12 Observed at 10x magnification. In XN (balanced lighting), euhedral clacite grain surounded by deformed calcite growth, sedimnetary rock fragments and calcareous

Thin Section Analysis Report		
Comula ID:	WD 1	4710701266
Sample ID.	WD-1 Oriskany Sandstana Wood County W/V	4/10/01200
Lithologic Classification:	Sandstone	
Donth /Donth Bangay		Observed @ 10v
Depth/Depth Range:	4197.1 ft	Observed @ 10x
Date of Analysis:	6/9/201	
Analyzed by:	Eric Hirschfeld	
	Texture	Comments
Grain Size	average grain size= Approx. 50 microns	homogeneous; massive texure
Rounding	angular to subangular	
Sorting	well sorted	
Compositi	on/Detrital Minerals	Comments
Compositi	Ouartz	connicito
Polycrystalline	n/a	
Monocrystalline	n/a	
Microcrystalline	most grains are visible under netroscone	
When ber ystamme		
	Feldspar	
Plagioclase	n/a	
Orthoclase	n/a	
Microcline	n/a	
	Carbonate	
Calcite	100% composition; low birefringence; euhedral to	Figures 1.1 through 1.12
	anhedral grains; deformation structures of calcite	
	grains; some grains globular; some grains semi-	
	fibrous; XN: tan-pink, light brown, PL: light brown,	
	tan white	
Dolomite	n/a	
Aragonite	n/a	
	-	
	Clay	
Smertite	n/a	
Kaolinito	n/a	
Kaolilite		
Nuscovite	n/a	
Chiorite	n/a	
Glauconite	n/a	
Rc	ock Fragments	
Sedimentary	Multiple remnants of detrital sedimentary rock	Figures 1.1 through 1.12
	fragments	
Volcanic	n/a	
Metamorphic	n/a	
Other //	Accessory Minerals)	
	n/a	
	n/a	
	n/a	
C	ning Matorials	Comments
Ceme		comments
Quartz	n/a	
relaspar Carbonata	nya Deformed calcite grains: calcaroous mud acting as	Figures 1.1 through 1.12
Carbonate	the comparing materials entire as well in white	rigui es 1.1 tiliougn 1.12
	the cementing material; entire sample is calcite; ver	4
	weil cemented	
Clay	n/a	
Iron Oxide, Hydoxide and/or Sulfide	n/a	
Other	n/a	
Vieual	Porosity Estimate	Comments
Visual Porosity Estimate	0% porosity	Images: WD1_0001 through
the state of the s	one policity	WD1_0020
		VVD1_0020



Figure 1.1 Observed at 10x magnificationIn XN, deformed calcite grains, calcite cement semi-fibrous texture.



Figrue 1.3 Observed at 10x magnification. In XN, highly deformed calcite grains intergrown and some subhedral calcite grains



Figure 1.5 Observed at 10x magnification. In XN, deformed semi-fibrous calcite grain, anhedral and subhedral calcite grains. Calcareous cement



Figure 1.2 Observed at 10x magnification. In XN, euhedral calcite grains and deformed calcite grains in a calcareous cement.



Figure 1.4 Observed at 10x magnification. In XN, masssive, globular calcite grain, some anhedral calcite grains



Figure 1.6 Observed at 10x magnification. In XN, massive, deformed calcite growth. Euhedral and subhedral calcite grains. Few remnants of detrital sedimnetray rock fragments



Figure 1.7 Observed at 10x magnification. In XN, massive, semiglobular, deformed calcite growth, euhedral and subhedral clacite grains, calcareous cement.



Figure 1.9 Observed at 10x magnification. In XN, massive, subhedral calcite grain surrounded by smaller anhedral to subhedral calcite grains. All within a calcareous cement.



Figure 1.11 Observed at 10x magnification.In XN, anhedral to subhedral grains of calcite in calcareous cement. Few sedimentary rock fragments



Figure 1.8 Observed at 10x magnification. In XN,many euhedral to anhedral calcite grains. Large deformed calcite growth



Figure 1.10 Observed at 10x magnification. In XN, subhedral to euhedral calcite grains. Some deformation of grains within calcareous cement



Figure 1.12 Observed at 10x magnification. In XN, euhedral calcite grains and deformed grains within calareous cement. Also present is a few sedimentary rock fragments.

Sample ID:	\N/7_1	
Sample ID: Formation/Member Name:	WZ-1 Weir	
Lithologic Classification:	Sandstone/Graywacke	
Depth/Depth Range:	2462 7 ft	
Date of Analysis:	6/28/2017	
Analyzed by:	S. Shank	
	Texture	Comments
Gr	ain Size very fine-grained, 62-125 μ	very fine-grained dirty sandstone, clays appear to be from alteration of feldspar, detrital and cement?, sparse carbonate
Ro	bunding subangular Sorting	
Compo	sition/Detrital Minerals	Comments
	Quartz	
Polycry	vstalline <<1%	
Monocry	vstalline 65%	
Microcry	vstalline	
	Feldspar	
Pla	gioclase 10%	
Ort	hoclase	rough estimates, now strongly altered to sericite
Mid	crocline 10%	
	Carbonate	
	Calcite	
D	olomite	
Ar	agonite	
	Clay	
c	mactita	
3 K		
M	iscovite <1%	few scattered flakes biotite also?
1010	Chlorite 5%	scattered greenish grunge
Gla	uconite	
	Rock Fragments	
Sedin	nentary	
N	/olcanic	
Metar	norphic	
Othe	r (Accessory Minerals)	
Ce	menting Materials	Comments
	Quartz	minimal, difficult to observe because very fine-grained
F	eldspar	
Car	rbonate 2%	scattered patches
	Clay 8%	rough guess, hard to distinguish from detrital clay, altered
		feldspar
Iron Oxide, Hydoxide and/or	Sulfide	
	Other	
Viso	ual Porosity Estimate	Comments
	<<1%	no porosity except for thin discontinuous fracture

50x magnification, 2.5 mm field of view



Sample ID:	WZ-2	
Formation/Member Name:	Weir Consistence (Consistence)	
Lithologic Classification:	Sandstone/Graywacke	
Depth/Depth Range:	2474.911	
Date of Analysis:	0/28/2017 S. Shank	
Analyzeu by.	5. Shank	
	Texture	Comments
	Grain Size very fine-grained, 62-125µ	very fine-grained dirty sandstone, clays appear to be from alteration of feldspar, detrital and cement?, sparse carbonate
	Rounding subangular to subrounded Sorting well sorted	
Com	position/Detrital Minerals	Comments
	Quartz	
Pol	ycrystalline	
Mone	ocrystalline 65%	
Micro	ocrystalline	
	Feldspar	
	Plagioclase 10%	
	Orthoclase	rough estimates, now strongly altered to sericite, alteration to carbonate also?
	Microcline 10%	
	Carbonate	
	Calcite 2%	scattered grains and patches
	Dolomite	
	Aragonite	
	Clay	
	Illite	
	Smectite	
	Kaolinite	
	Muscovite <1%	few scattered flakes, biotite also?
	Chlorite 5%	scattered greenish grunge
	Glauconite	
	Rock Fragments	
Se	edimentary <1%	1 mm shale clast
	Volcanic	
Me	etamorphic	
0	ther (Accessory Minerals) opaques	
	Cementing Materials	Comments
	Quartz	
		minimal, difficult to observe because very fine-grained
	Feldspar	
	Carbonate 2%	scattered patches
	Clay 8%	rough guess, hard to distinguish from detrital clay, altered feldspar
Iron Oxide, Hydoxide and	d/or Sulfide	
	Other	
	Visual Porosity Estimate	Comments
	<<1%	
		virtually no porosity except for thin discontinuous fractures

50x magnification, 2.5 mm field of view



	<<1%	virtually no porosity
	Visual Porosity Estimate	Comments
	Other	
Iron Oxide. Hydoxid	e and/or Sulfide	· · · · · · · · · · · · · · · · · · ·
		altered feldspar
	Clav 8%	rough guess hard to distinguish from detrital clay
	Carbonate 2%	scattered patches
	Feldspar	5
	Quartz	grained
	Quartz	minimal, difficult to observe because very fine-
	Cementing Materials	Comments
	opaques	
	Other (Accessory Minerals)	
	metanorphic	
	VOIcallic	
	Volcanic	
	Sedimentary	
	Rock Fragments	
	Glauconite	
	Chlorite 5%	scattered greenish grunge
	Muscovite <1%	few scattered flakes, biotite also?
	Kaolinite	
	Smectite	
	lilite Con a stitu	
	Aragonite	
	Dolomite	
	Calcite 2%	scattered grains and patches
	Carbonate	
	Microcline 10%	
		alteration to carbonate also?
	Orthoclase	rough estimates, now strongly altered to sericite.
	Plagioclase 10%	
	Feldspar	
	Microcrystalline	
I	Monocrystalline 65%	
	Polycrystalline	
	Quartz	connents
	Composition/Detrital Minerals	Comments
	Sorting well sorted	
	Rounding subangular to subrounded	
	Devending as here as least a sub-second ad	cement?, sparse carbonate
		be from alteration of feldspar, detrital and
	Grain Size very me-grained, 02-125µ	be from alteration of foldspar, detrital and
	Grain Size very fine-grained 62-125u	very fine-grained dirty sandstone, clays annear to
	Texture	Comments
Analyzed by:	S. Snank	
Analyzed by:	0/20/201/ S. Shank	
Depthy Depth Range.	6/29/2017	
Donth / Donth Pongo:	2492 E ft	
Lithologic Classification:	Sandstone/Graywacke	
Formation/Member Name	e Weir	
	WZ-3	

50x magnification, 2.5 mm field of view



Comple ID:	N/7 A	
Sample ID: Formation/Member Name:	WZ-4 Weir	
Lithologic Classification:	Sandstone/Graywacke	
Depth/Depth Range:	2489.8 ft	
Date of Analysis:	6/28/2017	
Analyzed by:	S. Shank	
Т	exture	Comments
Grai	in Size very fine-grained, 62-125 μ	
		very fine-grained dirty sandstone, clays appear to be from alteration of feldspar, detrital and cement?, carbonate
Rounding subangular to subround		
Si	orting well sorted	
Composition	/Detrital Minerals	Comments
	Quartz	
Polycrystalline		
Monocrystalline 75%		
Microcryst	talline	
-		
F	eldspar	
Plagio	oclase 5%	
Ortho	oclase	rough estimates, now strongly altered to sericite, alteration
		to carbonate also?
Micro	ocline 5%	
Ca	arbonate	
	Calcite 2%	scattered grains and patches
Dol	omite	
Arag	gonite	
	Clay	
C m	lille	
Sm		
Kac	olinite	
Muscovite <1%		few scattered flakes, blotite also?
Chlorite 5%		scattered greenish grunge
Glaud	conite	
Rock	Fragments	
Sedime	entary	
Vo	lcanic	
Metamo	orphic	
Other (Acc	cessory Minerals)	
	opaques	
Cement	ting Materials	Comments
		connents
C	Quartz	minimal, difficult to observe because very fine-grained
Feldspar		
Carb	onate 2%	scattered patches
	Clay 8%	rough guess, hard to distinguish from detrital clay, altered
		feldspar
Iron Oxide, Hydoxide and/or Sulfide		
	Other	
Visual Do	prosity Estimate	Comments
	1%	some intergranular porosity, patchy occurrence, few thin
		fractures

25x magnification, 5mm field of view



Iron Oxide, Hydoxide and Vi	Feldspar Carbonate 2% Clay 8% d/or Sulfide Other sual Porosity Estimate	scattered patches rough guess, hard to distinguish from detrital clay, altered feldspar Comments
Iron Oxide, Hydoxide and	Feldspar Carbonate 2% Clay 8% d/or Sulfide Other	scattered patches rough guess, hard to distinguish from detrital clay, altered feldspar
Iron Oxide, Hydoxide and	Feldspar Carbonate 2% Clay 8% d/or Sulfide Other	scattered patches rough guess, hard to distinguish from detrital clay, altered feldspar
Iron Oxide, Hydoxide and	Feldspar Carbonate 2% Clay 8% d/or Sulfide	scattered patches rough guess, hard to distinguish from detrital clay, altered feldspar
	Feldspar Carbonate 2% Clay 8%	scattered patches rough guess, hard to distinguish from detrital clay, altered feldspar
	Feldspar Carbonate 2%	scattered patches
	Feldspar	scattored patches
	Loldsnor	
	5.11	grained
	Quartz	minimal, difficult to observe because very fine-
C	ementing Materials	Comments
opaques		
Other (Accessory Minerals)		
	- P -	
М	etamorphic	
5	Volcanic	
Sedimentary		
	Rock Fragments	
	Giauconite	
	Glauconite	Statteren Breenisii Brunge
	Chlorite 5%	iew scattered makes, piolite also?
	Naumme Muscovite <1%	few scattered flakes histite also?
	Kaolinite	
	mile Smortite	
	Clay	
	Aragonite	
	Dolomite	
	Calcite 2%	scattered grains and patches
	Carbonate	
	Microcline 5%	
		alteration to carbonate also?
	Orthoclase	rough estimates, now strongly altered to sericite,
	Plagioclase 5%	
	Feldspar	
	,	
Micr	ocrystalline	
Mon	ocrystalline 75%	
Pol	vcrystalline	
Comp	Quartz	comments
Comp	osition/Detrital Minerals	Comments
	Sorting well sorted	
	Rounding subangular to subrounded	
		cement?, carbonate
		be from alteration of feldspar, detrital and
	Grain Size very fine-grained, 62-125µ	very fine-grained dirty sandstone, clays appear to
	Crain Size yory fine grained (2, 125)	Comments
	- t	.
Analyzed by:	S. Shank	
Date of Analysis:	7/2/2017	
Depth/Depth Range:	2492.4 ft	
Lithologic Classification:	Sandstone/graywacke	
Formation/Member Name:	Weir	
Sample ID:	WZ-5	

WZ-5

25x magnification, 5mm field of view



Sample ID:	W/Z-6	
Formation/Member Name	Weir	
Lithologic Classification:	Sandstone/Graywacke	
Depth/Depth Range:	2497.5 ft	
Date of Analysis:	7/2/2017	
Analyzed by:	S. Shank	
- , ,		
	Texture	Comments
	Grain Size very fine-grained, 62-125µ	
		very fine-grained dirty sandstone, clays appear to be from alteration of feldspar, detrital and cement?, carbonate
Rounding subangular to subrounded		
	Sorting well sorted	
Comp	osition/Detrital Minerals	Comments
comp	Ouartz	comments
Poly	crystalline	
Mono	crystalline 75%	
Micro	crystalline	
	Feldspar	
Р	lagioclase 5%	
C	Orthoclase	rough estimates, now strongly altered to sericite, alteration to carbonate also?
1	Microcline 5%	
	Carbonate	
	Calcite 2%	scattered grains and patches
	Dolomite	
	Aragonite	
	Clay	
	Illite	
	Smectite	
Kaolinite		
I	Muscovite <1%	few scattered flakes, biotite also?
	Chlorite 5%	scattered greenish grunge
0	Glauconite	
	Rock Fragments	
Sec	dimentary	
	Volcanic	
Met	tamorphic	
Oti	ner (Accessory Minerals)	
	opaques	
	Cementing Materials	Comments
		comments
	Foldenar	minimal, difficult to observe because very fine-grained
reiuspar		scattered natches
Carbonate 2%		scallered palches
		rougn guess, nard to distinguish from detrital clay, altered feldspar
Iron Oxide, Hydoxide and,	or Sulfide Other	
v	isual Porosity Estimate	Comments
	2%	some intergranular porosity
		,

25x magnification, 5mm field of view
Sample ID:		WZ-3	
Formation/Member Name:		Weir	
Lithologic Classification:		Sandstone/Graywacke	
Depth/Depth Range:		2502.8 ft	
Date of Analysis:		7/2/2017	
Analyzed by:		S. Shank	
	Тех	ture	Comments
	Grain Size	very fine-grained 62-125u	very fine-grained dirty sandstone, clays appear to be
	Grain Size	very line granied, oz 125µ	from alteration of feldspar, detrital and cement?, sparse carbonate
	Rounding	subangular to subrounded	
	Sorting	well sorted	
Co	omposition/D	Detrital Minerals	Comments
	Qu	artz	
F	Polycrystalline		
M	onocrystalline	65%	
M	icrocrystalline		
	Feld	Ispar	
	Plagioclase	10%	
	Orthoclase		rough estimates, now strongly altered to sericite, alteration to carbonate also?
	Microcline	10%	
	Carb	onate	
	Calcite	2%	scattered grains and patches
	Dolomite		
	Aragonite		
	c	lay	
	Illite		
	Smectite		
	Kaolinite		
	Muscovite	<1%	few scattered flakes, biotite also?
	Chlorite	5%	scattered greenish grunge
	Glauconite		
	Rock Fr	agments	
	Sedimentary		
	Volcanic		
	Metamorphic		
	Other (Acces	sory Minerals)	
		opaques	
	Cementin	g Materials	Comments
	Ouartz	8	connents
	5.11		minimal, difficult to observe because very fine-grained
	Feidspar	29/	contrained not the co
	Carbonate	270	scattered patches
	Clay	8%	rough guess, hard to distinguish from detrital clay, altered feldspar
Iron Oxide, Hydoxide a	and/or Sulfide		
	Other		
	Visual Poro	sity Estimate	Comments
		<<1%	virtually no porosity

W2 7. jpg

Sample ID:	WZ-8	
Formation/Member Name:	Weir	
Lithologic Classification:	Sandstone/Graywacke	
Depth/Depth Range:	2516.8 ft	
Date of Analysis:	7/2/2017	
Analyzed by:	S. Shank	
	Texture	Comments
Gra	in Size very fine-grained, 62-125µ	very fine-grained dirty sandstone, clays appear to be
		from alteration of feldspar, detrital and cement?, carbonate
Rou	inding subangular to subrounded	
S	orting well sorted	
Composi	tion/Detrital Minerals	Comments
Polycrys		
Monocrys	talline 70%	
Microcrys	talline	
Where our ys	tanne	
	Feldspar	
Plagi	oclase 8%	
Orth	oclase	rough estimates, now strongly altered to sericite, alteration to carbonate also?
Micr	ocline 8%	
	Carbonate	
(Calcite 2%	scattered grains and patches
Do	omite	
Ara	gonite	
	Clay	
c.	lilite	
Sm		
Ka	olinite	
Mus	covite <1%	tew scattered flakes, biotite also?
Ci	nlorite 5%	scattered greenish grunge
Glau	conite	
<u>R</u>	ock Fragments	
Sedimo	entary	
Vo	olcanic	
Metam	orphic	
Other	Accessory Minerals)	
	opaques	
Cem	enting Materials	Comments
(Luartz	minimal, difficult to observe because very fine-grained
Fe	ldspar	
Carb	onate 2%	scattered patches
	Clay 5%	rough guess, hard to distinguish from detrital clay,
Iron Oxide, Hydoxide and/or S	Sulfide	aitereu reiuspai
	Other	
Vicua	l Porosity Estimate	Comments
Visua	0%	no apparent porosity po blue epoyy?
	0,0	no apparent porosity, no blue epoxy:



Jampe ID: WC 9 Formation/Member Name: Weir Lithologic Classification: C. Cayey Sandstone Depti/Ogent Range: 2536.8 h Date of Analysis: 6/22/2017 Analyzed by: L. Ditzler Texture Comments Grain Size very time grained, 62.125µ Rounding subrounded Sorting very well sorted Composition/Detrital Minerals Comments Quart Polycrystalline Monocrystalline Program Pro	Comula ID:	W/7 0	
Pormation/memory Name: Ver	Sample ID:	WZ-9	
Linonger, Classification: Clayer Satitastone Depti/Depti Mange: 2536.8 ht Date of Analysis: 6/22/2017 Analyzed by: L. Dittler Carlo State very fine-grained, 62-125 μ Rounding subrounded Sorting very well sorted Composition/Detrital Minerals Comments Carbonate Carbonate Carbonate Carbonate Clay Utitle Smeetite Kaolinite Muscovite Chorie Clay Volcanite Sedimentary Volcanite Cementing Materials Comments Carbonate Clay Utitle Smeetite Kaolinite Clay Volcanite Clay Comments Carbonate Clay Clay Volcanite Clay Comments Clay Comments Clay Comments Carbonate Clay Clay Clay Clay Clay Clay Clay Clay	Formation/Wember Name:	weir Clause Candatana	
Deprotyceptin Marge: 2, 258,5 ft Deter of Analysis: 6/22/2017 Analyzed by: L. Ditzler Composition/Detrital Minerals Composition/Detrital Minerals Control Section Phagiocase 1% Orthoclase Microcine Carbonate Carbonate Carbonate Carbonate Clay Illite Simettie Kaolinite Muscorite Chorite Glauconite Carbonate 1% Sectimentary Volcanic Metamorphic Carbonate 1% Carbonate 1% C	Lithologic Classification:		
Date of Analyses b/2/2017 Analyzed by: L. Ditler Comments Grain Size very fine-grained, 62-125µ Rounding subrounded Sorting very well sorted Composition/Detrital Minerals Comments Quartz Polycrystalline Polycrystalline Polycrystalline Polycrystalline Polycrystalline Polycrystalline Polycrystalline Polycrystalline Polycrystalline Polycrystalline Polycrystalline Polycrystalline Polycrystalline Polycrystalline Carbonate Carbonate Carbonate Carbonate Carbonate Carbonate Carbonate Sectifie Somettie Kaolinite Muscovite Chorite Glauconite Carbonate 1 Sedimentary Volcanic Metarorphic Carbonate 1% Carbonate	Depth/Depth Range:	2536.8 ft	
Analyzed by: L. Ditzler Texture Comments Grain Size very fine grained, 52-125µ Rounding subrounded Sorting very well sorted Comments Composition/Detrilal Minerals Comments Quartz Polycrystalline Polycrystalline 7% Microcrystalline total feldspar Plagicities Total feldspar Plagicities Total feldspar Carbonate Carbonate Carbonate Scattered grains and patches Dolomite Aragonite Aragonite Scattered grains and patches Clay Illite Section Section Muscottle Glauconite Muscottle Glauconite Glauconite Section Quartz Feldspar Carbonate 1% comments Section Chiorite Glauconite Section Z% opaques Quartz Feldspar Carbonate 1% scattered patches Quartz Feldspar Carbonate 1% scattered patches Quartz Feldspar Carbonate 1% scattered patches Clay 18% grains of muscovite and chlorite exist, but c	Date of Analysis:	6/22/2017	
Texture Comments Grain Size very fine-grained, 62-125µ. Rounding subrounded Sorting very well sorted Composition/Detrital Minerals Comments Quart Quart Polycrystalline Monocrystalline Microcrystalline Total feldspar Plagiotase 1% total feldspar Orthoclase Microcrystalline Carlten 1% scattered grains and patches Dolomite Aragonite Calcte 1% Scattered grains and patches Dolomite Aragonite Clay Illite Smectite Kaolinite Maccovite Chlorite Glauconite Sedimentary Volcanic Volcanic Metamorphic 2% Other (Accessory Minerals) Comments Quartz Feldspar Sedimentary 2% Volcanic Metamorphic Chorite Scattered patches Canttar Feldspar Cartonate 1% comments Clay 18% grains of muscovite and chlorite exist, but clays occur mostly as a cement	Analyzed by:	L. Ditzler	
Grain Size very fine-grained, 62-125µ Rounding subrounded Sorting very well sorted Composition/Detrital Minerals Comments Quart Polycrystalline 77% Microcrystalline 78 Picipor Preidspar Preidspar Preidspar Preidspar Orthoclase Microcline Carbonate Calcite 1% Dolomite Aragonite Calcite 1% Dolomite Aragonite Calcite 1% Dolomite Aragonite Smectite Kaolinite Muscovite Chorte Glauconite Cements Sedimentary Volcanic Metamorphic Cements Calcite 1% Sedimentary Volcanic Metamorphic Cother (Accessory Minerals) 2% Opaques Comments Calcite 1% Scattered grains and patches Calcite 1% Dolomite Sedimentary Volcanic Metamorphic Cother (Accessory Minerals) 2% Opaques Comments Cantonate 1% Calcite 1% Scattered patches Calcite 2% Opaques Comments Calcite 2% Opaques		Texture	Comments
Rounding subrounded Sorting very well sorted Composition/Detrital Minerals Composition/Detrital Minerals Polycrystalline Monocrystalline Plagicotase 1% Orthoclase Microcrine Cather 1% Cather 1% Scattered grains and patches Dolomite Aragonite Clay Illite Smeetite Kaolinite Muscovite Clay Illite Sedimentary Volcanic Metamorphic Cementing Materials Comments Cather 1% Scattered patches Sedimentary Volcanic Metamorphic Comments Carbonate 1% Carbonate 5% Comments Carbonate 1% Carbonate 1% Carbonate 1% Carbonate 5% Comments Scattered patches Scattered patches Scattered patches Scattered patches Scattered patches Carbonate 1% Carbonate 1% Carbonate 1% Carbonate 1% Carbonate 1% Carbonate 1% Carbonate 1% Carbonate 1% Carbonate 1% Clay 18% Scattered patches Scattered patches	Gra	in Size very fine-grained, 62-125µ	
Sorting very well sorted Composition/Detrital Minerals Outart Polycrystalline	Rou	unding subrounded	
Composition/Detrital Minerals Comments Polycrystalline Polycrystalline Monocrystalline 77% Microcrystalline Plagodase 1% total feldspar Orthodase Microcrystalline Carbonate catche 1% Carbonate scattered grains and patches Dolomite Aragonite Clay Illife Smettite Kaolinite Moscovite Chiorite Glauconite Glauconite Metamorphic Z% Other (Accessory Minerals) comments Quartz Feldspar Feldspar Scattered patches Carbonate Comments Section Opaques	S	orting very well sorted	
Polycrystalline Polycrystalline Monocrystalline Plagoclase 1% Orthoclase Microcrystalline Carbonate Smettite Kaolinite Muscovite Chiorite Glauconite Rock Fragments Sedimentary Volcanic Metamorphic 2% opaques Carbonate 1% scattered patches Carbonate 1% scattered patches Carbonate 1% grains of muscovite and chlorite exist, but clays occur mostly as a cement Iron Oxide, Hydoxide and/or Suifide Other Visual Porosity Estimate Comments Visual Porosity Estimate Comments	Composit	ion/Detrital Minerals	Comments
Polycrystalline 77% Microcrystalline 77% Microcrystalline 77% Pragiodaze 1% Orthodaze 1% Orthodaze Microcline Carbonate Carbonate Calcite 1% Dolomite Aragonite Illite Smectite Kaolinite Muscovite Chorite Glauconite Bock Fragments Sedimentary Volcanic Metamorphic Other (Accessory Minerals) 2% Cementing Materials Quartz Feldspar Carbonate 1% Carbonate 1% Carbonate 1% Carbonate 1% Carbonate 1% Carbonate 1% Carbonate 1% Carbonate 1% Muscovite Carbonate 1% Carbonate 1% Comments Co		Quartz	
Monocrystalline 77% Microcrystalline 77% Plagioclase 1% Orthoclase Microcline Calcite 1% Calcite 1% Scattered grains and patches Dolomite Aragonite Clay Illite Smeetite Kaolinite Muscovite Chorite Glauconite Rock Fragments Sedimentary Volcanic Metamorphic Cementing Materials Quartz Feldspar Carbonate 1% Carbonate 1% Clay 18% grains of muscovite and chorite exist, but clays occur mostly as a cement Iron Oxide, Hydoxide and/or Sulfide Other Visual Porosity Estimate Visual Porosity Estimate Note Comments Comments Comments Comments Carbonate 1% Comments Comments Comments Carbonate 1% Comments Comments Carbonate 1% Carbonate 1% Carbonate 1% Carbonate 1% Comments Carbonate 1% Carbonate 1% Comments Carbonate 1% Comments	Polycrys	talline	
Microcrystalline Plagioclase 13 Orthoclase Microcline Carbonate Calcte 135 Dolomite Aragonite Clay Illite Smectite Kaolinite Muscovite Chorite Glauconite Sedimentary Volcanic Metamorphic Other (Accessory Minerals) Quartz Feldspar Carbonate Carbonate Chorite Glauconite Chorite Glauconite Chorite Glauconite Chorite Comments Sedimentary Volcanic Metamorphic Other (Accessory Minerals) Quartz Feldspar Carbonate 1% Scattered patches Clay 18% grains of muscovite and chlorite exist, but clays occur mostly as a cement Iron Oxide, Hydoxide and/or Sulfide Other 1% but no blue eposy?	Monocrys	talline 77%	
Feldspar total feldspar Plagicolase 1% total feldspar Orthoclase Orthoclase Microcline Scattered grains and patches Dolomite Aragonite Aragonite Scattered grains and patches Dolomite Aragonite Illite Smectrite Kaolinite Nuscovite Chlorite Glauconite Book Fragments Sedimentary Voltaric Metamorphic Other (Accessory Minerals) Opaques Quartz Feldspar Carbonate 1% scattered patches Carbonate 1% grains of muscovite and chlorite exist, but clays occur mostly as a cement Iron Oxide, Hydoxide and/or Sulfide Other Visual Porosity Estimate Comments 1% but no blue epoxy?	Microcrys	talline	
Plagiodase 1% total feldspar Orthodase Microcline Calore 1% scattered grains and patches Dolomite Aragonite Clay Illite Smectite Kaolinite Muscovite Chlorite Glauconite Glauconite Rock Fragments Sedimentary Volcanic Metamorphic Other (Accessory Minerals) 2% opaques Cementing Materials Quartz Feldspar Carbonate 1% scattered patches Clay 18% grains of muscovite and chlorite exist, but clays occur mostly as a cement Iron Oxide, Hydoxide and/or Sulfide Other Visual Porosity Estimate Comments Lisé but no blue epoxy?		Feldspar	
Orthoclase Microcline Carbonate Calcite 1% scattered grains and patches Dolomite Aragonite Clay Illite Smectite Kaolinite Muscovite Chiorite Glauconite Rock Fragments Sedimentary Volcanic Metamorphic Cther (Accessory Minerals) 2% oppaques Cermenting Materials Curriz Feldspar Carbonate 1% scattered patches Clay 18% grains of muscovite and chlorite exist, but clays occur mostly as a cement Iron Oxide, Hydoxide and/or Sufide Other Visual Porosity Estimate Comments Carbonate 1% scattered patches Clay 18% grains of muscovite and chlorite exist, but clays occur mostly as a cement Iron Oxide, Hydoxide and/or Sufide Other	Plagi	oclase 1%	total feldspar
Microcline Carbonate Calcite 1% Dolomite Aragonite Smectite Kaolinite Muscovite Chiorite Glauconite Sedimentary Volcanic Metamorphic 2% opaques Cementing Materials Quartz Feldspar Carbonate 1% Scattered patches Clay 18% grains of muscovite and chlorite exist, but clays occur mostly as a cement Iron Oxide, Hydoxide and/or Sulfide Other Visual Porosity Estimate Comments	Orth	oclase	
Carbonate Scattered grains and patches Doiomite Aragonite Clay Illite Smectite Kaolinite Muscovite Chorite Glauconite Glauconite Rock Fragments Sedimentary Volcanic Metamorphic Other (Accessory Minerals) 2% Quartz Feldspar Carbonate 1% scattered patches Clay 18% grains of muscovite and chlorite exist, but clays occur mostly as a cement Iron Dxide, Hydoxide and/or Sulfide Other Visual Porosity Estimate Comments 1% but no blue epoxy?	Micr	ocline	
Calcite 1% scattered grains and patches Dolomite Aragonite Clay. Illite Smectite Kaolinite Muscovite Chlorite Glauconite Rock Fragments Sedimentary Volcanic Metamorphic Comments 2% opaques Cementing Materials Quartz Feldspar Carbonate 1% scattered patches Clay 18% grains of muscovite and chlorite exist, but clays occur mostly as a cement Iron Oxide, Hydoxide and/or Sulfide Other Visual Porosity Estimate (Comments) Comments Difference Difference Comments		Carbonate	
Dolomite Aragonite Illite Smectite Kaolinite Muscovite Chlorite Glauconite Rock Fragments Sedimentary Volcanic Metamorphic Cother (Accessory Minerals) 2% opaques Cementing Materials Cuartz Feldspar Carbonate 1% scattered patches Clay 18% grains of muscovite and chlorite exist, but clays occur mostly as a cement Iron Oxide, Hydoxide and/or Sulfide Other Visual Porosity Estimate Comments 1% but no blue epoxy?		Calcite 1%	scattered grains and patches
Aragonite Clay Illite Smectite Kaolinite Muscovite Chlorite Glauconite Rock Fragments Sedimentary Volcanic Metamorphic Cther (Accessory Minerals) 2% Opaques Quartz Feldspar Carbonate 1% Scattered patches Clay 18% grains of muscovite and chlorite exist, but clays occur mostly as a cement Iron Oxide, Hydoxide and/or Sulfide Other Visual Porosity Estimate Comments 1% but no blue epoxy?	Dol	lomite	
Clay Illite Smectite Kaolinite Muscovite Chlorite Glauconite Sedimentary Volcanic Metamorphic Other (Accessory Minerals) 2% opaques Cementing Materials Quartz Feldspar Carbonate 1% scattered patches Clay 18% grains of muscovite and chlorite exist, but clays occur mostly as a cement Iron Oxide, Hydoxide and/or Sulfide Other Visual Porosity Estimate Comments 1% but no blue epoxy?	Ara	gonite	
Illite Smectite Kaolinite Muscovite Chlorite Glauconite Rock Fragments Sedimentary Volcanic Metamorphic Other (Accessory Minerals) 2% Opaques Cementing Materials Quartz Feldspar Carbonate 1% Clay 18% grains of muscovite and chlorite exist, but clays occur mostly as a cement Iron Oxide, Hydoxide and/or Sulfide Other Visual Porosity Estimate Comments 1% but no blue epoxy?		Clay	
Smectite Kaolinite Muscovite Chlorite Glauconite Sedimentary Volcanic Metamorphic Cementing Materials Quartz Feldspar Carbonate 1% Clay 18% grains of muscovite and chlorite exist, but clays occur mostly as a cement Iron Oxide, Hydoxide and/or Sulfide Other Visual Porosity Estimate Comments 1% but no blue epoxy?		Illite	
Kaolinite Muscovite Chlorite Glauconite Rock Fragments Sedimentary Volcanic Metamorphic 2% opaques Quertz Feldspar Carbonate 1% Clay 18% grains of muscovite and chlorite exist, but clays occur mostly as a cement Iron Oxide, Hydoxide and/or Sulfide Other Visual Porosity Estimate 1%	Sm	nectite	
Muscovite Chlorite Glauconite Sedimentary Volcanic Metamorphic 2% opaques Cementing Materials Quartz Feldspar Carbonate 1% scattered patches Clay 18% grains of muscovite and chlorite exist, but clays occur mostly as a cement Iron Oxide, Hydoxide and/or Sulfide Other Visual Porosity Estimate Comments	Ка	olinite	
Chlorite Glauconite Rock Fragments Sedimentary Volcanic Metamorphic 2% opaques Cementing Materials Comments Quartz Feldspar Carbonate 1% scattered patches Clay 18% grains of muscovite and chlorite exist, but clays occur mostly as a cement Iron Oxide, Hydoxide and/or Sulfide Other Visual Porosity Estimate Comments	Mus	covite	
Glauconite Rock Fragments Sedimentary Volcanic Metamorphic 2% opaques Quartz Feldspar Carbonate 1% Scattered patches Clay 18% grains of muscovite and chlorite exist, but clays occur mostly as a cement Iron Oxide, Hydoxide and/or Sulfide Other 1%	Cł	nlorite	
Rock Fragments Sedimentary Volcanic Wetamorphic Metamorphic 2% opaques Quert Feldspar Carbonate 1% grains of muscovite and chlorite exist, but clays occur mostly as a cement Iron Oxide, Hydoxide and/or Sulfide Other Visual Porosity Estimate Comments 1% but no blue epoxy?	Glau	conite	
Sedimentary Volcanic Metamorphic Other (Accessory Minerals) 2% 2% Quartz Feldspar Carbonate 1% Clay 18% grains of muscovite and chlorite exist, but clays occur mostly as a cement Iron Oxide, Hydoxide and/or Sulfide Other Visual Porosity Estimate Comments 1% but no blue epoxy?	R	ock Fragments	
Volcanic Metamorphic Other (Accessory Minerals)	Sedime	entary	
Metamorphic Other (Accessory Minerals) 2% opaques 2% opaques Quartz Feldspar Carbonate 1% scattered patches Clay 18% grains of muscovite and chlorite exist, but clays occur mostly as a cement Iron Oxide, Hydoxide and/or Sulfide Other Visual Porosity Estimate Comments 1% but no blue epoxy?	Vo	blcanic	
Other (Accessory Minerals) opaques 2% opaques Cementing Materials Comments Quartz Feldspar Carbonate 1% scattered patches Clay 18% grains of muscovite and chlorite exist, but clays occur mostly as a cement Iron Oxide, Hydoxide and/or Sulfide Other Visual Porosity Estimate Comments 1% but no blue epoxy?	Metam	orphic	
2% opaques 2% opaques 2% opaques Cementing Materials Comments Quartz Feldspar Feldspar Scattered patches Carbonate 1% scattered patches Clay 18% grains of muscovite and chlorite exist, but clays occur Iron Oxide, Hydoxide and/or Sulfide Other Visual Porosity Estimate Comments 1% but no blue epoxy?	Other (/	Accessory Minerals)	
Cementing Materials Comments Quartz Feldspar Feldspar Scattered patches Carbonate 1% scattered patches Clay 18% grains of muscovite and chlorite exist, but clays occur mostly as a cement Iron Oxide, Hydoxide and/or Sulfide Other Visual Porosity Estimate Comments 1% but no blue epoxy?		2%	opaques
Cementing Materials Comments Quartz Feldspar Feldspar Scattered patches Carbonate 1% grains of muscovite and chlorite exist, but clays occur Clay 18% grains of muscovite and chlorite exist, but clays occur Iron Oxide, Hydoxide and/or Sulfide Other Visual Porosity Estimate Comments 1% but no blue epoxy?			
Quartz Feldspar Carbonate 1% scattered patches Clay 18% grains of muscovite and chlorite exist, but clays occur Iron Oxide, Hydoxide and/or Sulfide other Visual Porosity Estimate Comments 1% but no blue epoxy?	Ceme	enting Materials	Comments
Feldspar Carbonate 1% scattered patches Clay 18% grains of muscovite and chlorite exist, but clays occur mostly as a cement Iron Oxide, Hydoxide and/or Sulfide Other <u>Visual Porosity Estimate</u> 1% but no blue epoxy?	(Quartz	
Carbonate 1% scattered patches Clay 18% grains of muscovite and chlorite exist, but clays occur mostly as a cement Iron Oxide, Hydoxide and/or Sulfide Other Visual Porosity Estimate Comments 1% but no blue epoxy?	Fe	ldspar	
Clay 18% grains of muscovite and chlorite exist, but clays occur mostly as a cement Other Comments 1% but no blue epoxy?	Carb	ponate 1%	scattered patches
Iron Oxide, Hydoxide and/or Sulfide Other Visual Porosity Estimate Comments 1% but no blue epoxy?	0012	Clav 18%	grains of muscovite and chlorite exist, but clays occur
Iron Oxide, Hydoxide and/or Sulfide Other Visual Porosity Estimate Comments 1% but no blue epoxy?			mostly as a cement
Other Visual Porosity Estimate Comments 1% but no blue epoxy?	Iron Oxide, Hydoxide and/or S	Sulfide	
Visual Porosity Estimate Comments 1% but no blue epoxy?		Other	
1% but no blue epoxy?	Visual	Porosity Estimate	Comments
		1%	but no blue epoxy?

₩2-9.1pg

Samula ID:	M/7 10	
Sample ID:	W2-10	
Formation/Wember Name:	Well Clavey Sandstone	
Denth /Denth Pangas		
Depth/Depth Kange.	2009.7 IL 6/00/2017	
Analyzed by:	0/22/2017	
Analyzeu by.		
	Texture	Comments
Grai	n Size very fine-grained, 62-125µ	
Rou	inding subrounded	
S	orting very well sorted	
Composit	ion/Detrital Minerals	Comments
	Quartz	
Polycryst	talline	
Monocryst	talline 78%	
Microcryst	talline	
	Feldspar	
Plagio	oclase 1%	total feldspar
Ortho	oclase	
Micr	ocline	
	Carbonate	
C	Calcite <1%	scattered grains and patches
Dol	omite	
Arag	gonite	
	Clay	
	Illite	
Sm	ectite	
Kao	olinite	
Mus	covite	
Cr	nlorite	
Glaud	conite	
R	ock Fragments	
Sedime	entary	
Vo	lcanic	
Metamo	orphic	
Other (Accessory Minerals)	
	1%	opaques
Cem	enting Materials	Comments
C	Quartz	
Fel	ldspar	
Carb	onate	
	Clay 20%	grains of muscovite and chlorite exist, but clays occur mostly as a cement
Iron Oxide, Hydoxide and/or S	ulfide	mostry us a coment
	Other	
Vicua	Porosity Estimate	Comments
VI300	2%	but no blue epoxy?
	_ /.	Sacho Blac epony.



Sample ID:	W7-11	
Formation/Member Name:	Weir	
Lithologic Classification:	Clavey Sandstone	
Depth/Depth Range:	2545.4 ft	
Date of Analysis:	6/19/2017	
Analyzed by:	L. Ditzler	
	Texture	Comments
Grain Size	very fine-grained, 62-125µ	
Rounding	poorly rounded	
Sorting	very well sorted	
Compositi	on/Detrital Minerals	Comments
	Quartz	
Polycrystalline		
Monocrystalline	87%	
Microcrystalline		
	Feldspar	
Plagioclase	2%	total feldspar
Orthoclase		
Microcline		
	Carbonate	
Calcite	<1%	scattered grains and patches
Dolomite		
Aragonite		
	Clay	
Illite		
Smectite		
Kaolinite		
Muscovite		
Chlorite		
Glauconite		
Ro	ck Fragments	
Sedimentary		
Volcanic		
Metamorphic		
Other (A	Accessory Minerals)	
	1%	opaques
Ceme	nting Materials	Comments
Quartz		
Feldspar		
Carbonate	2%	scattered patches
Clay	8%	cement
Iron Oxide, Hydoxide and/or Sulfide		
Other		
Visual	Porosity Estimate	Comments
	<1%	but no blue epoxy?

1211jg

Sample ID:	W7-12	
Formation / Member Name:	Weir	
Lithologic Classification:	Clavey Sandstone	
Donth /Donth Pango:	2550 5 ft	
Date of Analysis	2330.3 ft	
Date of Analysis:	0/19/2017	
Analyzed by:	L. Ditzier	
	Texture	Comments
Gra	ain Size very fine-grained, 62-125µ	
Ro	unding subangular	
	Sorting very well sorted	
Composit	ion/Detrital Minerals	Comments
	Quartz	
Polycry	stalline 2%	
Monocry	stalline 84%	
Microcry	stalline	
	Feldspar	
Plag	ioclase 2%	total feldspar
Orth	noclase	
Mic	rocline	
	Carbonate	
	Calcite	
Do	blomite	
Ara	agonite	
	Clay	
	Illite	
Sr	nectite	
Ka	aolinite	
Mu	scovite	
C	Chlorite	
Glau	uconite	
R	ock Fragments	
Sedim	nentary	
V	olcanic	
Metarr	norphic	
Other (Accessory Minerals)	
	2%	opaque, dark red brown
Cem	enting Materials	Comments
	Quartz	
Fe	eldspar	
Car	bonate 2%	scattered patches
	Clay 8%	
		grains of muscovite and chlorite exist, but
		clays occur mostly as a cement
Iron Oxide, Hydoxide and/or	Sulfide	
	Other	
Visua	l Porosity Estimate	Comments
	1%	but no blue epoxy?

Appalachian Storage Hub Project

50x magnification, 2.5 mm field of view



Sample ID:	WZ-13	
Formation/Member Name:	Weir	
Lithologic Classification:	clayey sandstone	
Depth/Depth Range:	2560.2 ft	
Date of Analysis:	6/19/2017	
Analyzed by:	L. Ditzler	
	Texture	Comments
Grai	in Size very fine-grained, 62-125µ	
Rou	inding subangular	
S	orting well sorted	
Com	position/Detrital Minerals	Comments
	Quartz	
Polycryst	talline	
Monocryst	talline	50%
Microcryst	talline	
	Feldspar	
Plagio	oclase <1%	total feldspar
Ortho	oclase	
Micr	ocline	
	Carbonate	
C	Calcite	
Dol	omite	
Arag	gonite	
	Clay	
	Illite	
Sm	ectite	
Kao	olinite	
Mus	covite <1%	
Cr	nlorite <1%	
Glaud	conite	
	Rock Fragments	
Sedime	entary	
VO		
Metamo	brpnic	
0	ther (Accessory Minerals)	
		1% opaque, dark red brown
	Cementing Materials	Comments
C	Quartz	
Fel	ldspar	
Carb	onate <1%	scattered patches
		some clay and mica grains, some clay
	Clay	49% cement
Iron Oxide, Hydoxide and/or S	ulfide	
	Other	
	Visual Porosity Estimate	Comments
		1% but no blue epoxy?



Sample ID:	WZ-14	
Formation/Member Name:	Weir	
Lithologic Classification:	clayey sandstone	
Depth/Depth Range:	2685 ft	
Date of Analysis:	6/19/2017	
Analyzed by:	L. Ditzler	
	Texture	Comments
Grain Size	very fine-grained, 62-125µ	
Rounding	subangular	
Sorting	well sorted	
Compositi	on/Detrital Minerals	Comments
	Quartz	
Polycrystalline		
Monocrystalline		85%
Microcrystalline		
	Feldspar	
Plagioclase	<1%	total feldspar
Orthoclase		
Microcline		
	Carbonate	
Calcite		
Dolomite		
Aragonite		
	Clay	
Smectite		
Kaolinite		
Muscovite		1%
Chlorite		170
Glauconite		
Re Re	ock Fragments	
Sedimentary		
Voicanic		
Metamorphic		
Other (/	Accessory Minerals)	
		5% opaque, dark red brown
C		<u> </u>
Ceme		Comments
Quartz		
Feldspar	-10/	and the second second second
Carbonate	<1%	scattered patches
Clay	<10/	9%
Iron Uxide, Hydoxide and/or Sulfide	S170	some re-oxide cement
Uther		
Visual	Porosity Estimate	Comments
	<1%	but no blue epoxy?



Sample ID:	39-2112-2	
Formation/Member Name:	Newburg	
Lithologic Classification:	Sandstone	
Depth/Depth Range:	5426.5 ft	
Date of Analysis:	6/2/2017	
Analyzed by:	L. Ditzler	
	Texture	Comments
Gra	in Size fine-grained, 125-177 μ	
Ro	unding well rounded to subrounde	ed
5	Sorting very well sorted	
Composit	ion/Detrital Minerals	Comments
	Quartz	
Polycrys	stalline	
Monocrys	stalline 93%	
Microcrys	stalline	
	Feldspar	
Plag	loclase	
Orth	ioclase	
IVIIC	rocine <1%	
	Carbonate	
_	Calcite	
Do	lomite 	
Ara	gonite	
	Clay	
	Illite	
Sn	nectite	
Ka	olinite	
Mus	scovite	
Clau	nionte	
Glat	come	
R	ock Fragments	
Sedim	entary	
Violatar		
Weldin	orphic	
Other (Accessory Minerals)	
	tourmaline	
	zircon	
Cem	enting Materials	Comments
	Quartz	overgrowths and intergranular
Fe	eldspar	
Carl	oonate 2%	scattered patches
	Clay	
Iron Uxide, Hydoxide and/or	Suitide	
	Other 5%	mystery mineral, moderate relief, coloriess, low to
		mouerate prefringence, optically continuous patches,
		patery distribution - locally abundant
Visua	l Porosity Estimate	Comments
	3%	intergranular, patchy distribution

39-2112-2.jpg

25x magnification, 5mm field of view



Sample ID:	39-2112-4	
Formation/Member Name:	Newburg	
Lithologic Classification:	Calcareous Sandstone	
Depth/Depth Range:	5428.2 ft	
Date of Analysis:	6/13/2017	
Analyzed by:	S. Shank	
	Texture	Comments
Grain Siz	ze fine-grained, 125-177μ	
Roundir	ng well rounded to subrounded	
Sortin	ng well sorted	
Composition	n/Detrital Minerals	Comments
	Quartz	
Polycrystallin	ie	
Monocrystallin	ne 75%	
Microcrystallin	e	
I	Feldspar	
Plagioclas	se	
Orthoclas	se	
Microclin	le	
C	arbonate	
Calcit	te	
Dolomit	te	
Aragonit	te	
	Clay	
Illit	Ce	
Smecti	ie .	
Kaolinit		
IVIUSCOVI	ie .	
Chlorit	Ce	
Glauconit	e	
Rock	k Fragments	
Sedimentar	ry	
Volcan	ic	
Metamorph	ic	
Other (Ac	cessory Minerals)	
	tourmaline	
Cemen	ting Materials	Comments
Quar	tz	
Feldspa	ar	
Carbonat	te 25%	
Cla	ау	
Iron Oxide, Hydoxide and/or Sulfid	le	
Othe	er <1	mystery mineral, colorless, moderate relief
Visual Po	prosity Estimate	Comments
	2%	very patchy distribution, most of section of
		almost no porosity



Jampe D. by Joseph D. Source Standsone Deput/Depth Research Range: Newburg Uthologic Classification: Quartz Standstone Deput/Depth Range: S 540 th Date of Analysis: 6/13/2017 Analyzed by: S. Shank 25x magnification, 5mm field of view Comments Comments Comments (J25:177), Reunding well rounded to subrounded Sorting well sorted Comments	Sample ID:	20 2112 6	
Lithologic Casification: Quart SondStone Depth/Depth Range: S430 ft Depth/Depth Range: S430 ft Depth/Depth Range: S430 ft Depth/Depth Range: S430 ft Grain Size fine=grained, 125-177µ Rounding: well rounded to subrounded Sorting: well sorted Composition/Defrital Minerals Composition/Defrital Minerals Minerals Minerals Minerals Composition Carbonate Composition Composition Minerals Composition Minerals Composition Minerals Composition Minerals Composition Minerals Composition C	Sample ID.	59-2112-0 Newburg	
Depti/Depti Range::::::::::::::::::::::::::::::::::::	Lithologic Classification:	Quartz Sandstone	
Date of Analysis: 6/13/2017 Analyzed by: S. Shank Texture Comments Grain Size fine-grained, 125-177µ Rounding well rounded to subrounded Soring well rounded to subrounded Comments Composition/Detrital Minerals Comments Quart Data Polycrystalline Monocrystalline Pilogicolase Orthodase Orthodase Microcrystalline Calcite Dolomite Anagonite Calcite Dolomite Anagonite Semette Kaolinite Muscovite Chiorite Glauconite Semette Kaolinite Wel rounded grains not uncommon Volcanic Metamorphic Chiorite Comments Chiorite Glauconite Glauconite well rounded grains not uncommon Volcanic well rounded grains not uncommon Cementing Materials Comments Quartz overgrowths and intertitial patches well cemented Feldspar Calvoante c1% Calv Comments Voladite Other (Accessory Minerals) uoraline well cemented Voladite Feldspar Carbonate c1% Comm	Denth/Denth Bange:	5430 ft	
Analyzed by: S. Shank 25x magnification, 5mm field of view Texture Comments Grain Size fine-grained, 125-177µ. Comments Rounding well concided to subrounded Sorting wells orted Composition/Detrital Minerals Comments Delorytalline Monocrystalline Palycrystalline Monocrystalline Phagioclase Orthoclase Orthoclase Microcine Calcite Dolomite Aragonite Calcite Dolomite Aragonite Calcite Sonectite Kaolinite Sonectite Kaolinite Sonectite Kaolinite Sonectite Kaolinite Socorre Chiorite Glauconite Glauconite Sedimentary Volcanite Volcanite Carto overgrowths and intertitial patches well conned grains not uncommon Cementing Materials Comments Carto overgrowths and intertitial patches well connected Feldspar Carbonate Carto overgrowths and intertitial patches well connected Carto overgrowths and intertitial patches well connected Feldspar Carbonate Comments Carto overgrowthine one p	Date of Analysis:	6/13/2017	
Texture Comments Grain Size fine-grained, 125-177µ Rounding well rounded to subrounded Sorting well sorted Comments Quart Quart Pelycrystalline Monocrystalline 99% Microcrystalline Feldgar Plagioclase Orthoclase Orthoclase Microcrystalline Califie Dolomite Aragonite Califie Sective Califie Sective Galifie Sective Sective Glauconite Sective Sedimentary Volcanic Volcanic Metamorphic Other (Accessory Minerals) well rounded grains not uncommon Candinic Well counted Quart overgrowths and intertitial patches well cemented Feldspar Califie Quart overgrowths and intertitial patches well counted Gray Comments Uron Oxide, Hydoxide and/or Suifide One patch of colories, moderate relief mystery Mineral Second te <1% one patch of colories, moderate relief mystery	Analyzed by:	S. Shank	25x magnification, 5mm field of view
Texture Comments Grain Size fine grained, 125-177µ Rounding well rounded to subrounded Sorting well sorted Comments Quart Quart Polycrystalline Monocrystalline 99% Microcrystalline Monocrystalline 99% Microcrystalline Polycrystalline Calcite Othoclase Orthoclase Microcriste Calcite Dolomite Aragonite Calcite Dolomite Aragonite Kascovite Chointe Kascovite Chointe Glauconite Sedimentary Volcanic Well rounded grains not uncommon Cementing Materials Comments Canonale Comments Sedimentary Volcanic Volcanic Well rounded grains not uncommon Control Comments Calcite Comments Sedimentary Volcanic Volcanic Well rounded grains not uncommon Control Comments Control Comments Control Comments Control Comments Color Comments Control Comments Colav Contest Control	· ·		
Cran size time graines, 12-3/74 Rounding well sorted Composition/Detrital Minerals Comments Quart Polycrystalline Monocrystalline Monocrystalline Plagloclase Orthoclase Microcolume Calcite Dolomite Aragonite Calcite Dolomite Aragonite Calcite Calcite Colorite Calcite Colorite Calcite Colorite Calcite Sedimentary Volcanic Metamorphic Cereenting Materials Comments Cereenting Materials Comments Cereenting Materials Comments Calcite Colorite Calcite Calcite Colorite Calcite Calcite Calcite Colorite Calcite Cal		Texture	Comments
Sorting well sourced Composition/Detrital Minerals Quart Polycrystalline Monocrystalline 99% Microcrystalline Monocrystalline Prajodase Orthodase Microcrystalline Catomate Catomate Cationate Calcite Dolomite Aragonite Smeetite Kaloninte Muscovite Chiorite Glauconite Sedimentary Volcanic Metamorphic Volcanic Metamorphic Volcanic Metamorphic Carbonate Catomate Sedimentary Volcanic Metamorphic Volcanic Metamorphic Volcanic Metamorphic Volcanic Metamorphic Volcanic Carbonate <1%	Grair	h Size fine-grained, 125-17/μ	
Composition/Detrital Minerals Comments Quart Polycrystalline 99% Microcrystalline 91% Microcrystalline 99% Microcrystalline 99% Microcrystalline 91% Microcr	Rour	naing well rounded to subrounded	
Composition/Detrital Minerals Comments Quartz Polycrystalline Polycrystalline 99% Microcrystalline Feldspar Plagicalase Orthoclase Orthoclase Orthoclase Microcrystalline Carbonate Calcite Dolomite Aragonite Clay Ullite Smectrite Kaolinite Muscovite Chrite Glauconite Glauconite Rock fragments Sedimentary Volcanic Volcanic well rounded grains not uncommon Cementing Materials Comments Quartz Outer (Accessory Minerals) tourmaline well rounded grains not uncommon Cementing Materials Comments Quartz Carbonate <1%	SO	orting well sorted	
Quartz Polycrystalline Projectystalline 9% Microcrystalline 9% Microcrystalline Plagioclase Orthoclase Orthoclase Orthoclase Microcline Calcite Dolomite Aragonite Calcite Dolomite Aragonite Clay Illite Smectite Kaolinite Muscovite Chiorite Glauconite Glauconite Metamorphic Metamorphic Chermentary Volcanic Metamorphic well rounded grains not uncommon Cementing Materials Comments Carbonate <1% Clay Iron Oxide, Hydoxide and/or Sulfide one patch of colorles, moderate relief mystery mineral Visual Porosity Estimate Comments Visual Porosity Estimate Common intergranular and larger voids	Composi	tion/Detrital Minerals	Comments
Polycrystalline Monocrystalline 99% Microcrystalline 99% Plagicclase Orthoclase Microcline Carbonate Calcite Dolomite Aragonite Clay Illite Smectite Kaolinite Muscovite Chlorite Glauconite Rock Fragments Sedimentary Volcanic Metamorphic Comments Comments Quartz overgrowths and intertitial patches Feldspar Carbonate <1% Carbonate state Carbonate state Carbonate state Comments Comments Comments Carbonate state Carbonate state Car		Quartz	
Monocrystalline 99% Microcrystalline 99% Plagioclase Orthoclase Orthoclase Microcline Carbonate Calotte Dolomite Aragonite Muscovite Clay Illite Smectite Kaolinite Muscovite Chiorite Glauconite Glauconite Chiorite Glauconite Muscovite Chiorite Glauconite Well rounded grains not uncommon Cementing Materials Curmaline Well rounded grains not uncommon Cementing Materials Quartz overgrowths and intertitial patches Feldspar Carbonate 43% Carbonate 43% Ca	Polycrysta	alline	
Microcrystalline Plagioclase Orthoclase Microcline Caloute Caloute Colomite Aragonite Clay Illite Section Glauconite Chorite Glauconite Rock Fragnents Sectimentary Volcanic Metamorphic Other (Accessory Minerals) tournaline well rounded grains not uncommon Cementing Materials Comments Quartz overgrowths and intertitial patches well cemented Feldspar Carbonate <1% Carbonate <1% one patch of colorless, moderate relief mystery mineral Other <1% one patch of colorless, moderate relief mystery mineral Visual Porosity Estimate Comments Stat common intergranular and larger voids	Monocrysta	alline 99%	
Feldspar Plagicclase Orthoclase Microcline Calcite Dolomite Aragonite Illite Smectite Kaolinite Muscovite Chlorite Glauconite Rock Fragments Sedimentary Volcanic Metamorphic Other (Accessory Minerals) tourmaline Vell rounded grains not uncommon Cementing Materials Carbonate <1%	Microcrysta	alline	
Plagioclase Orthoclase Microcline Calcite Dolomite Aragonite		Feldspar	
Orthoclase Microcline Carbonate Calcite Dolomite Aragonite Illite Smectite Kaolinite Muscovite Choirte Glauconite Sedimentary Volcanic Metamorphic Other (Accessory Minerals) tournaline well rounded grains not uncommon Cementing Materials Quartz overgrowths and intertitial patches Feldspar Carbonate <1%	Plagio	oclase	
Microcline Carbonate Calcite Dolomite Aragonite Aragonite Clay Illite Smectite Kaolinite Muscovite Chiorite Glauconite Sedimentary Volcanic Metamorphic Other (Accessory Minerals) tourmaline Well rounded grains not uncommon Cementing Materials Quartz overgrowths and intertitial patches Feldspar Carbonate <1%	Ortho	oclase	
Carbonate Calcite Dolomite Aragonite Clay Illite Smectite Kaolinite Muscovite Chlorite Glauconite Sedimentary Volcanic Metamorphic Other (Accessory Minerals) tournaline Quartz overgrowths and intertitial patches Feldspar Catbonate <1%	Micro	ocline	
Calcite Dolomite Aragonite Clay Illite Smectite Kaolinite Muscovite Chlorite Glauconite Chlorite Glauconite Notcanic Metamorphic Cother (Accessory Minerals) tournaline well rounded grains not uncommon Cementing Materials Comments Quartz overgrowths and intertitial patches Feldspar Carbonate <1% Clay Iron Oxide, Hydoxide and/or Sulfide Other <1% Clay Iron Oxide, Hydoxide Extinate Comments S%		Carbonate	
Dolomite Aragonite Illite Smectite Kaolinite Muscovite Chlorite Glauconite Sedimentary Volcanic Metamorphic Other (Accessory Minerals) tourmaline Well rounded grains not uncommon Cementing Materials Quartz overgrowths and intertitial patches Feldspar Carbonate <1% Clay Iron Oxide, Hydoxide and/or Sulfide Other <1% Other <1% Other <1% Other <1% Clay Iron Oxide, Hydoxide and/or Sulfide Other <1% Other <1% Clay Iron Oxide, Hydoxide and Jor Sulfide Other <1% Comments Visual Porosity Estimate Comments S% common intergranular and larger voids	C:	alcite	
Aragonite Clay Illite Smectite Kaolinite Muscovite Chlorite Glauconite Rock Fragments Sedimentary Volcanic Metamorphic Other (Accessory Minerals) tournaline Quartz overgrowths and intertitial patches Quartz overgrowths and intertitial patches Carbonate <1%	Dolo	omite	
Clay Illite Smectite Kaolinite Muscovite Chlorite Glauconite Sedimentary Volcanic Metamorphic Other (Accessory Minerals) tourmaline Vell rounded grains not uncommon Cementing Materials Quartz overgrowths and intertitial patches Feldspar Carbonate <1%	Arag	onite	
Clay Illite Smectite Kaolinite Muscovite Chlorite Glauconite Sedimentary Volcanic Metamorphic Conversion Cementing Materials Quartz overgrowths and intertitial patches Feldspar Carbonate <1%			
Smectite Somectite Kaolinite Muscovite Chlorite Glauconite Rock Fragments Sedimentary Volcanic Metamorphic Other (Accessory Minerals) tourmaline well rounded grains not uncommon Cementing Materials Quartz overgrowths and intertitial patches Feldspar Carbonate <1% Clay Iron Oxide, Hydoxide and/or Sulfide Other <1% Other <1% one patch of colorless, moderate relief mystery mineral Visual Porosity Estimate S% common intergranular and larger voids	···	Clay	
Silectite Kaolinite Muscovite Chlorite Glauconite Sedimentary Volcanic Metamorphic Other (Accessory Minerals) tourmaline well rounded grains not uncommon Cementing Materials Quartz overgrowths and intertitial patches Yeldspar Carbonate <1%	Sme		
Muscovite Chlorite Glauconite Rock Fragments Sedimentary Volcanic Metamorphic Other (Accessory Minerals) tourmaline well rounded grains not uncommon Cementing Materials Quartz overgrowths and intertitial patches Feldspar Carbonate <1%	Kao	linite	
Chlorite Glauconite Rock Fragments Sedimentary Volcanic Metamorphic Other (Accessory Minerals) tourmaline well rounded grains not uncommon Cementing Materials Comments Quartz overgrowths and intertitial patches well cemented Feldspar Carbonate <1% Clay Iron Oxide, Hydoxide and/or Sulfide Other <1% one patch of colorless, moderate relief mystery mineral Visual Porosity Estimate Comments 5% common intergranular and larger voids	Musc	rovite	
Glauconite Rock Fragments Sedimentary Volcanic Metamorphic Other (Accessory Minerals) tourmaline well rounded grains not uncommon Cementing Materials Quartz overgrowths and intertitial patches Feldspar Carbonate <1% Clay Iron Oxide, Hydoxide and/or Sulfide Other <1% Other <1% Other <1% Other <1% S%	Ch	lorite	
Rock Fragments Sedimentary Volcanic Metamorphic Other (Accessory Minerals) tourmaline well rounded grains not uncommon Cementing Materials Comments Quartz overgrowths and intertitial patches well cemented Feldspar Carbonate <1% Clay Clay Iron Oxide, Hydoxide and/or Sulfide one patch of colorless, moderate relief mystery mineral Visual Porosity Estimate Comments 5% common intergranular and larger voids	Glauc	onite	
Rock Fragments Sedimentary Volcanic Metamorphic Other (Accessory Minerals) tourmaline well rounded grains not uncommon Cementing Materials Quartz overgrowths and intertitial patches Feldspar Carbonate <1%			
Securiterially Volcanic Metamorphic Metamorphic Other (Accessory Minerals) tourmaline well rounded grains not uncommon Cementing Materials Comments Quartz overgrowths and intertitial patches well cemented Feldspar Carbonate <1% Clay Clay Iron Oxide, Hydoxide and/or Sulfide one patch of colorless, moderate relief mystery mineral Visual Porosity Estimate Comments 5% common intergranular and larger voids	F	Rock Fragments	
Metamorphic Other (Accessory Minerals) tourmaline well rounded grains not uncommon Cementing Materials Comments Quartz overgrowths and intertitial patches well cemented Feldspar Carbonate <1% Clay Clay Iron Oxide, Hydoxide and/or Sulfide one patch of colorless, moderate relief mystery mineral Visual Porosity Estimate Comments 5% common intergranular and larger voids	Sealine		
Other (Accessory Minerals) well rounded grains not uncommon tourmaline well rounded grains not uncommon Cementing Materials Comments Quartz overgrowths and intertitial patches well cemented Feldspar Carbonate <1% Clay Clay Iron Oxide, Hydoxide and/or Sulfide one patch of colorless, moderate relief mystery mineral Visual Porosity Estimate Comments 5% common intergranular and larger voids	Vol		
Other (Accessory Minerals) tourmaline well rounded grains not uncommon Cementing Materials Comments Quartz overgrowths and intertitial patches well cemented Feldspar Carbonate <1% Clay Clay Iron Oxide, Hydoxide and/or Sulfide one patch of colorless, moderate relief mystery mineral Visual Porosity Estimate Comments 5% common intergranular and larger voids	Wetanio	i princ	
tourmaline well rounded grains not uncommon Cementing Materials Comments Quartz overgrowths and intertitial patches well cemented Feldspar Carbonate <1% Clay Clay Iron Oxide, Hydoxide and/or Sulfide one patch of colorless, moderate relief mystery mineral Visual Porosity Estimate Comments 5% common intergranular and larger voids	Other	(Accessory Minerals)	
Cementing Materials Comments Quartz overgrowths and intertitial patches well cemented Feldspar Carbonate <1% Clay Clay Iron Oxide, Hydoxide and/or Sulfide one patch of colorless, moderate relief mystery mineral Visual Porosity Estimate Comments 5% common intergranular and larger voids		tourmaline	well rounded grains not uncommon
Cementing Materials Comments Quartz overgrowths and intertitial patches well cemented Feldspar Carbonate <1% Clay Clay Iron Oxide, Hydoxide and/or Sulfide one patch of colorless, moderate relief mystery mineral Visual Porosity Estimate Comments 5% common intergranular and larger voids			
Quartz overgrowths and intertitial patches well cemented Feldspar Carbonate <1% Clay Clay Iron Oxide, Hydoxide and/or Sulfide one patch of colorless, moderate relief mystery mineral Visual Porosity Estimate Comments 5% common intergranular and larger voids	Cerr	nenting Materials	Comments
Feldspar Carbonate <1% Clay Iron Oxide, Hydoxide and/or Sulfide Other <1% Other <1% Visual Porosity Estimate 5%	Q	uartz overgrowths and intertitial patches	well cemented
Carbonate <1% Clay Iron Oxide, Hydoxide and/or Sulfide Other <1% Other <1% one patch of colorless, moderate relief mystery mineral <u>Visual Porosity Estimate</u> 5% common intergranular and larger voids	Felo	dspar	
Clay Iron Oxide, Hydoxide and/or Sulfide Other <1% one patch of colorless, moderate relief mystery mineral Visual Porosity Estimate Comments 5% common intergranular and larger voids	Carbo	onate <1%	
Iron Oxide, Hydoxide and/or Sulfide Other <1% one patch of colorless, moderate relief mystery mineral Visual Porosity Estimate Comments 5% common integranular and larger voids		Clay	
Other Other Other Other Visual Porosity Estimate Comments 5% common intergranular and larger voids	Iron Oxide, Hydoxide and/or Su	ulfide	
Mineral Visual Porosity Estimate Comments 5% common intergranular and larger voids	C	Other <1%	one patch of colorless, moderate relief mystery
Visual Porosity Estimate Comments 5% common intergranular and larger voids			mineral
5% common intergranular and larger voids	Visua	al Porosity Estimate	Comments
		5%	common intergranular and larger voids

39-2112-6. jpg

Sample ID:	39-2112-9	
Formation/Member Name:	Newburg	
Lithologic Classification:	Calcareous Sandstone	
Depth/Depth Range:	5432.5 ft	
Date of Analysis:	6/13/2017	
Analyzed by:	S. Shank	
	Texture	Comments
Gra	in Size fine-grained, 125-250µ	
Rou	unding well rounded to subangular	
S	Sorting well sorted	
Compositi	on/Detrital Minerals	Comments
•	Quartz	
Polycrys	talline	
Monocrys	talline 70%	
Microcrys	talline	
	Feldspar	
Plagi	oclase	
Orth	oclase	
Mic	rocline	
	Carbonate	
	Calcite	
Do	lomite	
Ara	gonite	
	Clay	
	Illite	
Sn	nectite	
Ка	olinite	
Mus	scovite	
C	hlorite	
Glau	conite	
Ro	ock Fragments	
Sedim	entary	
Ve	blcanic	
Metam	orphic	
Other (/	Accessory Minerals)	
Ceme	enting Materials	Comments
	Quartz	
Fe	ldspar	
Carb	oonate 30%	well cemented, locally abundant - matrix
		supported patches
	Clay	
Iron Oxide, Hydoxide and/or	Sulfide	
	Other	
Visual	Porosity Estimate	Comments
	<1%	almost no intergranular porosity, some along
		thin fracture

19-212-9.jpt

Geologic Interval - Greenbrier Limestone	1	2	3	4	5	Area

Range							
Values	Criteria						Explanation:
	Distance to infrastructure	1	3	2	3	3	distance to Kanawha R used if closer than Ohio R
0	>30 mi						
1	>20 mi but <=30 mi						
2	>5 mi but <=20 mi						
3	<=5 mi						
	Average depth	3	3	3	3	3	
0	<1,800 ft						
3	>=1,800 ft but <=2,000 ft						
	Acreage	3	3	3	3	3	
0	< 25,000	174,000	365,000	452,140	533,745	173,735	ac of Net > 40 ft Greenbrier Lime Mudstone Facies
1	25,000 - 75,000						
2	75,000 - 125,000						
3	> 125,000						
	Average net thickness	3	3	3	3	3	
0	<40 ft						
3	>=40 ft						
	Trap integrity	2	0	1	1	3	
0	No data	44%	0%	9%	11%	81%	% of mud facies in footprint overlain & underlain by grainstone facies
1	Limited data on trap characteristics						
2	Inferred lithologic and/or structural closure						
3	Documented lithologic and/or structural closure						
	Legacy well penetrations	1	0	0	1	2	
0	No data or >=20 wells per 1,000 ac	11.23922	36.84658	23.64533	5.989752	2.664978	wells/1000 ac
1	>=5 wells per 1,000 ac but <20 wells per 1,000 ac	1044					# PA wells
2	>=2 wells per 1,000 ac but<5 wells per 1,000 ac	8	21		67	29	GB wells
3	<2 well per ac	1814	13428	10691	3130	434	WV wells
		2866	13449	10691	3197	463	wells
		81000					PA ac
		255	365	452.14	533.745	173.735	1000 acres
	Stacked opportunity?	1	3	2	2	2	
0	No other intervals in same footprint	_					

2 or 3 other intervals in same footprint
 4 or more intervals in same footprint

FID	TEST_ID_1	FIELD_NAME	Formation	Lithology	Geo_Age	DISC_YEAR	State	Pi	Pmax	MMP	Pi_MMP	Pmax_MMP	AvgProdDep
66	11256	Big Run-Burchfield	BGIJ, PRIC	Sandstone	Mississippian	1902	WV	975.982	1803.2	415.9422	560.0398	1387.2578	2254
47	11018	Burdett-St. Albans	Berea	Sandstone	Devonian-Mississippian	1906	WV	959.961	1773.6	414.505	545.456	1359.095	2217
150	11553	Cameron-Garner	Weir	Sandstone	Mississippian	1977	WV	1075.139	1986.4	424.7996	650.3394	1561.6004	2483
60	11249	Condit-Ragtown	BGIJ, PRIC	Sandstone	Mississippian	1898	WV	881.155	1628	401.2759	479.8791	1226.7241	2035
99	11361	Hendershot-Ogdin	Berea	Sandstone	Devonian-Mississippian	1895	WV	954.332	1763.2	422.5391	531.7929	1340.6609	2204
58	11247	Maple-Wadestown	BGIJ, PRIC, SQUW	Sandstone	Mississippian	1905	WV	1015.385	1876	405.4541	609.9309	1470.5459	2345
202	11733	Sidney	Berea	Sandstone	Devonian-Mississippian	1959	WV	1724.206	3185.6	481.3137	1242.8923	2704.2863	3982
156	11561	Stanley	Weir	Sandstone	Mississippian	1966	WV	971.652	1795.2	424.2368	547.4152	1370.9632	2244
201	11732	Whites Creek-Gragston	Berea	Sandstone	Devonian-Mississippian	1930	WV	1659.689	3066.4	475.8018	1183.8872	2590.5982	3833
154	11559	Wilbur	Weir	Sandstone	Mississippian	1971	WV	990.704	1830.4	426.1016	564.6024	1404.2984	2288

NETTHICK	PRESS	POROSITY	Perm	Area_sqft	acreage	store_mode	legacy well count	Revised distance rank	acreage	average depth	porosity	thickness	permeability	pressure
17	1000	0.11	0	469713557	10,783	2798511.513	322	3	3	2	3	2	0	3
21	1000	0.1	0	2165371660	49,710	7684749.364	597	3	3	2	2	3	0	3
49	1100	0.07	0	69935520	1,605	870057.3166	77	3	2	2	2	3	0	3
25	1000	0.176	0	324234255	7,443	1433750.88	552	2	3	2	3	3	0	3
5	1000	0.15	15	156095261	3,583	182836.258	130	3	2	2	3	1	2	3
47	1000	0.11	0	705884336	16,205	13133290.29	419	3	3	2	3	3	0	3
21	1700	0.9	0	570792619	13,104	4890733.603	78	3	3	3	3	3	0	2
59	1000	0.07	0	296201192	6,800	1702426.452	339	2	3	2	2	3	0	3
30	1700	0.9	0	675060539	15,497	5721032.308	215	3	3	3	3	3	0	2
49	1000	0.07	0	246926966	5,669	1184558.647	231	2	3	2	2	3	0	3

Stacked opportunity rank	mode CO2	Cum_Prod_BCF	Avg_Perm_mD	Trap-Type	Res_Cont	Prod rank	wells per 1000 acres	Legacy well penetrations rank
0	3	0.0662		Structural/Stratigraphic	2	1	30	0
0	3	8.7794		Stratigraphic	3	2	12	1
0	2		2	Structural/Stratigraphic	4	1	48	0
1	3	0.0073		Structural/Stratigraphic	2	1	74	0
0	2	1.3074		Stratigraphic	3	2	36	0
1	3	0.0759		Structural/Stratigraphic	2	1	26	0
0	3	0		Stratigraphic	3	1	6	1
2	3	0.0595		Stratigraphic	4	1	50	0
0	3	0.1362		Stratigraphic	3	1	14	1
1	3	0.0395		Stratigraphic	4	1	41	0

FIFLD NAME	Formations	Lithology	Geo Age	DISC YEAR	STATE	Pi	Pmax	MMP	Pi MMP	Pmax MMP	AvgProdDen	NETTHICK	PRESS	POROSITY	Perm	Area soft	Acreage
Abbott-French Creek	DVNN TRTE GRONS GRON FRTH FETH BYRD FLZB WRRN	Sandstone	Devonian	1977	WV	950 435	1756	422 1568	528 2782	1333 8432	2195	31	1000	0.09	0	1808783130	41 524
Antram Run	VNNG. BDFD	Sandstone	Devonian	1907	PA	1082.5	2000	430.8356	651.6644	1569.1644	2500	11.17	926	0.11	õ	335125521	7.693
Aspinall-Finster	BNSN FLK BRIR ALXD FLKP	Sandstone Siltstone	Devonian	1947	wv	2064 111	3813.6	527.16	1536 951	3286.44	4767	22	2100	0.08	ő	1178845920	27.063
Aspinall-Finster	BDED, SPCL, BLTN, BILY	Sandstone	Devonian	1975	wv	1548.408	2860.8	479.5256	1068.8824	2381.2744	3576	32	1500	0.08	õ	1180466230	27,100
Auburn	BNSN, FLK, ALXD, FLKP	Sandstone, Siltstone	Devonian	1973	WV	2090.524	3862.4	529,5592	1560.9648	3332,8408	4828	60	2100	0.07	0	241329429	5.540
Auburn	DVNN, GNTZ, FFTF, TRTF, GRDN, FFTH, WRRN	Sandstone, Siltstone	Devonian	1968	WV	1324.547	2447.2	458.34	866.207	1988.86	3059	26	1300	0.07	0	435392488	9,995
Beason Run	BNSN, ELK, ALXD, ELKP	Sandstone, Siltstone	Devonian	1979	WV	2104.813	3888.8	530.8556	1573.9574	3357,9444	4861	49	2100	0.07	0	756783028	17.373
Bridgeport-Pruntytown	BDFD. SPCL. BLTN. RILY	Sandstone	Devonian	1912	WV	1546.676	2857.6	465.9887	1080.6873	2391.6113	3572	38	1500	0.09	0	1799612250	41.313
Brown-Lumberport	BDFD, SPCL, BLTN, RILY, SPCL	Sandstone	Devonian	1902	wv	1440.158	2660.8	469.3222	970.8358	2191.4778	3326	69	1400	0.08	0	2203901700	50,595
Buckhannon-Century	BNSN, ELK, BRLR, ALXD, ELKP, HVRT, FOX	Sandstone, Siltstone	Devonian	1916	wv	1764.042	3259.2	486.4509	1277.5911	2772.7491	4074	26	1800	0.09	0	3181413330	73,035
Campbells Run-Miracle Run	FFTF, TRTF, GRDNS, GRDN, FRTH, FFTH, BYRD	Sandstone	Devonian	1929	WV	1393.394	2574.4	452.813	940.581	2121.587	3218	80	1400	0.09	0	409476011	9,400
Coburn-Earnshaw	DVNN, FFTF, TRTF, GRDNS, GRDN, FRTH, FFTH, BYRD	Sandstone, Siltstone	Devonian	1913	wv	1347.063	2488.8	448.7726	898.2904	2040.0274	3111	60	1300	0.09	0	622282020	14,286
Condit-Ragtown	GNTZ, FFTF, TRTF, GRDNS, GRDN, FRTH, FFTH, BYRD, ELZB	Sandstone	Devonian	1914	WV	1381.703	2552.8	450.2505	931.4525	2102.5495	3191	90	1400	0.09	0	723520415	16,610
Conings	BNSN, ELK, ALXD, LPLD, BLCK, ELKP	Sandstone, Siltstone	Devonian	1962	WV	2111.741	3901.6	531.4837	1580.2573	3370.1163	4877	90	2100	0.07	0	234252654	5,378
Elk Creek (Overfield)	BDFD, SPCL, BLTN, RILY	Sandstone	Devonian	1917	WV	1693.463	3128.8	493.0826	1200.3804	2635.7174	3911	49	1700	0.08	0	1550603480	35,597
Elk Creek (Overfield)	DVNN, GNTZ, FFTF, GRDNS, FRTH, FFTH, BYRD, ELZB, WRRN	Sandstone, Siltstone	Devonian	1921	WV	1000.23	1848	427.0329	573.1971	1420.9671	2310	21	1000	0.09	0	1672241240	38,389
Farmington	GNTZ, FFTF, TRTF, GRDNS, GRDN, FRTH, FFTH, BYRD, WRRN	Sandstone	Devonian	1909	WV	1149.182	2123.2	427.7405	721.4415	1695.4595	2654	28	1100	0.09	0	2153027930	49,427
Frvw-Statler Rn-Mt Morrs	FFTF, GRDN, FRTH, FFTH, BYRD, ELZB	Sandstone	Devonian	1913	WV	1318.052	2435.2	444.1278	873.9242	1991.0722	3044	100	1300	0.09	0	428278401	9,832
Glade Run	BDFD, SPCL, BLTN, RILY	Sandstone	Devonian	1962	WV	1577.852	2915.2	482.288	1095.564	2432.912	3644	62	1600	0.08	0	473084772	10,861
Glenville North	BNSN, ELK, BRLR, ALXD, BLCK, ELKP	Sandstone, Siltstone	Devonian	1957	WV	2024.708	3740.8	523.574	1501.134	3217.226	4676	81	2000	0.08	0	1755729840	40,306
Glenville South	DVNN, GNTZ, GRDNS, GRDN, FRTH, FFTH, BYRD, WRRN	Sandstone, Siltstone	Devonian	1930	WV	1140.522	2107.2	440.6693	699.8527	1666.5307	2634	30	1100	0.09	0	635846970	14,597
Grantsville-Arnoldsburg	BNSN, ELK, BRLR, ALXD	Sandstone, Siltstone	Devonian	1992	WV	2145.082	3963.2	534.5031	1610.5789	3428.6969	4954	75	2100	0.07	0	459346104	10,545
Greenwood	BNSN, ELK, BRLR, ALXD, ELKP	Sandstone, Siltstone	Devonian	1979	WV	2148.113	3968.8	534.7773	1613.3357	3434.0227	4961	52	2100	0.07	0	530143329	12,170
Hazel Green-Lawford-Berea	BNSN, ELK, ALXD	Sandstone, Siltstone	Devonian	1980	WV	2083.596	3849.6	528.9303	1554.6657	3320.6697	4812	58	2100	0.07	0	537280459	12,334
Heaters	BNSN, ELK, ALXD, ELKP	Sandstone, Siltstone	Devonian	1968	WV	1996.563	3688.8	521.0073	1475.5557	3167.7927	4611	35	2000	0.09	0	557965364	12,809
Heaters	BDFD, SPCL, BLTN, RILY, SPCL	Sandstone	Devonian	1973	WV	1243.576	2297.6	450.5942	792.9818	1847.0058	2872	36	1200	0.09	0	628589494	14,430
Hundred	HMPR, GNTZ, FFTF, TRTF, GRDNS, GRDN, FRTH, FFTH, BYRD	Sandstone	Devonian	1904	WV	1339.269	2474.4	448.0917	891.1773	2026.3083	3093	60	1300	0.09	0	660485390	15,163
Jarvisville	BDFD, SPCL, BLTN, RILY, SPCL	Sandstone	Devonian	1901	WV	1367.414	2526.4	462.4225	904.9915	2063.9775	3158	33	1400	0.08	0	2259984560	51,882
Jefferson	VNNG, CNMG	Sandstone	Devonian-Pennsylvanian	1889	PA	1366.981	2525.6	460.722	906.259	2064.878	3157	11.17	980	0.11	0	785178189	18,025
Llewellyn Run-Plum Run	DVNN, FFTF, TRTF, GRDNS, GRDN, FRTH, FFTH, BYRD	Sandstone, Siltstone	Devonian	1925	WV	1299.866	2401.6	455.9838	843.8822	1945.6162	3002	90	1300	0.09	0	277971674	6,381
Logansport	GNTZ, FFTF, TRTF, GRDNS, GRDN, FFTH, BYRD	Sandstone	Devonian	1914	WV	1225.823	2264.8	448.8899	776.9331	1815.9101	2831	80	1200	0.09	0	280287709	6,435
Lorentz	BNSN, ELK, ALXD	Sandstone, Siltstone	Devonian	1940	WV	1980.542	3659.2	519.5443	1460.9977	3139.6557	4574	23	2000	0.09	0	523374122	12,015
Lorentz	BDFD, SPCL, BLTN, RILY	Sandstone	Devonian	1937	WV	1588.244	2934.4	483.2617	1104.9823	2451.1383	3668	40	1600	0.08	0	252142265	5,788
Lorentz	GNTZ, FFTF, GRDNS, GRDN, FFTH, BYRD, ELZB, WRRN	Sandstone	Devonian	1977	WV	1120.171	2069.6	438.7002	681.4708	1630.8998	2587	25	1100	0.09	0	540880368	12,417
Mahone (Smithville)	BNSN, ELK, ALXD, ELKP	Sandstone, Siltstone	Devonian	1981	WV	2095.72	3872	530.0307	1565.6893	3341.9693	4840	51	2100	0.07	0	313251515	7,191
Mannington	DVNN, GNTZ, FFTF, TRTF, GRDNS, GRDN, FRTH, FFTH, BYRD	Sandstone, Siltstone	Devonian	1893	WV	1217.163	2248.8	448.0577	769.1053	1800.7423	2811	88	1200	0.09	0	456715822	10,485
Maple-Wadestown	DVNN, GNTZ, FFTF, TRTF, GRDNS, GRDN, FRTH, FFTH, BYRD	Sandstone, Siltstone	Devonian	1905	WV	1347.496	2489.6	435.1238	912.3722	2054.4762	3112	85	1300	0.09	0	891187468	20,459
Masontown	VNNG, BRGN	Sandstone	Devonian-Mississippian	1889	PA	1246.607	2303.2	448.1598	798.4472	1855.0402	2879	31.19	960	0.11	0	211818446	4,863
Mcgraw	GRDNS ,GRDN	Sandstone	Devonian	1985	WV	1729.402	3195.2	496.4216	1232.9804	2698.7784	3994	21	1700	0.07	0	3267562990	75,013
McKeesport	SPCL	Sandstone	Devonian	1919	PA	1385.6	2560	450.6245	934.9755	2109.3755	3200	17.17	1400	0.11	0	305164182	7,006
Meathouse Fork-Bristol	GN12, FFTF, TRTF, GRUNS, GRUN, FRTH, FFTH, BYRD, WRRN	Sandstone	Devonian	1985	wv	1235.782	2283.2	449.8463	/85.935/	1833.3537	2854	26	1200	0.09	0	533973099	12,258
Mooresville	DVNN, GNTZ, GRDNS, GRDN, FFTH, BYRD, ELZB	Sandstone, Siltstone	Devonian	1901	wv	1338.403	24/2.8	446.0885	892.3145	2026.7115	3091	100	1300	0.1	0	250299125	5,746
Murphy Creek	BUFU, SPCL, BLIN, RILY, SPCL	Sandstone	Devonian	1906	VV V	1384.734	2558.4	464.0685	920.6655	2094.3315	3198	34	1400	0.08	0	2361016070	54,201
Murphy Creek	BNSN, ELK, BRLR, ALXD, SCMR, LPLD, ELKP	Sandstone, Siltstone	Devonian	1917	WV	1945.469	3594.4	516.3366	1429.1324	3078.0634	4493	21	1900	0.08	0	1692492830	38,854
New Milton South	BINSIN, ELK, ALXD, LPLD	Sandstone, Siltstone	Devonian	1962	VV V	2158.938	3988.8	535.7502	1623.1818	3453.0438	4986	33	2200	0.07	0	380399585	8,870
Porto Rico	DIVISIN, ELK, ALAD, LPLD	Sandstone, Sittstone	Devonian	1978	VV V	1220.775	3964.6	457.0692	062 6010	1082 0218	4961	04 22	1200	0.07	0	450687254	10 346
POLO RICO		Sandstone Siltstone	Devonian	1901		2060 74	2440	437.9082	15/2 0692	2206 2292	4790	26	2100	0.08	0	450067254	10,540
Pural Pidgo	VINIG RDED	Sandstone, Sitistone	Devonian	1012	DA	1270 105	25/9	J27.0717	0/1 10/	2110.020	2195	21 10	024	0.07	0	127040605	2 027
Salem	RDED SPCI BITN RILY	Sandstone	Devonian	1972	WV	183/ 621	2340 6	506 1533	1328 /677	2883 4467	4237	62	1800	0.11	0	252716644	5 802
Shiloh-Wick Area	TRTE GRONS GRON FETH WRRN	Sandstone	Devonian	1979	WV	117/ 296	2169.6	1/13 030/	730 3656	1725 6696	2712	2/	1200	0.00	0	691705149	15 879
Shinnston	FETE TRTE GRDN FRTH FETH BYRD	Sandstone	Devonian	1964	WV	1075 572	1987.2	434 3744	641 1976	1552 8256	2484	25	1100	0.08	ő	357019980	8 196
Smithfield	DVNN HMPR FETE GRDNS GRDN FRTH FETH	Sandstone	Devonian	1909	WV	1303 763	2408.8	456 3561	847 4069	1952 4439	3011	40	1300	0.09	0	394964024	9.067
Smithton-Flint-Sedalia	BDED SPCI BITN BILY	Sandstone	Devonian	1936	wv	1744 99	3224	497 8674	1247 1226	2726 1326	4030	24	1700	0.07	ő	896856705	20 589
South Burns Chapel	SPCL, BLTN	Sandstone	Devonian	1968	wv	1080.335	1996	430.6055	649.7295	1565.3945	2495	56	1100	0.12	õ	164532369	3.777
Stanley	GNTZ, TRTE, GRDN, FETH, WRRN	Sandstone	Devonian	1971	WV	1372.61	2536	462.9165	909.6935	2073.0835	3170	35	1400	0.07	0	411904436	9.456
Straight Fk-Bluestone Ck	BNSN, ELK, BRLR, ALXD, LPLD, BLCK, ELKM	Sandstone, Siltstone	Devonian	1977	WV	2135.123	3944.8	533.6018	1601.5212	3411.1982	4931	33	2100	0.07	0	1283721340	29.470
Straight Fk-Bluestone Ck	TRTF. GRDNS. GRDN. FFTH. WRRN	Sandstone	Devonian	1930	WV	1230.153	2272.8	449.3058	780.8472	1823,4942	2841	26	1200	0.07	0	1272655710	29.216
Stumptwn-Normantwn-Shock	BNSN, ELK, BRLR, ALXD, BLCK, ELKP	Sandstone, Siltstone	Devonian	1977	WV	2139.453	3952.8	533,9938	1605.4592	3418.8062	4941	50	2100	0.07	0	1044320410	23,974
Stumptwn-Normantwn-Shock	GNTZ, FETF, GRDNS, GRDN, FETH, BYRD, ELZB, WRRN	Sandstone	Devonian	1985	wv	1158,708	2140.8	442,4263	716.2817	1698.3737	2676	30	1200	0.08	Ó	938207965	21.538
Thursday	BNSN, ELK, BRLR, ALXD, ELKP	Sandstone, Siltstone	Devonian	1980	wv	2103.947	3887.2	530.777	1573.17	3356.423	4859	76	2100	0.07	Ó	231698236	5,319
Wallace-Folsom	GNTZ, FFTF, TRTF, GRDNS, GRDN, FRTH, FFTH	Sandstone	Devonian	1903	wv	1327.145	2452	458.5878	868.5572	1993.4122	3065	60	1300	0.09	0	659098954	15,131
Weston-Jane Lew	BDFD, SPCL, BLTN, RILY	Sandstone	Devonian	1913	wv	1376.507	2543.2	463.2869	913.2201	2079.9131	3179	77	1400	0.08	0	2448116640	56,201
Weston-Jane Lew	BNSN, ELK, BRLR, ALXD, SCMR, LPLD, ELKP	Sandstone, Siltstone	Devonian	1909	wv	1877.488	3468.8	510.0997	1367.3883	2958.7003	4336	66	1900	0.08	0	2777449160	63,761
White Ash	VNNG, BDFD	Sandstone	Devonian	1910	PA	1328.011	2453.6	445.0876	882.9234	2008.5124	3067	31.19	1035	0.11	0	120378835	2,764
Wolf Summit	FFTF, TRTF, GRDNS, GRDN, FRTH, FFTH, BYRD	Sandstone	Devonian	1898	wv	1149.182	2123.2	441.5062	707.6758	1681.6938	2654	40	1100	0.09	0	268280272	6,159

store_mode	legacy well count	Revised distance rank	Acreage	Average depth	porosity	net thickness	permeability	pressure	Stacked opportunity rank	Cum_Prod_BCF	Trap-Type	Res_Cont	Mode CO2	Prod rank	wells per 1000 acres	Legacy well penetrations rank
6321557.392	4	2	3	2	2	3	0	3	0	32.6406	Stratigraphic	2	3	3	0	3
1196237.94	285	2	3	2	3	2	0	3	0		Stratigraphic	3	3	0	37	0
8483007.931	1083	3	3	3	2	3	0	2	0	25.1796	Stratigraphic	2	3	3	40	0
13169907.51		3	3	3	2	3	0	3	0	16.6803	Stratigraphic	2	3	3	0	3
3519097.197	441	2	3	3	2	3	0	2	1	5.4395	Stratigraphic	2	3	2	80	0
2869762.602		2	3	2	2	3	0	3	1	0.1974	Stratigraphic	2	3	1	0	3
9177142.114	918	2	3	3	2	3	0	2	1	13.4582	Stratigraphic	2	3	3	53	0
23432680.87	1408	1	3	3	2	3	0	3	0	51.2586	Stratigraphic	2	3	3	34	0
44555857.02	2729	2	3	2	2	3	0	3	1	105.1931	Stratigraphic	2	3	3	54	0
29486166.82	0	1	3	3	2	3	0	2	0	71.3801	Stratigraphic	2	3	3	0	3
12929238.9	864	2	3	2	2	3	0	3	0	0.498	Stratigraphic	2	3	1	92	0
14474706.25	465	3	3	2	2	3	0	3	0	0.8535	Stratigraphic	2	3	1	33	0
25412730.81	888	2	3	2	2	3	0	3	1	0.2246	Stratigraphic	2	3	1	53	0
5310166.133	136	2	3	3	2	3	0	2	2	1.8273	Stratigraphic	2	3	2	25	0
21891921.06	414	2	3	3	2	3	0	2	0	10.4916	Stratigraphic	2	3	3	12	1
4809094.11		2	3	2	2	3	0	3	0	4.9117	Stratigraphic	2	3	2	0	3
22817738.08	1575	2	3	2	2	3	0	3	1	3,838	Stratigraphic	2	3	2	32	0
16654003.37	919	2	3	2	2	3	0	3	1	3.0461	Stratigraphic	2	3	2	93	0
8253438.3	319	1	3	3	2	3	0	2	0	16.6103	Stratigraphic	2	3	3	29	0
45051466.31	1473	2	3	3	2	3	0	2	2	70.2819	Stratigraphic	2	3	3	37	0
6434533 401	51	2	3	2	2	3	0	3	-	1 7106	Stratigraphic	2	3	2	3	2
8835267.475	410	1	3	3	2	3	ő	2	1	2.5915	Stratigraphic	2	3	2	39	0
6950697.87	960	3	3	3	2	3	0	2	1	3 4257	Stratigraphic	2	3	2	79	0
7436756 341	/97	2	3	3	2	3	0	2	1	1.0556	Stratigraphic	2	3	2	10	0
7279259 //9	19	1	3	3	2	3	0	2	0	4 3728	Stratigraphic	2	3	2	40	3
7529606 494	15	2	2	2	2	2	0	2	0	7.0692	Stratigraphic	2	2	2	0	2
15353100.03	604	2	3	2	2	3	0	3	0	1 101	Stratigraphic	2	3	2	40	0
21706205 10	2917	2	2	2	2	2	0	2	1	04 5069	Stratigraphic	2	2	2	40	0
21700303.13	2017	2	2	2	2	3	0	2	1	54.5508	Stratigraphic	2	2	0	17	1
02201192.42	312	2	2	2	2	2	0	2	1	0.3500	Stratigraphic	2	2	1	22	1
9330166.307	211	2	2	2	2	2	0	2	1	0.5599	Stratigraphic	2	2	1	33	0
62///00.41/	279	2	2	2	2	2	0	2	1	0.1/1/	Stratigraphic	2	2	1	45	0
4551400.174	20	1	2	3	2	2	0	2	0	1.7796	Stratigraphic	2	2	2	2	2
2986716.24		2	3	3	2	3	0	2	0	1.204	Stratigraphic	2	3	2	0	3
4538770.96	202	2	3	2	2	3	0	3	0	3./11/	Stratigraphic	2	3	2	0	3
3952640.404	382	2	3	3	2	3	0	2	1	3.934	Stratigraphic	2	3	2	53	0
14816481.07	914	2	3	2	2	3	0	3	0	0.026	Stratigraphic	2	3	1	8/	0
30336172.37	604	3	3	2	2	3	0	3	1	0.8291	Stratigraphic	2	3	1	30	0
215/018.3/5	129	2	2	2	3	3	0	3	U			_	3	0	2/	0
17330822.13	0	1	3	3	2	3	0	2	0	0.3162	Stratigraphic	2	3	1	0	3
1785558.003	128	3	3	2	3	2	0	3	0	17	Structural/Stratigraphic	3	3	3	18	1
4839713.74	649	2	3	2	2	3	0	3	1	1.7841	Stratigraphic	2	3	2	53	0
10672932.64	162	2	3	2	2	3	0	3	1	0.3507	Stratigraphic	2	3	1	28	0
24554576.93	1931	3	3	2	2	3	0	3	2	22.4262	Stratigraphic	2	3	3	36	0
11404551.43	1222	3	3	3	2	3	0	2	2	33.9081	Stratigraphic	2	3	3	31	0
3215978.787	245	2	3	3	2	3	0	2	2	10.1658	Stratigraphic	2	3	3	28	0
7335461.043	809	3	3	3	2	3	0	2	1	3.1174	Stratigraphic	2	3	2	102	0
4313472.016		3	3	2	2	3	0	3	1	1.2128	Stratigraphic	2	3	2	0	3
4234035.064	456	2	3	3	2	3	0	2	1	0.9281	Stratigraphic	2	3	1	41	0
1397316.275	173	2	2	2	3	3	0	3	0		Stratigraphic	3	3	0	59	0
4621078.937	436	2	3	3	2	3	0	2	1	1.4723	Stratigraphic	2	3	2	75	0
5167439.913	939	3	3	2	2	3	0	3	1	0.5435	Stratigraphic	2	3	1	59	0
2749115.697	516	2	3	2	2	3	0	3	0	4.6303	Stratigraphic	2	3	2	63	0
5810597.498	746	3	3	2	2	3	0	3	0	0.4815	Stratigraphic	2	3	1	82	0
5348236.877	1309	3	3	3	2	3	0	2	1	2.5491	Stratigraphic	2	3	2	64	0
4751959.286	31	0	2	2	3	3	0	3	0				3	0	8	1
3793800.63	512	3	3	2	2	3	0	3	2	2.9367	Stratigraphic	2	3	2	54	0
10493114.86	2010	3	3	3	2	3	0	2	1	29.8571	Stratigraphic	2	3	3	68	0
8420570.614		3	3	2	2	3	0	3	1	7.0298	Stratigraphic	2	3	2	0	3
14750790.09	823	1	3	3	2	3	0	2	1	0.4602	Stratigraphic	2	3	1	34	0
8081968.425		1	3	2	2	3	0	3	1	1.2458	Stratigraphic	2	3	2	0	3
4204873.336	257	1	3	3	2	3	0	2	1	1.3343	Stratigraphic	2	3	2	48	0
14795624.61	1191	3	3	2	2	3	0	3	1	0.1112	Stratigraphic	2	3	1	79	0
73818353.77	2584	3	3	2	2	3	0	3	1	15.1306	Stratigraphic	2	3	3	46	0
59573062.89	896	3	3	3	2	3	0	2	1	55.0673	Stratigraphic	2	3	3	14	1
1275379.894	22	3	2	2	3	3	0	3	0		• •		3	0	8	1
3794286.568	747	2	3	2	2	3	0	3	1	0.9506	Stratigraphic	2	3	1	121	0

State	Thickness	Porosity	Reported_P	Permeability	Working_Gas_Capacity_MCF	Area	Acreage	Modal_Stor	Depth_of_R	legacy well count	Acreage
WV	20	0.91	1900	0	23,504,769	265773264.2	6,101	17,275,627	5858	321	3
WV	20	0.91	1670	0	8,540,000	110683949.9	2,541	7,159,667	5325	214	2
WV	15	0.087	1000	0		1974277920	45,323	2,657,298	2050	1840	3
WV	11	0.087	941	0	2,221,000	52629084.65	1,208	63,679	2174	86	2
PA	17.17	0.11	1400	0		31249858.34	717	182,847	3200	1	1
PA	12	0.16	0	0		171874394.4	3,946	1,996,113	2486	157	2
WV	13	0.087	1000	0	4,446,000	476884287.8	10,948	1,925,347	2400	464	3
WV	20	0.091	1835	0	10,553,000	405236463.4	9,303	2,611,318	4980	205	3
WV	50	0.091	1875	0	3,811,000	134271152.1	3,082	2,166,744	5126	69	2
WV	19	0.09	2200	0	3,811,000	428480561.5	9,837	2,597,995	5105	104	3
WV	20	0.107	680	0	3,811,000	368056388.5	8,449	708,962	2037	196	3
WV	20	0.107	710	0		1256638010	28,848	8,640,276	2313	1365	3

average depth	porosity	net thickness	permeability	pressure	mode CO2	distance	Stacked opportunity rank	wells per 1000 acres	Legacy well penetrations rank
1	3	2	0	2	3	2	1	53	0
1	3	2	0	2	3	2	1	84	0
2	2	2	0	3	3	3	2	41	0
2	2	2	0	3	1	2	1	71	0
2	3	2	0	3	2	3	1	1	3
2	3	2	0	0	3	3	0	40	0
2	2	2	0	3	3	2	2	42	0
3	2	2	0	2	3	3	2	22	0
1	2	3	0	2	3	3	0	22	0
1	2	2	0	2	3	3	1	11	1
2	3	2	0	1	2	3	0	23	0
2	3	2	0	1	3	3	1	47	0

FID	TEST_ID_1	FIELD_TYPE	FIELD_NAME	Formation	Lithology	Geo_Age	DISC_YEAR	State	Pi	Pmax	MMP	Pi_MMP	Pmax_MMP
4	827	Gas	ROCK CAMP	Oriskany	Sandstone	Devonian	1936	OH	1905.2	3520	531.316	1373.884	2988.684
7	961	Gas	PUTNAM	Oriskany	Sandstone	Devonian	1951	ОН	1775.3	3280	500.6747	1274.6253	2779.3253
10	964	Gas	LAUREL RUN	Oriskany	Sandstone	Devonian	1989	OH	1688.7	3120	492.6394	1196.0606	2627.3606
26	11118	Gas	Glenville North	MLTI	Chert, Dolomite, Limestone	Devonian	1972	WV	2875.553	5312.8	599.276	2276.277	4713.524
27	11119	Gas	Dekalb	MLTI	Limestone, Sandstone	Devonian	1985	WV	2678.538	4948.8	582.0531	2096.4849	4366.7469
33	11134	Gas	Kanawha Forest	Oriskany	Sandstone	Devonian	1966	WV	1988.336	3673.6	520.2562	1468.0798	3153.3438
34	11135	Gas	Campbell Creek	Oriskany	Sandstone	Devonian	1935	WV	2089.225	3860	529.4413	1559.7837	3330.5587
36	11137	Gas	Blue Ck (Falling Rk)	Oriskany	Sandstone	Devonian	1944	WV	2269.786	4193.6	545.745	1724.041	3647.855
37	11138	Gas	Red House	Oriskany	Sandstone	Devonian	1954	WV	1962.356	3625.6	517.8819	1444.4741	3107.7181
39	11140	Gas	Elk-Poca (Sissonville)	Oriskany	Sandstone	Devonian	1967	WV	2178.856	4025.6	537.5557	1641.3003	3488.0443
41	11143	Gas	New England	Oriskany	Sandstone	Devonian	1952	WV	1825.528	3372.8	505.3149	1320.2131	2867.4851
48	11150	Gas	Hurricane Creek	Oriskany	Sandstone	Devonian	1940	WV	1884.416	3481.6	494.9085	1389.5075	2986.6915

AvgProdDep	NETTHICK	PRESS	POROSITY	Perm	Area_sqft	acreage	store_mode	legacy well count	Revised distance rank	acreage	average depth	porosity	thickness
4400	22	1500	0.08	0	58890404	1,352	307357.6636	42	3	2	3	2	3
4100	20	1410	0.06	0	284757075	6,537	1047095.679	64	3	3	3	2	2
3900	24	1300	0.08	0	128311755	2,946	751753.1752	112	2	2	3	2	3
6641	30	2900	0.13	0	407121910	9,346	5502218.77	349	2	3	1	3	3
6186	40	2700	0.08	0	325008982	7,461	3593176.79	330	1	3	1	2	3
4592	11	2000	0.09	0	402087510	9,231	1402187.139	116	3	3	3	2	2
4825	15	2100	0.09	0	823957610	18,915	3930794.164	193	3	3	3	2	2
5242	23	2300	0.09	0	817180858	18,760	6006895.235	1260	2	3	1	2	3
4532	10	2000	0.09	0	379766518	8,718	1202877.338	58	3	3	3	2	1
5032	18	2200	0.14	0	10668353200	244,911	95245552.39	3515	3	3	1	3	2
4216	15	1800	0.04	0	777247960	17,843	1260302.512	166	3	3	3	1	2
4352	11	1900	0.06	0	251396100	5,771	441617.4277	49	3	3	3	2	2

permeability	pressure	Stacked opportunity rank	mode CO2	Cum_Prod_BCF	Trap-Type	Res_Cont	Prod rank	wells per 1000 acres	Legacy well penetrations rank
0	3	1	2				0	31	0
0	3	0	3		Stratigraphic	3	1	10	1
0	3	1	2				0	38	0
0	2	2	3	1.6525	Structural	3	2	37	0
0	2		3	0.1766	Structural	3	1	44	0
0	2	1	3		Structural/Stratigraphic	4	0	13	1
0	2	1	3	24.75	Structural/Stratigraphic	4	3	10	1
0	2	1	3	66.55	Structural/Stratigraphic	4	3	67	0
0	2	1	3	1.1238	Structural/Stratigraphic	4	2	7	1
0	2	1	3	962.207	Structural/Stratigraphic	4	3	14	1
0	2	1	3	5.4067	Stratigraphic	3	2	9	1
0	2	1	2	0.0172	Stratigraphic	3	1	8	1

	Geologic Interval – Salina F4 Salt	1	2	3	4	Area
Range of						
Values	Criteria					Explanation
	Distance to infrastructure					
0	- 20 ml	3	3	3	3	Ohio River
1	>30 mi >20 mi hut <=30 mi					
2	>5 mi but <=20 mi					
3	<=5 mi					
	Average depth	2	2	1	1	from structure map
0	<=2,000 ft					
1	>3,000 ft but <=5,000 ft					
3	>2.000 ft but <=3.000 ft					
-	,					
		2	3	2	1	Net Acreage
	Acreage	2	3	2	1	Gross Acreage
0	<25,000	83,775	129,016	80,867	40,952	acreage per F4 net salt polygons GROSS AC
1	25,000-50,000	16,266	27,627	16,590	2,395	cities + river
2	50,000-100,000 >100,000	67,509	700	64,277	38,557	F4 acreage minus cities
5	2100,000	83 025	128 316	80 867	40 202	F4 acreage minus laterals
		16,266	28,327	16,590	3,145	laterals, cities + rivers
		67,509	100,689	64,277	37,807	F4 acreage minus cities + laterals NET AC
	Average net thickness	2	2	2	2	E4 polygons = 100 ft min
0	<=10 ft	5	3	3	5	
1	>10 ft but <=50 ft					
2	>50 ft but <=100 ft					
3	>100 ft					
	Prossuro	0	0	0	2	Bools Bun data for polygon 4
0	No data	0	U	U	2	Ben's Kun data for polygon 4
1	>0 psi but <=900 psi					
2	>900 psi but <=1,500 psi					
3	>1,500 psi					
		2		2	2	
0	Irap integrity	3	3	3	3	
1	Limited data on tran characteristics					
2	Inferred lithologic and/or structural closure					
3	Documented lithologic and/or structural closure					
		1	1	1	0	wells/NET 1000 ac
	Legacy well penetrations	1	1	1	0	wells/GROSS 1000 ac
0	No data or >=20 wells per 1,000 ac	/25 02 775	1615	528	18//	well penetration
1 2	>=2 wells per 1,000 ac but <5 wells per 1,000 ac	os,775 16,266	27,627	00,807 16,590	2.395	gi uss au GKUSS city + river ac
2	<2 well per ac	67,509	101,389	64,277	38,557	ac- cities
-		0	700	0	750	lateral ac
		83,775	128,316	80,867	40,202	ac - laterals
		16,266	28,327	16,590	3,145	ac- city, river + lateral
		67,509	100,689	64,277	37,807	ac- (cities + laterals) NET
		9 65/122	10 51700	6 520220	AE 9241E	wells per 1000 pc, pet percess
		0.004133	16 03070	8 214447	43.63415	wells per 1000 ac gross acreage
		10.75551	10.03343	5.21444/	13.04003	wens per 2000 de, 51035 deleage

Stacked opportunity? No other intervals in same footprint

2 or 3 other intervals in same footprint

 States opportunity?

 0
 No other intervals in same footprint

 1
 1 other interval in same footprint

 2
 or 3 other intervals in same footprint

 3
 4 or more intervals in same footprint
 4 or more intervals in same footprint 1 0 0 2
FID	TEST_ID_1	FIELD_TYPE	FIELD_NAME	Formation	Lithology	Geo_Age	DISC_YEAR	STATE	Pi	Pmax	MMP	Pi_MMP	Pmax_MMP	AvgProdDep	NETTHICK
1	11735	Gas	Groundhog Creek	Newburg	Sandstone	Silurian	1969	WV	2127.329	3930.4	532.8961	1594.4329	3397.5039	4913	8
3	11737	Gas	North Ripley	Newburg	Sandstone	Silurian	1969	WV	2329.107	4303.2	551.0648	1778.0422	3752.1352	5379	77
4	11738	Gas	Wheaton Run	Newburg	Sandstone	Silurian	1971	WV	2398.387	4431.2	557.2554	1841.1316	3873.9446	5539	5
7	11741	Gas	Rocky Fork	Newburg	Sandstone	Silurian	1966	WV	2434.759	4498.4	560.4961	1874.2629	3937.9039	5623	140
8	11742	Gas	Cooper Creek	Newburg	Sandstone	Silurian	1968	WV	2491.482	4603.2	565.5371	1925.9449	4037.6629	5754	30
9	11743	Gas	Kanawha Forest	Newburg	Sandstone	Silurian	1964	WV	2328.674	4302.4	551.026	1777.648	3751.374	5378	48

PRESS	POROSITY	Perm	Area_sqft	acreage	store_mode	legacy well count	Revised distance rank	acreage	average depth	porosity	thickness	permeability	pressure
2100	0.11	0	110413232	2,535	458319.0539	13	3	2	3	3	1	0	2
2300	0.14	0	837237403	19,220	35473678.35	201	3	3	1	3	3	0	2
2400	0.13	0	70266226	1,613	182644.8922	89	3	2	1	3	1	0	2
2400	0.18	0	1830852180	42,031	204839637.1	653	3	3	1	3	3	0	2
2500	0.15	0	373834312	8,582	7161427.579	109	2	3	1	3	3	0	2
2300	0.11	0	1204570710	27,653	33330365.64	285	3	3	1	3	3	0	2

Stacked opportunity rank	mode CO2	Cum_Prod_BCF	Avg_Perm_mD	Trap-Type	Res_Cont	Prod rank	wells per 1000 acres	Legacy well penetrations rank
0	2	10.177		Structural/Stratigraphic	4	3	5	1
2	3	86.654		Stratigraphic	4	3	10	1
1	2	1.1		Structural/Stratigraphic	3	2	55	0
2	3	136.451	46	Structural/Stratigraphic	4	3	16	1
1	3	17.752		Structural	4	3	13	1
2	3	49.185	14	Structural/Stratigraphic	3	3	10	1

FID	TEST_ID_1	FIELD_TYPE	FIELD_NAME	FMTN_CODE	Lithology	Geo_Age	DISC_YEAR	STATE	Pi	Pmax	MMP	Pi_MMP	Pmax_MMP	AvgProdDep
36	649	Gas	PHILO CONSOLIDATED	CLNN, MDIN	Sandstone	Silurian	1928	ОН	2013.45	3720	539.1473	1474.3027	3180.8527	4650
63	1005	Gas	CANTON CONSOLIDATED	CLNN	Sandstone	Silurian	1921	ОН	1983.14	3664	523.3013	1459.8387	3140.6987	4580
65	1060	Gas	CANTON CONSOLIDATED	CLNN	Sandstone	Silurian	1921	ОН	1983.14	3664	523.3013	1459.8387	3140.6987	4580
110	1543	Gas	NORTH ELLSWORTH CONSOLIDATED	CLNN	Sandstone	Silurian	1963	ОН	2208.3	4080	563.461	1644.839	3516.539	5100
124	1981	Gas	CANTON CONSOLIDATED	CLNN	Sandstone	Silurian	1921	OH	1983.14	3664	523.3013	1459.8387	3140.6987	4580
141	2048	Gas	CANTON CONSOLIDATED	CLNN	Sandstone	Silurian	1921	OH	1983.14	3664	523.3013	1459.8387	3140.6987	4580
189	2216	Gas	TRIADELPHIA CONSOLIDATED	CLNN, MDIN	Sandstone	Silurian	1927	ОН	1723.34	3184	495.8589	1227.4811	2688.1411	3980
198	2240	Gas	TRIADELPHIA CONSOLIDATED	CLNN, MDIN	Sandstone	Silurian	1927	ОН	1723.34	3184	495.8589	1227.4811	2688.1411	3980
258	2342	Gas	RAVENNA-BEST CONSOLIDATED	CLNN	Sandstone	Silurian	1949	ОН	2100.05	3880	552.0548	1547.9952	3327.9452	4850
259	2343	Gas	SUFFIELD-SMITH	CLNN	Sandstone	Silurian	1960	ОН	2152.01	3976	557.5398	1594.4702	3418.4602	4970

NETTHICK	PRESS	POROSITY	Perm	Area_sqft	acreage	store_mode	legacy well count	Revised distance rank	acreage	average depth	porosity	thickness	permeability	pressure
18	1400	0.065	0	258448763	5,933	1268564.437	34	3	3	3	2	2	0	3
15	1400	0.07	0	3445312460	79,093	16655292.91	276	3	3	3	2	2	0	3
15	1400	0.07	0	330975566	7,598	1599998.566	22	3	3	3	2	2	0	3
50	1500	0.078	0	4740884540	108,836	88346392.13	1509	3	3	1	2	3	0	3
15	1400	0.07	0	376286626	8,638	1819040.812	8	3	3	3	2	2	0	3
15	1400	0.07	0	429948805	9,870	2078453.947	158	3	3	3	2	2	0	3
21	1200	0.079	0	247246866	5,676	1504614.33	141	2	3	3	2	3	0	3
21	1200	0.079	0	218920059	5,026	1332232.288	291	2	3	3	2	3	0	3
40	1500	0.083	0	2986159320	68,553	44314865.27	745	3	3	3	2	3	0	3
45	1400	0.08	0	307148619	7,051	3298574.757	188	3	3	3	2	3	0	3

Stacked opportunity rank	mode CO2	Cum_Prod_BCF	Avg_Perm_mD	Trap-Type	Res_Cont	Prod rank	wells per 1000 acres	Legacy well penetrations rank
0	3	31.215	2.3	Stratigraphic	4	3	6	1
0	3	58.847		Stratigraphic	4	3	3	2
0	3	58.847		Stratigraphic	4	3	3	2
0	3					0	14	1
0	3	58.847		Stratigraphic	4	3	1	3
0	3	58.847		Stratigraphic	4	3	16	1
0	3	15.59	6.2	Stratigraphic	3	3	25	0
0	3	15.59	6.2	Stratigraphic	3	3	58	0
0	3	33.457	2	Stratigraphic	3	3	11	1
0	3	12.833		Structural	3	3	27	0

EID	TEST ID 1			Formation	Lithology	Goo Ago		STATE	D;	Dmax	MMD		Dmax MMD	AugBrodDop
FID		FIELD_TTPE	FIELD_INAME	Formation	Lithology	Geo_Age	DISC_TEAK	STATE	F1	Fillax	IVIIVIE	FI_IVIIVIF	PILIAX_IVIIVIP	AvgriouDep
1	2	Gas	KIRKERSVILLE	Rose Run	Sandstone	Cambrian	1992	OH	1610.76	2976	458.156	1152.604	2517.844	3720
3	5	Gas	DUMM RIDGE	Rose Run	Sandstone	Cambrian	1992	OH	1580.45	2920	455.3367	1125.1133	2464.6633	3650
4	6	Gas	DUMM RIDGE	Rose Run	Sandstone	Cambrian	1992	OH	1580.45	2920	469.0019	1111.4481	2450.9981	3650
5	7	Gas	ROCKBRIDGE	Rose Run	Sandstone	Cambrian	1993	OH	1874.89	3464	494.1037	1380.7863	2969.8963	4330
6	9	Gas	ROCKBRIDGE	Rose Run	Sandstone	Cambrian	1993	ОН	1874.89	3464	494.1037	1380.7863	2969.8963	4330
7	10	Gas	DUMM RIDGE	Rose Run	Sandstone	Cambrian	1992	OH	1580.45	2920	455.3367	1125.1133	2464.6633	3650
8	11	Gas	DUMM RIDGE	Rose Run	Sandstone	Cambrian	1992	OH	1580.45	2920	455.3367	1125.1133	2464.6633	3650
15	116	Gas	FRAZEYBURG	Rose Run	Sandstone	Cambrian	1990	ОН	2524.39	4664	555.8541	1968.5359	4108.1459	5830
28	161	Gas	ROCKBRIDGE	Rose Run	Sandstone	Cambrian	1993	OH	1874.89	3464	494.1037	1380.7863	2969.8963	4330
57	219	Gas	RANDOLPH	Rose Run	Sandstone	Cambrian	1990	ОН	3074.3	5680	628.3089	2445.9911	5051.6911	7100

NETTHICK	PRESS	POROSITY	Perm	Area_sqft	acreage	store_mode	legacy well count	Revised distance rank	acreage	average depth	porosity	thickness
35	1300	0.08	0	37830589	868	340358.1197	10	1	1	3	2	3
35	1300	0.08	0	24474155	562	220036.3612	8	0	1	3	2	3
35	1300	0.08	0	72771945	1,671	636957.2799	29	0	2	3	2	3
35	1500	0.08	0	71038170	1,631	630034.0489	34	0	2	3	2	3
35	1500	0.08	0	22632338	520	200725.0967	27	0	1	3	2	3
35	1300	0.08	0	136366663	3,131	1226012.678	23	0	2	3	2	3
35	1300	0.08	0	73985424	1,698	665170.4003	8	0	2	3	2	3
30	2000	0.08	0	373427707	8,573	4000720.153	269	3	3	1	2	3
35	1500	0.08	0	44112044	1,013	391227.5567	16	0	2	3	2	3
30	2400	0.08	0	233475675	5,360	2441340.943	135	2	3	1	2	3

permeability	pressure	Stacked opportunity rank	mode CO2	Cum_Prod_BCF	Avg_Perm_mD	Trap-Type	Res_Cont	Prod rank	wells per 1000 acres	Legacy well penetrations rank
0	3	0	2					0	12	1
0	3	0	2					0	14	1
0	3	0	2					0	17	1
0	3	0	2					0	21	0
0	3	0	2					0	52	0
0	3	0	3					0	7	1
0	3	0	2					0	5	2
0	2	0	3					0	31	0
0	3	0	2					0	16	1
0	2	0	3	0.425		Structural	2	1	25	0

Unweighted Ranking	Container Type	FID	Test_ID	Field/Location	Normalized Rating	Distance to infrastructure	Acreage	Average depth	Net thickness	Trap integrity	Legacy well penetrations	Stacked opportunity?
1	mined-rock cavern			M-R5	19	3	3	3	3	3	2	2
2	depleted Newburg Sandstone	3	11737	North Ripley	16	3	3	1	3	3	1	2
2	depleted Newburg Sandstone	7	11741	Rocky Fork	16	3	3	1	3	3	1	2
2	depleted Newburg Sandstone	9	11743	Kanawha Forest	16	3	3	1	3	3	1	2
2	mined-rock cavern			M-R4	16	3	3	3	3	1	1	2
3	depleted Oriskany Sandstone	34	11135	Campbell Creek	15	3	3	3	2	2	1	1
3	mined-rock cavern			M-R2	15	3	3	3	3	0	0	3
3	salt cavern			S-1	15	3	2	2	3	3	1	1
3	salt cavern			S-2	15	3	3	2	3	3	1	0
2	depleted Upper Devonian sands	553	11104	Weston-Jane Lew	14	3	3	3	3	0	1	1
4	depleted Clinton/Medina Group	124	1981	CANTON CONSOLIDATED	14	3	3	3	2	0	3	0
4	depleted Newburg Sandstone	8	11742	Cooper Creek	14	2	3	1	3	3	1	1
4	depleted Upper Devonian sands	643	11223	Abbott-French Creek	14	2	3	2	3	1	3	0
4	gas storage field	14		Ripley	14	3	3	3	2	1	0	2
5	depleted Keener-Berea	58	11247	Maple-Wadestown	13	3	3	2	3	1	0	1
5	depleted Oriskany Sandstone	39	11140	Elk-Poca (Sissonville)	13	3	3	1	2	2	1	1
5	gas storage field	12		Racket-Newberne (Sinking Creek)	13	2	3	2	2	2	0	2
5	salt cavern			S-4	13	3	1	1	3	3	0	2
4	depleted Clinton/Medina Group	63	1005	CANTON CONSOLIDATED	13	3	3	3	2	0	2	0
5	depleted Clinton/Medina Group	65	1060	CANTON CONSOLIDATED	13	3	3	3	2	0	2	0
5	depleted Clinton/Medina Group	258	2342	RAVENNA-BEST CONSOLIDATED	13	3	3	3	3	0	1	0
6	depleted Keener-Berea	47	11018	Burdett-St. Albans	12	3	3	2	3	0	1	0
6	depleted Keener-Berea	60	11249	Condit-Ragtown	12	2	3	2	3	1	0	1
7	depleted Rose Run-Gatesburg Ss	8	11	DUMM RIDGE	11	0	2	3	3	1	2	0
7	depleted Rose Run-Gatesburg Ss	15	116	FRAZEYBURG	11	3	3	1	3	1	0	0
8	depleted Rose Run-Gatesburg Ss	1	2	KIRKERSVILLE	10	1	1	3	3	1	1	0
8	depleted Rose Run-Gatesburg Ss	4	6	DUMM RIDGE	10	0	2	3	3	1	1	0
8	depleted Rose Run-Gatesburg Ss	7	10	DUMM RIDGE	10	0	2	3	3	1	1	0
8	depleted Rose Run-Gatesburg Ss	28	161	ROCKBRIDGE	10	0	2	3	3	1	1	0
8	depleted Rose Run-Gatesburg Ss	57	219	RANDOLPH	10	2	3	1	3	1	0	0

Depleted Gas Reservoirs

Mined-Rock Caverns	Rating_Norm	Salt Caverns	Rating_Norm	FID	Gas Storage Fields	Rating_Norm	FID	Test_ID	Keener-Berea	Rating_Norm
1	14	1	15	26	Coco "A"	11	66	11256	Big Run-Burchfield	11
2	15	2	15	28	Coco "C"	10	47	11018	Burdett-St. Albans	12
3	14	3	13	5	Fink-Kennedy-Lost Creek (Murphy Creek)	13	150	11553	Cameron-Garner	10
4	16	4	13	7	Logansport	11	60	11249	Condit-Ragtown	12
5	19			32	McKeesport	13	99	11361	Hendershot-Ogdin	8
				56	Mehaffy	12	58	11247	Maple-Wadestown	13
				12	Racket-Newberne (Sinking Creek)	13	202	11733	Sidney	13
				14	Ripley	14	156	11561	Stanley	12
				13	Rockport	10	201	11732	Whites Creek-Gragston	13
				1	Rockport (Deep)	12	154	11559	Wilbur	11
				8	Victory "A" (Kausooth-Cameron)	12				
				9	Victory "B" (Kausooth-Cameron)	13				

FID	Test ID	Upper Devonian sandstones	Rating Norm	FID	Test ID	Oriskany Sandstone	Rating Norm	FID	Test ID	Newburg Sandstone	Rating Norm
643	11223	Abbott-French Creek	14	4	827	ROCK CAMP	14	1	11735	Groundhog Creek	13
1165	15592	Antram Run	9	7	961	PUTNAM	13	3	11737	North Ripley	16
412	10841	Aspinall-Finster	12	10	964	LAUREL RUN	12	4	11738	Wheaton Run	11
447	10921	Aspinall-Finster	12	26	11118	Glenville North	13	7	11741	Rocky Fork	16
556	11107	Auburn	12	27	11119	Dekalb	10	8	11742	Cooper Creek	14
632	11211	Auburn	11	33	11134	Kanawha Forest	15	9	11743	Kanawha Forest	16
547	11098	Beason Run	12	34	11135	Campbell Creek	15				
371	10740	Bridgeport-Pruntytown	10	36	11137	Blue Ck (Falling Rk)	11				
364	10732	Brown-Lumberport	11	37	11138	Red House	13				
399	10804	Buckhannon-Century	10	39	11140	Elk-Poca (Sissonville)	13				
477	10981	Campbells Run-Miracle Run	10	41	11143	New England	15				
481	10985	Coburn-Earnshaw	11	48	11150	Hurricane Creek	14				
597	11171	Condit-Ragtown	11								
400	10805	Conings	13								
429	10881	Elk Creek (Overfield)	13								
626	11205	Elk Creek (Overfield)	13								
601	11175	Farmington	11								
476	10980	Frvw-Statler Rn-Mt Morrs	11								
425	10876	Glade Run	12								
407	10836	Glenville North	13								
649	11233	Glenville South	13								
417	10848	Grantsville-Arnoldsburg	11								
539	11088	Greenwood	13								
560	11112	Hazel Green-Lawford-Berea	12								
381	10753	Heaters	13								
521	11067	Heaters	13								
598	11172	Hundred	11								
423	10873	Jarvisville	11								
1100	10097	Jenerson	11								
483	10987	Lieweilyn Run-Plum Run	11								
402	10940	Logalisport	11								
402	11061	Lorentz	12								
620	11219	Lorentz	13								
551	11102	Mahone (Smithville)	12								
459	10936	Mannington	10								
596	11170	Maple-Wadestown	12								
1156	15547	Masontown	9								
469	10949	Mcgraw	10								
847	13828	McKeesport	11								
619	11197	Meathouse Fork-Bristol	11								
595	11169	Mooresville	11								
443	10896	Murphy Creek	13								
559	11111	Murphy Creek	14								
555	11106	New Milton South	13								
550	11101	Porto Rico	13								
624	11203	Porto Rico	12								
557	11108	Prunty	12								
1074	14887	Rural Ridge	9								
372	10741	Salem	12								
465	10943	Shiloh-Wick Area	12								
605	11180	Shinnston	10								
461	10939	Smithfield	11								
424	10874	Smithton-Flint-Sedalla	13								
363	10/31	South Burns Chapel	8								
612	11188	Stanley	14								
543	111094	Straight FK-Bluestone CK	13								
020	10750	Strangert FK-Bluestone CK	12								
3/9	11721	Stumptwn Normantwn Shack	10								
48	10200	Thursday	10								
405	109/2	Wallace-Folsom	17								
404	10942	Weston-Jane Lew	12								
553	11104	Weston-Jane Lew	14								
1145	15401	White Ash	11								
616	11193	Wolf Summit									
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FID	Test_ID	Clinton/Medina Group	Rating_Norm	FID	Test_ID	Rose Run - Gatesburg sandstones	Rating_Norm
36	649	PHILO CONSOLIDATED	12	1	2	KIRKERSVILLE	10
63	1005	CANTON CONSOLIDATED	13	3	5	DUMM RIDGE	9
65	1060	CANTON CONSOLIDATED	13	4	6	DUMM RIDGE	10
110	1543	NORTH ELLSWORTH CONSOLIDATED	11	5	7	ROCKBRIDGE	8
124	1981	CANTON CONSOLIDATED	14	6	9	ROCKBRIDGE	7
141	2048	CANTON CONSOLIDATED	12	7	10	DUMM RIDGE	10
189	2216	TRIADELPHIA CONSOLIDATED	11	8	11	DUMM RIDGE	11
198	2240	TRIADELPHIA CONSOLIDATED	11	15	116	FRAZEYBURG	11
258	2342	RAVENNA-BEST CONSOLIDATED	13	28	161	ROCKBRIDGE	10
259	2343	SUFFIELD-SMITH	12	57	219	RANDOLPH	10

	FID		25	27	4	6	31	55	11	13	12	0	7	8
	Test_ID		26	28	5	7	32	56	12	14	13	1	8	9
					Fink-Kennedy-				Racket-				Victory "A"	Victory "B"
Range of					Lost Creek				Newberne				(Kausooth-	(Kausooth-
Values	Criteria		Coco "A"	Coco "C"	(Murphy Creek)	Logansport	McKeesport	Mehaffy	(Sinking Creek)	Ripley	Rockport	Rockport (Deep)	Cameron)	Cameron)
	Distance to infrastructure													
0	>30 mi		2	2	3	2	3	3	2	3	3	3	3	3
1	>20 mi but <=30 mi													
2	>5 mi but <=20 mi													
3	<=5 mi													
	Acreage		3	2	3	2	1	2	3	3	2	3	3	3
0	<=500 ac													
1	>500 ac but <=1,000 ac													
2	>1,000 ac but <=5,000 ac													
3	>5,000 ac													
	Average depth													
0	<=2,000 ft		1	1	2	2	2	2	2	3	1	1	2	2
1	>5,000 ft													
2	>2,000 ft but <=3,500 ft													
3	>3,500 ft but <=5,000 ft													
	, ,													
	Net thickness		2	2	2	2	2	2	2	2	3	2	2	2
0	<=1 ft													
1	>1 ft but <=10 ft													
2	>10 ft but <=20 ft													
3	>20 ft													
5	- 2010													
	Tran integrity		2	2	1	2	1	3	2	1	1	1	2	2
0	No data		-	-	-	-	-	0	-	-	-	-	-	-
1	Limited data on tran characteristics													
2	Inferred lithologic and/or structural closure													
2	Documented lithologic and/or structural closure													
5														
	Legacy well penetrations		0	0	0	0	3	0	0	0	0	1	0	0
0	No data or $>=20$ wells per 1 000 ac		0	0	0	0	5	0	0	0	0	T	0	0
1	\sim 5 wells per 1 000 ac but < 20 wells per 1 000 ac													
1	>-3 wells per 1,000 ac but <20 wells per 1,000 ac													
2	2 wells per 1,000 ac but<5 wells per 1,000 ac													
3	<z ac<="" per="" td="" wen=""><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></z>													
	Stacked opportunity?		1	1	2	1	1	0	2	2	0	1	0	1
0	No other intervals in same footprint		T	T	2	T	T	U	2	2	U	Ŧ	U	T
1	1 other interval in same footprint													
1	2 or 2 other intervals in some footprint													
2	2 of 5 other intervals in same footprint													
3	4 of more intervals in same rootprint													
		Totala	11	10	10	11	10	17	10	14	10	13	17	10
		iotuis	11	10	13	11	12	12	12	14	10	12	14	12

1	2	3	4
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Range of					
Values	Criteria				
	Distance to infrastructure	3	3	3	3
0	>30 mi				
1	>20 mi but <=30 mi				
2	>5 mi but <=20 mi				
3	<=5 mi				
	Average depth	2	2	1	1
0	<=2,000 ft				
1	>5,000 ft but <=7,000 ft				
2	>3,000 ft but <=5,000 ft				
3	>2,000 ft but <=3,000 ft				
	Acreage	2	3	2	1
0	<25,000 ac				
1	>=25,000 ac but <50,000 ac				
2	>=50,000 ac but <100,000 ac				
3	>=100,000 ac				
_	Average net thickness	3	3	3	3
0	<=10 ft				
1	>10 ft but <=50 ft				
2	>50 ft but <=100 ft				
3	>100 ft				
	Turn internity	2	2	2	2
0		3	3	3	3
0	NO Udla				
1	Limited data on trap characteristics				
2	Desumented lithelesis and (or structural closure				
3	Documented lithologic and/or structural closure				
	Logacy well popotrations	1	1	1	0
0	No data or >=20 wells por 1 000 ac	T	T	T	0
1	\sim 5 wells per 1 000 ac but <20 wells per 1 000 ac				
1	>-3 wells per 1,000 ac but <20 wells per 1,000 ac				
2	2 wells per 1,000 at but<5 wells per 1,000 at 2 well per ac				
5					
	Stacked opportunity?	1	0	0	2
0	No other intervals in same footprint	-	0	0	2
1	1 other interval in same footprint				
2	2 or 3 other intervals in same footprint				
3	4 or more intervals in same footprint				
-	Totals	15	15	13	13

Geologic	Interval	-	Greenbrier	Limestone
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	Geologic Interval - Greenbrier Limestone	1	2	3	4	5
_ •						
Range of						
Values	Criteria					
	Distance to infrastructure	1	3	2	3	3
0	>30 mi					
1	>20 mi but <=30 mi					
2	>5 mi but <=20 mi					
3	<=5 mi					
	Average depth	3	3	3	3	3
0	<1,800 ft					
3	>=1,800 ft but <=2,000 ft					
	Acreage	3	3	3	3	3
0	<25,000 ac					
1	>=25,000 ac but <75,000 ac					
2	>=75,000 ac but <125,000 ac					
3	>=125,000 ac					
	Average net thickness	3	3	3	3	3
0	<40 ft					
3	>=40 ft					
	Trap integrity	2	0	1	1	3
0	No data	_				
1	Limited data on trap characteristics					
2	Inferred lithologic and/or structural closure					
3	Documented lithologic and/or structural closure					
	Legacy well penetrations	1	0	0	1	2
0	No data or >=20 wells per 1,000 ac	_				
1	>=5 wells per 1,000 ac but <20 wells per 1,000 ac					
2	>=2 wells per 1,000 ac but<5 wells per 1,000 ac					
3	<2 well per ac					
	Stacked opportunity?	1	3	2	2	2
0	No other intervals in same footprint					
1	1 other interval in same footprint					
2	2 or 3 other intervals in same footprint					

Totals

4 or more intervals in same footprint

	Geologic Interval –				G	eologic Interv	val – Keener_	Berea				Geologic Inte	rval – Upper De	evonian	
	FID Test_ID	Field 66 11256	47 11018	150 11553	60 11249	99 11361	58 11247	202 11733	156 11561	201 11732	154 11559	643 11223	1165 15592	412 10841	447 10921
Range of Values	Criteria	Big Run- Burchfield	Burdett-St. Albans	Cameron- Garner	Condit- Ragtown	Hendershot- Ogdin	Maple- Wadestown	Sidney	Stanley	Whites Creek- Gragston	Wilbur	Abbott-French Creek	Antram Run	Aspinall-Finster	r Aspinall-Finster
	Distance to infrastructure														
0	>30 mi	3	3	3	2	3	3	3	2	3	2	2	2	3	3
1	>20 mi but <=30 mi														
2	>5 mi but <=20 mi														
3	<=5 mi														
	Acreage	3	3	2	3	2	3	3	3	3	3	3	3	3	3
0	<=500 ac														
1	>500 ac but <=1.000 ac														
2	>1.000 ac but <=5.000 ac														
3	>5,000 ac														
	Average donth	2	2	2	2	2	2	2	2	2	2	2	2	2	2
0		2	2	2	2	2	2	3	2	5	2	2	2	3	5
0	<=2,000 ft														
1	>3,000 ft but $>3,000$ ft														
3	>3,500 ft but <=5,000 ft														
		_													
	Net thickness	2	3	3	3	1	3	3	3	3	3	3	2	3	3
0	<=1 ft														
1	>1 ft but <=10 ft														
2	>10 ft but <=20 ft														
3	>20 ft														
	Trap integrity	1	0	0	1	0	1	0	0	0	0	1	0	0	0
0	No data														
1	Limited data on trap characteristics														
2	Inferred lithologic and/or structural closure														
3	Documented lithologic and/or structural closure														
	Legacy well penetrations	0	1	0	0	0	0	1	0	1	0	3	0	0	0
0	No data or >=20 wells per 1,000 ac														
1	>=5 wells per 1,000 ac but <20 wells per 1,000 ac														
2	>=2 wells per 1,000 ac but<5 wells per 1,000 ac														
3	<2 well per 1000 ac														
	Stacked opportunity?	0	0	0	1	0	1	0	2	0	1	0	0	0	0
Ο	No other intervals in same footprint		0	U	T	U	Ŧ	U	2	U	Ŧ	U	U	0	0
1	1 other interval in same footprint														
2	2 or 3 other intervals in same footprint														
2	4 or more intervals in same footprint														
5															
	Tota	ls 11	12	10	12	8	13	13	12	13	11	14	9	12	12

	Geologic Interval –													
	FID Test ID	556 11107	632 11211	547 11098	371 10740	364 10732	399 10804	477 10981	481 10985	597 11171	400 10805	429 10881	626 11205	601 11175
Range of Values	- Criteria	Auburn	Auburn	Beason Run	Bridgeport- Pruntytown	Brown- Lumberport	Buckhannon- Century	Campbells Rui Miracle Run	n- Coburn- Earnshaw	Condit-Ragtown	n Conings	Elk Creek (Overfield)	Elk Creek (Overfield)	Farmington
	Distance to infrastructure				·		•						. ,	
0	>30 mi	2	2	2	1	2	1	2	3	2	2	2	2	2
1	>20 mi but <=30 mi													
2	>5 mi but <=20 mi													
3	<=5 mi													
	Acreage	3	3	3	3	3	3	3	3	3	3	3	3	3
0	<=500 ac													
1	>500 ac but <=1,000 ac													
2	>1,000 ac but <=5,000 ac													
3	>5,000 ac													
	Average denth	2	2	2	2	2	2	2	2	2	2	2	2	2
0		3	2	3	3	2	3	2	2	2	3	3	2	2
0	<=2,000 ft													
1	>3,000 ft but $= 2,500$ ft													
2	>2,000 ft but <=5,500 ft													
5	>5,500 It but <=5,000 It													
	Net thickness	3	3	3	3	3	3	3	3	3	3	3	3	3
0	<=1 ft													
1	>1 ft but <=10 ft													
2	>10 ft but <=20 ft													
3	>20 ft													
	Trap integrity	0	0	0	0	0	0	0	0	0	0	1	1	0
0	No data	_												
1	Limited data on trap characteristics													
2	Inferred lithologic and/or structural closure													
3	Documented lithologic and/or structural closure													
	Legacy well penetrations	0	0	0	0	0	0	0	0	0	0	1	2	0
0	No data or >=20 wells per 1,000 ac													
1	>=5 wells per 1,000 ac but <20 wells per 1,000 ac													
2	>=2 wells per 1,000 ac but<5 wells per 1,000 ac													
3	<2 well per 1000 ac													
	Stacked opportunity?	1	1	1	0	1	0	0	0	1	2	0	0	1
0	No other intervals in same footprint		-	-	-	-	-	-	-	-	-	-	-	-
1	1 other interval in same footprint													
2	2 or 3 other intervals in same footprint													
3	4 or more intervals in same footprint													
	·													
	Totals	s 12	11	12	10	11	10	10	11	11	13	13	13	11

	Geologic Interval –													
	FID Test_ID	476 10980	425 10876	407 10836	649 11233	417 10848	539 11088	560 11112	381 10753	521 11067	598 11172	423 10873	1166 15594	483 10987
Range of Values	Criteria	Frvw-Statler Rn Mt Morrs	- Glade Run	Glenville North	Glenville South	Grantsville- Arnoldsburg	Greenwood	Hazel Green- Lawford-Berea	Heaters	Heaters	Hundred	Jarvisville	Jefferson	Llewellyn Run- Plum Run
0 1	Distance to infrastructure >30 mi >20 mi but <=30 mi	2	1	2	2	1	3	2	1	2	3	2	3	2
2 3	>5 mi but <=20 mi <=5 mi													
0 1	Acreage <=500 ac >500 ac but <=1,000 ac	3	3	3	3	3	3	3	3	3	3	3	3	3
3	>1,000 ac but <=5,000 ac >5,000 ac													
0 1 2 3	Average depth <=2,000 ft >5,000 ft >2,000 ft but <=3,500 ft >3,500 ft but <=5,000 ft	2	3	3	2	3	3	3	3	2	2	2	2	2
0 1 2 3	Net thickness <=1 ft >1 ft but <=10 ft >10 ft but <=20 ft >20 ft	3	3	3	3	3	3	3	3	3	3	3	2	3
0 1 2 3	Trap integrity No data Limited data on trap characteristics Inferred lithologic and/or structural closure Documented lithologic and/or structural closure	0	2	0	0	0	0	0	0	0	0	0	0	0
0 1 2 3	Legacy well penetrations No data or >=20 wells per 1,000 ac >=5 wells per 1,000 ac but <20 wells per 1,000 ac >=2 wells per 1,000 ac but<5 wells per 1,000 ac <2 well per 1000 ac	0	0	0	2	0	0	0	3	3	0	0	1	0
0 1 2 3	Stacked opportunity? No other intervals in same footprint 1 other interval in same footprint 2 or 3 other intervals in same footprint 4 or more intervals in same footprint	_ 1	0	2	1	1	1	1	0	0	0	1	0	1
	Totals	11	12	13	13	11	13	12	13	13	11	11	11	11

	Geologic Interval –														
	FID	462	402	516	638	551	459	596	1156	469	847	619	595	443	559
	Test_ID	10940	10808	11061	11218	11102	10936	11170	15547	10949	13828	11197	11169	10896	11111
Range of						Mahone		Maple-				Meathouse Fork	(-	Murphy	Murphy
Values	Criteria	Logansport	Lorentz	Lorentz	Lorentz	(Smithville)	Mannington	Wadestown	Masontown	Mcgraw	McKeesport	Bristol	Mooresville	Creek	Creek
2	Distance to infrastructure	-		2	2			2			2		2		2
0	>30 mi	2	1	2	2	2	2	3	2	1	3	2	2	3	3
1	>20 fm but <= 30 fm \sim														
2	>5 IIII but <=20 IIII														
5	<-3111														
	Acreage	3	3	3	3	3	3	3	2	з	3	3	3	3	3
0	<=500 ac	_ 0	5	0	0	5	0	5	-	5	0	5	0	5	5
1	>500 ac but <=1.000 ac														
2	>1,000 ac but <=5,000 ac														
3	>5,000 ac														
	Average depth	2	3	3	2	3	2	2	2	3	2	2	2	2	3
0	<=2,000 ft														
1	>5,000 ft														
2	>2,000 ft but <=3,500 ft														
3	>3,500 ft but <=5,000 ft														
	Net thickness	3	3	3	3	3	3	3	3	3	2	3	3	3	3
0	<=1 ft	_													
1	>1 ft but <=10 ft														
2	>10 ft but <=20 ft														
3	>20 ft														
	Trap integrity	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	No data	_													
1	Limited data on trap characteristics														
2	Inferred lithologic and/or structural closure														
3	Documented lithologic and/or structural closure														
	Legacy well penetrations	0	3	2	2	0	0	0	0	0	1	0	0	0	0
0	No data or >=20 wells per 1,000 ac	_													
1	>=5 wells per 1,000 ac but <20 wells per 1,000 ac														
2	>=2 wells per 1,000 ac but<5 wells per 1,000 ac														
3	<2 well per 1000 ac														
	Stacked opportunity?	1	0	0	0	1	0	1	0	0	0	1	1	2	2
0	No other intervals in same footprint	_													
1	1 other interval in same footprint														
2	2 or 3 other intervals in same footprint														
3	4 or more intervals in same footprint														
	Totals	s 11	13	13	12	12	10	12	9	10	11	11	11	13	14

	Geologic Interval –																		
	FID Test_ID	555 11106 New	550 11101	624 11203	557 11108	1074 14887	372 10741	465 10943	605 11180	461 10939	424 10874 Smithton-	363 10731 - South	612 11188	543 11094 Straight Fk-	620 11199 Straight Fk-	379 10750 Stumptwn-	648 11231 Stumptwn-	403 10809	464 10942
Range of		Milton				Rural		Shiloh-			Flint-	Burns		Bluestone	Bluestone	Normantwn-	Normantwn-		Wallace-
Values	Criteria	South	Porto Rico	Porto Rico	Prunty	Ridge	Salem	Wick Area	Shinnston	Smithfield	Sedalia	Chapel	Stanley	Ck	Ck	Shock	Shock	Thursday	Folsom
	Distance to infrastructure																		
0	>30 mi	2	3	3	2	2	2	3	2	3	3	0	3	3	3	1	1	1	3
1	>20 mi but <=30 mi																		
2	>5 mi but <=20 mi																		
3	<=5 mi																		
	A	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
0		_ 3	5	5	3	2	3	5	5	3	3	2	3	5	5	3	5	3	5
1	$\sim -300 \text{ ac}$																		
1	>1000 ac but <=5000 ac																		
2	>5,000 ac																		
5	, 5,000 de																		
	Average depth	3	3	2	3	2	3	2	2	2	3	2	2	3	2	3	2	3	2
0	<=2,000 ft	_																	
1	>5,000 ft																		
2	>2,000 ft but <=3,500 ft																		
3	>3,500 ft but <=5,000 ft																		
	Net thickness	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
0	<=1 ft																		
1	>1 ft but <=10 ft																		
2	>10 ft but <=20 ft																		
3	>20 ft																		
	Tran integrity	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
0	No data	_ 0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
1	Limited data on tran characteristics																		
2	Inferred lithologic and/or structural closure																		
3	Documented lithologic and/or structural closure																		
	Legacy well penetrations	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
0	No data or >=20 wells per 1,000 ac																		
1	>=5 wells per 1,000 ac but <20 wells per 1,000 ac																		
2	>=2 wells per 1,000 ac but<5 wells per 1,000 ac																		
3	<2 well per 1000 ac																		
	Charles descention in D	2	4	4	4	0			•	0	4	0	2				4	4	4
0	Stacked Opportunity?		1	1	1	U	1	1	U	U	1	U	2	1	1	1	1	1	1
0	No other intervals in same footprint																		
1	2 or 2 other interval in same footneint																		
2	A or more intervals in same footprint																		
5	4 of more intervals in same tootprint																		
	Totals	13	13	12	12	9	12	12	10	11	13	8	14	13	12	11	10	11	12

	Geologic Interval –									(Geologic In	iterval – O	riskany					Geologic In	terval – N	ewburg
	FID Test_ID	436 10888	553 11104	1145 15401	616 11193	4 827	7 961	10 964	26 11118	27 11119	33 11134	34 11135	36 11137 Blue Ck	37 11138	39 11140	41 11143	48 11150	1 11735	3 11737	4 11738
Range of Values	Criteria	Weston- Jane Lew	Weston- Jane Lew	White Ash	Wolf Summit	ROCK CAMP	PUTNAM	LAUREL RUN	Glenville North	Dekalb	Kanawha Forest	Campbell Creek	(Falling Rk)	Red House	Elk-Poca (Sissonville)	New England	Hurricane Creek	Groundhog Creek	North Ripley	Wheaton Run
	Distance to infrastructure	_																		
0	>30 mi	3	3	3	2	3	3	2	2	1	3	3	2	3	3	3	3	3	3	3
1	>20 mi but <=30 mi																			
2 3	>5 mi but <=20 mi <=5 mi																			
	Acreage	3	3	2	3	2	3	2	3	3	3	3	3	3	3	3	3	2	3	2
0	<=500 ac	_																		
1	>500 ac but <=1,000 ac																			
2	>1,000 ac but <=5,000 ac																			
3	>5,000 ac																			
	Average depth	2	3	2	2	3	3	3	1	1	3	3	1	3	1	3	3	3	1	1
0	<=2,000 ft																			
1	>5,000 ft																			
2	>2,000 ft but <=3,500 ft																			
3	>3,500 ft but <=5,000 ft																			
	Net thickness	3	3	3	3	3	2	3	3	3	2	2	3	1	2	2	2	1	3	1
0	<=1 ft																			
1	>1 ft but <=10 ft																			
2	>20 ft																			
	Trap integrity	0	0	0	0	2	1	1	2	2	2	2	1	1	2	2	1	3	3	3
0	No data																			
1	Limited data on trap characteristics																			
3	Documented lithologic and/or structural closure																			
-																				
	Legacy well penetrations	0	1	1	0	0	1	0	0	0	1	1	0	1	1	1	1	1	1	0
0	No data or >=20 wells per 1,000 ac																			
1	>=5 wells per 1,000 ac but <20 wells per 1,000 ac																			
2 3	>=2 wells per 1,000 ac but<5 wells per 1,000 ac <2 well per 1000 ac																			
	Stacked opportunity?	1	1	0	1	1	0	1	2		1	1	1	1	1	1	1	0	2	1
0	No other intervals in same footprint		-	5	-	-	č	-	-		-	-	-	-	-	-	-	5	-	-
1	1 other interval in same footprint																			
2	2 or 3 other intervals in same footprint																			
3	4 or more intervals in same footprint																			
	Totals	12	14	11	11	14	13	12	13	10	15	15	11	13	13	15	14	13	16	11

	Geologic Interval –							G	eologic Interval –	Clinton-Medina				
	FID Test_ID	7 11741	8 11742	9 11743	36 649	63 1005	65 1060	110 1543 NORTH	124 1981	141 2048	189 2216	198 2240	258 2342	259 2343
Range of Values	Criteria	Rocky Fork	Cooper Creek	Kanawha Forest	PHILO CONSOLIDATED	CANTON CONSOLIDATED	CANTON CONSOLIDATED	ELLSWORTH	CANTON CONSOLIDATED	CANTON CONSOLIDATED	TRIADELPHIA CONSOLIDATED	TRIADELPHIA CONSOLIDATED	RAVENNA-BEST CONSOLIDATED	SUFFIELD- SMITH
	Distance to infrastructure													
0	>30 mi	3	2	3	3	3	3	3	3	3	2	2	3	3
1	>20 mi but <=30 mi													
2	>5 mi but <=20 mi													
3	<=5 mi													
	Acreage	3	3	3	3	3	3	3	3	3	3	3	3	3
0	<=500 ac	_												
1	>500 ac but <=1,000 ac													
2	>1,000 ac but <=5,000 ac													
3	>5,000 ac													
	Average depth	1	1	1	3	3	3	1	3	3	3	3	3	3
0	<=2,000 ft	_												
1	>5,000 ft													
2	>2,000 ft but <=3,500 ft													
3	>3,500 ft but <=5,000 ft													
	Net thickness	3	3	3	2	2	2	3	2	2	3	3	3	3
0	<=1 ft	_												
1	>1 ft but <=10 ft													
2	>10 ft but <=20 ft													
3	>20 ft													
	Trap integrity	3	3	3	0	0	0	0	0	0	0	0	0	0
0	No data	_												
1	Limited data on trap characteristics													
2	Inferred lithologic and/or structural closure													
3	Documented lithologic and/or structural closure													
	Legacy well penetrations	1	1	1	1	2	2	1	3	1	0	0	1	0
0	No data or >=20 wells per 1,000 ac	_												
1	>=5 wells per 1,000 ac but <20 wells per 1,000 ac													
2	>=2 wells per 1,000 ac but<5 wells per 1,000 ac													
3	<2 well per 1000 ac													
	Stacked opportunity?	2	1	2	0	0	0	0	0	0	0	0	0	0
0	No other intervals in same footprint	_												
1	1 other interval in same footprint													
2	2 or 3 other intervals in same footprint													
3	4 or more intervals in same footprint													

	Geologic Interval –	Geologic Interval – Rose Run										
	FID Test ID	1 2	3	4	5 7	6	7 10	8 11	15 116	28 161	57 219	
Range of Values	Criteria	KIRKERSVILLE			ROCKBRIDGE	ROCKBRIDGE		DUMM BIDGE	FRAZEYBURG	ROCKBRIDGE	RANDOI PH	
	Distance to infrastructure											
0	>30 mi	1	0	0	0	0	0	0	3	0	2	
1	>20 mi but <=30 mi	_	-	-	-	-	-	•	-	-	_	
2	>5 mi but <=20 mi											
3	<=5 mi											
	Acreage	1	1	2	2	1	2	2	3	2	3	
0	<=500 ac											
1	>500 ac but <=1,000 ac											
2	>1,000 ac but <=5,000 ac											
3	>5,000 ac											
	Average depth	3	3	3	3	3	3	3	1	3	1	
0	<=2,000 ft											
1	>5,000 ft											
2	>2,000 ft but <=3,500 ft >3.500 ft but <=5.000 ft											
	Netskielwee	2	2	2	2	2	2	2	2	2	2	
0	x=1 ft	_ 3	3	3	5	5	3	3	5	5	3	
1	≤ 1 it but $z = 10$ ft											
1 2	>10 ft but <= 20 ft											
3	>20 ft											
	Tran intervity	1	1	1	0	0	1	1	1	1	1	
0	No data	_ 1	1	1	0	0	1	1	1	1	1	
1	Limited data on tran characteristics											
1	Informed lithologic and/or structural closure											
2	Documented lithologic and/or structural closure											
					2	0			<u>_</u>		2	
	Legacy well penetrations	_ 1	1	1	0	0	1	2	0	1	0	
0	No data or >=20 wells per 1,000 ac											
1	>=5 wells per 1,000 ac but <20 wells per 1,000 ac											
2	>=2 wells per 1,000 ac but<5 wells per 1,000 ac											
3	<2 well per 1000 ac											
	Stacked opportunity?	0	0	0	0	0	0	0	0	0	0	
0	No other intervals in same footprint											
1	1 other interval in same footprint											
2	2 or 3 other intervals in same footprint											
3	4 or more intervals in same footprint											
	Totals	; 10	9	10	8	7	10	11	11	10	10	

APPENDIX G – CORE AND THIN SECTION DATA FOR JONES & LAUGHLIN #1, BEAVER COUNTY, PENNSYLVANIA

			Earlougher Engineering		PAG	5
Sample Number	Formation	Depth (ft)	Permeability (mD)	Porosity (%)	Permeability (mD)	Porosity (%)
1	Huntersville Chert	5250	0.01	0.14	0.174	0.074
10	Huntersville Chert	5258	0	0.14	0.19	0.025
20	Huntersville Chert	5268	0	0.43	0.671	0.228
30	Huntersville Chert	5346	0	0.58	0.185	0.052
40	Huntersville Chert	5356	0	0.14	0.188	0.144
49	Huntersville Chert	5366	0	0.14	0.196	0.039
60	Oriskany Sandstone	5385	0	0.43	0.192	0.199
61	Oriskany Sandstone	5386			0.199	0.026
62	Oriskany Sandstone	5387			0.199	0.367
63	Oriskany Sandstone	5388	0.04		0.191	0.605
64	Oriskany Sandstone	5389	0		0.218	0.029
65	Oriskany Sandstone	5390	0.07		0.314	1.04
66	Oriskany Sandstone	5391	0		0.221	1.03
67	Oriskany Sandstone	5392	0.2		0.323	2.61
68	Oriskany Sandstone	5393	3.3		1.27	4.38
69	Oriskany Sandstone	5394	0.94		2.23	5.19
70	Oriskany Sandstone	5395	1.2	4.8	1.74	4.36
71	Oriskany Sandstone	5396	0.68		1.04	4.26
	Oriskany Sandstone	5397-		malaa		
	Oriskany Sandstone	5403	No core sa	mpies		
72	Oriskany Sandstone	5404	2.3		1.94	4.73
73	Oriskany Sandstone	5405	3		3.27	4.88
74	Oriskany Sandstone	5406	4.2		4.59	5.36
75	Oriskany Sandstone	5407	2.7	5.5	3.15	4.35
76	Oriskany Sandstone	5408	1.9		2.07	5.03
77	Oriskany Sandstone	5409	3.4		4.56	5.44
78	Oriskany Sandstone	5410	1.8		2.66	6.44
79	Oriskany Sandstone	5411	3.1		3.83	5.6
80	Oriskany Sandstone	5421	0.01	2.0	0.251	0.865
81	Oriskany Sandstone	5422	0.08		0.333	3.1
82	Oriskany Sandstone	5423	0.03		0.295	2.31
83	Oriskany Sandstone	5424	0.02		0.243	1.01
84	Oriskany Sandstone	5425	0.02		0.285	1.02
85	Oriskany Sandstone	5426	0.01	1.2	0.248	1.81

Core No.	Formation	Depth (ft)	Drv Weight (g)	Wet Weight (g)	Difference (g)	Bulk Volume (cc)	Pore Volume (cc)	Porosity (%)
41	Huntersville Chert	5357	34.7149	34.7162	0.0013	12.95	0.00173	0.013
42	Huntersville Chert	5358	25.14	25.1425	0.0025	9.311	0.00333	0.036
43	Huntersville Chert	5359	30.4366	30.4421	0.0055	11.345	0.00733	0.065
44	Huntersville Chert	5360	32.4891	32.493	0.0039	12.033	0.00919	0.043
45	Huntersville Chert	5361	35.2397	35.2419	0.0022	12.95	0.00293	0.023
46	Huntersville Chert	5363	31.8703	31.8725	0.0022	11.8038	0.00293	0.025
47	Huntersville Chert	5364	14.4666	14.4798	0.0032	5.358	0.00426	0.08
48	Huntersville Chert	5365	31.2625	31.2665	0.004	11.746	0.00533	0.045
49	Huntersville Chert	5366	32.0247	32.0282	0.0035	11.861	0.00966	0.039
50	Huntersville Chert	5367	15.4	15.4058	0.0058	6.303	0.00773	0.123
51	Huntersville Chert	5368	30.6315	30.6377	0.0062	11.345	0.00826	0.073
52	Huntersville Chert	5369	29.8562	29.8581	0.0019	11.303	0.00253	0.023
53	Huntersville Chert	5370	18.1427	18.1447	0.002	6.818	0.00266	0.039
54	Huntersville Chert	5371	34.398	34.4038	0.005	12.692	0.00666	0.052
55	Huntersville Chert	5380	17.3848	17.3874	0.0026	6.532	0.00346	0.053
56	Huntersville Chert	5381	29.1627	29.1665	0.0038	10.801	0.0051	0.047
57	Huntersville Chert	5382	33.3341	33.34	0.0059	12.549	0.00786	0.063
58	Huntersville Chert	5383	18.9513	18.9544	0.0031	7.019	0.00413	0.059
59	Oriskany Sandstone	5384	27.6939	27.6979	0.004	10.257	0.00533	0.052
60	Oriskany Sandstone	5385	32.7926	32.8109	0.0183	12.262	0.02437	0.199
61	Oriskany Sandstone	5386	37.6074	37.6101	0.0027	13.809	0.0036	0.026
62	Oriskany Sandstone	5387	33.5575	33.5919	0.0344	12.491	0.0458	0.367
63	Oriskany Sandstone	5388	29.7823	29.8391	0.0568	11.059	0.0757	0.685
64	Oriskany Sandstone	5389	37.5406	37.5436	0.003	13.695	0.004	0.029
65	Oriskany Sandstone	5390	28.9666	29.0516	0.085	10.881	0.113	1.04
66	Oriskany Sandstone	5391	33.9981	34.0976	0.0995	12.778	0.132	1.03
67	Oriskany Sandstone	5392	34.5054	34.7628	0.2574	13.112	0.3429	2.61
68	Oriskany Sandstone	5393	33.7255	34.1572	0.4317	13.112	0.575	4.38
69	Oriskany Sandstone	5394	34.491	35.0187	0.5277	13.551	0.7029	5.19
70	Oriskany Sandstone	5395	34.2145	34.6511	0.4366	13.351	0.5816	4.36
71	Oriskany Sandstone	5396	34.0314	34.4534	0.422	13.208	0.5621	4.26
		:	2 feet, unmarked c	ores				
72	Oriskany Sandstone	5404	34.3839	34.8603	0.4764	13.408	0.6346	4.73
73	Oriskany Sandstone	5405	30.5221	31.0323	0.5102	12.033	0.6796	4.82
74	Oriskany Sandstone	5406	32.6152	33.1301	0.5149	12.807	0.6859	5.36
75	Oriskany Sandstone	5407	33.9678	34.4769	0.5091	13.294	0.6781	4.35
76	Oriskany Sandstone	5408	30.7374	31.1907	0.4533	12.004	0.6038	5.03
77	Oriskany Sandstone	5409	31.6332	32.1394	0.5062	12.405	0.6743	5.44
78	Oriskany Sandstone	5410	33.364	34.0002	0.6362	13.15	0.8474	6.44
79	Oriskany Sandstone	5411	34.3147	34.8811	0.5664	13.466	0.7544	5.6
80	Oriskany Sandstone	5421	35.1305	35.2165	0.086	13.236	0.1145	0.856

Thin Section Analysis Report

Sample ID: Formation/Member Name:	0-2 JL-1-A Oriskanv Sandstone Reaver County, PA	
Lithologic Classification: Depth/Depth Range:	Sandstone 5383 ft	
Date of Analysis:	6/7/2017	
Analyzed by:	Ellen Davis	observed at 10v
	Texture	Comments
	Grain Size 50-800 μm, average grain size ~300 μm	connents
	Rounding subangular, subrounded Sorting moderately to poorly sorted	
	Composition/Detrital Minerals	Comments
	Quartz	
Pol Mon Micr	Vycrystalline ocrystalline ~80% monocrystalline quartz -larger, subrounded to rounded grains -many smaller subangular grains -not much overgrowth -primarily subhedral with moderate relief ocrystalline grains can be easily observed under petroscope Via black which earry DNL large back percent.	images 02_0002, 02_0004, 02_0009 - 02_0013
	*small holes present: could just be the image	
	Feldspar	
	Plagioclase valbite twinning present	images 02_0001, 02_0006, 02_0007
	Orthoclase N/A Microcline -tartan twinning present	image 02_0008
	Carbonate Calcite ~20% calcite -moderate relief -primarily cementing material/overgrowth -primarily anhedral	images 02_0017 - 02_0023
	XN: brown, green, pink PPL: light brown Dolomite N/A Aragonite N/A	
	liite NA	
	Smectite N/A	
	Kaolinite N/A	
	Muscovite <1% muscovite -small, subrounded to rounded grains	
	xn: Diue, purpie, orange PPL: gray-green Chlorite N/A	
	Glauconite N/A	
	Rock Fragments	
S	edimentary Volcanic N/A etamorphic N/A	
U	Other (Accessory Minerals)	
	Cementing Materials	Comments
	Quartz Feldspar	
	Carbonate ·primarily carbonate cementing	images 02_0025 - 02_0030
	Clay	
Iron Oxide Hydoxide an	d/or Sulfide	
non oxide, nydoxide an	Other	
	Visual Porosity Estimate	Comments
	difficult to determine porosity due to absence of dye	



This XN image shows subangular quartz grains varying from smaller to larger grain sizes. The image also contains polycrystalline quartz although it makes up a small percentage of the sample's composition.





This image shows much smaller quartz grains surrounded by cementing calcite.



(10x, XN)



This image shows subangular and subrounded quartz grains with medium relief. The quartz is in a matrix of calcite and does not show much overgrowth.

(10x, XN)



calcite. (10x, XN)



This image shows a large grain of calcite surrounded by cementing calcite and larger quartz grains.

(10x, XN)



The small, brightly-colored minerals in this XN image are grains of muscovite

(10x, XN)



The tartan twinning in this image shows the presence of microcline feldspar. (10x, XN)



This is a larger quartz grain, embedded in a matrix of calcite and smaller quartz grains.

(10x, XN)



A large section of calcite is shown in this image. Here, smaller quartz grains are cemented by the calcite. (10x, XN)



This image shows subangular birefringent muscovite in a matrix of small quartz grains and calcite cement.



This image of plagioclase feldspar shows albite twinning. The striped pattern is visible under XN. (10x, XN)

	Thin Section Analysis Report	
Sample ID:	0-3-A JL-1-A	
Formation/Member Name:	Uriskany Sandstone Beaver County, PA	
Lithologic Classification:	Sandstone	
Depth/Depth Range:	5384 IL	
Date of Analysis:	0///201/ Film Davis	
Analyzed by:	Elieli Davis	absorved at 10v
	Taxtura	Observed at 10x
Grain Size	100-700 um average grain size ~350 um	connicits
Bounding	subrounded to rounded	
Sorting	well sorted	
	Composition/Detrital Minerals	Comments
	Quartz	
Polycrystalline		images 03A_0002 - 03A_0004, 03A_0006 - 03A_0009
Monocrystalline	~95% quartz mostly large, subrounded to rounded grains small holes present in grains overgrowth is present some	
	polycrystalline as well) subnedral with moderate relier	
Microcrystalline	grains can be easily observed under petroscope	
	XN: black, white, gray PPL: light brown	
Dissistan	reiospar	
Plagioclase	N/Δ	
Microcline	tartan twinning present	image 034_0015
Wierbeine		mage osk_oors
	Carbonate	
Calcite	~5% calcite ·primarily cementing material/overgrowth ·anhedral grains	
		images 034 0010 034 0014
	VN: brown groon nink PDI: light brown/grov	Inages 03A_0010 - 03A_0014
Dolomite	N/A	
Aragonite	N/A	
, augume		
	Clay	
Illite	N/A	
Smectite	N/A	
Kaolinite	N/A	
Muscovite	<1% muscovite -small grains -subrounded to rounded grains	images 03A_0016, 03A_0017
	XN: blue, green, orange, pink PPL: green/gray	
Chlorite	N/A	
Glauconite	N/A	
	Rock Fragments	
Sedimonton		
Volcanic		
Metamorphic		
	Other (Accessory Minerals)	
Uncertainties	image 03A_0005	
	Cementing Materials	Comments
Quartz	·overgrown quartz and calcite present	images 03A_0018 - 03A_0023
Feldspar		image 03A_0001
Carbonate		-
Clay		
Iron Oxide, Hydoxide and/or Sulfide		
Other	·possibly mud present?	
	Visual Porosity Estimate	Comments
	absence of use limited accuracy of porosity estimate	



This image shows the primary composition of this sample: overgrown quartz. With XN, polycrystalline grains can be seen among the overgrowth. (10x, XN)



This image shows one of the larger grains of calcite in this sample under XN. Smaller bits of calcite can also be seen between the quartz grains in this image. (10x, XN)



The quartz grains in this image are overgrown, forming a cementing material. There is some calcite present but the matrix is primarily quartz. (10x, XN)



The large grain of calcite in this image is embedded in overg quartz and some smaller grains of calcite.

(10x, XN)



The tartan twinning in this image shows the presence of microcline feldspar, here cemented by quartz grains. (10x, XN)



This image shows a grain of brightly colored muscovite in a matrix of overgrown quartz and calcite. (10x, XN)



This is a particularly large quartz grain and other large, overgro quartz grains. Some cementing calcite is also shown.

(10x, XN)



Although the compositon of this sample is primarily overgrown quartz, this image shows a large grain of calcite cemented by overgrown quartz. (10x, XN)



(10x, XN)







These are small quartz grains embedded in calcite. Some overgrown quartz is also present in the top-left of this image.

(10x, XN)



This overgrown quartz is the predominant mineral in the sample. The overgrowth cements larger grains of calcite.

Thin Section Analysis Report

Commite ID:	0.2 0 1 4 4	
Sample ID: Formation/Member Name:	U-3-B JL-1-A Oriskany Sandstone Reaver County, PA	
Lithologic Classification:	Sandstone	
Depth/Depth Range:	5384 ft	
Date of Analysis:	6/9/2017	
Analyzed by:	Ellen Davis	
		observed at 10x
	Texture	Comments
Grain S	ize 50-900 μm, average grain size ~450 μm	
Round	ing subangular to subrounded	
Sort	ing moderately to well sorted	
	Composition/Detrital Minerals	Comments
	Quartz	
Polycrystall	ine	images 03B_0003 - 03B_0009, 03B_0012
Monocrystall	ine ~85% quartz ·subangular to subrounded grains ·primarily larger than the other grains ·large amounts of	
	overgrowth ·mostly subhedral grains ·small holes are present in grains	
Microcrystall	ine grains can be easily observed under petroscope	
	XN: black, white, gray PPL: light brown	
	Feldspar	
Plagiocli	ase <1% feldspar ·albite twinning ·small, subhedral grains	images 03B_0001, 03B_0010, 03B_0020
Orthock	ase N/A	
Microcl	ine N/A	
	Carbonate	
Calc	ite ~15% calcite ·primarily annedral cementing material	images 03B 0011, 03B 0013 - 03B 0018
	XN: brown, green, pink PPL: light brown/gray	
Dolom	ite N/A	
Aragor	ite N/A	
-		
	Clay	
11	lite N/A	
Smect	ite N/A	
Kaolir	ite N/A	
Muscov	ite <1% muscovite ·small, rounded grains	images 03B_0019, 03B_0021, 03B_0024
	XN: blue, orange, pink, green PPL: yellow-green/brown	
Chlor	ite N/A	
Glaucon	ite N/A	
	Rock Fragments	
Sediment	ary	
Volca	nic	
Metamorp	hic	
	Other (Accessory Minerals)	
	Cementing Materials	Comments
	rtz -overgrown quartz and calcite cementing	images 03B 0002 03B 0023 03B 0025 - 03B 0029
Felds	Dar	
Carbon	ate	
C	lav	
Iron Oxide, Hvdoxide and/or Sulf	ide	
Otl	her -mud possibly present(?)	
	· · · · · · · · · · · · · · · · · · ·	
	Visual Porosity Estimate	Comments
	no uye made it difficult to determine porosity	



This image shows large, subhedral quartz grains. Quartz comprises 85% of this sample.



ese smaller, subangular quartz grains are embedded in a grain of calcite. Larger, subrounded quartz grains are also shown.

(10x, XN)



This grain of birefringent muscovite is cemented in a matrix of small, subangular calcite and large grains of quartz.

(10x, XN)



This is an image of polycrystalline quartz. Small grains of calcite and larger grains of monocrystalline quartz surround the polycrystalline quartz. (10x, XN)



These quartz grains are large, subhedral and subrounded. Some quartz overgrowth is shown as well.



image shows many small, subangular grains of calcite cement quartz grains.

(10x, XN)



The albite twinning shown in this image is due to plagioclase feldspar. The feldspar is cemented in a matrix of quartz and calcite.

(10x, XN)



These subangular and subrounded quartz grains are in a matrix of calcite and smaller quartz grains. There is also a small grain of muscovite in the center of the image. (10x, XN)



This image shows overgrown quartz and some smaller grains of calcite embedded in it.



This image shows several grains of overgrown quartz as well as a large grain of calcite. Some smaller grains of calcite cement the overgrown quartz. (10x, XN)



This image shows plagioclase feldspar with albite twinning surrounded by calcite and large, subrounded quartz.

(10x, XN)



Overgrown quartz is shown in this image, surrounded by calcite.

Sample ID: Formation/Member Name:	0-4 JL-1-A Oriskany Sandstone Reaver County, PA	
Lithologic Classification:	Sandstone	
Depth/Depth Range:	5387 ft	
Date of Analysis: Analyzed by:	6/12/2017 Ellen Davis	
		observed at 10x
	Texture	Comments
	Grain Size S0-800 µm, average grain size "300 µm Rounding subangular to subrounded. subhedral	
	Sorting moderately to well sorted	
	Composition/Detrital Minerals	Comments
	Quartz	images 04,0001, 04,0005, 04,0007, 04,0000
Mon	ocrystalline ~95% guartz-subangular to subrounded grains -medium grain size -abundant overgrowth: polycrystalline grains	Infages 04_0001 - 04_0005, 04_0007 - 04_0009
Micr	rocrystalline grains can be easily observed under petroscope	
	XN: black, white, gray PPL: light brown	
	Plagioclase -albite twinning present	image 04_0016
	Orthoclase N/A	
	Microcline -tartan twinning present	image 04_0015
	Carbonate	
	Calcite <5% calcite ·medium, subhedral grains ·mostly anhedral	images 04_0011 - 04_0014, 04_0018, 04_0019
	XN: brown, green, pink PPL: light brown/gray	
	Dolomite	
	Alagunite	
	Сіау	
	Illite N/A Smertite N/A	
	Kaplinite N/A	
	Muscovite <1% muscovite -small, subrounded to rounded grains	image 04_0017
	XN: blue, orange, pink PPL: yellow-green/gray	
	Chlorite N/A Glauconite N/A	
	Rock Fragments	04,0000 (0002)
5	sedimentary some sedimentary rock tragments present	Image 04_0006 (SRF?)
	Volcanic	
M	letamorphic	
	Other (Accessory Minerals)	
U	ncertainties 04_0010 (right side), 04_0023 (unknown circles)	
	Cementing Materials	Comments
	Quartz ·mostly overgrown quartz	images 04_0020 - 04_0022, 04_0024 - 04_0025
	Feldspar	
	Carbonate -some calcite present	
Iron Oxide, Hydoxide and	d/or Sulfide	
	Other	
	Visual Porosity Estimate	Comments
	difficult to determine porosity due to absence of dye	



This sample is about 95% quartz and this image shows subhedreal, overgrown quartz grains. Some grains of calcite are also present.

(10x, XN)



These two large grains of subhedral calcite are cemented by overgrown quartz. (10x, XN)



This image shows subangular, overgrown quartz cementing severa smaller grains of calcite.

(10x, XN)



This image shows a grain of calcite surrounded by subrounded grains of overgrown quartz. (10x, XN)



These large, subrounded/subangular quartz grains are overgrown with only some void space separating the grains.

(10x, XN)



(10x, XN)



This is an image of microcline feldspar with tartan twinning in a matrix of overgrown quartz. Some calcite is also shown in this image. (10x, XN)



This image shows overgrown quartz cementing grains of calcite.

(10x, XN)



This image shows a subrounded grain of plagioclase feldspar with albite twinning. A small grain of muscovite is in the top right corner. (10x, XN)



These small grains of calcite are surrounded by subrounded and subangular overgrown quartz. Some void space is shown as well.

(10x, XN)



This sedimentary rock fragment is embedded in overgrown quartz grains with some small grains of calcite also present.

(10x, XN)



This image shows subhedral, overgrown quartz grains along with some void space.

Thin Section Analysis Report

Sample ID:	0-5 JL-1-A	
Formation/Member Name:	Oriskany Sandstone Beaver County, PA	
Lithologic Classification:	Sandstone	
Depth/Depth Range:	5388 ft	
Date of Analysis:	6/12/2017	
Analyzed by:	Ellen Davis	
		observed at 10x
	Texture	Comments
Grain Size	100-800 μm, average grain size ~300 μm	
Rounding	subangular to subrounded grains; subhedral	
Sorting	moderately to poorly sorted grains	
	Composition/Detrital Minerals	Comments
	Quartz	
Polycrystalline		images 05 0003 - 05 0009
Monocrystalline	~90% quartz ·abundant overgrowth ·subangular to subrounded grains ·mostly subhedral	
Microcrystalline	grains can be easily observed under petroscope	
	XN: black, white, gray PPL: light brown	
	Feldspar	
Plagioclase	N/A	
Orthoclase	N/A	
Microcine	N/A	
	Carbonate	
Calcite	~10% calcite	images 05_0010 - 05_0013, 05_0015 - 05_0016
	XN: brown, green, pink PPL light brown/gray	
Dolomite		
Aragonite		
	Clav	
	N/A	
Smectite	N/A	
Kaolinite	N/A	
Muscovite	<5% muscovite ·small, angular-subangular grains	images 05, 0006
	XN: blue, orange, pink PPL: grav-brown	
Chlorite	N/A	
Glauconite	N/A	
	,	
	Rock Fragments	
Sedimentary	sedimentary rock fragments present in thin section	images 05_0001 (SRF)
Volcanic		
Metamorphic		
Uncertainties	05_0014	
	Cementing Materials	Comments
Quartz	·primarily overgrown quartz	images 05_0018 - 05_0023
Feldspar		
Carbonate	·some (not much) calcite cementing	
Clay		
Iron Oxide, Hydoxide and/or Sulfide		
Other	-possibly mud	
	Visual Porosity Estimate	Comments
	lack of dye makes it difficult to determine porosity	


This image shows large, subrounded quartz grains. This comprises about 90% of the sample. (10x, XN)



This larger grain of subhedral calcite is in a matrix of overgrown quartz.





This image shows a matrix of calcite among several subrounded quartz grains.

(10x, XN)



grains. (10x, XN)



This image shows a strained grain of calcite surrounded by subround and subangular overgrown quartz. (10x, XN)



This image shows a sedimentary rock fragment in a matrix of overgrown quartz.

(10x, XN)



This image shows overgrown quartz, subangular calcite, and pore space in between the grains.

(10x, XN)



This subhedral overgrown quartz is the primary cementing material in this image but some pore space can be seen separating the quartz.

(10x, XN)



This is a large quartz grain with other overgrown quartz grains surrounding it. (10x, XN)



In this image, overgrown quartz surrounds a grain of calcite.

(10x, XN)



Although only about 50 μm large, this grain of birefringent muscovite is embedded in a grain of quartz. Other overgrown grains of quartz are present in this image.

(10x, XN)



This image shows a good example of the overall composition of this sample. A grain of calcite is shown with overgrown quartz and void space.

(10x, XN)

Thin Section Analysis Report

Semale ID:	0.0	
Sample ID:	U-D JL-1-A	
Formation/Wember Name:	Conditione Beaver County, PA	
Denth /Denth Bangar		
Date of Analysis:	6/12/2017	
Analyzed by:	0/15/2017 Ellen Davis	
Analyzed by.		observed at 10x
	Texture	Comments
Grain Size	50-700 µm, average grain size ~350 µm	connents
Rounding	subangular to subrounded grains: mostly subhedral	
Sorting	moderately sorted	
	Composition/Detrital Minerals	Comments
	Quartz	
Polycrystalline		images 06_0004 - 06_0010, 06_0012
Monocrystalline	~90% quartz ·large amounts of overgrowth ·subangular to subrounded grains ·mostly subhedral grains ·some	
	polycrystalline quartz	
Microcrystalline	grains can be easily observed under petroscope	
	XN: black, white, gray PPL: light brown	
	Feldspar	
Plagioclase	albite twinning present	image 06_0001
Orthoclase	N/A	
Microcline	-tartan twinning present	image 06_0014
-	O selected a	
	Carbonate	
Calcite		images 06_0013, 06_0015, 06_0017 - 06_0021
	<10% calcite ·medium sized, subhedral grains ·some small grains present	
	XN: brown, green, pink PPL: light brown	
Dolomite	N/A	
Aragonite	N/A	
	Clay	
Illite	N/A	
Smectite	N/A	
Kaolinite	N/A	
(?) Muscovite	-small, subangular grains	image 06_0068
	XN: blue, yellow, green PPL: gray-brown	
Chlorite	N/A	
Glauconite	N/A	
	Deal Francisco	
Sedimentary	some sedimentary rock fragments	06_0002 (SRF?)
Volcanio		
Metamorphic		
	Other (Accessory Minerals)	
Uncertainties	i images 06_0026 (4:00), 06_0011 (small, clear/ blue)	
	06_0016 (clear, yellow)	
	Cementing Materials	Comments
Quartz	·primarily overgrown quartz	images 06_0022 - 06_0025, 06_0027, 06_0029
Feldspar		
Carbonate	-small amounts of calcite	
Clay		
Iron Oxide, Hydoxide and/or Sulfide		
Other	·some mud (?)	image 06_0003 (mud)
	Visual Porosity Estimate	Comments
	difficult to estimate porosity due to lack of dye	



(10x, XN)



(10x, XN)



(10x, XN)



grains of calcite. (10x, XN)

This image shows calcite in a matrix of overgrown quartz and smaller grains of calcite. Some void space can be seen here as well.

(10x, XN)



This microcline feldspar with tartan twinning is cemented between subangular and subrounded overgrown quartz.

(10x, XN)



This image shows larger, overgrown quartz grains

(10x, XN)



These grains of calcite are embedded in subrounded, overgrown quartz grains.

(10x, XN)



This image shows a more subtle example of albite twinning indicating the presence of plagioclase feldspar. The feldspar is cemented in overgrown quartz.

(10x, XN)



This image shows overgrown quartz as well as pore space inbetween the quartz grains. (10x, XN)



Pore space can be seen between the overgrown quartz in this image.

(10x, XN)



This image shows subhedral overgrown quartz grains and pore space.

(10x, XN)

Thin Section Analysis Report

Sample ID:	0-7-A JL-1-A	
Formation/Member Name:	Oriskany Sandstone Beaver County, PA	
Lithologic Classification:	Sandstone	
Date of Analysis:	6/13/2017	
Analyzed by:	Ellen Davis	
,,		observed at 10x
	Texture	Comments
Grain Size	e 50-500 μm, average grain size ~350 μm	
Rounding	g subangular to subrounded	
Sorting	g poorly to moderately sorted	
	Composition/Detrital Minerals	Comments
	Quartz	
Polycrystalline	e N/A	images 07A_0007 - 07A_0013
Monocrystalline	~60% quartz ·medium sized, overgrown grains ·mostly monocrystalline	
Microcrystalline	e grains can be easily observed under petroscope	
	XN: white, black, gray PPL: light brown	
Discipulation	Feldspar	images 074 0001 074 0002 074 0014
Plagioclase	e raibite twitning present	images 07A_0001, 07A_0002, 07A_0014
Orthoclase	2 N/A	image 074, 0002 (2)
WICTOCITIE		Inlage 07A_0003 (F)
Calcite		
	~40% caclite ·large line of calcite running down top of slide ·medium sized grains ·primarily euhedral	images 07A_0015 - 07A_0021
	XN: brown, green, pink PPL: light brown/gray	
Dolomite		
	N/A	
Aragonite	e N/A	
	Clav	
	e N/A	
Smectite	e N/A	
Kaolinite	e N/A	
Muscovite	e <1% muscovite -small, subangular to subrounded grains	images 07A_0004 - 07A_0006
	XN: orange, blue, pink PPL: green-brown	
Chlorite	e N/A	
Glauconite	e N/A	
Cadimanta a	Rock Fragments	
Sedimentar		
VOICATIO	L	
Metamorphie	c	
Uncertaintie	Other (Accessory Minerals)	
Uncertaintie.	image 07A_0024 (black with calcite, no extinction, smooth PPL, pores?)	
	Cementing Materials	Comments
Quart	z ·about 50% overgrown quartz	images 07A_0025 - 07A_0030
Feldspa	r	
Carbonate	e ·50% calcite	
Clay	1	
Iron Oxide, Hydoxide and/or Sulfide		
Othe	r	
	Visual Porosity Estimate	Comments
	no dye, difficult to determine porosity	



This image shows subrounded overgrown quartz grains ranging in size.

(10x, XN)



There is a large grain of calcite stretching across part of the sample. This image shows part of that line of calcite. Some pore space is also shown.

(10x, XN)



This image shows two grains of plagioclase feldspar with albite twining in a matrix of calcite and overgrown quartz.

(10x, XN)



This image shows polycrystalline quartz, a sedimentary rock fragment. It is surrounded by overgrown quartz.

(10x, XN)



These monocrystalline, overgrown quartz grains cement about 60% of the sample.

(10x, XN)



This is another image of calcite in the sample. This calcite is more striated and some quartz grains are also present in the image.

(10x, XN)



This subangular grain of birefringent muscovite is embedded in a matrix of overgrown quartz.

(10x, XN)



This image is an example of the diverse composition of this sample. Some overgrown quartz is shown and calcite is cementing other quartz grains.

(10x, XN)



This overgrown quartz cements some smaller grains of calcite.

(10x, XN)



This is also an image of calcite in this sample. The grains are small and there is overgrown quartz embedded in the calcite.

(10x, XN)



This image shows a small, subrounded grain of birefringent muscovite cemented by overgrown quartz.

(10x, XN)



Plagioclase feldspar with albite twinning is shown in this image. The feldspar is embedded in a matrix of overgrown quartz.

(10x, XN)

Thin Section Analysis Report

Sample ID:	0-7-B JL-1-A	
Formation/Member Name:	Oriskany Sandstone Beaver County, PA	
Lithologic Classification:	Sandstone	
Depth/Depth Range:	5418 ft	
Date of Analysis:	6/13/2017	
Analyzed by:	Ellen Davis	
	Territoria	observed at 10x
Croin Size	Iexture	Comments
Grain Size Rounding	subappulat to subrounded	
Sorting	moderately to well mixed	
Soliting	moderately to well mixed	
	Composition/Detrital Minerals	Comments
	Quartz	
Polycrystalline		images 07B_0007 - 07B_0013
Monocrystalline	~50% quartz wide range of sizes overgrowth present oprimarily monocrystalline quartz	
Microcrystalline	grains can be easily observed under petroscope	
	XN: white, black, gray PPL: light brown	
Diagioglass	Feldspar	images 070, 0001, 070, 0006
Plaglociase		Inages 078_0001, 078_0006
Microclino	N/A	images 078, 0002, 078, 0004
Wicrochile	tartan twinning	IIIages 078_0002, 078_0004
	Carbonate	
Calcite	~50% calcite ·medium sized, anhedral grains	images 07B_0014 - 07B_0019
	XN: brown, green, pink PPL: brown-gray	
Dolomite	N/A	
Aragonite	N/A	
-	Gav	
Smertite	N/A	
Kaolinite	N/Δ	
(2) Muscovite	<1% muscovite -subrounded	images 07B 0003 07B 0005
(1) 110500110	XN: orange red vellow numbe	
Chlorite	N/A	
Glauconite	N/A	
Chatconice		
	Rock Fragments	
Sedimentary		
Volcanic		
Metamorphic		
	Other (Accessory Minerals)	
	Convention Materials	6t-
Quartz	orimarily overgrown quartz	images 07B_0020 - 07B_0026
Quartz	printerny overbrown quartz	11105c3 010_0020 - 010_0020
relaspar	.come calcite present	
Carbonate	some calcite present	
Udy Iron Ovide, Hydovido and/or Sulfida		
other		
Other		
	Visual Porosity Estimate	Comments
	difficult to determine porosity, no dye	



This image shows polycrystalline quartz among overgrown monocrystalline quartz grains. (10x, XN)



Overgrown quartz in this image is cemented by calcite.

(10x, XN)



ldspar with tartan twinning overgrown quartz.

(10x, XN)



This large grain of quartz is overgrown with smaller quartz grains, cementing grains of calcite. (10x, XN)



This image shows calcite embedded in grains of subangular, overgrown quartz.

(10x, XN)



This image shows plagioclase feldspar with albite twinning and is in a matrix of overgrown quartz and calcite.

(10x, XN)



nage shows a grain of orange and purple muscovite in a ma of overgrown quartz, calcite, and some pore space.

(10x, XN)



This image shows two subangular grains of birefringent muscovite surrounded by subrounded grains of quartz and calcite.

(10x, XN)



This image shows different sized quartz grains, overgrown with each other and cementing calcite.

(10x, XN)



This image shows overgrown quartz in a matrix of calcite.

(10x, XN)



The tartan twinning in the image shows the presence of microcline feldspar. This feldspar is embedded in overgrown quartz.

(10x, XN)



Both the calcite and the overgrown quartz act as cementing materials in this image. Some pore space can also be seen.

(10x, XN)

APPENDIX H – WESTON-JANE LEW FIELD CROSS SECTION PLATES







S









Log Depth(ft) - 2900
- 3000
- 3100
- 3200
- 3300
- 3400
- 3500
- 3600
- 3700
- 3800
- 3900
- 4000
- 4100
- 4200
- 4300
- 4400
- 4500
- 4600
- 4700
- 4800
- 4900
- 5000
- 5100

APPENDIX I – ORISKANY SANDSTONE PETROGRAPHY, WOOD COUNTY, WEST VIRGINIA

ORISKANY SANDSTONE PETROGRAPHY, WOOD COUNTY, WEST VIRGINIA

The Darrell Matheny #2 (API No. 4710701266) is located about 25 mi north of the Southern Prospect in Wood County, West Virginia (Figure 1). In the Southern Prospect, the Elk-Poca (Sissonville) Field (highlighted yellow in Figure 1) produced natural gas for decades before a portion of the area (Ripley Field – highlighted orange in Figure 1) was converted to natural gas storage.



Figure 1. Location of the Darrell Matheny #2 relative to the Southern Prospect.

Thin sections were analyzed using a Leica DM 4500 P microscope, fitted with a Leica DFC400 camera, using a magnification of 10x power under both plane and polarized light (PL and XN, respectively). Photomicrographs were taken using the Leica DCF400 camera affixed to the microscope. The analysis included the following steps: (1) identify and estimate the percentage of mineral groups present; (2) examine textures and grain properties; (3) analyze the cementing materials that hold the rock matrix together; and (4) prepare a visual estimate of porosity

(porosity is indicated with blue epoxy in these sections). Observations were made using Ulmer-Scholle and others (2014) as a guide, and visual estimates of mineral composition and porosity were based on the comparison chart for visual percentage estimation by Terry and Chilingar (1955).

Thin section WD-1 was sampled from the Onondaga Limestone, the caprock above the Oriskany Sandstone (Figure 2). Notable are the lack of porosity and abundance of calcite cement. Homogeneous calcite grains are approximately 50 microns in size. Larger grains exhibit minor deformity.



Figure 2. Thin section WD-1, 4197.1 ft (PL).

Thin section WD-5 is typical of the Oriskany Sandstone (Figures 3 and 4). Grains are subangular to subrounded, moderately sorted and are comprised of monocrystalline quartz. Both quartz and calcite cement are present. Porosity in this thin section is intergranular and estimated at about 11 percent.



Figure 3. Thin section WD-5, 4212.1 ft (PL).



Figure 4. Thin section WD-5 (XN). Note the calcite cement between quartz grains.

Thin section WD-7 (Figure 5) exhibits lower intergranular porosity (approximately 8 percent) than the previously presented sample (WD-5), due to more complete cementation of quartz grains. Both quartz and carbonate cement are present. Grain size remains fairly uniform at 300-400 microns.



Figure 5. Thin Section WD-7, 4215.8 ft (PL).

Thin section WD-10 shows quartz overgrowths (Figures 6 and 7). Grains are subangular to subrounded, moderately sorted and comprised of monocrystalline quartz. Quartz grains average 500 microns in size. Intergranular porosity in this thin section is partially occluded by quartz cementation, but still estimated to be about 10 percent.



Figure 6. WD-10, 4222.5 ft (PL).



Figure 7. WD-10, 4222.5 ft (XN).

Overall, the Oriskany Sandstone thin sections from the Darrell Matheny #2 (API No. 4710701266) were observed to contain clean quartz sand (70 percent or more) with uniform grain size and shape and minimal inclusions. Calcite was observed as the primary cementing material.

APPENDIX J – ENGINEERING DESIGN CONSIDERATIONS

ENGINEERING DESIGN CONSIDERATIONS

1.0 MINED-ROCK CAVERNS

1.1 Infrastructure Requirements, Timeline and Anticipated Costs

Significant infrastructure requirements exist for construction of mined-rock caverns. These include power (5.0 MVA or greater) to enable use of hoists, ventilation fans and water pumps; road access; and labor, as "the required skilled construction labor force is greater for mined-rock caverns than either salt caverns or oil and gas reservoir storage" (Nelson and others, 2011). Mined-rock caverns have several characteristics that make them a more environmentally benign process; namely, a smaller footprint, decreased water requirements, and minimal waste production. In addition, the limestone produced from mining may be of suitable lithology for use in other aspects of the storage hub network, such as pipeline corridors, access roads, or site construction.

Mined-rock storage caverns in the United States are constructed in several different lithologies. Most are built in extremely low-permeability shales, with others constructed in dolomite, limestone and granite. Hard-rock cavern storage volumes range from 20,000 to 1,400,000 barrels (BBL) (average of 320,000 BBL). Worldwide, the maximum volume is 5 million BBL. A potential mined-rock cavern project has a step economic of scale curve; costs are fixed with regard to initial activities, such as geological investigation, shaft sinking, and initial development mining, so overall project cost per barrel decreases with increasing cavern volume. Nelson and others (2011) estimated a mined-rock cavern in the Greenbrier could host a volume between 2.0 and 2.5 million BBL.



Figure 1. Rough Order of Magnitude (ROM) timeline for construction of a mined-rock cavern.

Item	Option 1	Option 2	Option 3	
Storage Volume (millions of barrels)	2	4	10	
Number of Caverns	1	2	4	
Fixed Costs	Fixed Costs (\$ millions)			
Engineering	\$1.5	\$1.5	\$1.5	
Geological Investigation	\$2.0	\$2.0	\$2.0	
Mainshaft	\$9.0	\$18.0	\$36.0	
Mainshaft Conversion	\$2.0	\$4.0	\$8.0	
Pump/Vent Wells	\$8.4	\$16.8	\$33.6	
Hoist and Headframe	\$5.0	\$10.0	\$10.0	
Breakout Mining	\$2.0	\$4.1	\$8.1	
Variable Costs (\$ millions)				
Production Mining	\$150.0	\$300.0	\$750.0	
Convert and Outfit	\$9.0	\$15.0	\$33.0	
Test and Purge	\$1.6	\$3.1	\$7.7	
Total Cost	\$190.5	\$374.5	\$889.9	
Unit Cost (\$/barrel)	\$95.3	\$93.6	\$89.0	
Lower Range (\$/barrel)	\$79.0	\$78.0	\$74.0	
Upper Range (\$/barrel)	\$114.0	\$112.0	\$107.0	

Figure 2. Mined rock cavern details and estimated costs (Nelson and others, 2011).

1.2 Host Rock Requirements and Cavern Design

Structural stability and low permeability to groundwater flow are the two main host rock criteria for a mined-rock cavern. The cavern operates under hydraulic containment – the surrounding natural hydrostatic pressure must be greater than the pressure of the stored product. This ensures containment of the product; a leak path will result in water flowing in, rather than flowing out and causing product to escape.

Modern mined-rock caverns are typically equipped with three shafts. An 8- to 14- foot (ft) diameter main shaft serves as an access point during initial construction and waste disposal tasks. Upon completion, this shaft is used for the cavern's instrumentation, piping and pump systems. A smaller set of two 36- to 48-inch (in) vent/pump shafts are used for ventilation in the construction phases and are then recompleted to serve as submersible pump wells in the production phase (Figure 3).



Figure 3. Schematic (cross section view) design of a mined-rock cavern.

A typical hard-rock cavern design operates using a brine-compensated style. This type of cavern remains full of liquid at all times. During product injection, the brine is displaced and the brine is re-injected to deliver the product and to regulate reservoir pressure. Nelson and others (2011) estimates the following pressure ranges:

- Minimum ethane wellhead pressure to ensure product remains liquid = 900 to 1,200 pounds per square inch (psi)
- Operating pressure gradients = 0.55 to 0.85 psi per ft
- Brine pressures for hydrocarbon storage caverns = 25 to 100 psi

Given these pressure ranges the authors suggest a cavern depth of 1,000 to 3,000 ft and warn that construction of a cavern at depths shallower than 1,000 ft would require higher brine pressures to maintain minimum ethane wellhead pressure.



Figure 4. Plan view conceptual design for a mined-rock cavern (Nelson and others, 2011).

In a "brine-compensated storage" cavern, brine is injected when product is withdrawn and vice versa. Therefore, surface storage (brine ponds) must be provided for the productdisplacement brine. Subsurface brine storage (in caverns with a nitrogen surcharge) is possible. However, roughly 3 BBL of cavern space is required for every barrel of stored brine to ensure that the nitrogen pressure (following brine withdrawal) is sufficient for cavern structural support.

The following equation can be used to compute the gross volume of a mined-rock cavern, where cross-sectional area of a room [length (l) * width (w)] is multiplied by its (height (h) to determine volume in cubic feet (ft^3). The volume is divided by 5.615 to convert units of cubic ft^3 to BBL.

$$V = (l \times w \times h) / 5.615$$

Additional factors or corrections (not given here) will need to be applied to this equation to account for the pressure-dependence of ethane or other NGLs at reservoir depth, as well as the portion of the cavern's volume used for product vs. brine.

2.0 SALT CAVERNS

2.1 Infrastructure requirements, Timeline and Anticipated Costs

The main infrastructure requirements for salt cavern construction are related to transportation corridors for water and brine, brine disposal requirements, fresh water source(s) to leach the cavern, and 2.0 to 5.0 MVA capacity electrical service. Many of these requirements are already in-place in the region surrounding the Ohio River. This is especially true in the tristate region of eastern Ohio, northern West Virginia and western Pennsylvania where the thickest salt intervals are observed. The maximum thickness of the Salina F4 salt in the ASH area of interest typically does not exceed 100 ft. Given a cavern width of 200 ft, a typical cavern volume is approximately 200,000 BBL. Therefore, multiple caverns would be necessary to obtain overall storage volumes of a million barrels or more. Figure 5 shows the Rough Order of Magnitude (ROM) timeline for construction of a salt-brine cavern complex (Nelson and others, 2011).



Figure 5. ROM timeline for construction of a salt-brine cavern complex.

Estimated costs for a salt brine cavern (Figure 6) depend on cavern depth (the cost generally increases with depth), as well as the volume of brine disposal necessary to complete

the project. Figure 6 gives an estimate (Nelson and others, 2011) of costs assuming brine disposal into a saline aquifer.

Item	Option 1	Option 2	Option 3	
Storage Volume (millions of barrels)	2	4	10	
Number of Caverns	10	20	50	
Number of Brine Disposal Wells	35	53	71	
Leach Rate (gpm)	1,000	1,500	2,000	
Leach Pumping (days)	412	550	1,031	
Overall Leaching Duration (months)	18	23	42	
Fixed Costs	(\$ millions)			
Engineering	\$2.0	\$2.0	\$2.0	
Geological Investigation	\$2.0	\$2.0	\$2.0	
Leach Plant	\$3.0	\$3.0	\$3.0	
Leach Headers	\$0.6	\$0.6	\$0.6	
Brine Disposal Wells	\$157.5	\$238.5	\$319.5	
Variable Costs (\$ millions)				
Storage Wells (13% inch)	\$85.0	\$170.0	\$425.0	
Brine Ponds	\$10.0	\$20.0	\$50.0	
Leach Plant	\$6.0	\$8.0	\$12.0	
Leaching Pipelines	\$8.1	\$13.1	\$21.8	
Leaching O&M	\$3.0	\$6.0	\$15.0	
Conversion	\$4.3	\$8.5	\$21.3	
Total Cost	\$281.5	\$471.7	\$872.1	
Unit Cost (\$/barrel)	\$140.7	\$117.9	\$87.2	
Lower Range (\$/barrel)	\$117	\$98	\$73	
Upper Range (\$/barrel)	\$169	\$142	\$105	

Figure 6. Estimate of costs associated with salt cavern construction assuming brine disposal into a saline aquifer (Nelson and others, 2011).

2.2 Host Rock Requirements and Cavern Design

In terms of cavern development, a very important consideration is the nature of salt bed accumulation in a potential location. As opposed to storage in a pure salt column or diapir, the Salina F4 and associated units are bedded salts; that is, interlayered evaporite and non-evaporite units of varying "purity." Therefore, the targeted salt bed must be of a thickness to allow cavern dissolution of the desired height while allowing for accumulation of the insoluble lithologies at

the cavern's base. These insoluble/impure materials tend to expand as they are immersed and accumulate at the cavern base; this "bulking factor" is typically around 50 percent of the initial material volume. A final consideration for the target salt bed is that it must be of adequate thickness to allow for sufficient preservation of roof material (often referred to as a 'saltback').



Figure 7. Schematic diagram of a salt cavern (Nelson and others, 2011).

Parameters		Value	
Volume (thousands of barrels)	200	200	200
Well Diameter (inches)	13%	13%	13%
Leaching Tubulars (inches)	7 × 4½	10¾ × 7	10¾ × 7
Leach Rate (gpm)	500	1,000	1,500
Max Injection/Delivery Rate (gpm)	1,300	1,300	1,300
Injection/Delivery Rate (barrels per day)	44,600	44,600	44,600
Overall Leaching Duration (days)	132	77	59
Approx. Leach Injection Pressure (psi)	2,000	1,550	2,750
Assumed Brine Injection Pressure (psi)	1,200	1,200	1,200
Approx. Leaching Power (horsepower)	1,400	2,500	5,200
Approx. Leaching Power Usage (Megawatt hours)	2,400	2,150	3.000

Figure 8. Design parameters for a salt cavern (Nelson and others, 2011).

The following equation can be used to compute the gross volume of a solution-mined salt cavern, where cross-sectional area is circular $[\pi * radius (r)^2]$ is multiplied by its (height (h) to determine volume in ft³. The volume is divided by 5.615 to convert units of ft³ to BBL.

$$V = (\pi \times r^2 \times h) / 5.615$$

Additional factors or corrections (not given here) will need to be applied to this equation to account for the pressure-dependence of ethane or other NGLs at reservoir depth, as well as the portion of the cavern's volume used for product vs. brine.

3.0 RESERVOIR STORAGE

3.1 Infrastructure requirements, Timeline and Anticipated Costs

Main infrastructure requirements for reservoir storage will depend on the type, age and depth of the target field. Existing gas storage fields represent the lowest infrastructure requirements, as it is assumed much of the necessary infrastructure is in-place and field limits (trap integrity) considerations have already been addressed. Depleted fields that have not been converted to storage will have varying infrastructure needs, including (but not limited to) access roads, pipeline rights-of-ways and mitigation costs associated with identification and mitigation/plugging of legacy wells. Given the decreased infrastructure and construction

requirements associated with reservoir storage, timeline for development is shorter than for either mined-rock or salt cavern construction (Figure 9). The estimated costs are also significantly lowered (Figure 10).



Figure 9. ROM timeline for construction of reservoir storage (Nelson and others, 2011).

Item	Small	Medium	Large
Storage Volume (millions of barrels)	2	4	10
Number of Horizontal Wells	6	6	6
Fixed Costs (\$ millions)			
Engineering	\$1.0	\$1.0	\$1.0
Reservoir Test/Characterize	\$0.5	\$0.5	\$0.5
Pipeline (20 mi, 10 inch)	\$29.6	\$29.6	\$29.6
Compression	\$6.1	\$6.1	\$6.1
Gas Processing	\$2.0	\$2.0	\$2.0
Variable Costs (\$ millions)			
New Horizontal Wells	\$36.0	\$36.0	\$36.0
Gas in Place (\$/MMbbl/Ethane)	\$1.0	\$2.0	\$5.0
Total Cost	\$76.2	\$77.2	\$80.2
Unit Cost (\$/barrel)	\$38.1	\$19.3	\$8.0
Lower Range (\$/barrel)	\$25.1	\$12.8	\$5.4
Upper Range (\$/barrel)	\$67.6	\$34.0	\$13.9

Figure 10. Estimate of costs associated with reservoir construction (Nelson and others, 2011).

In order to compute the storage capacity of a depleted reservoir to store ethane, the produced volume and reservoir pressure conditions must be known for the area being converted to storage. As reported by Nelson and others (2011), the storage capacity can be estimated by dividing the cumulative production of natural gas from the reservoir by the ratio of reservoir pressure to atmospheric pressure (i.e., at standard temperature and pressure conditions). The resulting volume is divided by 5.615 to convert units of ft³ to BBL.

4.0 PROJECT COMPARISON

Each of these three potential storage options has relative strengths and weaknesses when compared to one another. For example, deliverability is highest in mined-rock and salt cavern options; these options also require the highest capital investment costs. Figure 11 lists the advantages and disadvantages of the various storage options. The costs associated with each design option also vary with overall storage volume; a comparison of these relative costs is provided in Figure 12.

Storage Option	Advantages	Disadvantages
Salt Caverns Without Brine Takeaway	 Ability to meet a very high deliverability (80,000 bbls/day per well). 	 Generally the largest unit cost. Significant brine disposal cost. Large acreage requirement. Requires large surface brine ponds. Cavern depth outside industry experience. Limited site options.
Salt Caverns With Brine Takeaway	 Ability to meet a very high deliverability (80,000 bbls/day per well). 	 Large unit cost. Considerable brine disposal cost for 4 and 10 MMbbls of storage. Large acreage requirement. Requires large surface brine ponds. Cavern depth outside industry experience. Limited site options.
Mined-Rock Caverns	 Ability to meet a very high deliverability. Least risk of environmental impact. Smallest acreage requirement. 	Large unit cost.Longest development time.
Oil and Gas Reservoir	 Lowest unit cost: \$38.1, \$19.3, and \$8.0/bbl for 2, 4, and 10 MMbbls of storage. Shortest development time: 37, 38, and 40 months for 2, 4, and 10 MMbbls of storage. Greatest flexibility of site options. 	• Would require processing to separate hydrocarbons.

Figure 11. Comparison of various NGL storage options (Nelson and others, 2011).



Figure 11. Comparison of unit costs associated with different storage types and volumes (Nelson and others, 2011).