Appalachian Storage Hub (ASH) Study

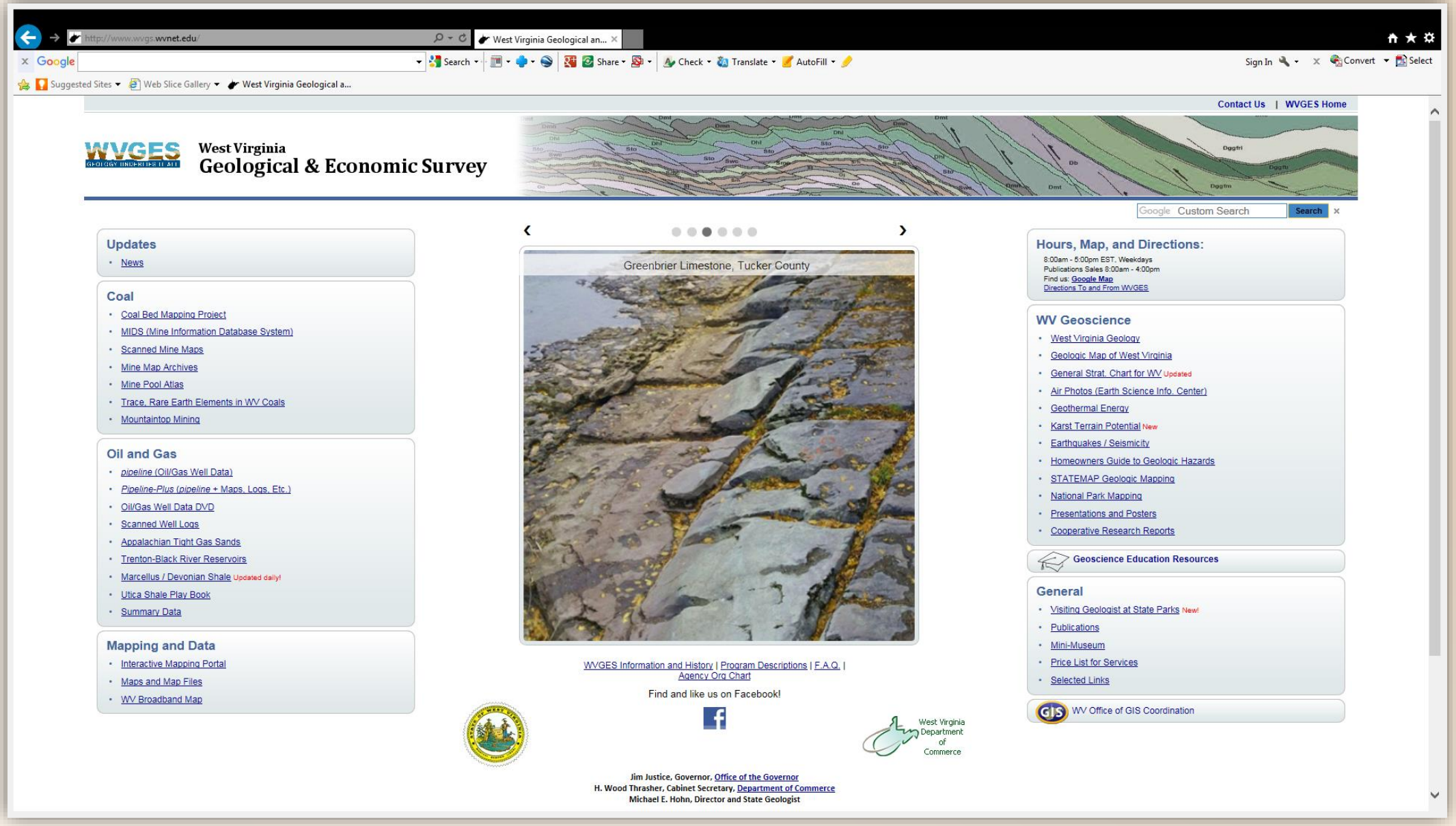
Project Database and Website

Jessica Moore, John Bocan, John Saucer and Gary Daft
West Virginia Geological and Economic Survey

INTRODUCTION AND PURPOSE

- Project database created at beginning of project
- Website serves as main portal to project data, presentations and reports
- Data search enables customized queries of the project database
- Where possible, separated by storage type (Salina, Greenbrier, depleted gas, existing storage)
- Available to the public on September 1, 2017

Save the Date: September 1, 2017



Project website available at www.wvgs.wvnet.edu

Mozilla Firefox Start Page | ASH - Main Page

https://gisonline.wvgs.wvnet.edu/ASH/securepages/Default.aspx

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"The date of the first use of petroleum or its residual products, pitch and asphaltum, precedes authentic history. Probably the first recorded utilization is that of the eleventh chapter of Genesis in which it is stated that the soft or semi-fluid bitumen found in the valley of the Euphrates and translated "slime", was used as a mortar in the building of Babylon, more than forty centuries ago. Erastosthenes, a celebrated Grecian writer who lived in the third century B.C., has described this bitumen from the Springs of Hit, on the Euphrates, and has also told of its use in the construction of mosaics, pavements, etc., in the beautiful palaces and temples of ancient Nineveh and Babylon."

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Ishtar Gate:
https://en.wikipedia.org/wiki/Ishtar_Gate

1 2 **3** 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18

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ABOUT ASH AND PROJECT SUMMARY

The first public release of results from a one-year, regional geologic study

PROJECT BACKGROUND

State officials in Ohio, Pennsylvania, and West Virginia are promoting a high-technology program to enhance economic development by expanding the market for ethane and other natural gas liquids (NGLs) production from the liquids-rich Marcellus and Utica shale plays. The vision is to create a robust infrastructure supporting the creation of value from the prolific NGLs production in the Appalachian Basin, including NGLs storage and trading plus pipeline infrastructure.

The **Tri-State Shale Coalition** (see below) realized that a critical first step in the development of infrastructure and expanded industrial growth would be to conduct a geologic investigation of the potential to develop adequate subsurface storage along the pipeline route to provide consistent product flow to industries. Such a study would provide data essential to decision-makers intent on supporting the development of an Appalachian Storage Hub and the petrochemical industry.

The Appalachian Oil and Natural Gas Research Consortium (AONGRC), a program of the WVU Energy Institute's National Research Center for Coal and Energy, was tasked with evaluating the storage potential of subsurface stratigraphic units along the pipeline route. Individual formations and intervals of interest include the Greenbrier Limestone for subsurface mining; the Salina salt for the creation of cavities through brine extraction; and depleted gas fields and gas storage fields in sandstone reservoirs in the Lower Mississippian (Keener to Berea Interval); Upper Devonian (Venango, Bradford and Elk Intervals), Lower Devonian (Oriskany Sandstone); Upper Silurian (Newburg sandstone); Lower Silurian (Clinton/Medina Group); and Lower Ordovician (Rose Run Formation) - Upper Cambrian (Gatesburg Formation).

- The goal of the study was to complete a geologic study of all potential options for subsurface storage of liquid ethane and other NGLs along and adjacent to the Ohio River from southwest Pennsylvania to eastern Kentucky, with a similar study along the Kanawha River in West Virginia. This involved the mapping and identification of areas where the Salina F Salt is at least 100 feet thick and suitable for solution mining; mapping and identification of areas of the Greenbrier Limestone that are at least 40 feet thick and suitable for hard-rock mining; and mapping the thickness and extent of sandstone reservoirs in depleted gas fields that could be converted to NGLs storage.

- The study was completed July 31, 2017, and produced three main products: (1) a regional subsurface geologic investigation of all geologic units of interest; (2) a detailed reservoir characterization effort, including field-level studies, rating criteria used to screen candidate fields, the final ranking of storage candidates and presentation of three prospect areas; and (3) the publicly accessible website in which all of the above reside. These deliverables are intended to guide the future site investigations conducted by any operators interested in developing the Appalachian Storage Hub.

During this technical workshop, members of the Research Team will present the research that was conducted, areas that "graded" the highest for subsurface storage of NGLs, and recommendations for the next phase of subsurface research prior to creating the Appalachian Storage Hub.

ACKNOWLEDGMENTS

The PTTC and WVU Energy Institute thank the Benedum Foundation for providing the initial funding for the ASH project and the following companies for providing the matching funding that made this project possible: AEP, Antereo, Blue Racer, Charleston Area Alliance, Chevron, Dominion, EQT, First Energy/Team NEO, Mountaineer NGL Storage LLC, Noble Energy, Southwestern Energy, XTO Energy and WVONGA, the West Virginia Oil & Natural Gas Association.

We also would like to acknowledge the efforts of the WVU Foundation for taking the lead in obtaining these matching funds, and the WVU Research Corporation and the WVU Corporate Relations Office for their administrative support.

TRI-STATE SHALE COALITION

Promoting a World Scale Economic Opportunity

In 2015 the Governors of Pennsylvania and West Virginia and the Lt. Governor of Ohio signed a Tri-State Regional Cooperation Agreement – an unprecedented commitment to cross-border promotion of the economic opportunities presented by the Marcellus and Utica Shales to build a global petrochemical hub.

The Coalition's founding organizations – Team NEO, the Allegheny Conference, VisionShared, and the Claude Worthington Benedum Foundation – have since been working with partners including JobsOhio, the Pennsylvania Department of Community and Economic Development, the West Virginia Department of Commerce, and the Appalachian Partnership for Economic Growth to advance initiatives in policy, workforce, transportation and infrastructure, innovation, and marketing.

This workshop is the first work product of the Tri-State Shale Coalition's Transportation and Infrastructure working group. Coalition member WVU defined and organized the research through the Appalachian Oil and Natural Gas Research Consortium of the WVU Energy Institute's National Research Center for Coal and Energy. Researchers from WVU and the West Virginia, Pennsylvania, and Ohio Geological Surveys conducted the work. Initial funding for the project was provided by Tri-State Coalition Member, the Benedum Foundation, with WVU's Energy Institute securing matching funding from 13 industrial partners.

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REPORTS and PRESENTATIONS

ASH Final Report

Note: For large files, you may wish to right click on the link and choose "save link as" so to save the file to your computer rather than the file opening in your web browser.

- ASH Project Final Report 8/29/2017 (PDF, 31.8 MB) *NEW!*
- ASH Project Final Report Appendices, (ZIP, 44.1 MB)

ASH Meeting Minutes

- 07-10-17 Meeting (PDF, 695 KB)
- 06-07-17 Meeting (PDF, 687 KB)
- 04-11-17 Meeting (PDF, 679 KB)
- 03-07-17 Meeting (PDF, 683 KB)
- 02-07-17 Meeting (PDF, 692 KB)
- 01-05-17 Meeting (PDF, 661 KB)
- 12-07-16 Meeting (PDF, 658 KB)
- 11-09-16 Meeting (PDF, 652 KB)
- 10-05-16 Meeting (PDF, 703 KB)
- 09-08-16 Meeting (PDF, 562 KB)

ASH Quarterly Reports

- May 2017, Appalachian Storage Hub (ASH) Quarterly Report with Appendices (PDF, 27.0 MB)
- May 2017, Appalachian Storage Hub (ASH) Quarterly Report (PDF, 7.31 MB)
- Feb 2017, Appalachian Storage Hub (ASH) Quarterly Report (PDF)
- Oct 2016, Appalachian Storage Hub (ASH) Quarterly Report (PDF)

Presentations: 8/16/2016 Kickoff Meeting

- Carter, Kris - PAPG, Reservoir Characterization Studies:
  Powerpoint (4.15 MB) - or - PDF (8.98 KB)
- Moore, Jessica - WVGES:
  Powerpoint (8.54 MB) - or - PDF (8.54 MB)
- Patchen, Doug:
  Powerpoint (488 KB) - or - PDF (176 KB)
- Solis, Michael; Fakhari, Mohammad - ODNR:
  Powerpoint (13.4 MB) - or - PDF (2.14 MB)

Presentations: 3/14/17 Semi-Annual Meeting

- Carter, Kris - PAPG, Reservoir Characterization Studies:
  Powerpoint (9.91 MB) - or - PDF (3.35 MB)
- Metz, Kyle - ODNR, Stratigraphic Correlation:
  Powerpoint (17.1 MB) - or - PDF (5.01 MB)
- Moore, Jessica - WVGES, Data Collection:
  Powerpoint (15.7 MB) - or - PDF (6.03 MB)
- Moore, Jessica - WVGES, ASH History: The Role of Petroleum Geology and Salt Production on Manufacturing and Development in the Appalachian Basin:
  Powerpoint (13.6 MB) - or - PDF (4.61 MB)
  This presentation is featured on the Main Page of this website

  Also, "I.C. White History of Petroleum Industry" DOCX (842 KB)
- Patchen, Doug:
  Powerpoint (490 KB) - or - PDF (444 KB)

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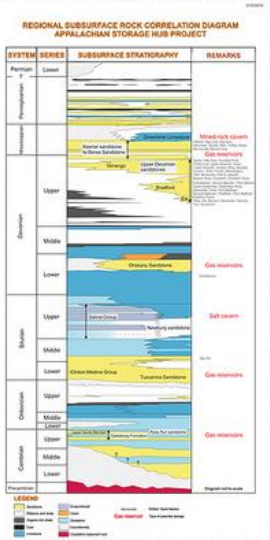
STRATIGRAPHIC INTERVALS

AOI Stratigraphic Chart and Three Prospects

Click on image to view larger.

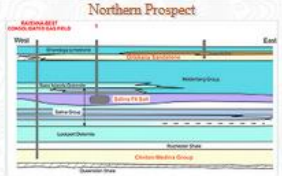
AOI Stratigraphic Chart



Final Strat Diagram (PDF, 437 KB)

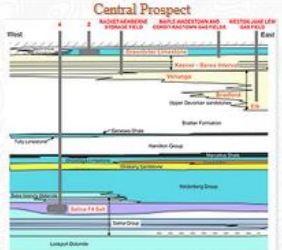
AOI Three Prospects

Northern Prospect



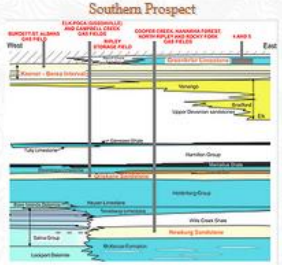
Northern Prospect Cartoon (JPEG, 2.11 MB)

Central Prospect



Central Prospect Cartoon (JPEG, 2.71 MB)

Southern Prospect



Southern Prospect Cartoon (JPEG, 3.00 MB)

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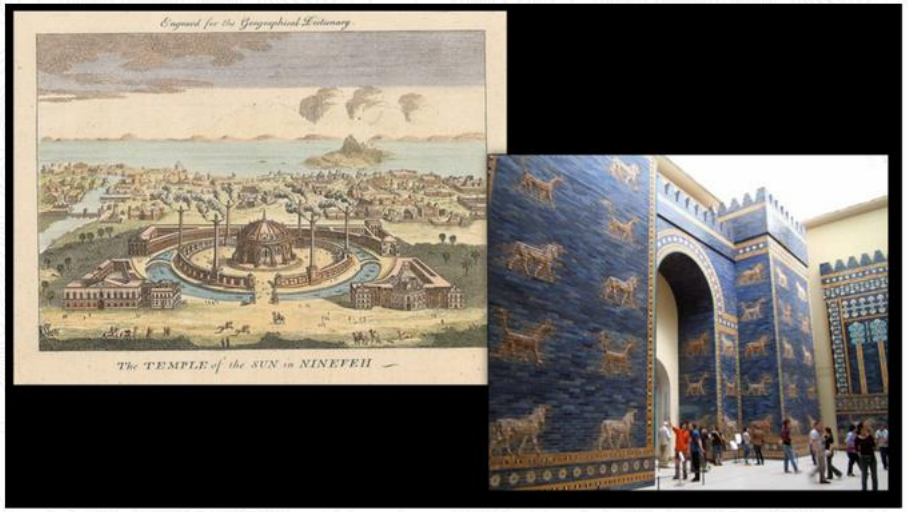

"The date of the first use of petroleum or its residual products, pitch and asphaltum, precedes authentic history. Probably the first recorded utilization is that of the eleventh chapter of Genesis in which it is stated that the soft or semi-fluid bitumen found in the valley of the Euphrates and translated "slime", was used as a mortar in the building of Babylon, more than forty centuries ago. Erastosthenes, a celebrated Grecian writer who lived in the third century B.C., has described this bitumen from the Springs of Hit, on the Euphrates, and has also told of its use in the construction of mosaics, pavements, etc., in the beautiful palaces and temples of ancient Nineveh and Babylon."

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https://en.wikipedia.org/wiki/Ishtar_Gate

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Excel

File Category	Code
Biostratigraphy	BIOSTRAT
Bitumen Reflectance Report	BRR
CT Image	CTIMG
CT Scan Data	CTDAT
CT Zipped Images(CTIMGZ)	CTIMGZ
Core Analysis	CRAN
Core Analysis Crossplot	CRANXPLT
Core Description	CRDS
Core Photos	CRPH
Core Photos Zipped	CRPHZ
Cross Section	XSEC
Crushed Stone Properties (CSP)	CSP
Digitized Logs	DLOG
Federal Energy Regulatory Commison Documents	FERC
Fluid Inclusion Report	FIR
General Mineralogy (MNRLGY)	MNRLGY
Geo Chem	GEOCHEM
High Pressure Mercury Injection Porosity (MICP)	MICP
Isotopes	ISO
Log Tops	LOGT
Map	MAP
Microscopic Organic Analysis (MOA)	MOA
Non-Well Document	NWDOC
Other Well Documents	OTHR
Permeability	PERM
Porosity	PORO
Production Data	PROD
Project Presentation	PRST
Publication	PUB
Ro Histograms	ROHIST
Rock Mechanics	RKMECH
Routine Core Analysis (grain size) (RCA)	RCA
SEM Zipped Images (SEMZ)	SEMZ
Sample Descriptions	SMDS
Scanned Logs	ELOG
Scanning Electron Microscope (SEM)	SEM
Source Rock Analyses (SRA)	SRA
Thin Section Description	TSDESC
Thin Section Image	TSIMG
Thin Section Zipped Images	TSIMGZ
Tight Rock Analysis (TRA)	TRA
Total Organic Carbon (TOC)	TOC
X-Ray Defraction (XRD)	XRD
X-Ray Fluorescence (XRF)	XRF

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County:
Well API #:
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File Name (click to open or save)		API#	State	County	File Category	FileType	ModDate	Size
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4705100645_CRDS_FmSLNA_Salina_Core_Description.docx	☐	4705100645	West Virginia	Marshall (WV)	Core Data (Various)	DOCX	05/18/2017	15 KB
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DATA SEARCH

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- County
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Select files of interest

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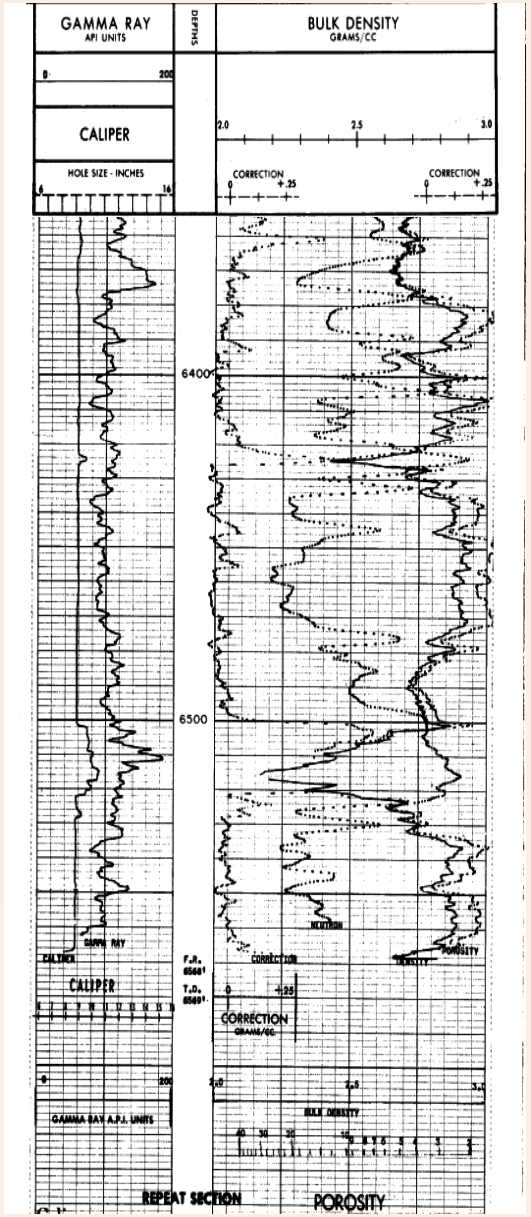
Well Logs



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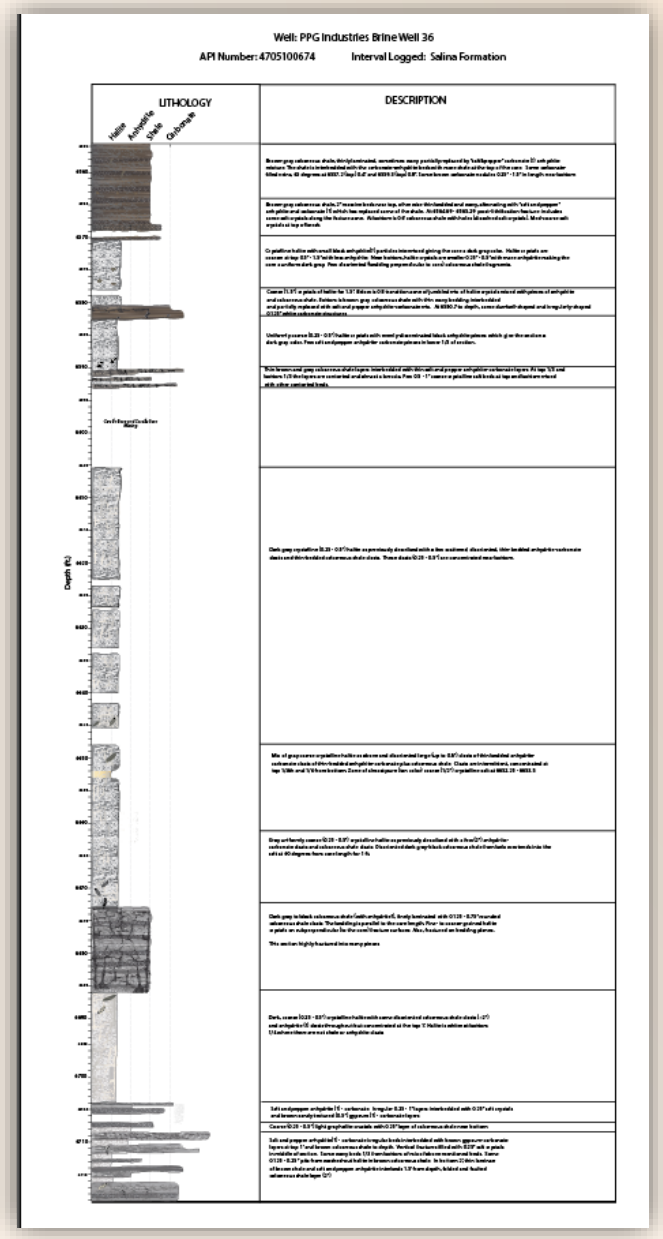

Core Photos

BIBLIOGRAPHY

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

[Document Link: http://pages.geo.wvu.edu/~kammer/reprints/Matchen&Kammer1994.pdf (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 providing 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 (Purchase)]

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 "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 was high as it represented a commercial economic resource. Today, these same salt beds present the opportunity for geologic sequestration. 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 Silurian Albion ("Clinton" Sand) Sandstone for the Gribble well in Harrison County. Two simplified cross-sections of the salt position were created: the first, between 4 wells spanning Washington County, Ohio and the Gribble Well in Harrison County, West Virginia; and the second, spanning 5 wells between Wayne County, Ohio and Harrison County, West Virginia. While these cross-sections lack much detail, they show approximate stratigraphic 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 the 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]

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

In 1968, the Pennsylvania Bureau of Topographic and Geological Survey produced a Bulletin describing the thickness and geography of the Salina Group across Pennsylvania. While at the time, the Group 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 in an effort to draw a

SELECTED LINKS

Geological Resources ♦ Government Agencies ♦ Research Information ♦ Geospatial Resources and Services ♦ News

Geological Resources:

- **Appalachian Basin Tight Gas Reservoirs** — http://www.wvgs.wvnet.edu/atg/SystemOverview.aspx; Provides a collection of tools/applications giving the user the ability to search and gather information about gas and oil wells in WV and PA, organized by six plays: Berea/Murrysville, Venango, Bradford, Elk, Medina/"Clinton", and Tuscarora.
- **Trenton-Black River Reservoirs** — http://www.wvgs.wvnet.edu/www/tbr/; Provides a collection of data, reports, and maps designed to assess the model of the Trenton-Black River reservoirs of NY, Ohio, and NY; define fairways; and develop an integrated model of the origin of the hydrothermal dolomite reservoirs.
- **A Geological Play Book for Utica Shale Appalachian Basin Exploration** — http://www.wvgs.wvnet.edu/utica/playbook/index.aspx; Contains a comprehensive geological resources on the potential for the Utica play in the region, including data, maps, cross-sections, inorganic and source rock geochemistry, core studies, reservoir porosity, and resource assessment.
- **Midwest Regional Carbon Sequestration Partnership (MRCSP)** — http://www.mrcsp.org/; The Midwestern Regional Carbon Sequestration Partnership (MRCSP) has been established to assess the technical potential, economic viability, and public acceptability of carbon sequestration within its region. A group of leading universities, state geological surveys, nongovernmental organizations and private companies from ten contiguous states, led by Battelle, has been assembled to carry out this important research.
- **Regional Partnership to Secure Energy for America (RPSEA) Brine Disposal Framework Study** — http://www.rpsea.org/projects/11122-73/ Developed a geologic and operational framework for brine disposal in the Northern Appalachian Basin so that the produced fluids from unconventional onshore resource exploitation can be disposed safety and economically. This project addresses a crucial need of unconventional oil and gas production by assessing the geologic and reservoir management aspects, conducting source-sink analysis to predict the future capacity for brine disposal in the region, and providing guidance for operators, gas producers, regulators, and public stakeholders.

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Government Agencies:

State Agencies

- **ODNR Division of Geological Survey** — http://geosurvey.ohiodnr.gov/; Provides information, data, and maps about the geology of Ohio.
- **Pennsylvania Bureau of Topographic and Geological Survey** — http://www.dcnr.state.pa.us/topogeo/index.aspx; Provides a compendium of information, data, and maps about the geology of Pennsylvania.
- **West Virginia Geological and Economic Survey** — http://www.wvgs.wvnet.edu/; Makes available geoscience maps and data including topics such as energy, environmental geology, geologic mapping on the geology of West Virginia.

Selected Links, continued…

Federal Agencies

- **U.S. Department of Energy (DOE)** — https://www.energy.gov/
- **U.S. Department of Energy – National Energy Technology Laboratory (DOE NETL)** — http://www.netl.doe.gov/; A national laboratory which studies technology solutions to enhance the nation's energy foundation; studies fossil-energy science and engineering resources.
- **U.S. Energy Information Administration (EIA)** — https://www.eia.gov/; Collects, analyzes, and disseminates energy information for policymaking and public understanding of energy and its interaction with the economy and the environment; includes an electric system operating tool for the country and an energy mapping system.
- **U.S. Geological Survey (USGS)** — https://www.usgs.gov/

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Research Information:

- **U.S. Ethane/Ethylene Stocks by Type – EIA** — https://www.eia.gov/dnav/pet/PET_STOC_TYP_C_NUS_EPLLE_MBBL_M.htm; Addresses current issues and trends in petroleum liquids, including data, analysis, and projections.
- **International Energy Agency Monthly Gas Statistics** — http://www.iea.org/media/statistics/surveys/gas/Natgas.pdf; Monthly summary of gross production, import, and export data for countries participating in the international Organization for Economic Co-operation and Development (OECD) program

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Geospatial Resources and Services:

- **Pennsylvania Spatial Data Access** — http://www.pasda.psu.edu/; A clearinghouse for access to geospatial data for Pennsylvania, including imagery, LIDAR, boundaries, energy, and more.
- **GEOhio Spatial Data Discovery Portal** — http://ogrip-geohio.opendata.arcgis.com/; Provides access to Ohio's spatial data infrastructure and services.
- **West Virginia State GIS Technical Center** — http://wvgis.wvu.edu/; A clearinghouse for statewide GIS services to advance the state's spatial data infrastructure.
- **Map West Virginia** — http://www.mapwv.gov/; A public gateway to mapping resources in WV; enables users to download maps and GIS mapping services.

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News:

- **Bloomberg: Appalachian States Look Past Coal, Ask Trump to Aid Natural Gas** — (July 25, 2017) https://www.bloomberg.com/news/articles/2017-07-25/appalachian-states-look-past-coal-ask-trump-to-aid-natural-gas
- **Charleston Gazette-Mail: Kevin DiGregorio: WV Shale Boom a Marathon, Not a Sprint** — (July 19, 2017) http://www.wvgazettemail.com/daily-mail-commentary/20170719/kevin-digregorio-wv-shale-boom-a-marathon-not-a-sprint-daily-mail
- **Bloomberg Bureau of National Affairs: Manchin Aims to Tack Appalachian Ethane Hub on Energy Bill** — (July 13, 2017) https://www.bna.com/manchin-aims-tack-n73014461714/
- **CNBC: Appalachia Joins the Race for the Multibillion-Dollar Petrochemicals Boom** — (July 11, 2017) http://www.cnbc.com/2017/07/11/appalachia-joins-the-race-for-the-petrochemicals-boom.html
- **WV Metro News: Capito Says Private Sector Starting to Get Interested in Storage Hub Proposal** — (July 7, 2017) http://wvmetronews.com/2017/07/07/capito-says-private-sector-starting-to-get-interested-in-storage-hub-proposal/
- **Storage hub carries big concept, price, but enormous economic potential** — http://www.observer-reporter.com/20170520/storage_hub_carries_big_concept_price_but_enormous_economic_potential&template=amp; background information about a conference on the proposed Appalachian Storage Hub, in the Pittsburgh area in June 2017.
- **Benedum Foundation funds the future through training initiatives** — https://www.post-gazette.com/in-the-lead/itl-2017-companies/2017/05/02/Claude-Worthington-Benedum-Foundation-grants-education-training-programs-energy-jobs-in-the-lead/stories/201705260019
- **WV, OH, PA, KY Should Cooperate on $10B NGL Storage Hub** — http://marcellusdrilling.com/2016/07/wv-oh-pa-ky-should-cooperate-on-10b-ngl-storage-hub/
- **Appalachian Storage Hub: Big Plan, Big Price Tag** — http://www.ongmarketplace.com/appalachian-storage-hub-big-plan-big-price-tag/

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MAPS

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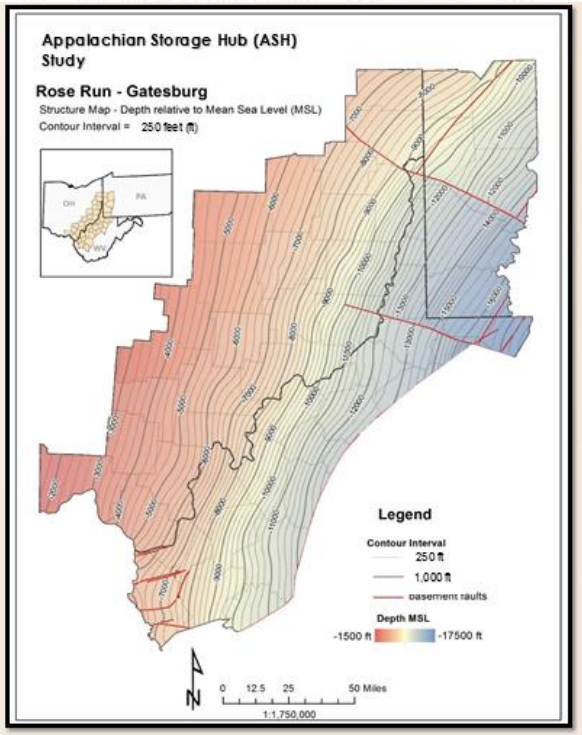
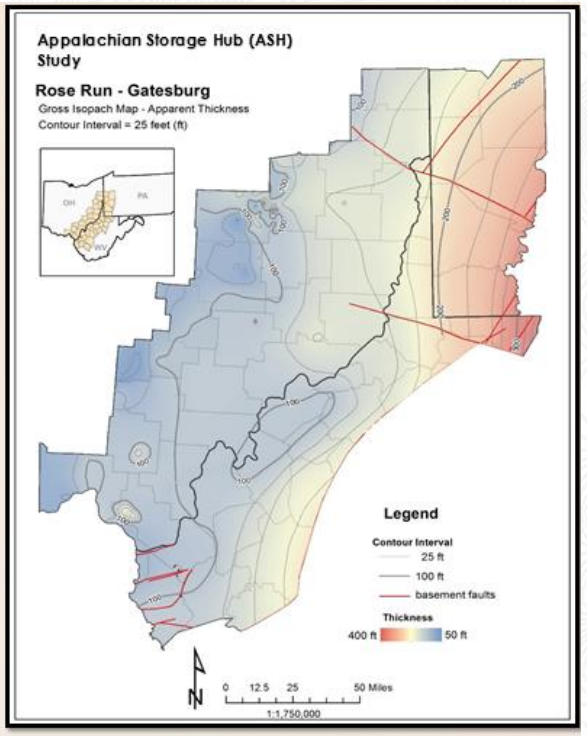
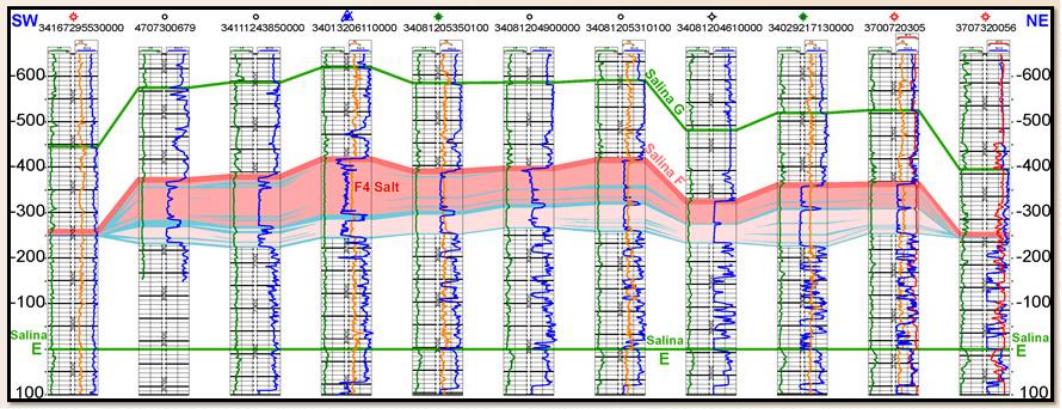




Regional Maps



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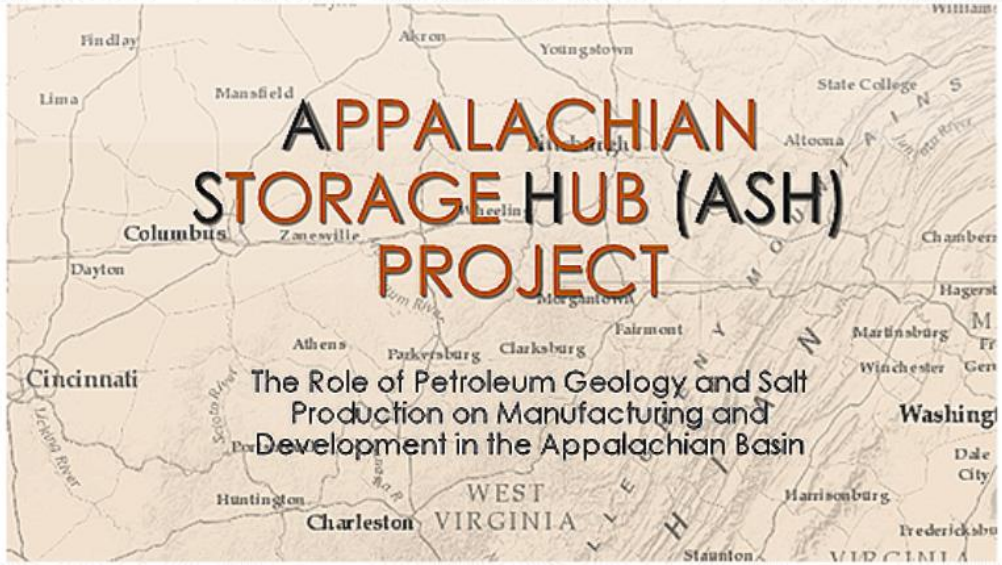

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