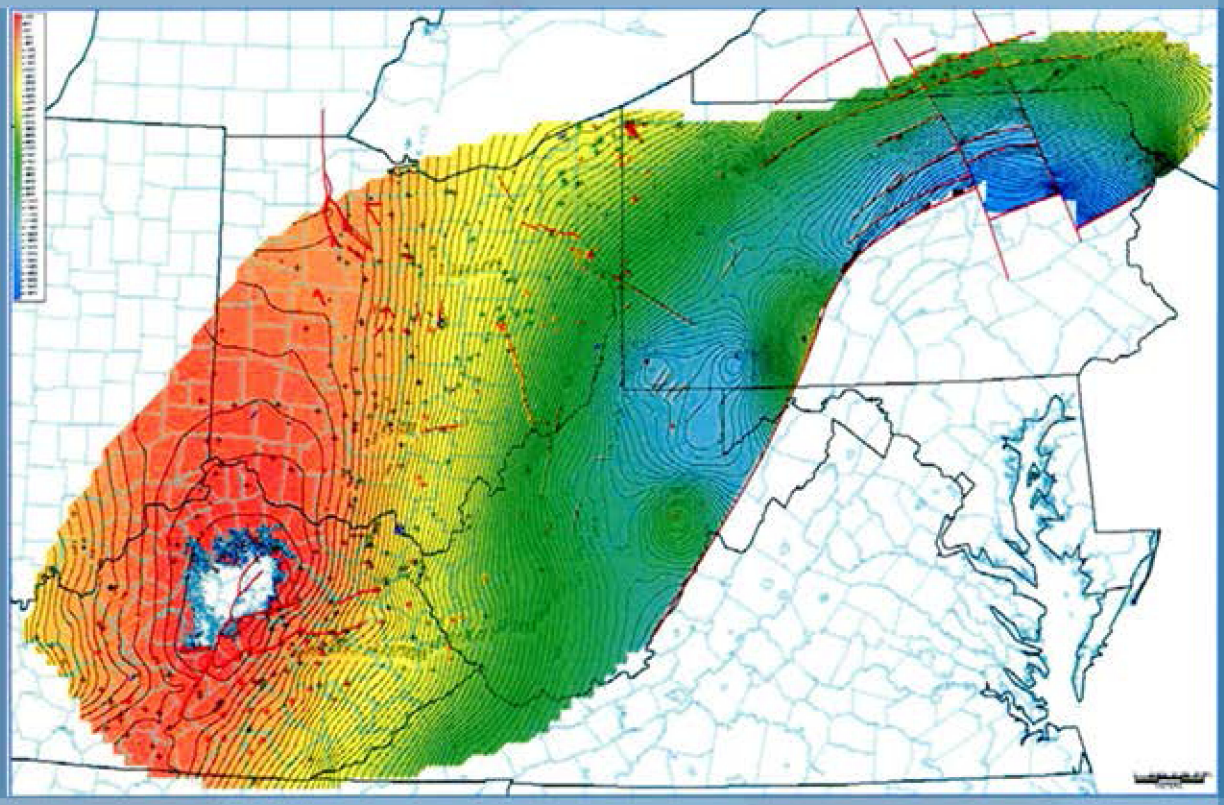
A Geologic Play Book for Utica Shale Appalachian Basin Exploration



FINAL REPORT
April 1, 2012
July 1, 2015

(Sections)

11.0 REFERENCES CITED

Utica Shale Appalachian Basin Exploration Consortium
Coordinated by the Appalachian Oil & Natural Gas Consortium at West Virginia University

original gas-in-place is approximately 3192.4 Tcf. Based on the results of both assessment methods, it is expected that given current technology the play-wide oil recovery factor will be approximately 3% and the gas recovery factor will be approximately 28% in the "sweet spot" areas (Figure 9-8).

11.0 REFERENCES CITED

Note: Links are considered live as of access date; some links may become disabled after time

Advanced Resources International, Inc., 2008, Optimal Development of Utica Shale Wells: Arlington, Virginia, 29 p.

Advanced Resources International, Inc., 2012, Coal and Shale Property Database: Arlington, Virginia, Report Number DE-FE0001560-6, Task 6.7 (DE-FE0001560), 18 p.

Antero Resources, 2013, Antero press release: [http://investors.anteroresources.com/files/doc_news/2013/Antero-Resources-Reports-Second-Quarter-2013-Financial-Results_v001_i03b3o.pdf], 16 p., accessed April 30, 2014.

Boggs, Sam, Jr., 2006, Principals of sedimentology and stratigraphy (4th ed.): Upper Saddle River, New Jersey, Pearson Prentice Hall - Pearson Education, Inc., 662 p.

Bohacs, K.M., 1998, Contrasting expressions of depositional sequences in mudrocks from marine to non marine environs, *in* J. Schieber, W. Zimmerle, and P. Sethi, eds., Shales and mudstones, Vol. 1 – Basin studies, sedimentology, and paleontology: Stuttgart, E. Schweizerbart'sche Verlagsbuchhandlung, p. 33-78.

Camp, W.K., Diaz, Elizabeth, and Barry Wawak, eds., 2013, Electron Microscopy of Shale Hydrocarbon Reservoirs, Memoir 102: Tulsa, Oklahoma, American Association of Petroleum Geologists, 260 p.

Charpentier, R.R., and T.A. Cook, 2010, Improved USGS methodology for assessing continuous petroleum resources, version 2: U.S. Geological Survey Data Series 547, 22 p. and program.

Chesapeake presentation, 2013, Investor presentation: [http://www.chk.com/investors/documents/Latest_IR_Presentation.pdf], 23 p., accessed May 7, 2014.

Clendening, J.A., and M.W. McCown, 1999, Swan Creek field: Potential giant develops in Tennessee: Oil & Gas Journal, April 19, 1999, p. 95-99.

Cluff, Robert, and Michael Holmes, 2013, Petrophysics of unconventional resources [course handbook]: PTTC Technology Connections, Rocky Mountain Region [workshop], Colorado School of Mines, January 31-February 1, 2013.

Cooney, M.L., 2013, The Utica Shale in Pennsylvania: A characterization of the Reedsville, Antes, Utica and Point Pleasant formations: Undergraduate Thesis, Allegheny College, Meadville, PA, 64 p.

Crain, E.R., 2013a, Special cases – Gas Shales, *in* Crain's Petrophysical Handbook: http://www.spec2000.net/17-specshgas.htm, accessed October 14, 2013.

Crain, E.R., 2013b, Shale volume from neutron density crossplot model, *in* Crain's Petrophysical Handbook: http://www.spec2000.net/11-vshnd.htm, accessed November 17, 2013.

Crain, E.R., 2013c, Water saturation from Simandoux method, *in* Crain's Petrophysical Handbook: http://www.spec2000.net/14-sws.htm, accessed November 17, 2013.

Dow, W.G., 1977, Kerogen studies and geologic interpretations: Journal of Geochemical Exploration, v. 7, p.79-99.

Finnegan, Seth, Bergmann, Kristin, Eiler, J.M., Jones, D.S., Fike, D.A., Eisenman, Ian, Hughes, N.C., Tripati, A.K., and W.W. Fischer, 2011, The magnitude and duration of Late Ordovician–Early Silurian glaciation: Science, v. 331, p. 903-906.

Gulfport Energy Corporation, 2013, Investor presentation: [http://files.shareholder.com/downloads/GPOR/2162620688x0x661649/42586D2E-22EB-43C7-B961-5034A1D28470/GPOR_InvestorPres_GPOR_InvestorPres_3Q2013.pdf], 51 p., accessed November 1, 2013.

Gulfport Energy Corporation, 2014, Investor presentation: [http://files.shareholder.com/downloads/GPOR/2162620688x0x661649/42586D2E-22EB-43C7-B961-5034A1D28470/GPOR_InvestorPres_GPOR_InvestorPres_4Q2013.pdf], 43 p., accessed April 30, 2014.

Harris, A.G., 1979, Conodont color alteration, an organo-mineral metamorphic index, and its application to Appalachian Basin geology, *in* Scholle, P.A., and P.R. Schluger, eds., Aspects of diagenesis: Society of Paleontologists and Mineralogists Special Publication 26, p. 3-16.

Herron, S.L., 1991, In situ evaluation of potential source rocks by wireline logs, *in* R.K. Merrill, ed., Treatise of petroleum geology: Handbook of petroleum geology, source and migration processes and evaluation techniques, American Association of Petroleum Geologists, p.127-134.

Hess Corporation, 2014, Howard Weil 42nd Annual Energy Conference presentation, March 24, 2014: [http://phx.corporate-ir.net/phoenix.zhtml?c=101801&p=irol-presentations], 25 p., accessed April 30, 2014.

Holmes, Michael, 2013, A petrophysical model to analyze unconventional shale gas and shale oil reservoirs: Petrophysics of unconventional reservoirs [workshop], February 1, 2013.

Jacob, H., 1976, Petrologie, Nomenklatur, und Genesis naturlicher fester Erdolbitumina: Comp. Ergazungsband Erdol u. Kohle 76, p. 36-49.

Jacob, H., 1989, Classification, structure, genesis, and practical importance of natural solid bitumen ("migrabitumen"): International Journal of Coal Geology, v.11(1), p.65-79.

Jacob, H., 1993, Nomenclature, classification, characterization, and genesis of natural solid bitumen ("migrabitumen"), *in* J. Parnell, H. Kucha, P. Landais, eds., Bitumens in ore deposits: Special Publication No. 9 of the Society for Geology Applied Mineral Deposits: Springer-Verlag, p. 11-27.

Jarvie, D.M., 1991, Chapter 11: Total organic carbon (TOC) analysis: Geochemical methods and exploration, source and migration processes and evaluation techniques: American Association of Petroleum Geologists, p. 113-118.

Jarvie, D.M., Claxton, B.L., Henk, F., and J.T. Breyer, 2001, Oil and shale gas from the Barnett Shale, Fort Worth basin, Texas: AAPG Annual Meeting, Program and Abstracts, p. A100.

Karacan, C. Özgen, 2003, Heterogeneous sorption and swelling in a confined and stressed coal during CO_2 injection: Energy & Fuels, v. 17, no. 6, p. 1595-1608.

Kirschbaum, M.A., Schenk, C.J., Cook, T.A., Ryder, R.T., Charpentier, R.R., Klett, T.R., Gaswirth, S.B., Tennyson, M.E., and K.J. Whidden, 2012 (rev. November 2012), Assessment of undiscovered oil and gas resources of the Ordovician Utica Shale of the Appalachian Basin Province, 2012: U.S. Geological Survey Fact Sheet 2012–3116, 6 p.

Kolata, D.R., Huff, W.D., and Bergström, S.M., 2001, The Ordovician Sebree trough: an oceanic passage to the Midcontinent United States: Geological Society of America Bulletin, v. 113, no. 8, p. 1067-1078.

Kump, L.R., and M.A. Arthur, 1999, Interpreting carbon-isotope excursions: carbonates and organic matter: Chemical Geology, v. 161, p. 181-198.

Landis, C.R., and J.R. Castaño, 1994, Maturation and bulk chemical properties of a suite of solid hydrocarbons: Organic Geochemistry, v. 22, p. 137-149.

Luft, S.J., 1972, Geologic map of the Butler quadrangle, Pendleton and Campbell counties, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ-982, scale 1: 24,000.

Lunig, Sebastian, and S. Kolonic, 2003, Uranium spectral gamma-ray response as a proxy for organic richness in black shales – Applications and limitations: Journal of Petroleum Geology, v. 26, no. 2, p. 153-174.

MacQuaker, J.H.S., Keller, M.A., and S.J. Davies, 2010, Algal blooms and "marine snow": mechanisms that enhance preservation of organic carbon in ancient fine-grained sediments: Journal of Sedimentary Research, v.80, p.934-942.

MacQuown, W.C., 1967, Factors controlling porosity and permeability in the Curdsville Member of the Lexington Limestone: Lexington, Kentucky, Water Resources Institute, University of Kentucky, Research Report No. 7.

Magnum Hunter Resources Corporation, 2014, IPAA Oil & Gas Investment Symposium New York presentation, April 2014: [http://magnumhunterresources.com/Magnum-Hunter-Resources.pdf], 56 p., accessed April 30, 2014.

McDowell, R.C., ed., 1986, The Geology of Kentucky-A text to accompany the geologic map of Kentucky: Washington, U.S. Geological Survey Professional Paper 1151-H, 76 p.

Metzger, J.G., and D.A. Fike, 2013, Techniques for assessing spatial heterogeneity of carbonate $\delta^{13}C$ values: Implications for craton-wide isotope gradients: Sedimentology, v. 60, p.1405-1431.

Metzger, J.G., Fike, D.A., and L.B. Smith, in press, Applying C-isotope stratigraphy using well cuttings for high-resolution chemostratigraphic correlation of the subsurface, *in* L.B. Smith, ed., AAPG Bulletin Special Volume in Honor of Fred Read.

Meyer, B.L., and M.H. Nederlof, 1984, Identification of source rocks on wireline logs by density/resistivity and sonic transit time/resistivity crossplots: AAPG Bulletin, v. 68, no. 2, p. 121-129.

Ohio Department of Natural Resources, Division of Geologic Survey, 2013, Calculated % Ro average per well of the Upper Ordovician shale interval in Ohio (includes "Utica", "Point Pleasant", "Lexington", and "Logana": [www.ohiodnr.com/portals/geosurvey/energy/utica/ordov-shale_Ro_average_03-2013], 1 plate, accessed July 2, 2014.

Passey, Q.R., Creaney, S., Kulla, J.B., Moretti, F.J., and J.D. Stroud, 1990, A practical model for organic richness from porosity and resistivity logs: AAPG Bulletin, v. 74, no. 12, p. 1777-1794.

Patchen, D.G., and others, 2006, A geologic play book for Trenton-Black River Appalachian basin exploration: U.S. Department of Energy, Final Report, Contract No. DE-FC26-03NT41856, 582 p.

PDC Energy, 2014, Analyst Day presentation, New York, April 17, 2014: [http://files.shareholder.com/downloads/PETD/2762178579x0x744853/11BE17C5-86D9-4D38-8FB2-4CBE738DFC3D/2014_04_17_Analyst_Day_-_Final6.pdf], 96 p., accessed April 30, 2014.

Peters, K.E., 1986, Guidelines for evaluating petroleum source rock using programmed pyrolysis: AAPG Bulletin, v. 70, no. 3, p. 318-329.

Repetski, J.E., Ryder, R.T., Weary, D.J., Harris, A.G., and M.H. Trippi, 2008, Thermal maturity patterns (CAI and %Ro) in Upper Ordovician and Devonian rocks of the Appalachian basin: A major revision of USGS Map I–917–E using new subsurface collections: U.S. Geological Survey Scientific Investigations Map 3006, one CD-ROM.

Rex Energy, 2014, Corporate presentation: [http://files.shareholder.com/downloads/REXX/3079288293x0x744435/57e634ab-6cd7-41d1-a508-577cf54d8cab/Rex%20Energy%20Corporate%20Presentation%20-%20April%202014.pdf], 54 p., accessed April 30, 2014.

Riediger, C.L., 1993, Solid bitumen reflectance and Rock-Eval Tmax as maturation indices: an example from the "Nordegg member", western Canada sedimentary basin: International Journal of Coal Geology, v. 22, p. 295-315.

Riley, R.A., Erenpreiss, M.S., and J.G. Wells, 2011, Data compilation and source rock mapping of the Upper Ordovician black shale interval in Ohio: Ohio Department of Natural Resources, Division of Geological Survey, final report for the U.S. Geological Survey, U.S Geological Survey Cooperative Agreement No. 0020003512, 17 p.

Rodriguez, R., Crandall, D., Song, X., Verba, C., and D.J. Soeder, in press, Imaging techniques for analyzing shale pores and minerals; NETL-TRS-XX-2014; Technical Report Series; U.S. Department of Energy, National Energy Technology Laboratory: Morgantown, WV.

Ruppert, L.F., Hower, J.C., Ryder, R.T., Levine, J.R., Trippi, M.H., and W.C. Grady, 2010, Geologic controls on thermal maturity patterns in Pennsylvanian coal-bearing rocks in the Appalachian basin: International Journal of Coal Geology, v. 81, p. 69-181.

Schieber, Juergen, Southard, J.B., and K. Thaisen, 2007, Accretion of mudstone beds from migrating floccule ripples, Science, v.318, p. 1760-1763.

Schlumberger, 1997, Logging tool response in sedimentary minerals, Appendix B *in* Log interpretation charts: Houston, Texas, Schlumberger Wireline and Testing, p. B5-B6.

Schmoker, J.W., 1993, Use of formation-density logs to determine organic-carbon content in Devonian shales of the western Appalachian basin and an additional example based on the Bakken Formation of the Williston basin, *in* Roen, J.B., and R.C. Kepferle, eds., Petroleum geology of the Devonian and Mississippian black shale of eastern North America: U.S. Geological Survey Bulletin 1909, p. J1-J14.

Schoenherr, J., Littke, R., Urai, J.L., Kukla, P.A., and Z. Rawahi, 2007, Polyphase thermal evolution in the Infra-Cambrian Ara Group (South Oman salt basin) as deduced by maturity of solid reservoir bitumen: Organic Geochemistry, v. 38, p. 1293-1318.

Schumacher, G.A., Mott, B.E., and M.P. Angle, 2013, Ohio's geology in core and outcrop – A field guide for citizens and environmental and geotechnical investigators: Ohio Department of Natural Resources, Division of Geological Survey Information Circular 63, p. 182-186.

Senftle, J.T., Brown, J.H., and S.R. Larter, 1987, Refinement of organic petrographic methods for kerogen characterization: International Journal of Coal Geology, v. 7, p. 105-117.

Smith, L.B., 2013, Shallow transgressive onlap model for Ordovician and Devonian organic-rich shales, New York State: Unconventional Resources Technology Conference, Denver, CO, Unconventional Resources Technology Conference (URTEC).

Soeder, D.J., 1988, Porosity and permeability of eastern Devonian gas shale: SPE Formation Evaluation, DOI 10.2118/15213-PA, v. 3, no. 1, p. 116-124.

Swanson, V.E., 1960, Oil yield and uranium content of black shales: U.S. Geological Survey Professional Paper 356-A, 44 p.

Ting, F.T.C., 1978, Petrographic techniques in coal analysis, *in* C. Karr, Jr., ed., Analytical Methods for Coal and Coal Products: New York, Academic Press, v.1, p. 3-26.

Wickstrom, L.H., Erenpreiss, M.S., Riley, R.A., Perry, Christopher, and Dean Martin, 2012, Geology and Activity Update of the Ohio Utica-Point Pleasant Play, presentation by Ohio Department of Natural Resources, Division of Geological Survey at Ohio Oil & Gas Association Meeting, March 16, 2012.

Young, S. A., Saltzman, M.R., and S.M. Bergström, 2005, Upper Ordovician (Mohawkian) carbon isotope (δ13C) stratigraphy in eastern and central North America: Regional expression of a perturbation of the global carbon cycle: Palaeogeography, Palaeoclimatology, Palaeoecology, v. 222, p. 53-76.

Utica Shale Play Book

The AONGRC's Utica Shale Appalachian Basin Exploration Consortium includes the following members:

Research Team:
WVU National Research Center for Coal and Energy, Washington University, Kentucky Geological Survey, Ohio Geological Survey, Pennsylvania Geological Survey, West Virginia Geological and Economic Survey, U.S. Geological Survey, Smith Stratigraphic, and U.S. DOE National Energy Technology Laboratory.

Sponsorship:
Anadarko, Chevron, CNX, ConocoPhillips, Devon, EnerVest, EOG Resources, EQT, Hess, NETL Strategic Center for Natural Gas and Oil, Range Resources, Seneca Resources, Shell, Southwestern Energy, and Tracker Resources.

Coordinated by:
Appalachian Oil & Natural Gas Research Consortium at West Virginia University

Utica Shale Play Book

The AONGRC's Utica Shale Appalachian Basin Exploration Consortium includes the following members:

Research Team:
WVU National Research Center for Coal and Energy, Washington University, Kentucky Geological Survey, Ohio Geological Survey, Pennsylvania Geological Survey, West Virginia Geological and Economic Survey, U.S. Geological Survey, Smith Stratigraphic, and U.S. DOE National Energy Technology Laboratory.

Sponsorship:
Anadarko, Chevron, CNX, ConocoPhillips, Devon, EnerVest, EOG Resources, EQT, Hess, NETL Strategic Center for Natural Gas and Oil, Range Resources, Seneca Resources, Shell, Southwestern Energy, and Tracker Resources.

Coordinated by:
Appalachian Oil & Natural Gas Research Consortium at West Virginia University