[PS]New Albany Shale Maps in the Illinois Basin*

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Abstract

The New Albany Shale (NAS) in the Illinois Basin is a Middle and Upper Devonian to Lower Mississippian unit correlative with the Antrim Shale of the Michigan Basin and the Ohio and Marcellus Shales of the Appalachian Basin. NAS is an organic-matter-rich formation that extends through Indiana, Illinois, and western Kentucky with a thickness from <6 to 140 m (<20 to 460 ft) and an elevation from 228 m near outcrops to −1370 m in the deepest, central part of the basin (750 ft to −4,500 ft). Depth ranges from 0 to 1,585 m (5,200 feet). The principal rock types are brownish-black shale that is rich in organic matter, greenish-gray shale, dolomite, and siltstone.

The Indiana, Kentucky, and Illinois State Geological Surveys have been collecting physical and chemical data and mapping the New Albany Shale for many years. We are in a process of developing an online New Albany Shale application as a part of the IGS Map. The application will be the most comprehensive digital compilation of geologic information about the New Albany Shale and its members. It allows users to interactively search, explore, and compare data. These data are important for regional evaluations and can be used by the public, industry, and state and federal governments. This presentation will highlight the newest maps of the NAS.

NEW ALBANY SHALE MAPS IN THE ILLINOIS BASIN

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INTRODUCTION

The New Albany Shale (NAS) in the Illinois Basin is a Middle and Upper Devonian to Lower Mississippian unit correlative with the Antrim Shale of the Michigan Basin and the Ohio and Marcellus Shales of the Appalachian Basin. These shale units are thought to be part of an epicontinental succession deposited in response to a sea-level rise over large areas of the North American craton (e.g., Johnson et al., 1985; de Witt et al., 1993).

NAS is an organic-matter-rich formation that extends through Indiana, Illinois, and western Kentucky with a thickness from <6 to 140 m (<20 to 460 ft) and an elevation from 228 m near outcrops to -1,370 m in the deepest, central part of the basin (750 ft to -4,500 ft). Depth ranges from 0 to 1,585 m (5,200 feet). The principal rock types are brownish-black shale that is rich in organic matter, greenish-gray shale, dolomite, and siltstone (Lineback, 1970).

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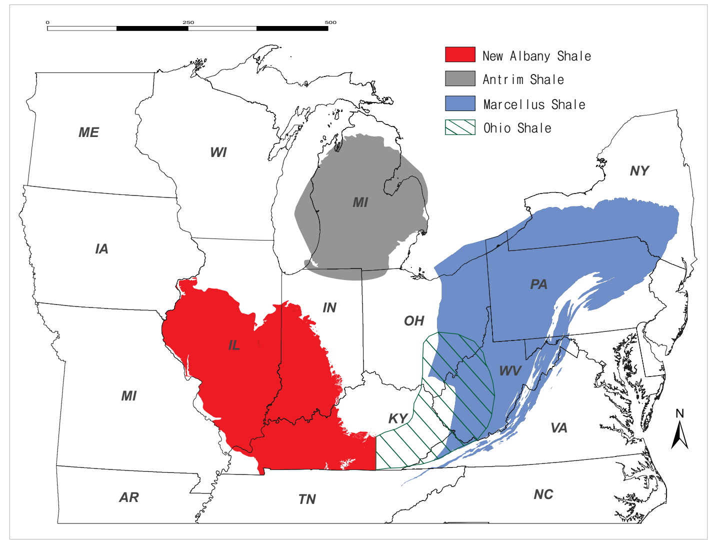
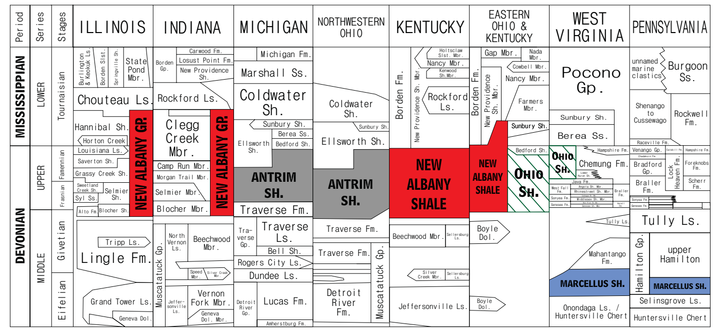



Regional stratigraphy the New Albany Shale, Antrim Shale, Ohio Shale and Marcellus Shale (modified from Shaver, 1985).

NEW ALBANY SHALE GAS AND OIL PRODUCTION

The presence of gas in the New Albany Shale sparked continued industrial interest since the Civil War. Gas production from the New Albany Shale commenced near Tobacco Landing in Harrison County, Indiana in 1884, whereas Kentucky started production of biogenic and mixed gas in 1885 (Sorgenfrei, 1952; Sullivan, 1995; Hamilton-Smith et al., 1994; Partin, 2004). Limited early production in Harrison County with time was expanded into other areas of Indiana. Initial production test rates (IPs) of wells typically ranged from 567 to 11,327 m^3/day (20 to 400 thousand cubic feet of gas per day, Mcf per day), although some wells in northern Daviess and in southern Sullivan Counties are believed to have produced more than 28,316 m^3/day (1 million cubic feet of gas per day, MMcf per day). Many of New Albany Shale wells of the last decade were drilled with horizontal boreholes. Gas-in-place estimates of the Illinois Basin New Albany Shale gas reserves vary from 86 to 160 Tcf (Hill and Nelson, 2000), out of which technically recoverable resources are estimated between 1.3 to 8.1 Tcf (mean 3.8 Tcf; Swezey et al., 2007).

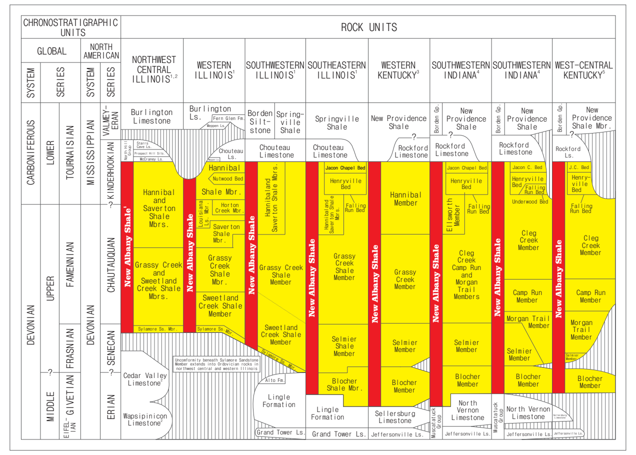
Even though it has been long known that most of the conventional oil found in the Illinois Basin was sourced from the NAS, little is known about the volumes and distribution of liquid hydrocarbons that currently exist within this formation. Commercial and academic interest in in-situ liquid hydrocarbons in the NAS arose only recently owing to the possibility of producing oil via horizontal drilling and hydraulic fracturing. The available data on organic matter (OM) maturity of the NAS indicate that significant areas in Illinois and some in Indiana and Kentucky lie within the oil window at suitable depths and have sealing units in place to preserve generated hydrocarbon liquids. Abundant OM of marine origin provides an excellent source for hydrocarbons. The presence of oil in the NAS is confirmed by oil shows and core analyses. Finally, recent production of oil in Kentucky clearly confirms the presence of in-situ liquids. Yet, the amounts of in-situ hydrocarbons are unknown, and former estimates of the near absence of oil in the NAS were based on a dearth of relevant data that hindered rigorous evaluation.

GEOLOGICAL CHARACTERISTICS OF THE NEW ALBANY SHALE

The New Albany Shale is underlain unconformably by Middle Devonian North Vernon Limestone and is lithostratigraphically subdivided into the following six member units in succession from the oldest to the youngest: the Blocher Member, the Selmier Member, the Morgan Trail Member, the Camp Run Member, the Clegg Creek Member, and the Ellsworth Member (e.g., Lineback, 1970). In most of Indiana New Albany Shale is overlain by the Rockford Limestone (0.6 to 6.7 m thick). Where the limestone is absent New Albany Shale is overlain unconformably by the New Providence Shale. Recent studies using sequence stratigraphic criteria (analysis of sedimentary structures, locations of flooding surfaces, identification of erosional events, etc.) suggest that the upper boundary of the New Albany Shale should be placed at the top of the Clegg Creek Member (Lazar and Schieber, 2004).

The interpretation of the sedimentary record originally suggested that the New Albany Shale was deposited in a marine, stratified, anoxic depositional environment (Cluff et al., 1981). Across the Frasnian-Famennian boundary, from the upper part of the Selmier Member to the lower part of the Morgan Trail Member, de la Rue et al. (2007) more recently suggested an abrupt change in water column redox conditions from oxic/dysoxic to anoxic, and possibly euxinic with free hydrogen sulfide. Additional detailed sedimentological and sequence stratigraphic scrutiny identified a range of facies from relatively shallow to deep water environment (Schieber, 2004).

Previous research and gas production practices in the NAS are briefly summarized as follows: (1) The origin of gas in the NAS ranges from biogenic to thermogenic. Most production originates from a shallow biogenic play in the eastern part of the Illinois Basin in Indiana. An attempt to access deeper, thermogenic gas in Indiana, Kentucky, and Illinois via horizontal drilling has yielded mixed results and identified challenges. (2) Methane content and gas adsorption capacity in the NAS are closely related to the amount and characteristics of OM in shale. Total organic carbon (TOC) is usually a good proxy for gas adsorption capacity and often for gas-in-place. (3) The presence of different natural fracture systems in the NAS complicates predictions of stimulated reservoir volumes (SRV). Interactions of natural fractures and hydraulically induced fractures may cause undesirable out-of-zone penetration. (4) Extremely low permeability in the NAS renders natural fractures and hydraulically-induced fractures as dominant pathways for gas migration and transport. (5) Low gas production and decline rates from wells in the NAS make it difficult to estimate long-term gas production and reserves.



Correlation of the New Albany Shale in the Illinois Basin (modified from Hasenmuller and others, 1994).

THERMAL HISTORY OF THE NEW ALBANY SHALE

The New Albany Shale spans a thermal maturity range corresponding to vitrinite reflectance (R_o) values between less than 0.5% closer to the basin margins to 1.5 % in the southern part of the basin in Illinois. Thermal maturity in some areas may be somewhat higher than indicated by R_o nvalues because of the suppression of vitrinite reflectance (Comer et al., 1994, Nuccio and Hatch, 1996, Akar, 2014). The heat-flow regime throughout the geological history of the Illinois basin follows the hybrid model of Rowan et al. (2002), in which Permian overburden and magmatic intrusions in the southern end of the basin play an important role.

The burial model generated for Pike County in Indiana (Strąpoć et al., 2010) indicates that the maximum temperatures of the New Albany Shale reached ~100°C in Pike County and ~90°C in Owen County and assured pasteurization or the killing of microbes within this formation and the underlying units. Erosional uplift caused cooling to present-day temperatures of 30 to 40°C. During the glacial and interglacial periods of the Pleistocene and during the Holocene ice loading, postglacial rebound and the supply of fresh water caused recharge into Illinois basin formations, including relatively shallow Pennsylvanian coals (Strąpoć et al., 2008). Infiltration of meteoric water in the most marginal parts of the basin entailed significant dilution of basinal brines normally present in the New Albany Shale (McIntosh et al., 2002, Person et al., 2015). Decreased temperatures and freshening of formation waters not only made the New Albany Shale habitable for microbial consortia, but may also have re-inoculated the formation with microbes. Such conditions stimulated microbial biodegradation of shale organic matter and generation of microbial methane.

REFERENCES:
- Akar, C., 2014. Maturity and hydrocarbon potential of the New Albany Shale and Maquoketa Shale in the Illinois Basin, USA. Unpublished MS thesis, Indiana University, 70p.
- Cluff, R.M., M.L. Reinbold, and J.A. Lineback, 1981, The New Albany Shale Group of Illinois: Illinois State Geological Survey Circular v. 518, 83 p.
- Comer, J.B., T. Hamilton-Smith, and W.T. Frankie, 1994, Source rock potential, in N.R. Hasenmueller and J.B. Comer, eds., Gas potential of the New Albany Shale (Devonian and Mississippian) in the Illinois Basin: Gas Research Institute GRI-92/0391, Illinois Basin Studies 2, p. 47–57.
- Hamilton-Smith, T., N.R. Hasenmueller, W.S. Boberg, Z. Smidchens, and W.T. Frankie, 1994, Gas production, in N.R. Hasenmueller, and J.B. Comer, eds., Gas Potential of the New Albany Shale (Devonian and Mississippian) in the Illinois Basin: Gas Research Institute, GRI-00/0068, Illinois basin Studies 2, p. 23–40.
- Hasenmueller, N.R., and J.B. Comer, eds., 1994, Gas potential of the New Albany Shale (Devonian and MIssissippian) in the Illinois Basin: Illinois Basin Consortium Illinois Basin Study 02, 83 p., 19 fig.
- Hill, D. G., and C.R. Nelson, 2000, Gas productive fractured shales - an overview and update: Gas Tips, Summer 2000, 6 p.
- Johnson, J.G., G. Klapper, and C.A. Sandberg, 1985, Devonian eustatic fluctuations in Euroamerica: Geological Society of America Bulletin, v. 96, p. 567–587.
- de la Rue, S.R., H.D. Rowe, and S.M. Rimmer, 2007, Palynological and bulk geochemical constrains on the paleoceanographic conditions across the Frasnian-Famennian boundary, New Albany Shale, Indiana: International Journal of Coal Geology, v. 71, p. 72–84.
- de Witt, W.J., J.B. Roen, and L.G. Wallace, 1993, Stratigraphy of Devonian black shales and associated rocks in the Appalachian Basin, in J.B. Roen, and R.C Kepferle, eds., Petroleum Geology of the Devonian and Mississippian black shale of eastern North America: United States Geological Survey Bulletin, v. 1909, B1-B57.
- Lazar, R., and J. Schieber, 2004, New Albany and Ohio Shales: An Introduction, in J. Schieber, and R. Lazar, eds., Devonian black shales of the Eastern U.S. New Insights into sedimentology and stratigraphy from the subsurface and outcrops in the Illinois and Appalachian basins: Field Guide for the 2004 Annual Field Conference of the Great Lake Section of SEPM, Indiana Geological Survey Open-File Study 04-05, p. 31–34.
- Lineback, J.A., 1970, Stratigraphy of the New Albany Shale in Indiana: Indiana Geological Survey Bulletin 44, 72 p.
- McIntosh, J.C., L. M. Walter, and A.M. Martini, 2002, Pleistocene recharge to midcontinent basins: effects on salinity structure and microbial gas generation: Geochimica et Cosmochimica Acta, v. 66, p. 1681–1700.
- Nuccio, V.F., Hatch, J.R., 1996. Vitrinite reflectance suppression in the New Albany Shale, Illinois Basin – Vitrinite reflectance and Rock-Eval data: United States Geological Survey Open-File report 96-665, 37p.
- Partin, T., 2004, Demand for high price spurs a new era of drilling for new Albany Shale gas wells in Harrison County, Indiana, in J. Schieber, and R. Lazar, eds., Devonian black shales of the Eastern U.S. New insights into sedimentology and stratigraphy from the subsurface and outcrops in the Illinois and Appalachian basins: Field Guide for the 2004 Annual Field Conference of the Great Lake Section of SEPM, Indiana Geological Survey Open-File Study 04-05, p. 68–76.
- Person , M., Schlegel, M. Zhang, Y., Rupp, J., Ellet, K., Bowen, B., Gable, C., McIntosh, J., Bandilla, K., Elliot, T., Celia, M., 2015, Pleistocene glaciations, hydraulic fracturing and the distribution of freshwater and brines across the Illinois Basin, USA: Geofluids, in press.
- Rowan E. L., M. B. Goldhaber, and J. R. Hatch, 2002, Regional fluid flow as a factor in the thermal history of the Illinois Basin: Constraints from fluid inclusions and thee maturity of Pennsylvanian coals, AAPG Bulletin, v. 86, p. 257–277.
- Schieber, J., 2004, Connecting the dots: Sequence stratigraphic correlations in Devonian black shales of the Eastern U.S. and relationship to global sea level variations, in J. Schieber, and R. Lazar, eds., Devonian black shales of the Eastern U.S. New Insights into sedimentology and stratigraphy from the subsurface and outcrops in the Illinois and Appalachian basins: Field Guide for the 2004 Annual Field Conference of the Great Lake Section of SEPM. Indiana Geological Survey Open-File Study 04-05, p. 80–82.
- Shaver, R. H., (compiler), 1985, Midwestern basin and arches region, in Lindberg, F. A., ed., Correlation of stratigraphic units of North America: American Association of Petroleum Geologists COSUNA Chart Series, 1 sheet.
- Songenfrei, H. Jr., 1952, Gas production for the New Albany Shale: Indiana University, Bloomington, Ms Thesis (unpublished), 26 p.
- Strąpoć, D., Mastalerz, M., Schimmelmann, A., Drobniak, A., Hasenmueller, N.R., 2010. Geochemical constraints on the origin and volume of gas of the New Albany Shale (Devonian – Mississippian) in the eastern part of the Illinois Basin. AAPG Bulletin 94, 1713-1740.
- Strąpoć , D., Picardal, F., Turich, C., Schaperdott, I., Macalady, J., Lipp, J.S., Yu-Shih Lin,. Ertefai, T.F., Schubotz, F., Hinrichs, K-U, Mastalerz, M., Schimmelmann, A., 2008. Methane-producing microbial community in a coal bed of the Illinois Basin. Journal of Applied and Environmental Microbiology 74, 2424-2432.
- Sullivan, D.M., 1995, Natural gas fields of Indiana: Indiana Geological Survey Special Report 51, 69 p.
- Swezey, C.S., Hatch, J.R., Brennan, S.E., East, J.A., Rowan, E.L., Repetski, J.E., Charpentier, R.R., Cook, T.A., Klett, T.R., Pollastro, R.M., and Schenk , C.J., 2007, Assessment of Undiscovered Oil and Gas Resources of the Illinois Basin, 2007: United States Geological Survey Fact Sheet FS-2007-3058, 2 p.

NEW ALBANY SHALE MAPS

Many research projects related to New Albany Shale were conducted over the years. Various physical and chemical data were collected and many maps were generated. The gallery of the maps below presents just few of the New Albany Shale maps generated in the last 3 years based on comprehensive data compiled from several different sources, including data from Indiana, Illinois State and Kentucky Geological Surveys. Completed maps include (among others) depth, thickness, elevation, vitrinite reflectance and total organic carbon content of the entire New Albany Shale Formation. Maps of the NAS members were also genarated.

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New Albany Shale outcrop in Kentucky.