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U.S. Geological Survey Open-File Report 2005-1268

Published 2005
Online Only
Version 1.0

Assessment of Undiscovered Natural Gas Resources in Devonian Black Shales, Appalachian Basin, Eastern U.S.A.

by Robert C. Milici

What do we Assess?

Technically recoverable undiscovered hydrocarbon resources –

- oil, natural gas, natural gas liquids

The Devonian Shale - Middle and Upper Paleozoic TPS

Conventional Oil and Gas Resources

- Accumulations in structural, stratigraphic, combination traps.

- Segregation of fluids within reservoirs (Water, oil, gas cap)

The Devonian Shale - Middle and Upper Paleozoic TPS

Continuous (unconventional) resources

- Blanket-like accumulations, commonly with multi-storied reservoirs.

- Coalbed methane, Radioactive black shales, tight sandstones -

How do we do it?

Conventional: Estimate numbers and sizes of undiscovered fields – maximum, median, minimum, most likely.

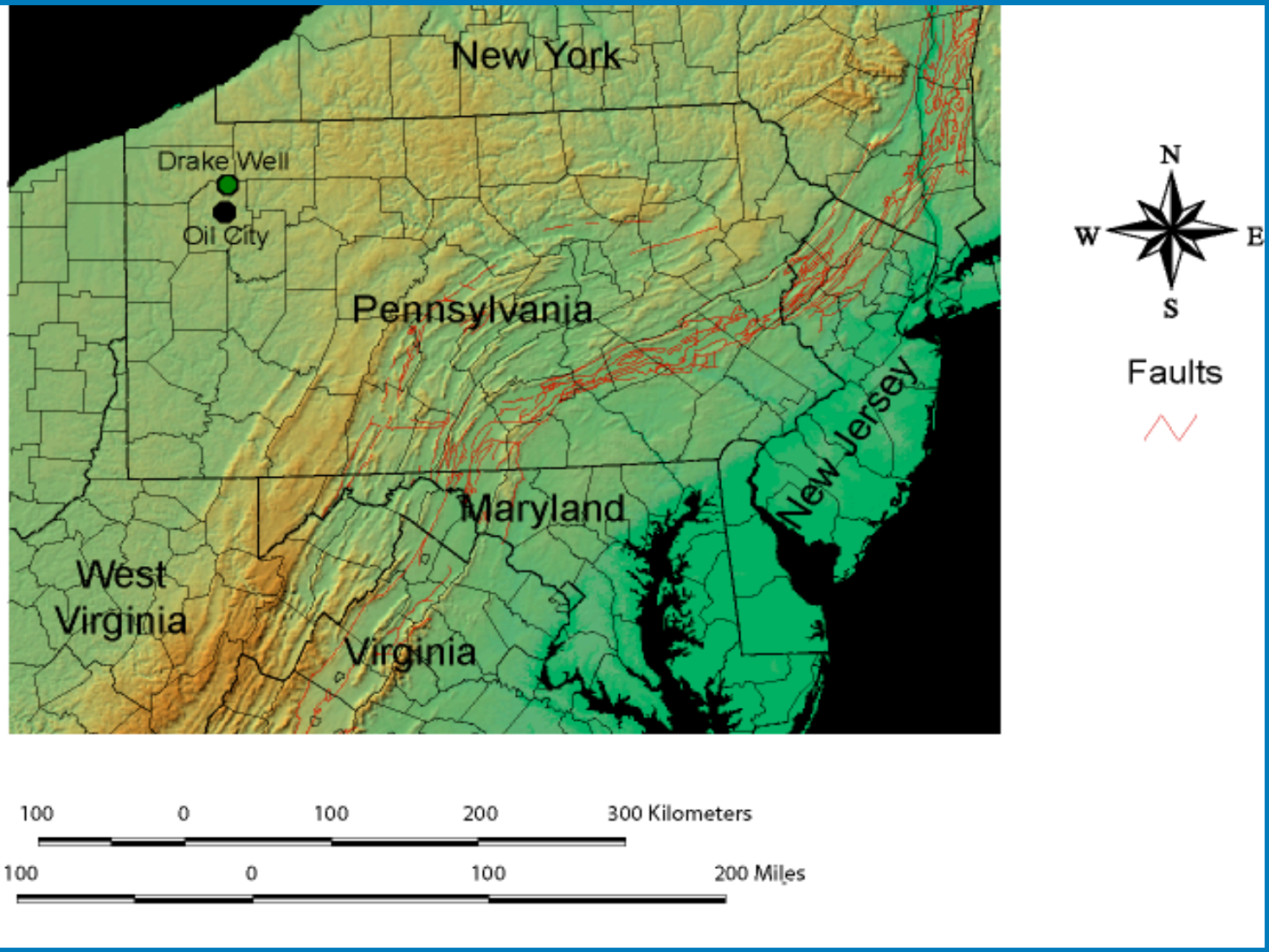
Continuous (unconventional): Estimate numbers of untested cells (40 acres, 80 acres, etc.) and the range of the cumulative production from each cell (max, min, median, mean).

The Devonian Shale-Middle and Upper Paleozoic TPS (Cont.)

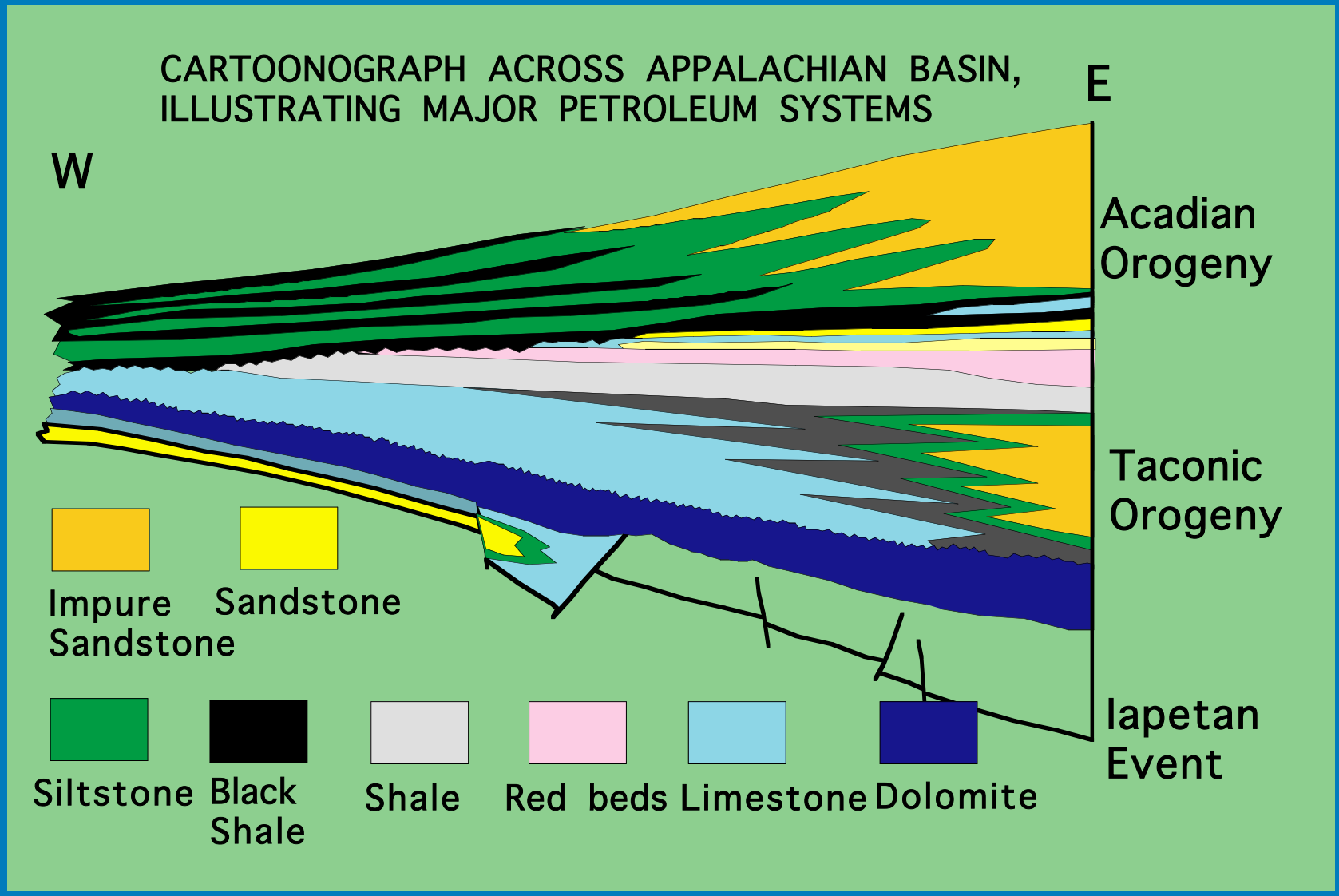
Continuous Oil and Gas Resources

- **Northwestern Ohio Shale (NWOS) AU**
- **Greater Big Sandy (GBS) AU**
- **Devonian Siltstone And Shale (DSS) AU**
- **Marcellus Shale AU**
- Catskill Sandstones and Siltstones AU
- Berea Sandstone AU

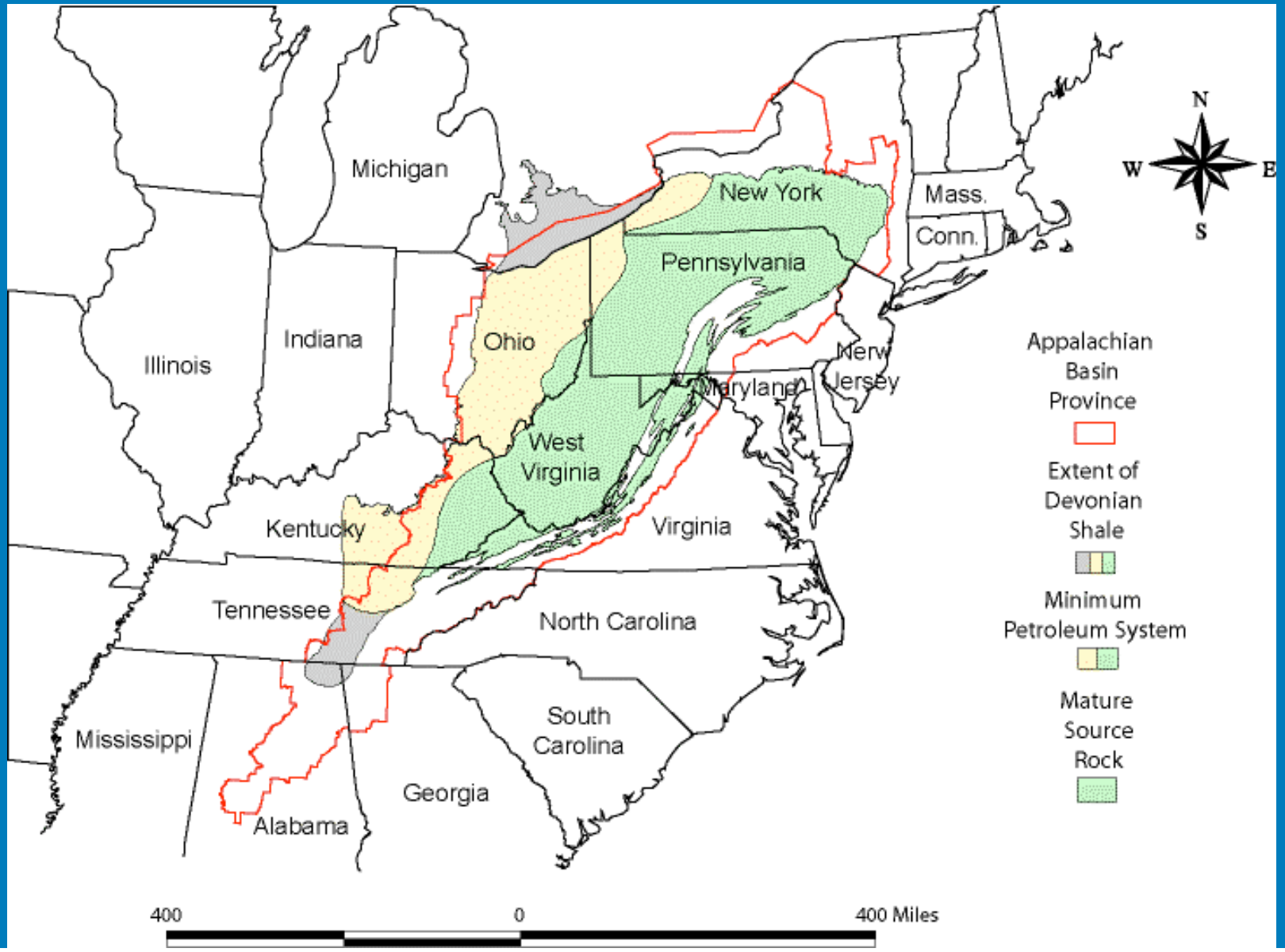
The Drake Well: Where it all began



USGS

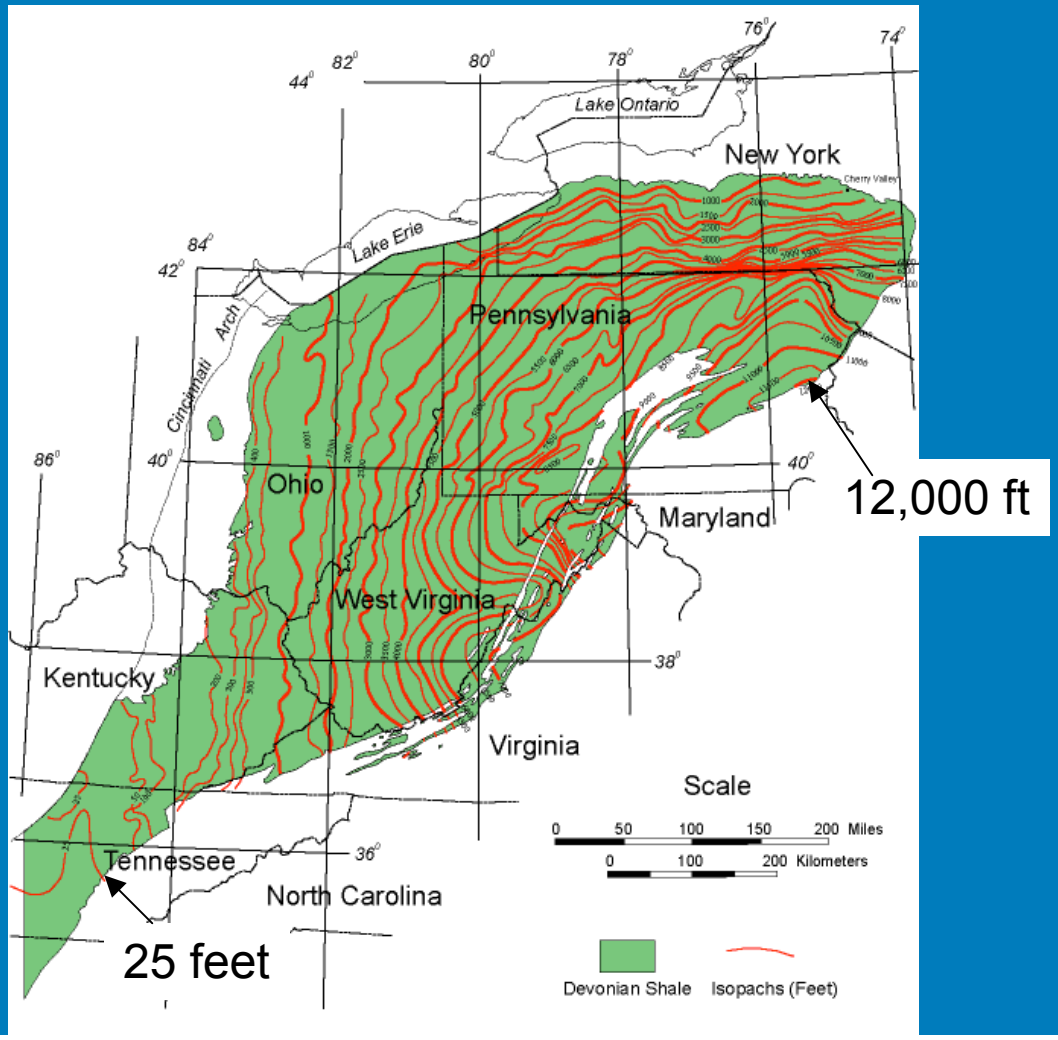

CARTOONOGRAPH ACROSS APPALACHIAN BASIN,
ILLUSTRATING MAJOR PETROLEUM SYSTEMS
W
E
Acadian Orogeny
Taconic Orogeny
Iapetan Event
Impure Sandstone
Sandstone
Siltstone
Black Shale
Shale
Red beds
Limestone
Dolomite

The Devonian Shale-Middle and Upper Paleozoic TPS

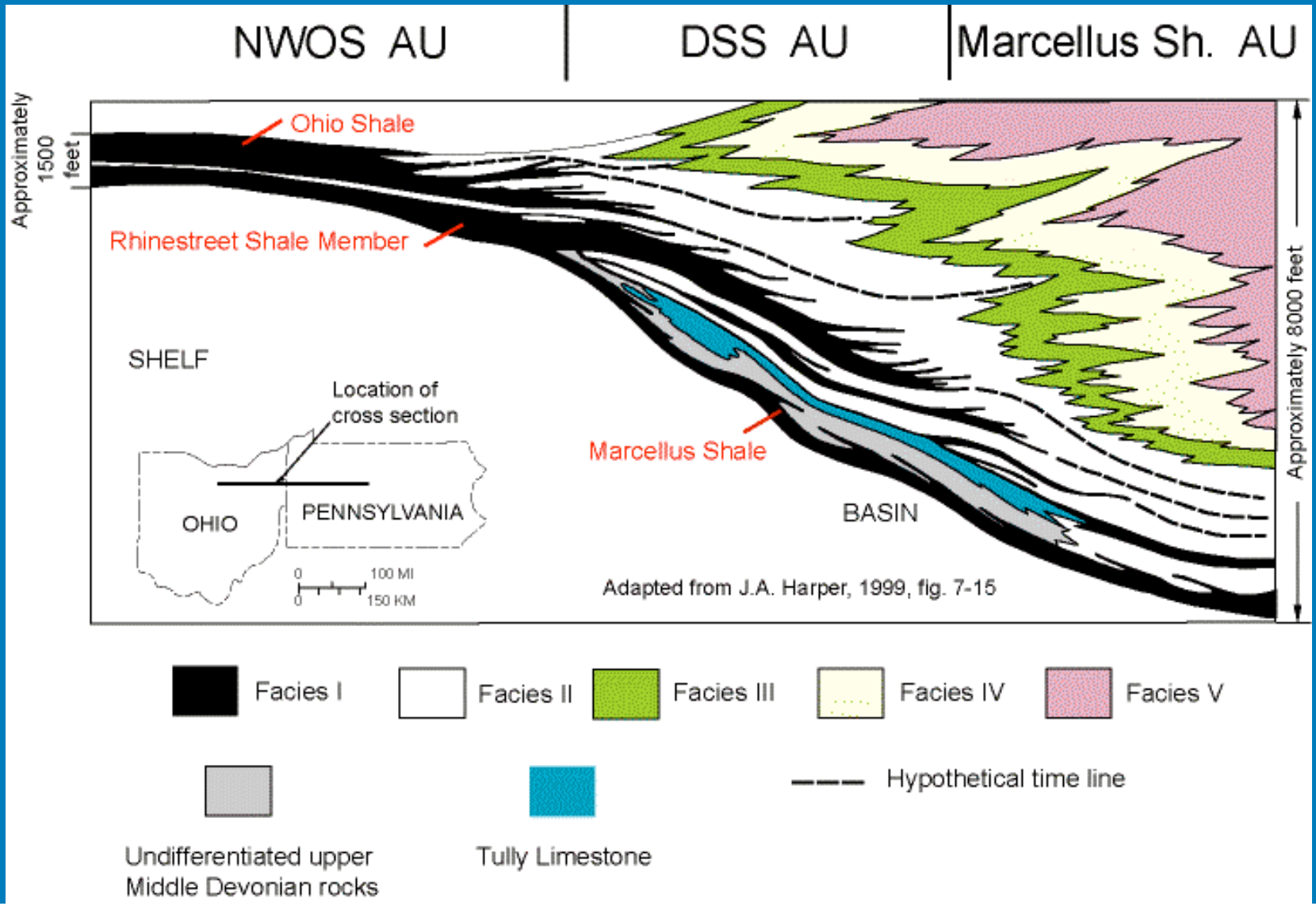


Extent and thickness of Devonian rocks in the Appalachian basin

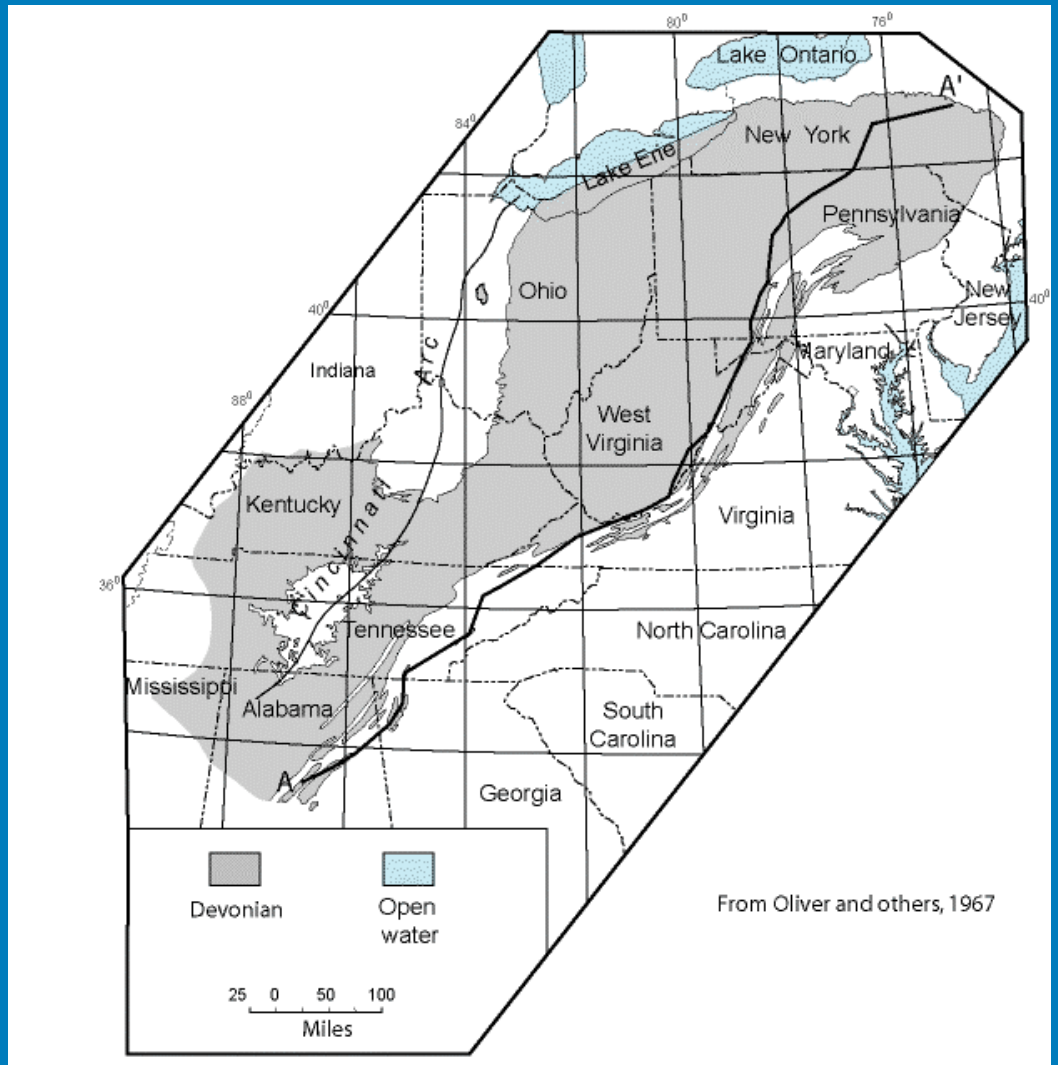
(adapted from deWitt and others,1975)



Catskill Magnafacies
(adapted from Harper, 1999)



Extent of Devonian Shale in Eastern U.S. – Section A-A' (Oliver and others, 1967)

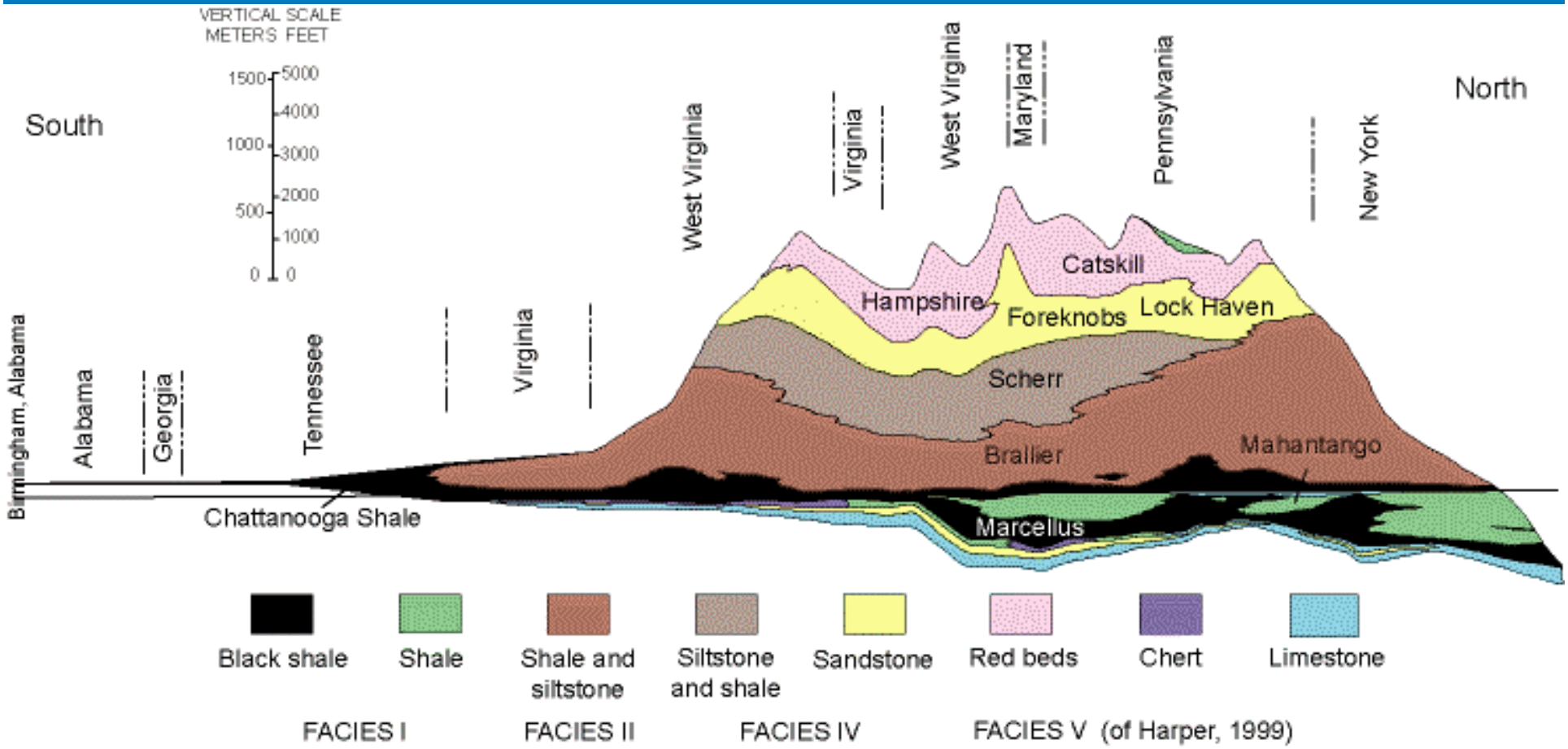


Cross Section A - A’

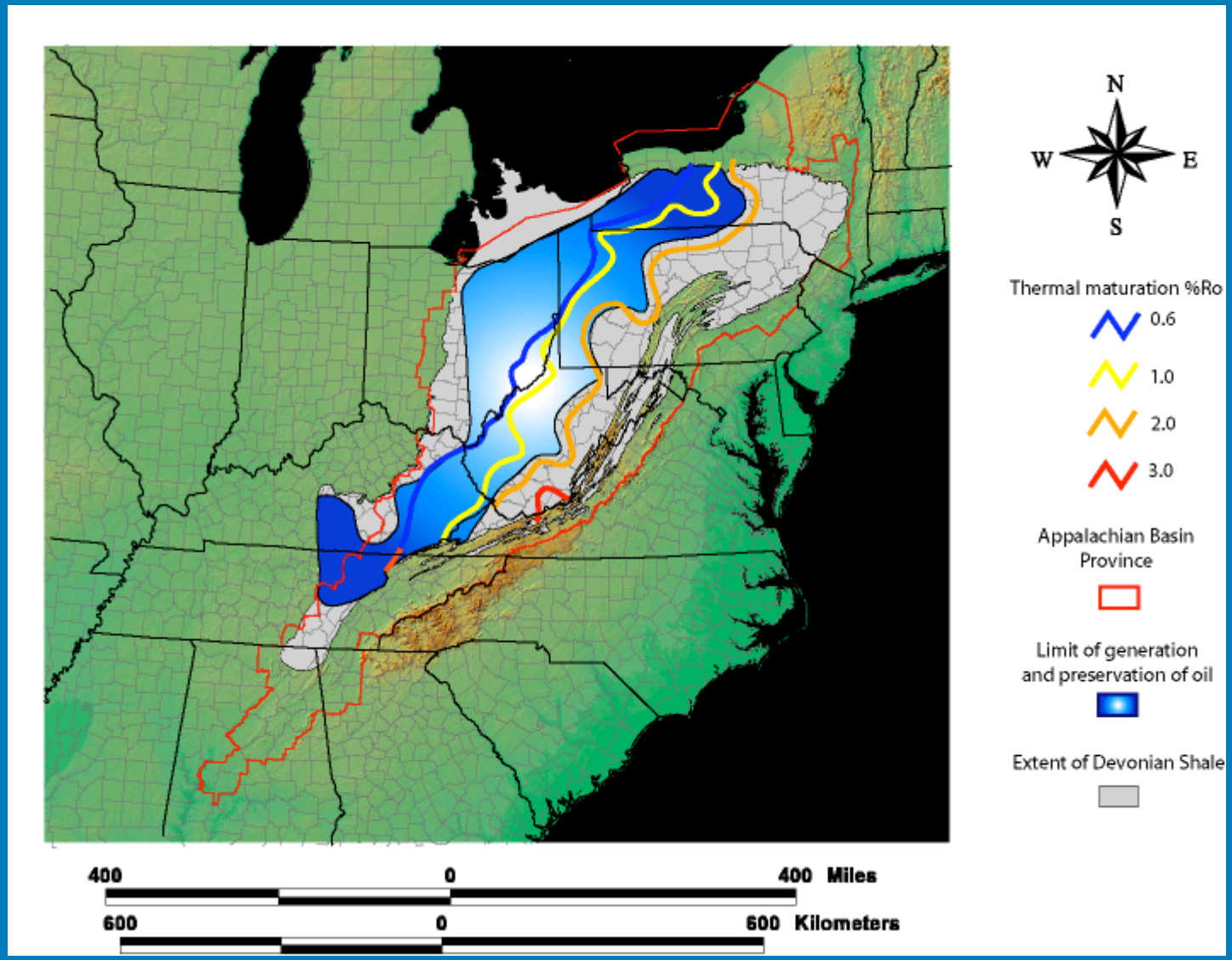
(de Witt and others, 1975)

A

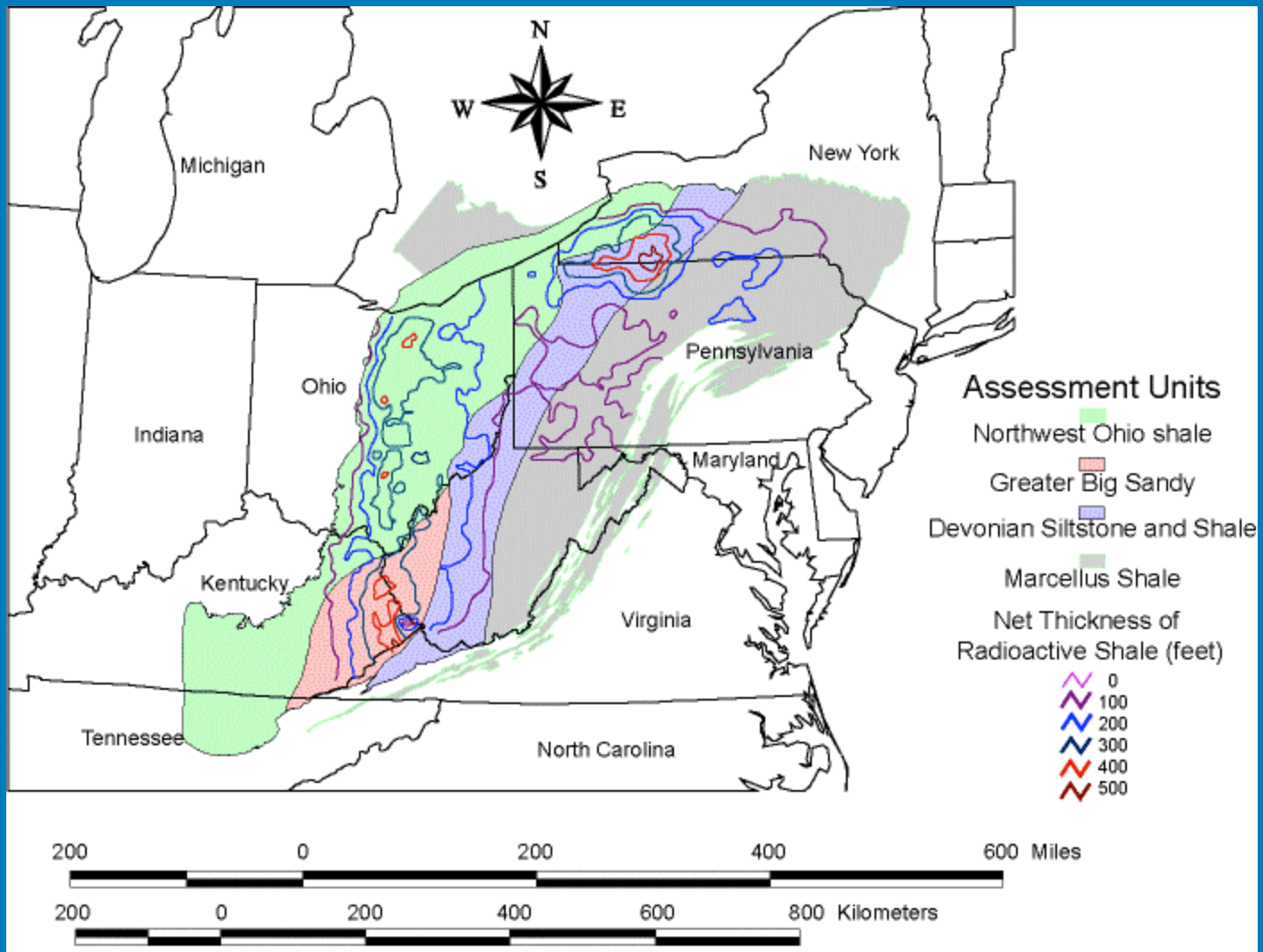
A’



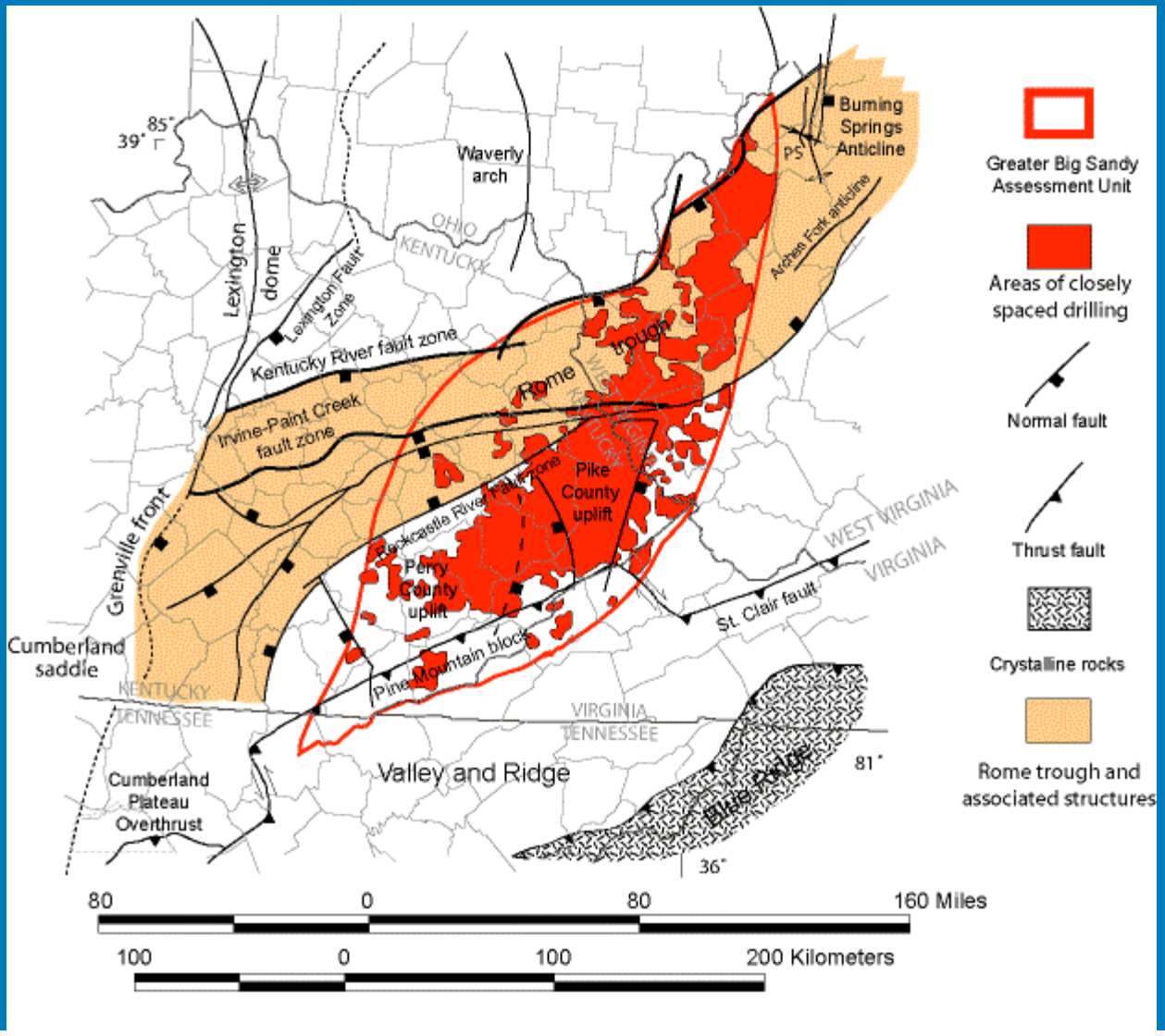
Oil in Devonian Shale and Oriskany Sandstone



Devonian shale assessment units, showing net thickness of radioactive shale

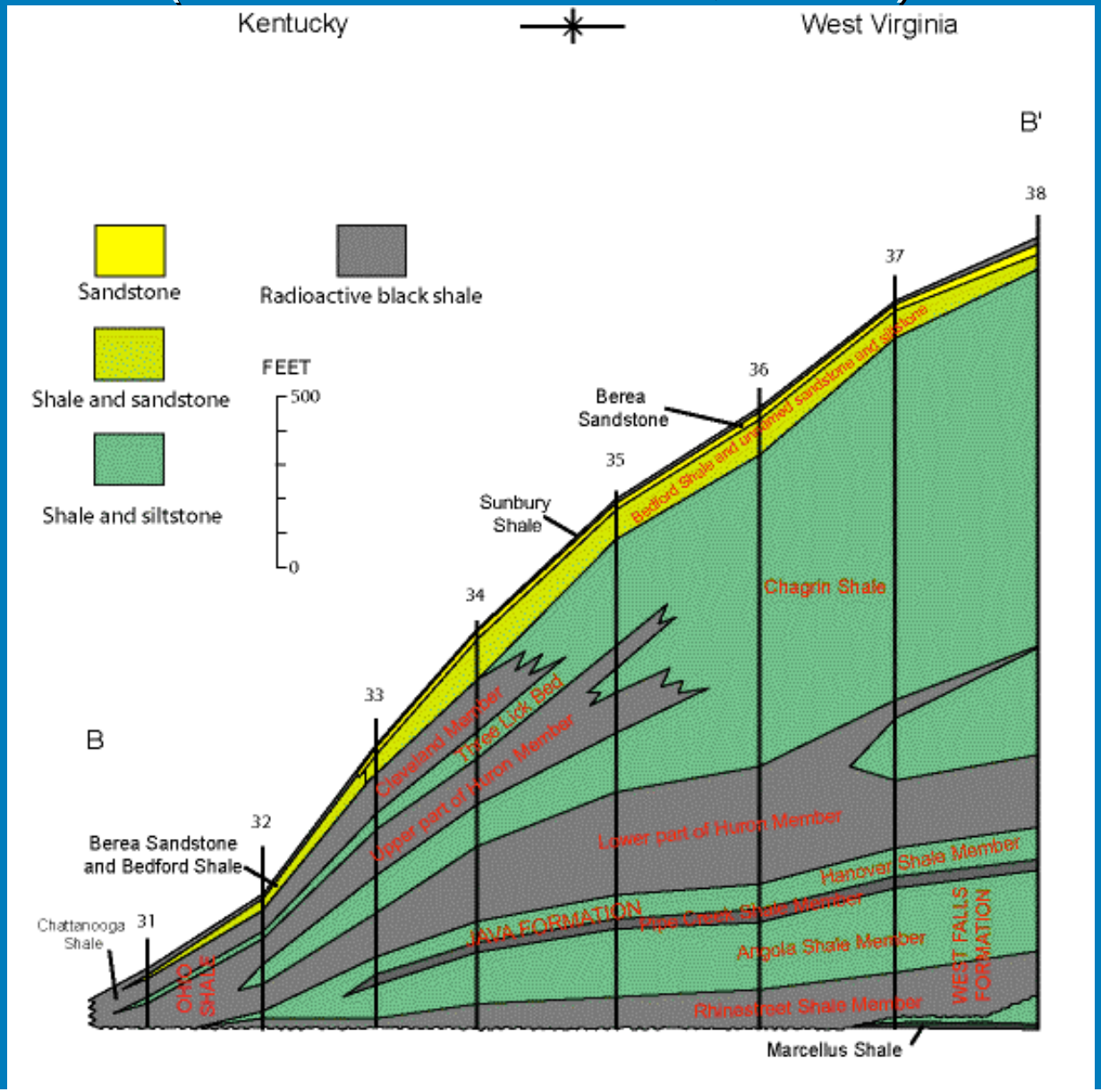


Greater Big Sandy AU



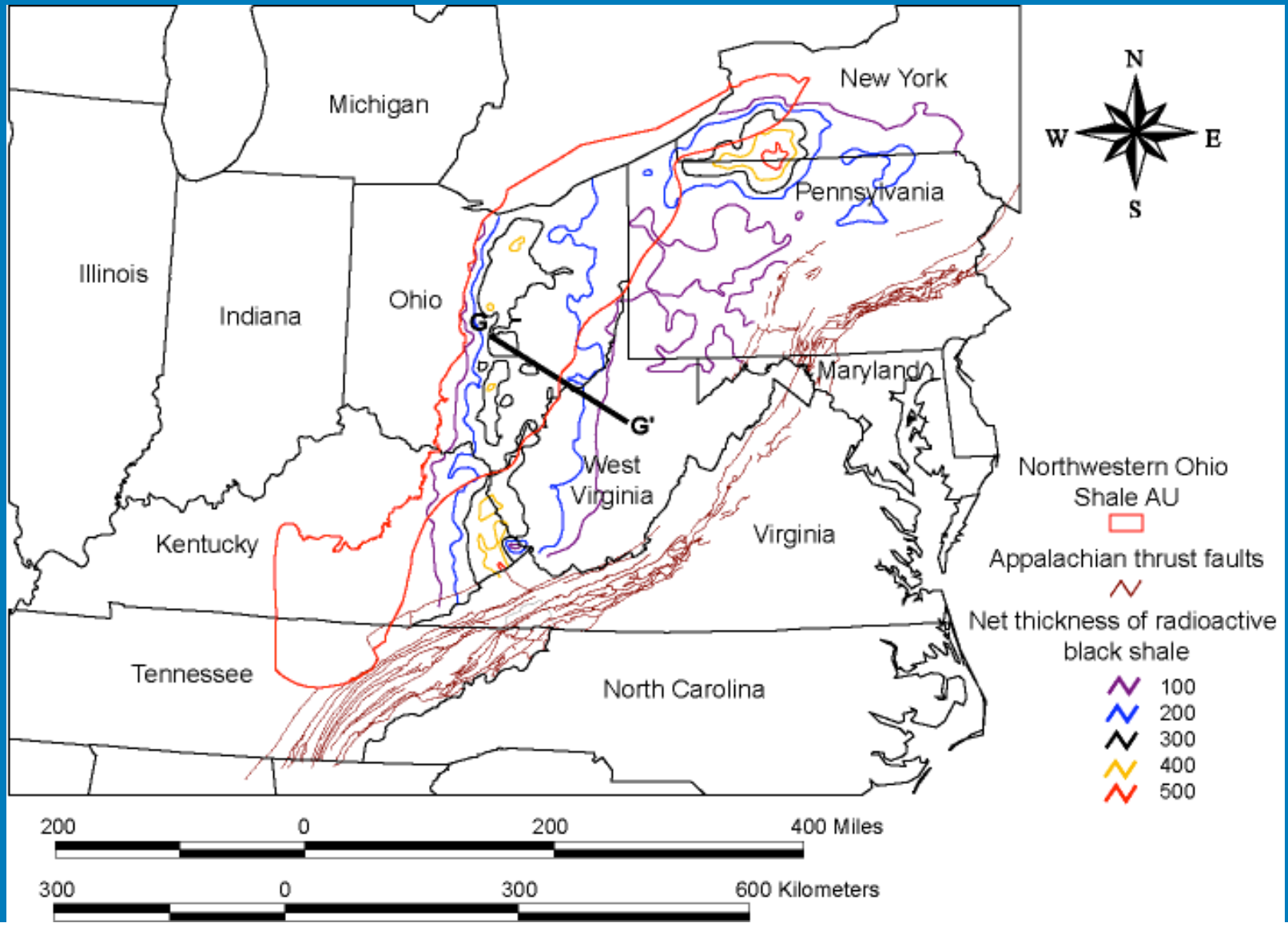
Cross-Section B - B’

(deWitt and others, 1993)



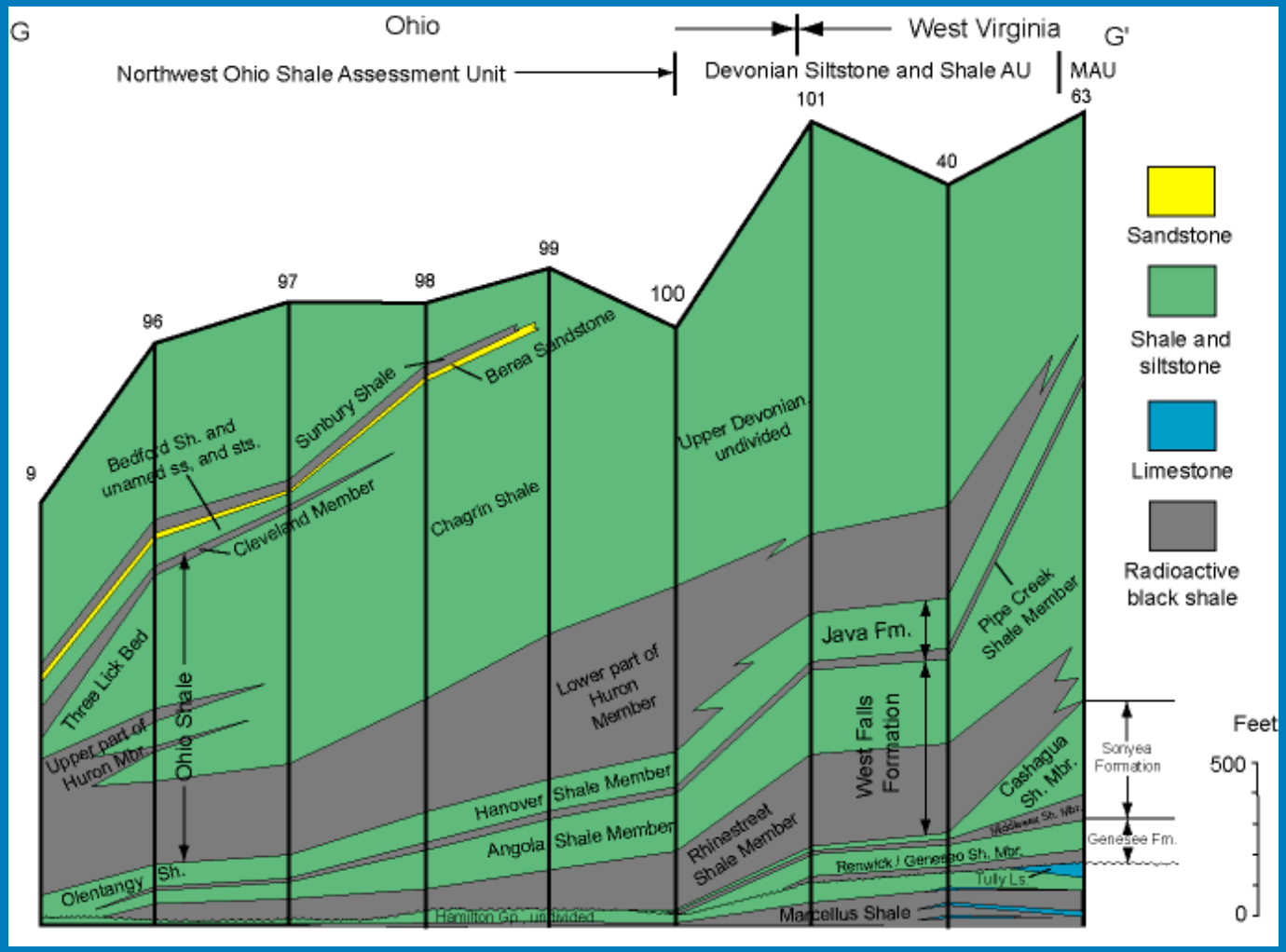
Devonian Shale Thickness

(deWitt and others, 1993)

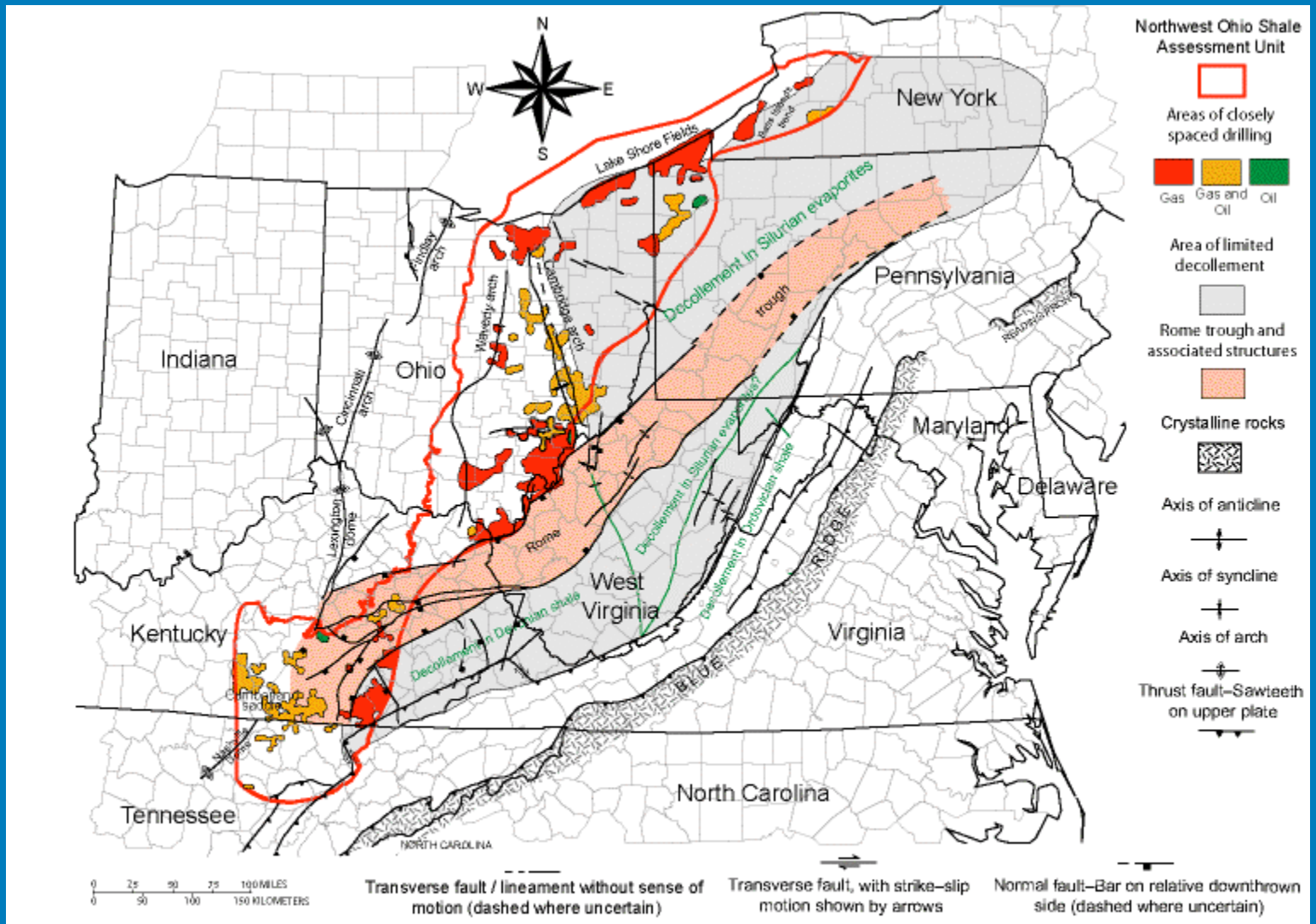


Cross Section G - G'

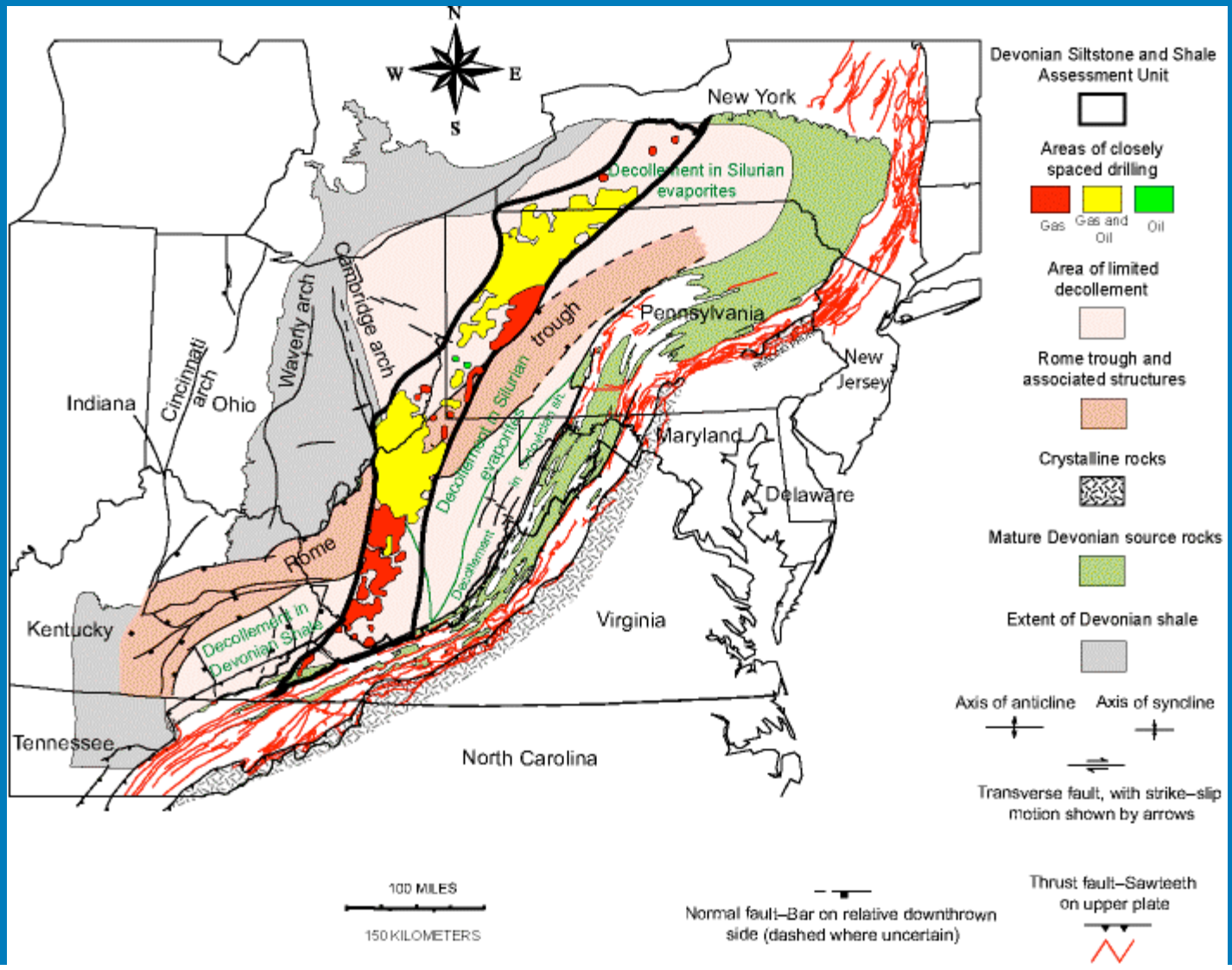
(deWitt and others, 1993)



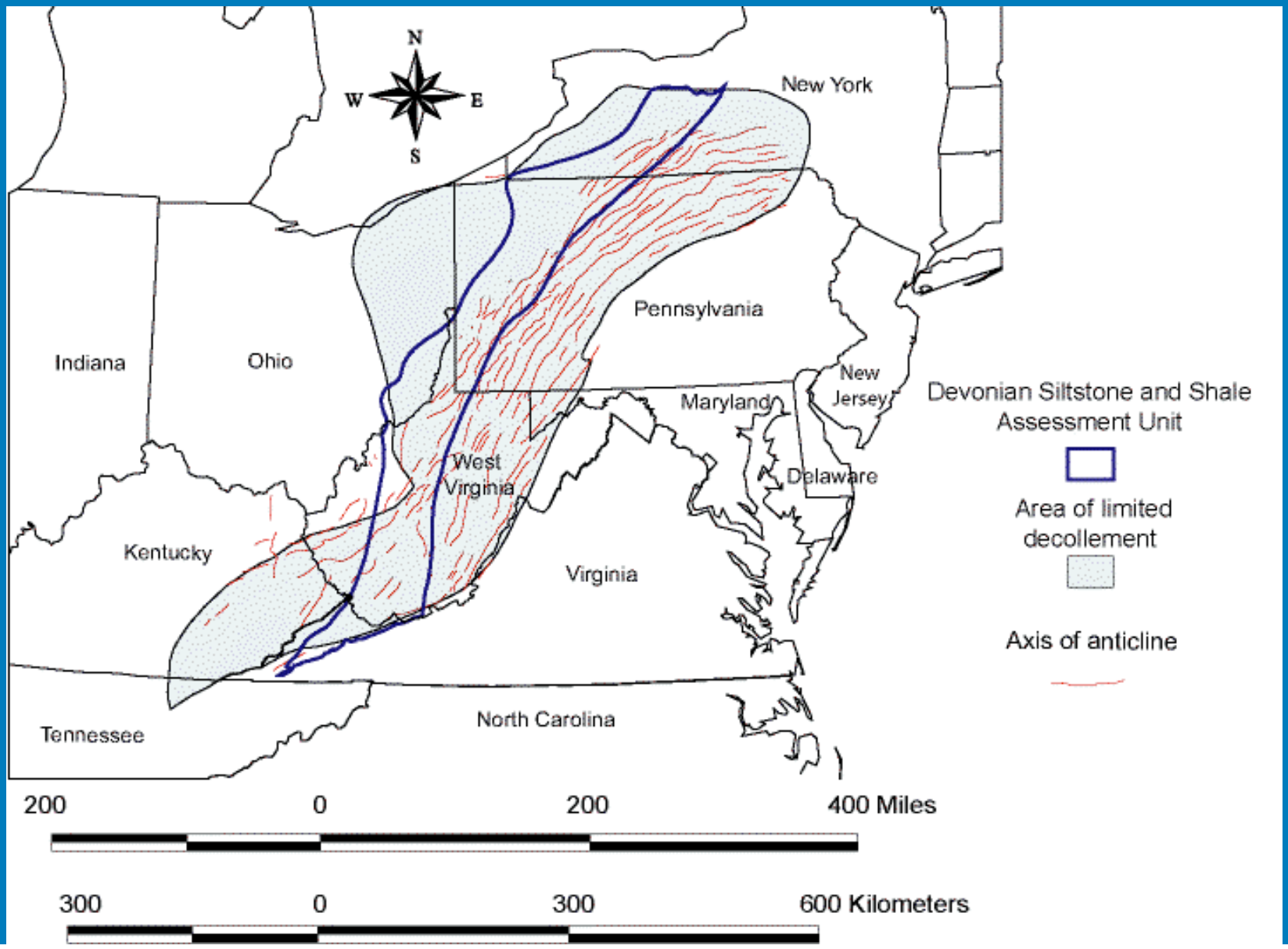
Relation of NWOS to Regional Structure



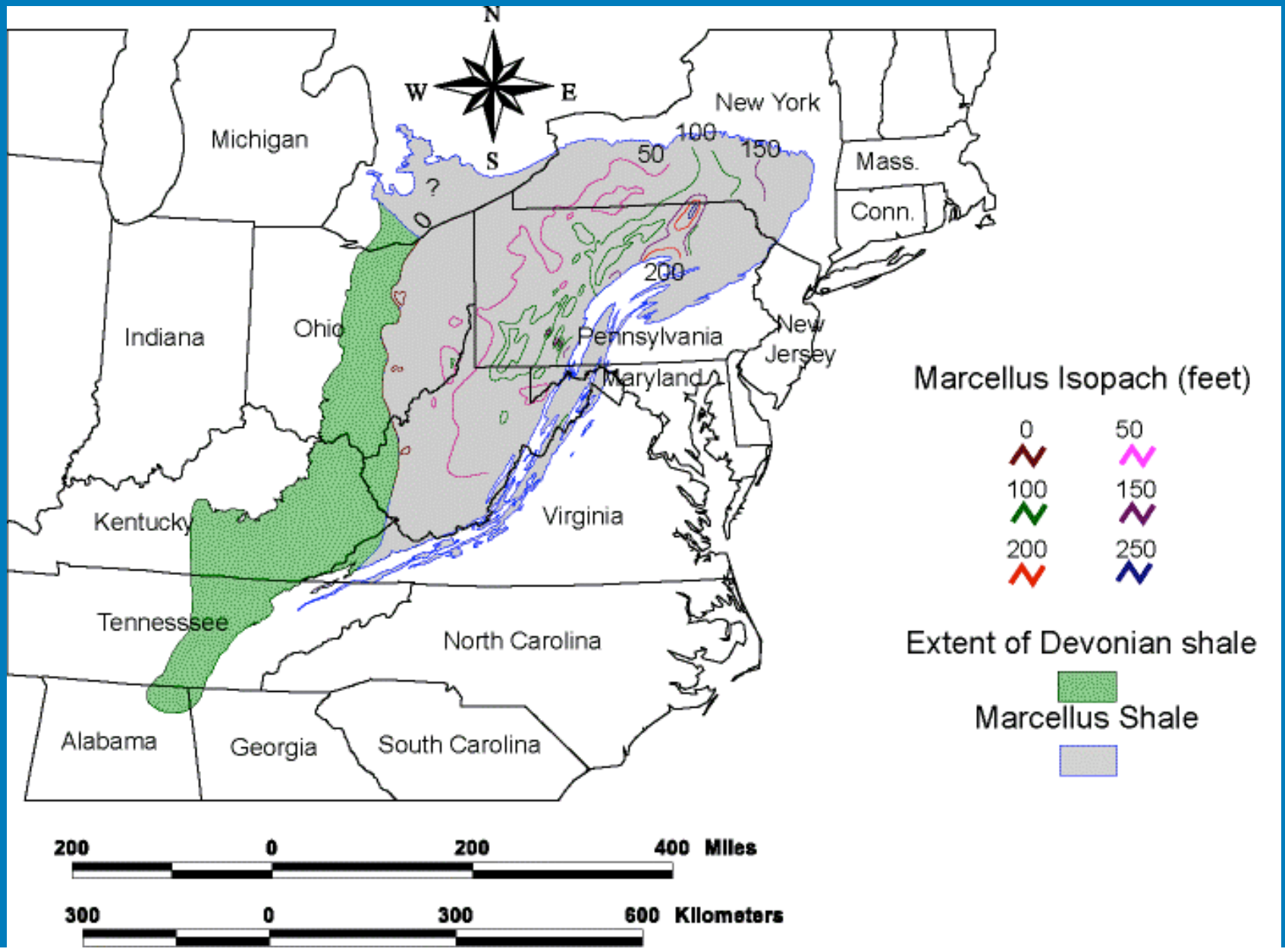
Devonian Siltstone and Shale AU



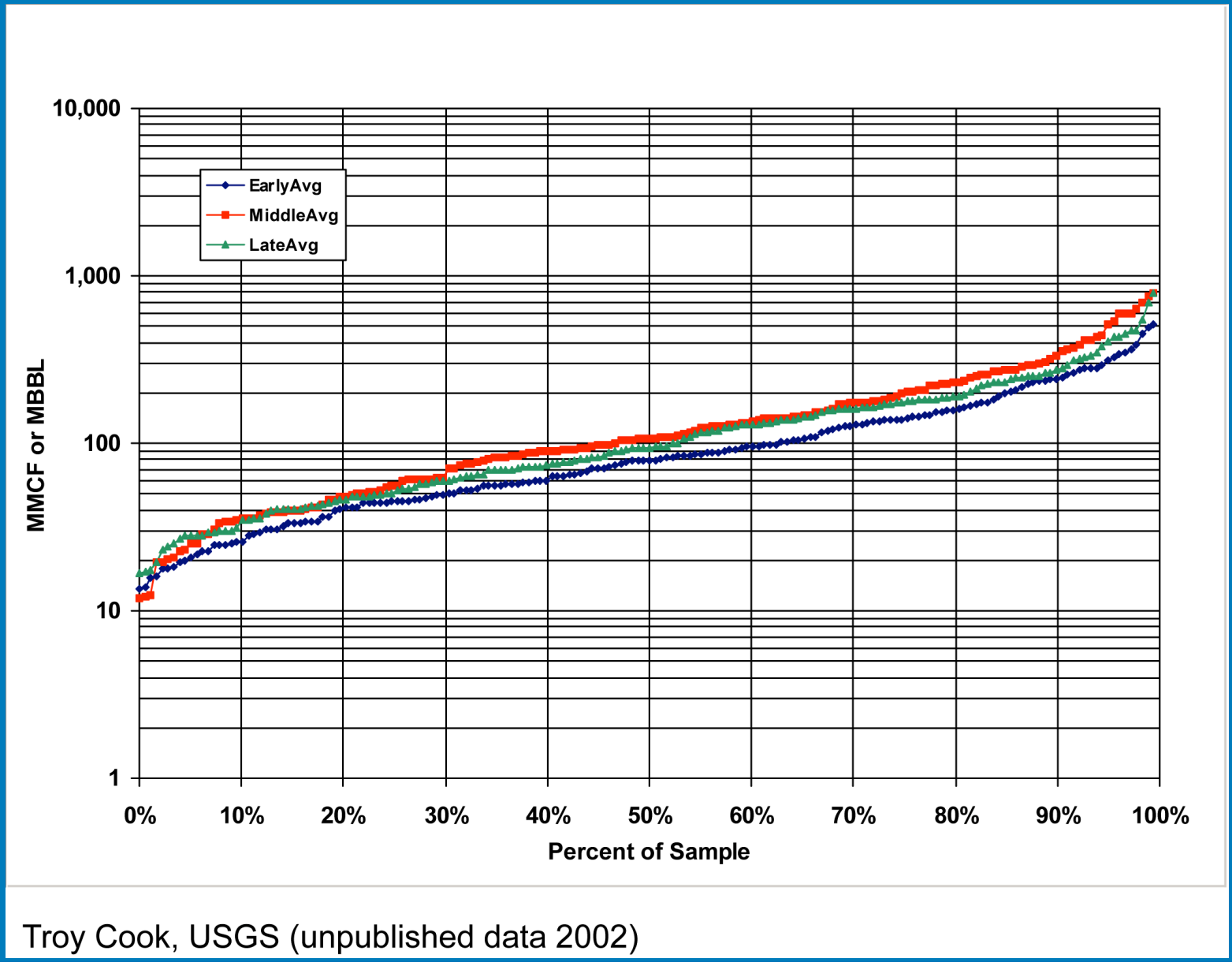
Regional Decollement and Folds



Marcellus Shale

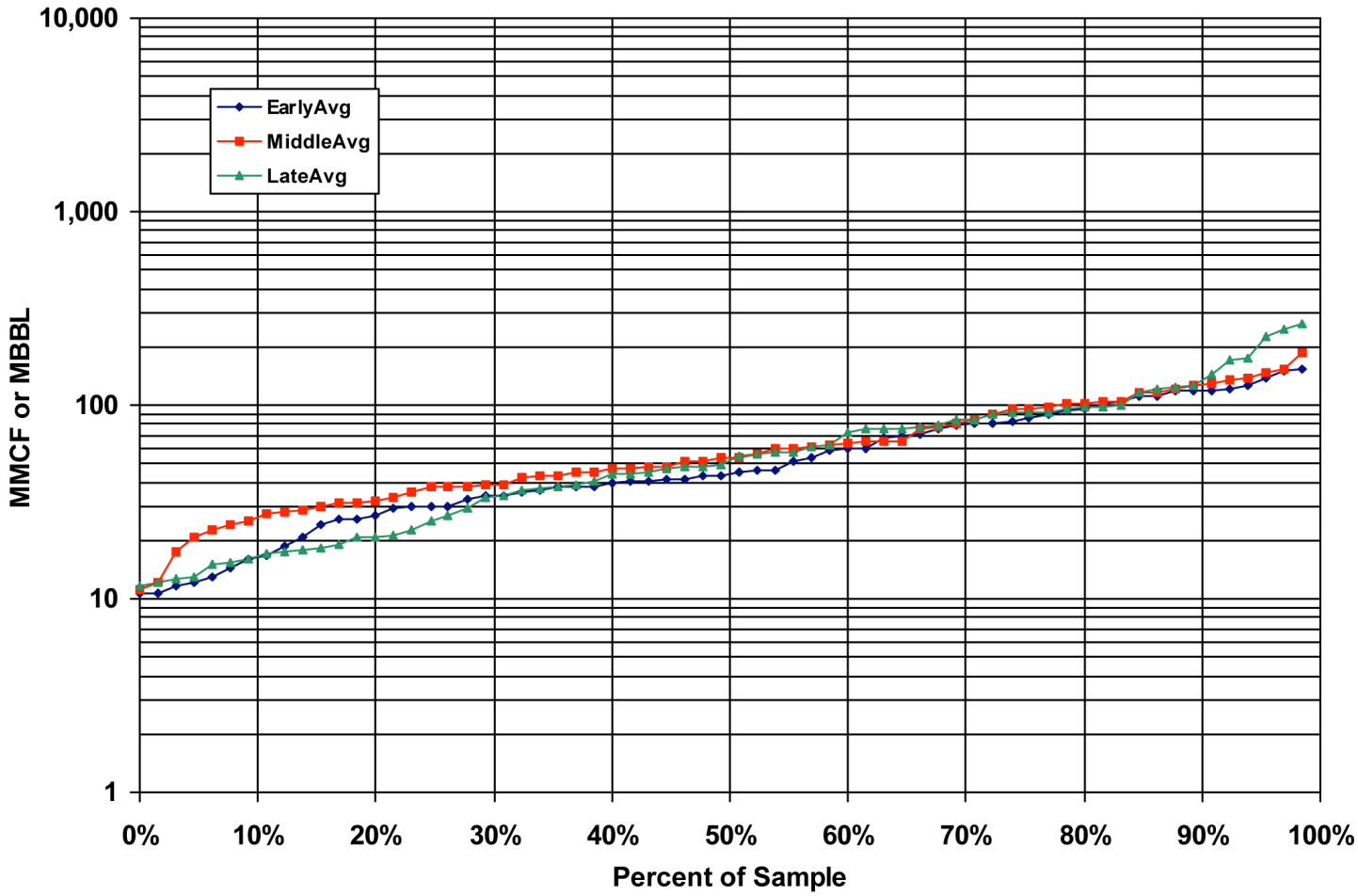


EUR distribution: Greater Big Sandy AU by thirds



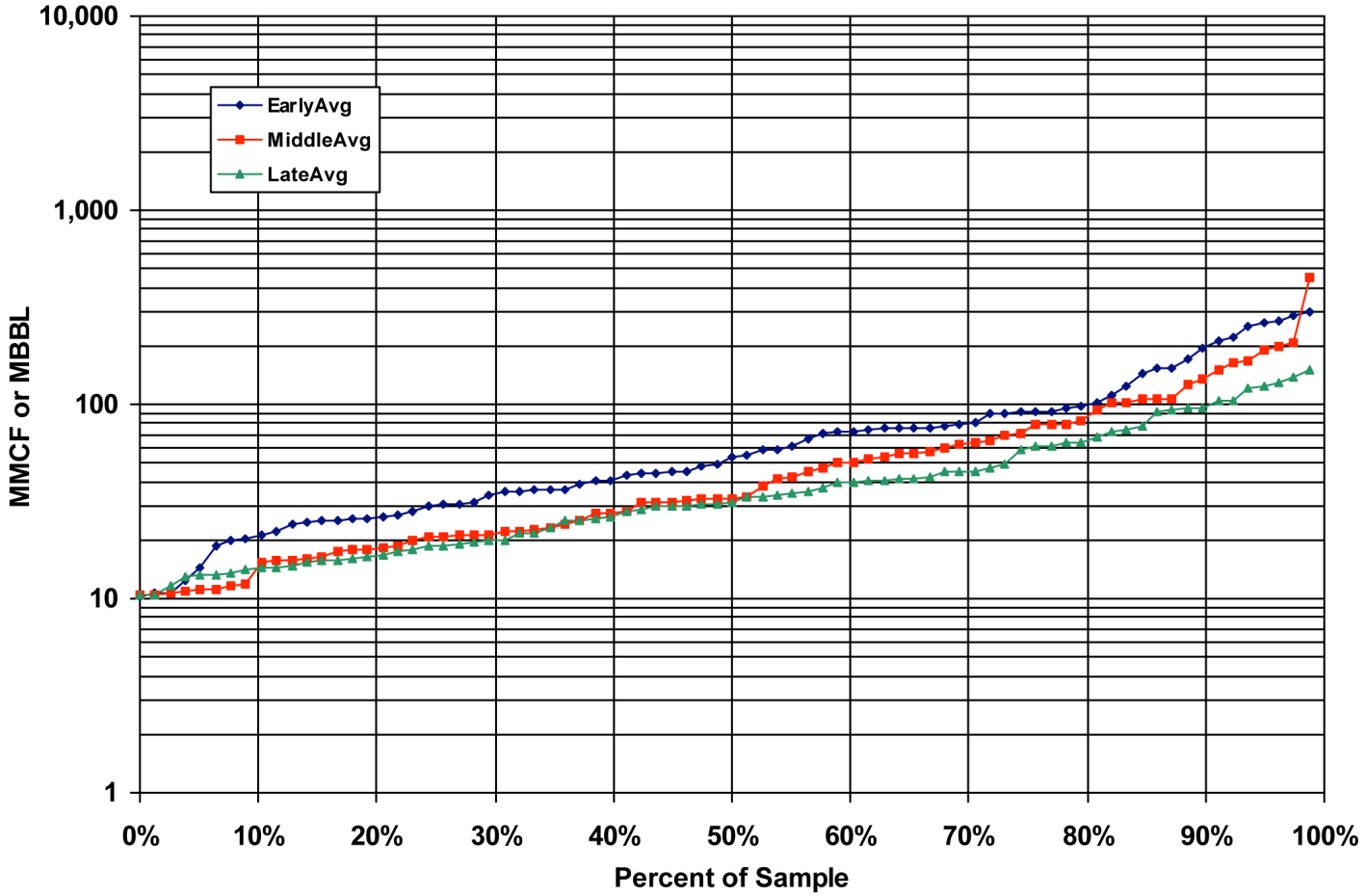
Troy Cook, USGS (unpublished data 2002)

EUR distribution: NWOS AU by thirds



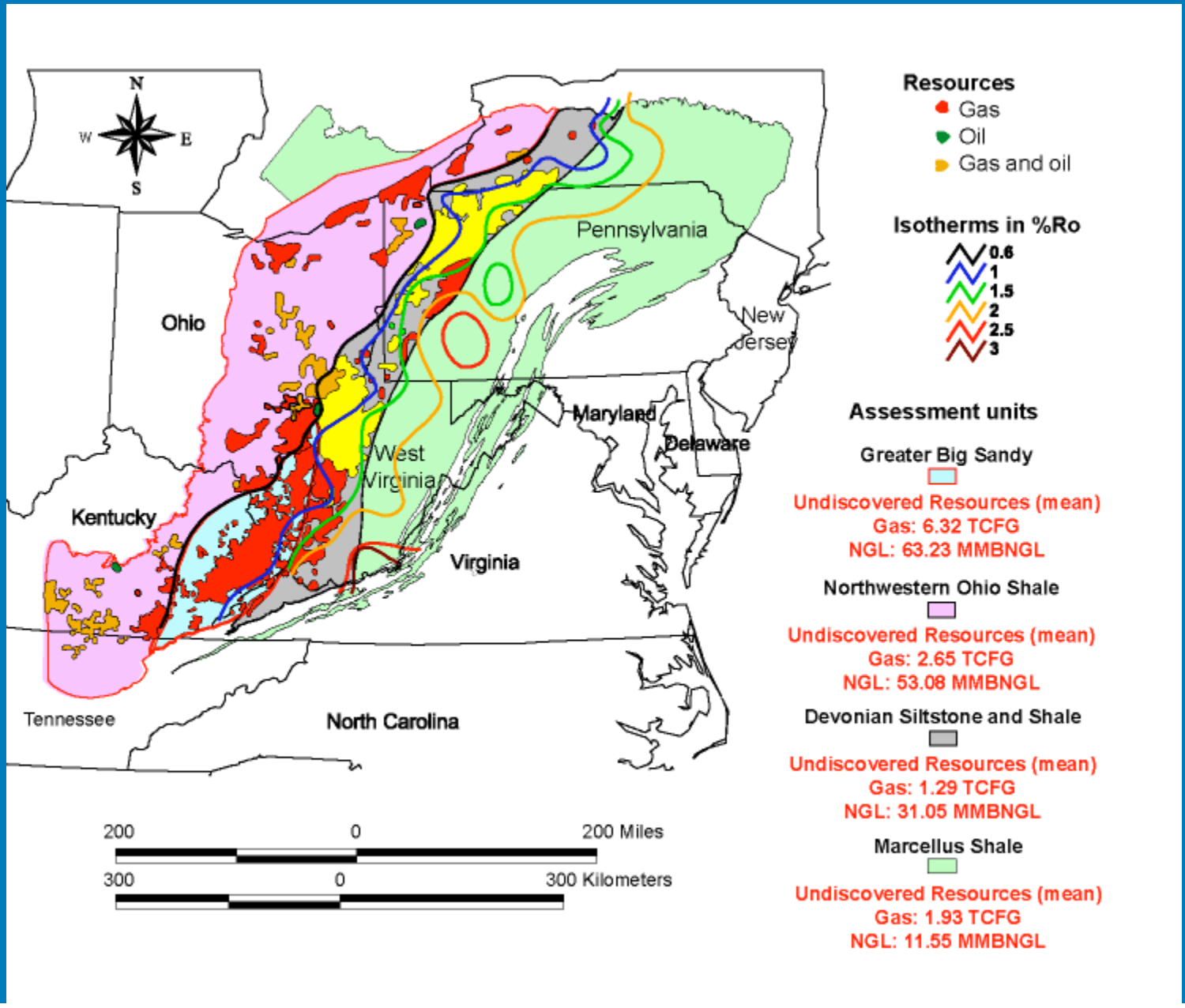
Troy Cook, USGS, Unpublished data

EUR distribution: DSS by Thirds

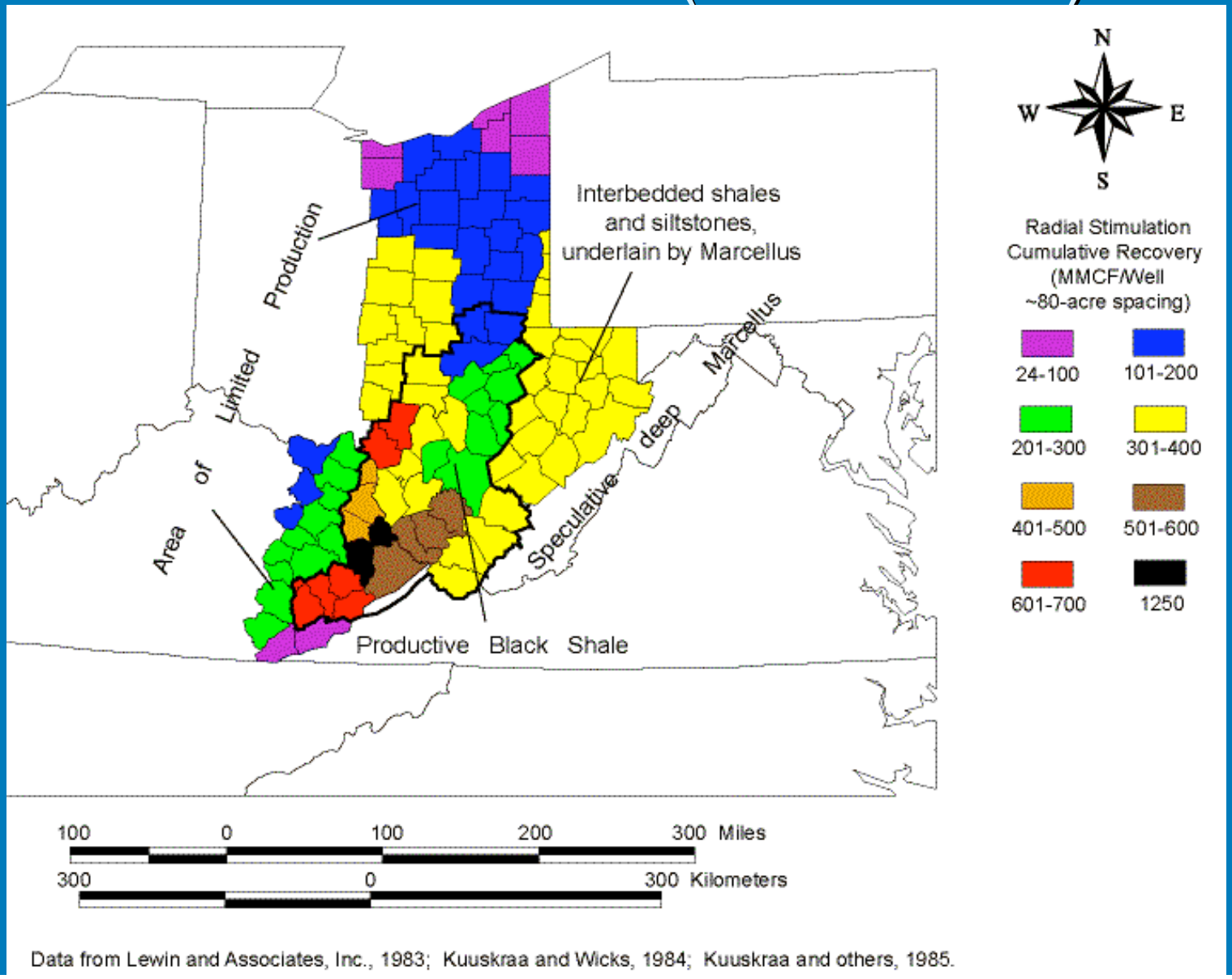


Troy Cook, USGS (unpublished data, 2002)

Undiscovered Resources



Per Well Estimates of Technically Recoverable Gas (DOE EGSP)



Data from Lewin and Associates, Inc., 1983; Kuuskraa and Wicks, 1984; Kuuskraa and others, 1985.

Selected References

Boswell, Ray, 1996, Play UDs: Upper Devonian black shales, *in* Roen, J.B., and Walker, B.J., 1996, The Atlas of Major Appalachian Gas Plays: West Virginia Geological and Economic Survey Publication V-25, p. 93-99.

Colton, G.W., 1970, The Valley and Ridge and Appalachian Plateau; stratigraphy and sedimentation; the Appalachian basin; its depositional sequences and their geologic relationships, *in* Fisher, George W., Pettijohn, F.J., and Reed, J. C., Jr., Studies of Appalachian Geology, Central and Southern: Interscience Publishers, New York, N.Y., p. 5-47.

Charpentier, R.R., deWitt, Wallace, Claypool, G.E., Harris, L.D., Mast, R.F., Megeath, J.D., Roen, J.B., and Schmoker, J.W., 1993, Estimates of unconventional natural gas resources of the Devonian shales of the Appalachian basin, *in* Roen, J.B., and Kepferle, R.C., 1993, Petroleum geology of the Devonian and Mississippian black shale of eastern North America: U.S. Geological Survey Bulletin 1909B, p. N1-N 20.

deWitt, Wallace, Jr., Perry, W.J., Jr., and Wallace, L.G., 1975, Oil and gas data from Devonian and Silurian rocks in the Appalachian basin: U.S. Geological Survey Miscellaneous Investigations Series Map I-917 B, scale: 1:2,500,000.

deWitt, Wallace, Jr., Roen, J.B., and Wallace, L. G., 1993, Stratigraphy of Devonian black shales and associated rocks in the Appalachian basin, *in* Roen, J.B., and Kepferle, R.C., 1993, Petroleum geology of the Devonian and Mississippian black shale of eastern North America: U.S. Geological Survey Bulletin 1909B, p. B1-B57.

Faill, R.T., 1997a, A geologic history of the north-central Appalachians, part 1. Orogenesis from the mesoproterozoic through the Taconic orogeny: American Journal of Science, v. 297. p. 551-619.

Faill, R.T., 1997b, A geologic history of the north-central Appalachians, part 2. The Appalachian basin from the Silurian through the Carboniferous: American Journal of Science, v. 297. p. 729-761.

Frey, M. G., 1973, Influence of Salina salt on structure in New York-Pennsylvania part of the Appalachian Plateau: American Association of Petroleum Geologists Bulletin, v. 57, no. 6, p. 1027-1037.

Harper, J.A., 1999, Chapter 7, Devonian, *in* Schultz, C.H., ed., The Geology of Pennsylvania, p. 129-137.

Kuuskraa, V.A., and Wicks, D. E., 1984, Technically recoverable Devonian Shale gas in West Virginia: U.S. Department of Energy Morgantown Energy Technology Center DOE/MC/19239-1750 (DE85003367), 119 p.

Kuuskraa, V.A., Sedwick, K.B., Thompson, K.B., and Wicks, D. E., 1985, Technically recoverable Devonian Shale gas in Kentucky: U.S. Department of Energy Morgantown Energy Technology Center DOE/MC/19239-1834 (DE85008608), 120 p.

Lewin and Associates, Inc., 1983, Technically recoverable Devonian Shale gas in Ohio: U.S. Department of Energy Morgantown Energy Technology Center DOE/MC/19239-1525 (DE84003057), 101 p.

Lundegard, P.D., Samuels, N.D., and Pryor, W. D., 1985, Upper Devonian turbidite sequence, central and southern Appalachian basin: contrasts with submarine fan deposits, *in* Woodrow and Sevon, eds., The Catskill delta: Geological Society of America Special Paper 201, p. 107-121.

Milici, R.C., 1993, Autogenic gas (self-sourced) from shales- An example from the Appalachian basin, *in* Howell, D.G., ed., The future of energy gases: U.S. Geological Survey Professional Paper 1570, p. 253-278.

References (Cont.)

Milici, R.C., 1996, Play Dbg: Upper Devonian fractured black shales and siltstones, *in* Roen, J.B., and Walker, B.J., 1996, The Atlas of Major Appalachian Gas Plays: West Virginia Geological and Economic Survey Publication V-25, p. 86-92.

Milici, R.C., 2005, Assessment of undiscovered natural gas resources in Devonian black shales, Appalachian basin, eastern U.S.A.: American Association of Petroleum Geologists Abstracts Volume for the 2005 Annual Convention, p. A93.

Milici, R.C. and Statler, 1980, fractures related to major thrusts – possible analogues to tectonically fractured Chattanooga Shale in Tennessee: *in* Wheeler, R.L., and Dean, C.S., eds., Proceedings western limit of detachment and related structures in the Appalachian foreland: U.S. Department of Energy Morgantown Energy Technology Center DOE/METC/SP-80/23, p.157-166.

Milici, R.C., Ryder, R.T., Swezey, C.S., Charpentier, R.R., Cook, T. A., Crovelli, R.A., Klett, T.R., Pollastro, R.M., and Schenk, C.J., 2003, Assessment of undiscovered oil and gas resources of the Appalachian Basin Province, 2003: U.S. Geological Survey Fact Sheet FS-009-03, 2 p.

Oliver, W.A., Jr.; deWitt, Wallace, Jr.; Dennison, J.M.; Hoskins, D.M.; and Huddle, J. W., 1967, Devonian of the Appalachian Basin, United States, *in* Oswald, G.H., ed., International Symposium on the Devonian System: Alberta Society of Petroleum Geologists, Calgary, Alberta, p. 1001 - 1040.

Oliver, W.A., Jr.; deWitt, Wallace, Jr.; Dennison, J.M.; Hoskins, D.M.; and Huddle, J. W., 1971, Isopach and lithofacies maps of the Devonian in the Appalachian Basin: Pennsylvania Bureau of Topographic and Geologic Survey Progress Report 182.

Repetski, J.E.., Ryder, R.T., Harper, J.A., and Trippi, M.H., 2002, Thermal maturity patterns in the Ordovician and Devonian rocks of the Appalachian basin in Pennsylvania: U.S. Geological Survey Open-File Report 02-302, 57 p.

Repetski, J.E.., Ryder, R.T., Avary, K.L., and Trippi, M.H., 2005, Thermal maturity patterns (CAI and %Ro) in the Ordovician and Devonian rocks of the Appalachian basin in West Virginia: U.S. Geological Survey Open-File Report 2005-1087, 69 p.

Ryder, R.T., Swezey, C.S., Crangle, R.D., Jr., and Trippi, M.N., in press, Geologic cross section through the central Appalachian basin from the Findlay arch, Wood County, Ohio, to the Allegheny structural front, Pendleton County, West Virginia: U.S. Geological survey Scientific Investigations Map I-XX.

Roen, J.B. and Kepferle, R.C., eds., 1993, Petroleum geology of the Devonian and Mississippian black shale of eastern North America: U.S. Geological Survey Bulletin 1909.

Roen, J. B., and Walker, B.J., 1996, The atlas of major Appalachian gas plays: West Virginia Geological and Economic Survey Publication V-25, 201p.

Rowan, E. L., Ryder, R.T., Repetski, J.E., Trippi, M.H., and Ruppert, L.F., (2004), Initial results of a 2d burial/thermal history model through the c entral Appalachian basin, Ohio and West Virginia: U.S. Geological Survey Open-file report 2004-1445.

References (Cont.)

Schmoker, J.W., 1995, Method for assessing continuous-type (unconventional) hydrocarbon accumulations, *in* Gautier, D.L., Dolton, G.L., Takahashi, K.I., and Varnes, K.L., eds., 1995 national assessment of United States oil and gas resources-results, methodology, and supporting data: U.S. Geological Survey Digital Data Series DDS-30, 1 CD-ROM.

Schmoker, J.W., 1999, U.S. Geological Survey assessment model for continuous (unconventional) oil and gas accumulations-the "FORESPAN" model: U.S. Geological Survey Bulletin 2168, <http:// greenwood.cr.usgs.gov> Accessed December 1999.

Schmoker, J.W., 2002, Resource-assessment perspectives for unconventional gas systems: American Association of Petroleum Geologists Bulletin, v. 86, no. 11, p. 1993-1999.

Shumaker, R.C., 1980, Porous fracture facies in Devonian shales of eastern Kentucky and West Virginia: *in* Wheeler, R.L., and Dean, C.S., eds., Proceedings western limit of detachment and related structures in the Appalachian foreland: U.S. Department of Energy Morgantown Energy Technology Center DOE/METC/SP-80/23, p.124-132.

Shumaker, R.C., 1993, Structural parameters that affect Devonian Shale gas production in West Virginia and eastern Kentucky, *in* Roen, J.B., and Kepferle, R.C., 1993, Petroleum geology of the Devonian and Mississippian black shale of eastern North America: U.S. Geological Survey Bulletin 1909B, p. K1-K38.

Shumaker, R.C., 1996, Structural history of the Appalachian basin, *in* Roen, J.B., and Walker, B.J., 1996, The Atlas of Major Appalachian Gas Plays: West Virginia Geological and Economic Survey Publication V-25, p. 8-21.

U. S. Department of the Interior, undated, Success at Oil Creek: U.S. Department of Interior Historical Vignettes, 1776-1976, 16 p.

Van Tyne, A. M., Play SBI: Upper Silurian Bass Islands Trend, *in* Roen, J.B., and Walker, B.J., 1996, The Atlas of Major Appalachian Gas Plays: West Virginia Geological and Economic Survey Publication V-25, p. 130-132.

Weary, D.J., Ryder, R.T., and Nyahay, R.E., 2000, Thermal maturity patterns (CAI and %Ro) in the Ordovician and Devonian of the Appalachian basin in New York State: U.S. Geological Survey Open-File Report 00 496, 39 p.

Zelinski, R.E., and McIver, R.D., 1982, Resource and exploration assessment of the oil and gas potential in the Devonian shales of the Appalachian Basin: U.S. Department of Energy Morgantown Energy Technology Center MLM-MU-82-61-0002, DOE/DP/0053-1125, 326 p.