The MARCELLUS SHALE Play in Pennsylvania

PART 2: BASIC GEOLOGY

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PENNSYLVANIA GEOLOGICAL SURVEY EST. 1836

MARCELLUS AND OTHER DEVONIAN SHALES IN THE SUBSURFACE OF PENNSYLVANIA

Upper Devonian organic-rich shales

Middle Devonian organic-rich shales (Marcellus mostly)

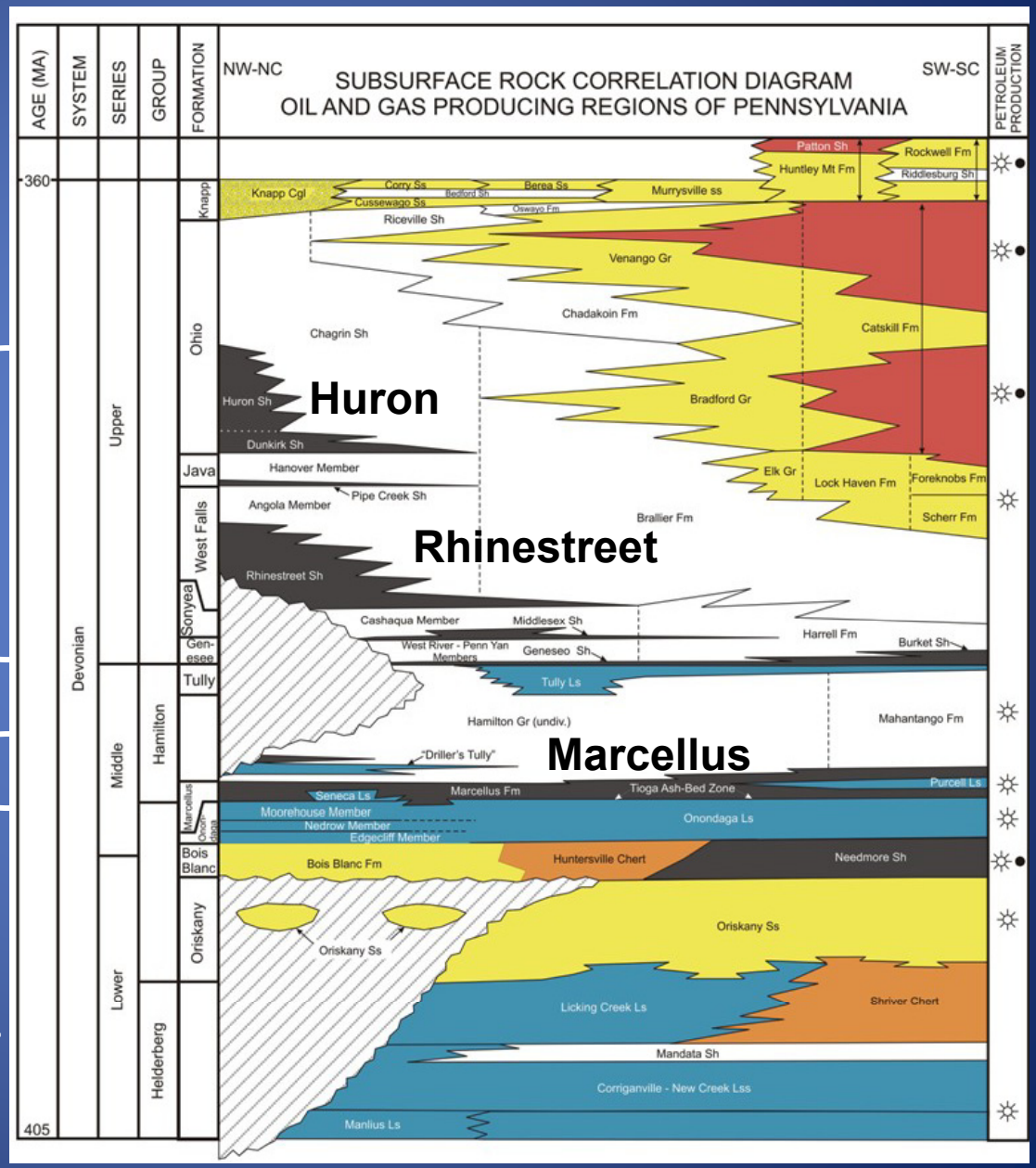
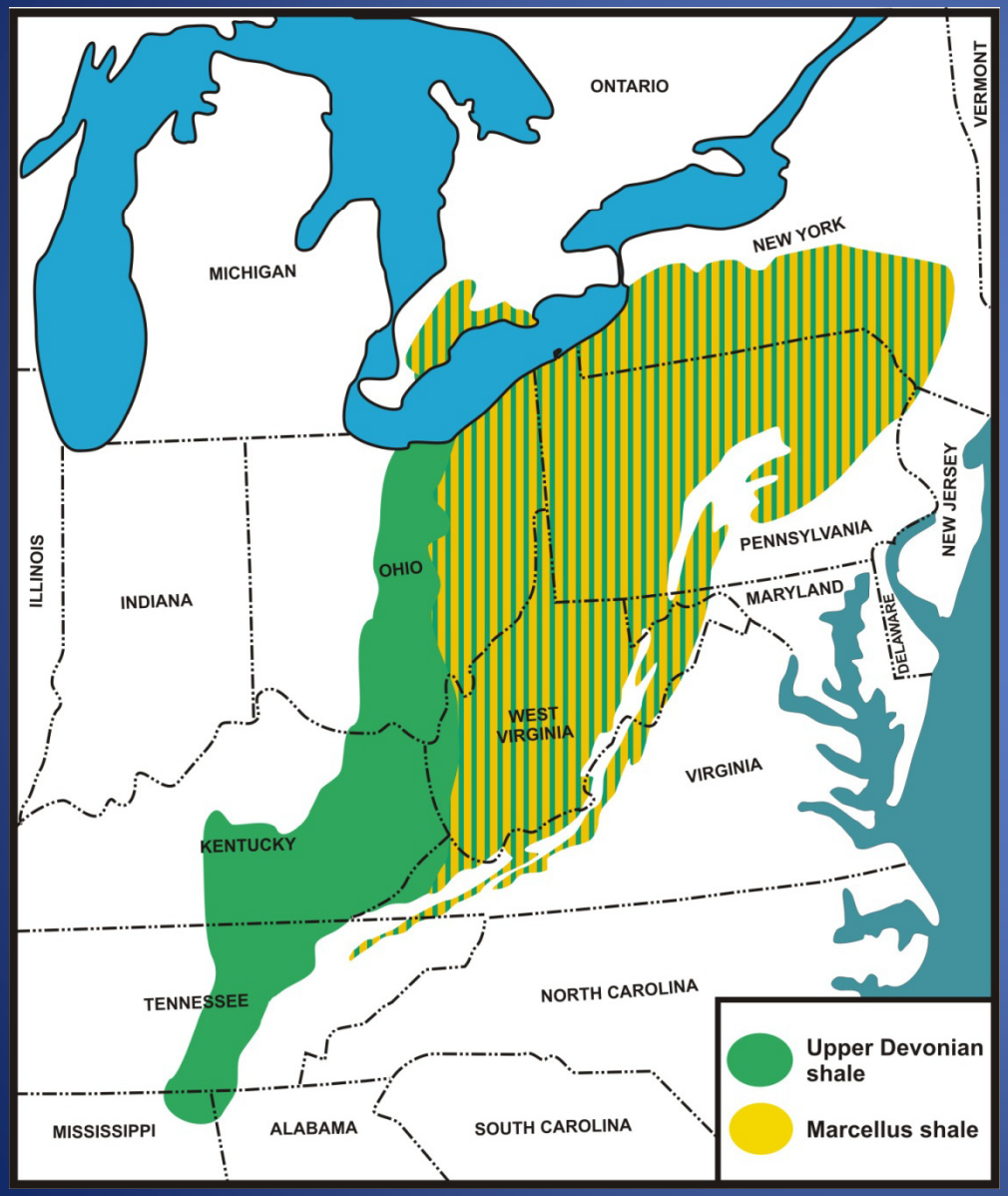


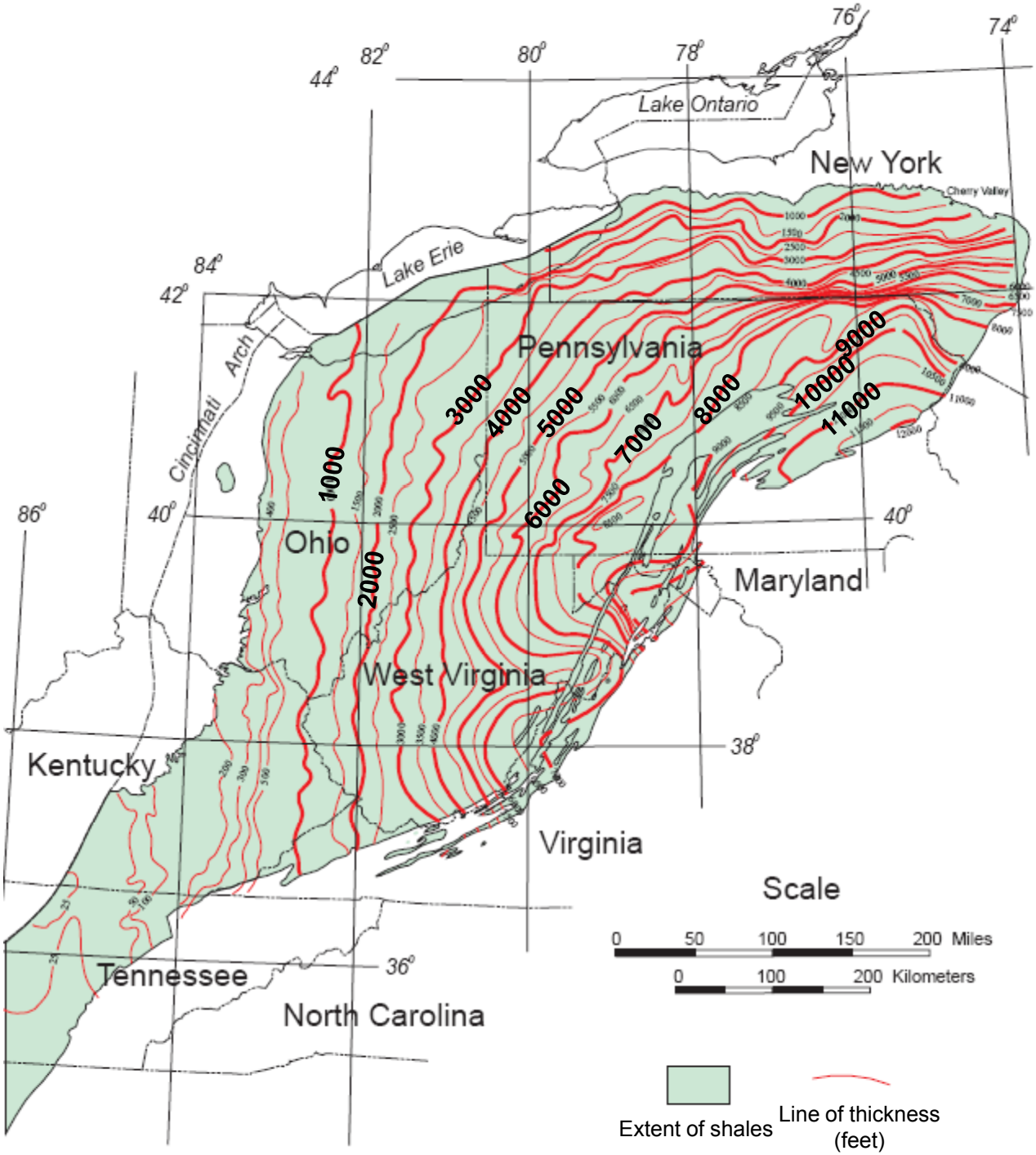
Diagram modified from Carter, 2007

EXTENT OF DEVONIAN SHALES IN THE APPALACHIAN BASIN



SOME UPPER DEVONIAN SHALES OCCUR IN THE SAME AREAS AS THE MARCELLUS, AS WELL AS FARTHER TO THE WEST AND SOUTH

Based on Milici and Swezey, 2006



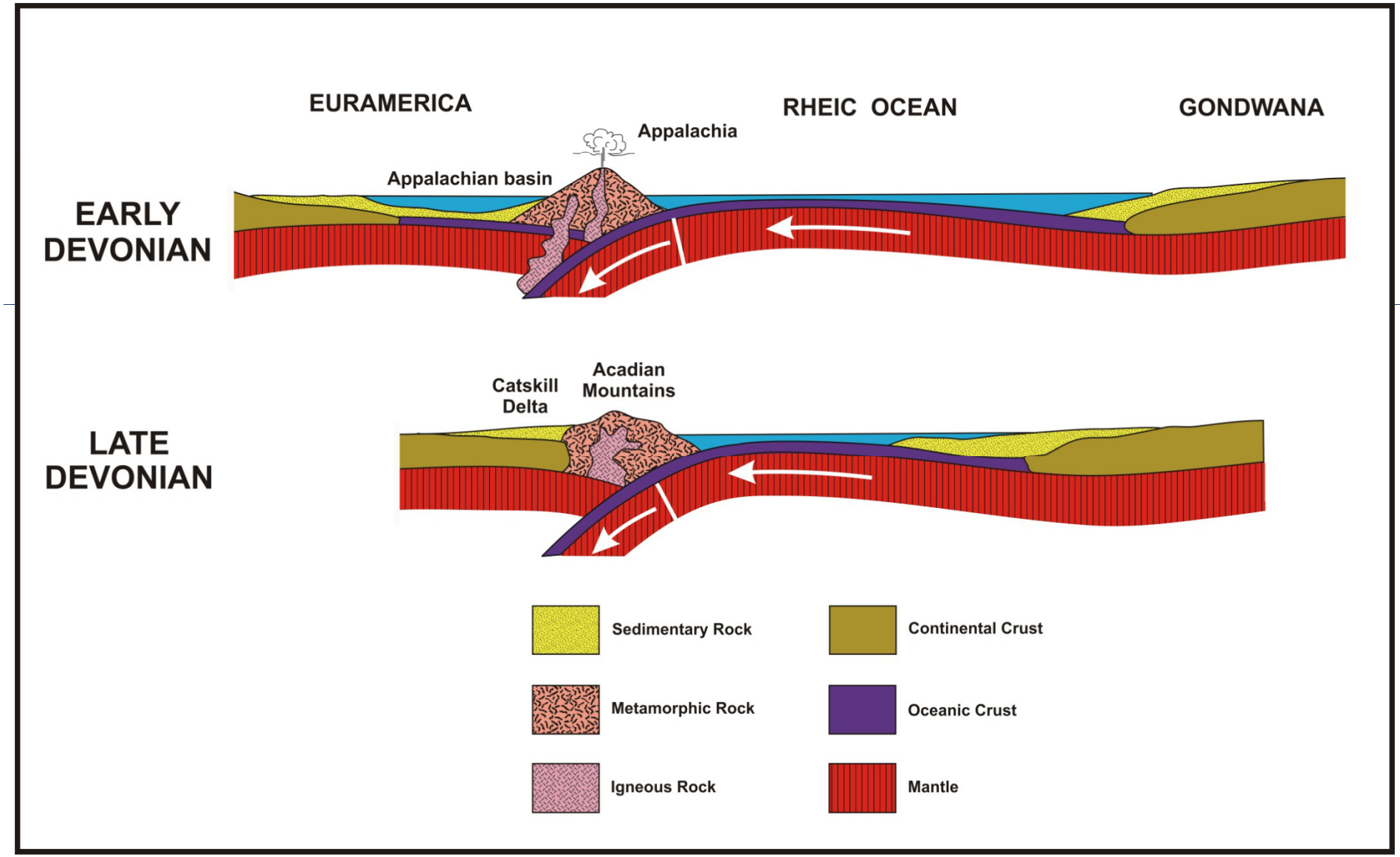
THICKNESS AND EXTENT OF THE DEVONIAN SHALE INTERVAL IN THE NORTHERN APPALACHIAN BASIN

Milici and Swezey, 2006

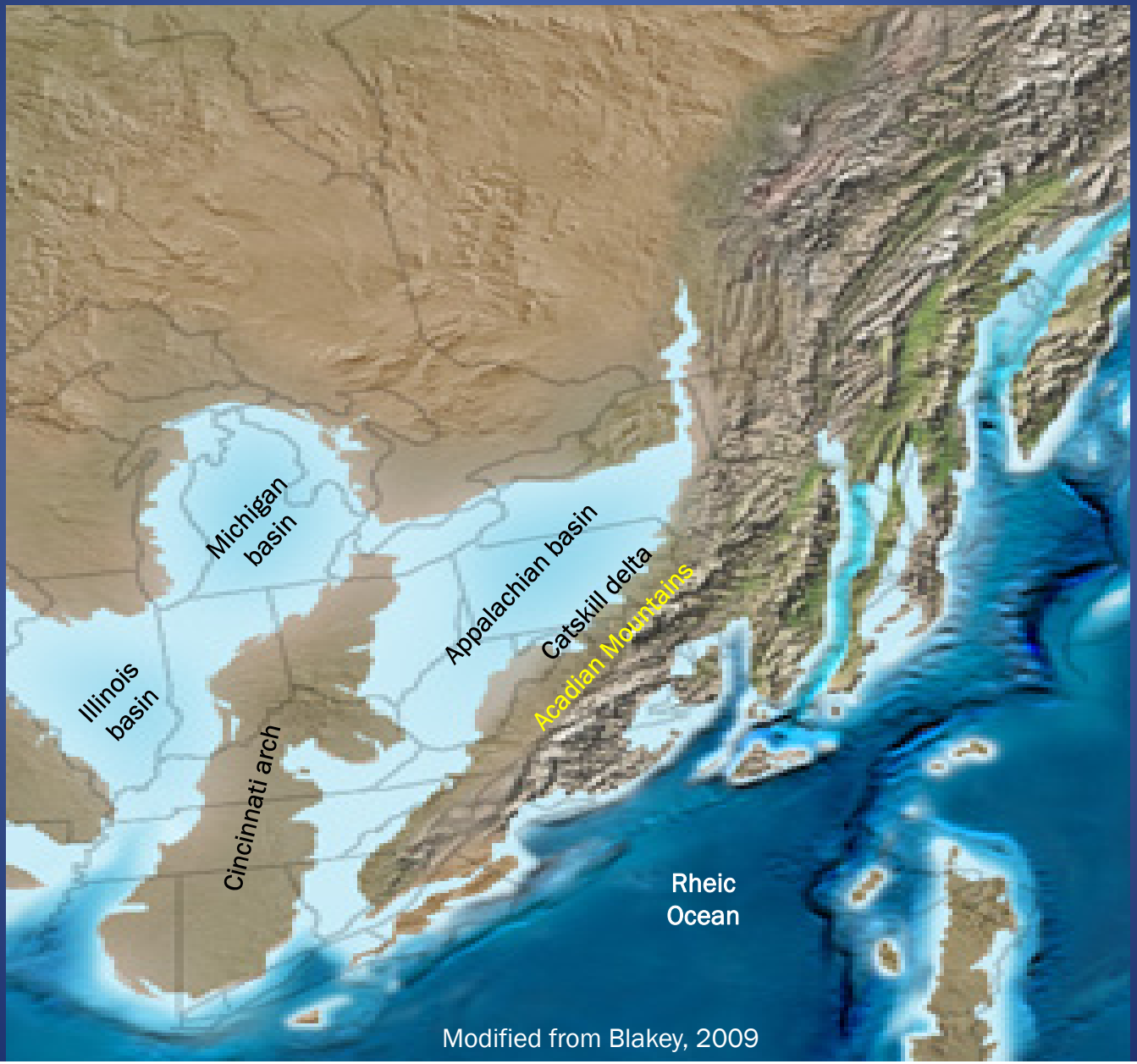
PLATE TECTONICS AND THE MARCELLUS

The Rheic Ocean, which opened about 480 million years ago, separated two major land masses, Euramerica (ancestor of North America, Europe, Greenland, and part of Asia) and Gondwana (ancestor of Africa, Antarctica, Australia, India, and South America). The oceanic plate, which carried some smaller land masses on it, began to close in the Devonian by subduction beneath the plates carrying Euramerica and Gondwana. This created the Acadian Mountains in what is now eastern North America. Erosion of the Acadian Mountains shed huge amounts of sediment into the Appalachian basin, causing it to subside rapidly (in geologic terms) in the east and forming an enormous wedge of sediment called the Catskill delta. As a result, the organic-rich Marcellus mud in central and eastern Pennsylvania was diluted and thickened with less organic-rich mud, silt, and even some sand.

DEVONIAN PLATE TECTONICS

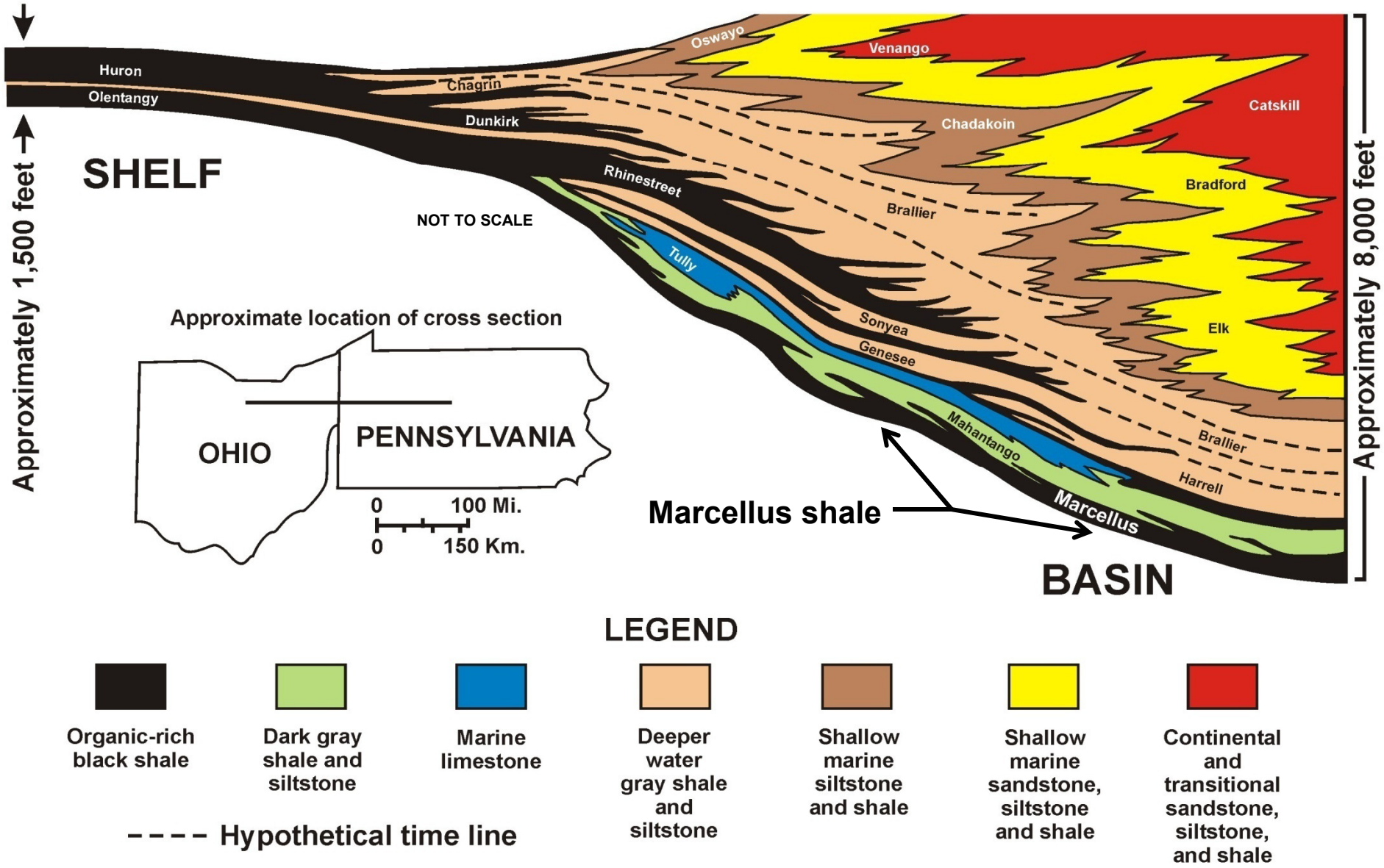


MIDDLE DEVONIAN (385 MA) PALEOGEOGRAPHY OF EURAMERICA



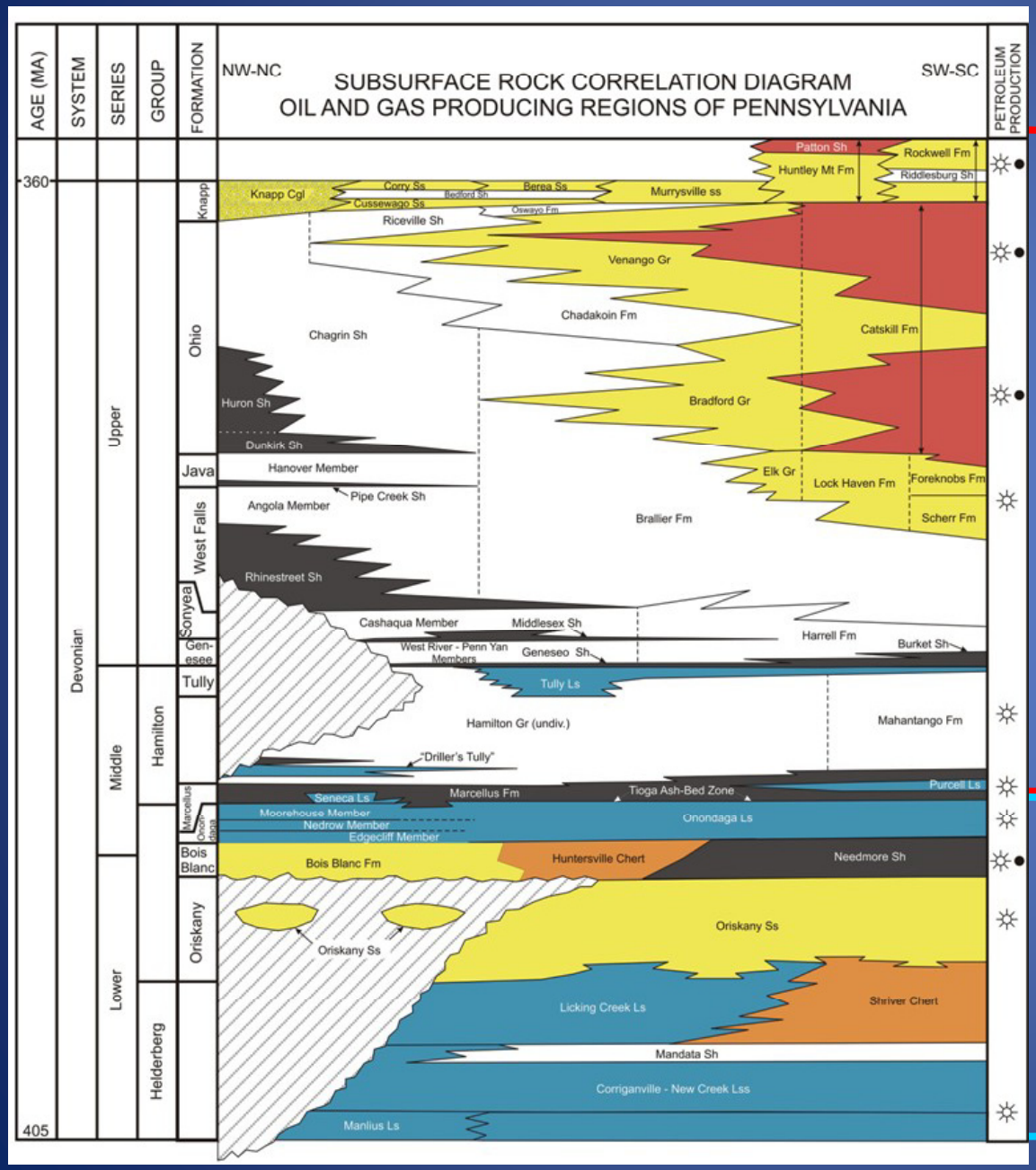
Modified from Blakey, 2009

DEVONIAN SEDIMENTS THICKENED TO THE EAST AS THE BASIN SUBSIDED



Modified from Harper, 1999

RELATIONSHIP OF TECTONICS AND DEVONIAN SEDIMENTATION

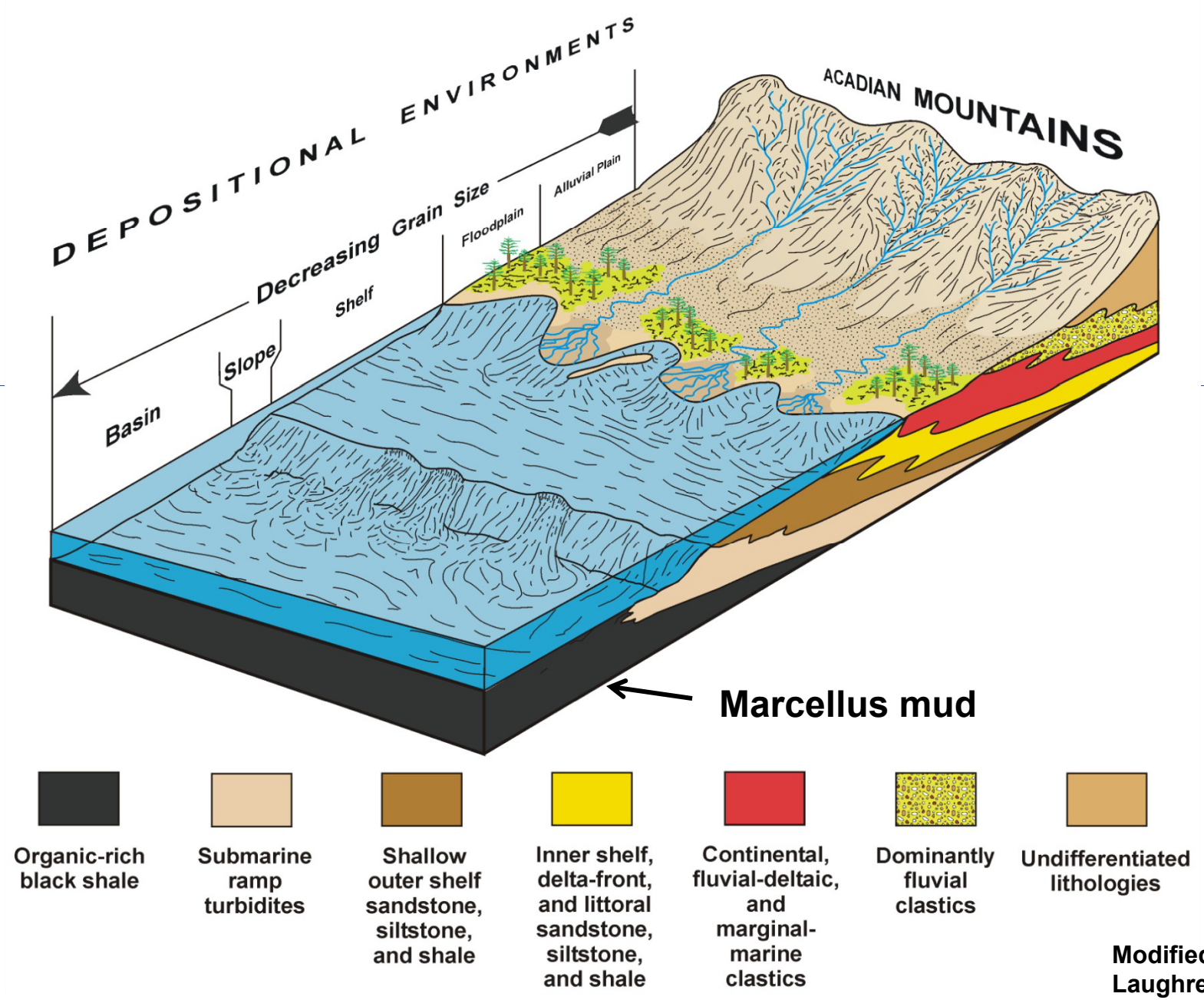


Acadian foreland basin deposits

Pre-Acadian stable continental shelf deposits

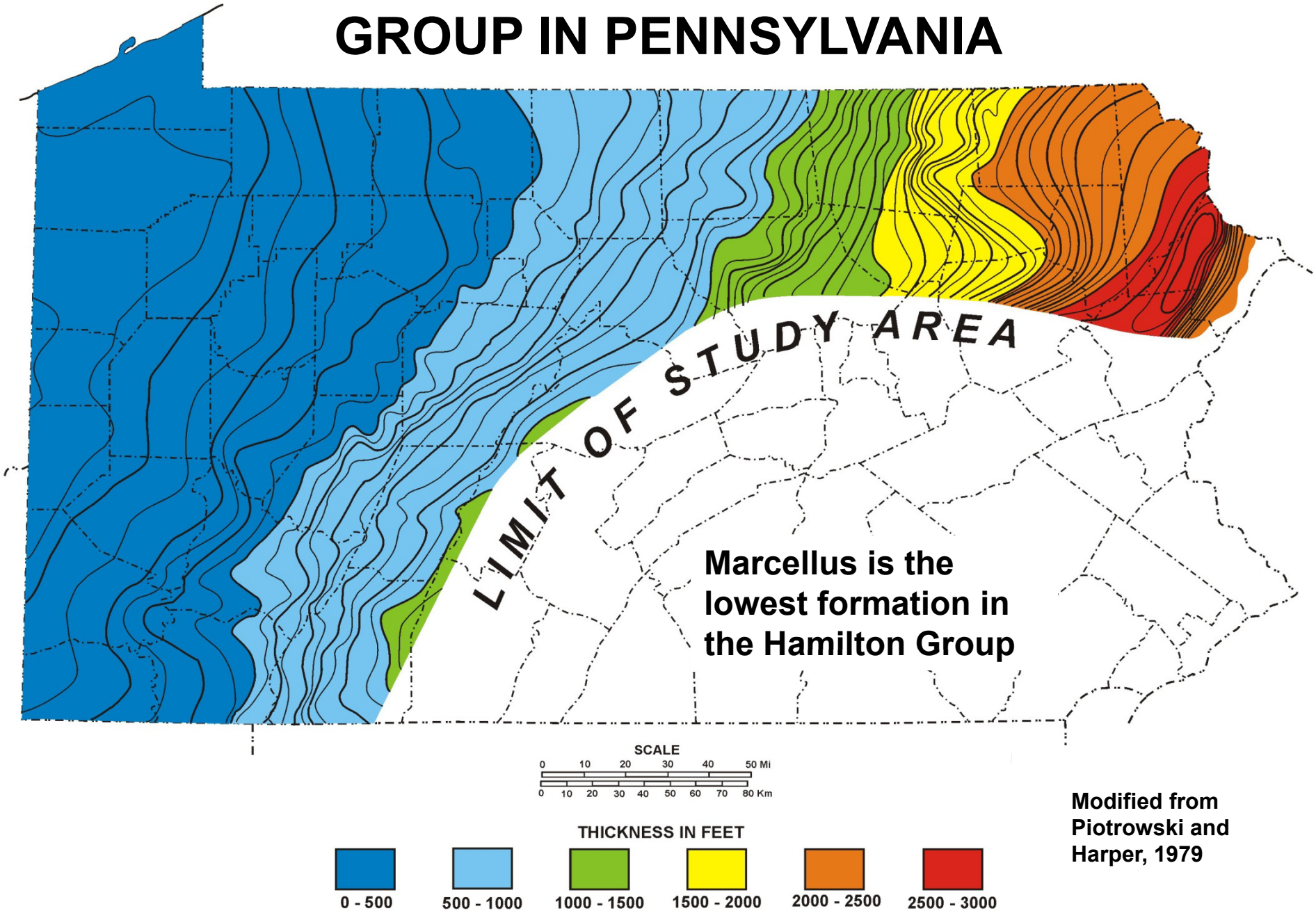
Carter, 2007

DEVONIAN DEPOSITIONAL ENVIRONMENTS



Modified from Laughrey, 2009

THICKNESS MAP OF THE HAMILTON GROUP IN PENNSYLVANIA



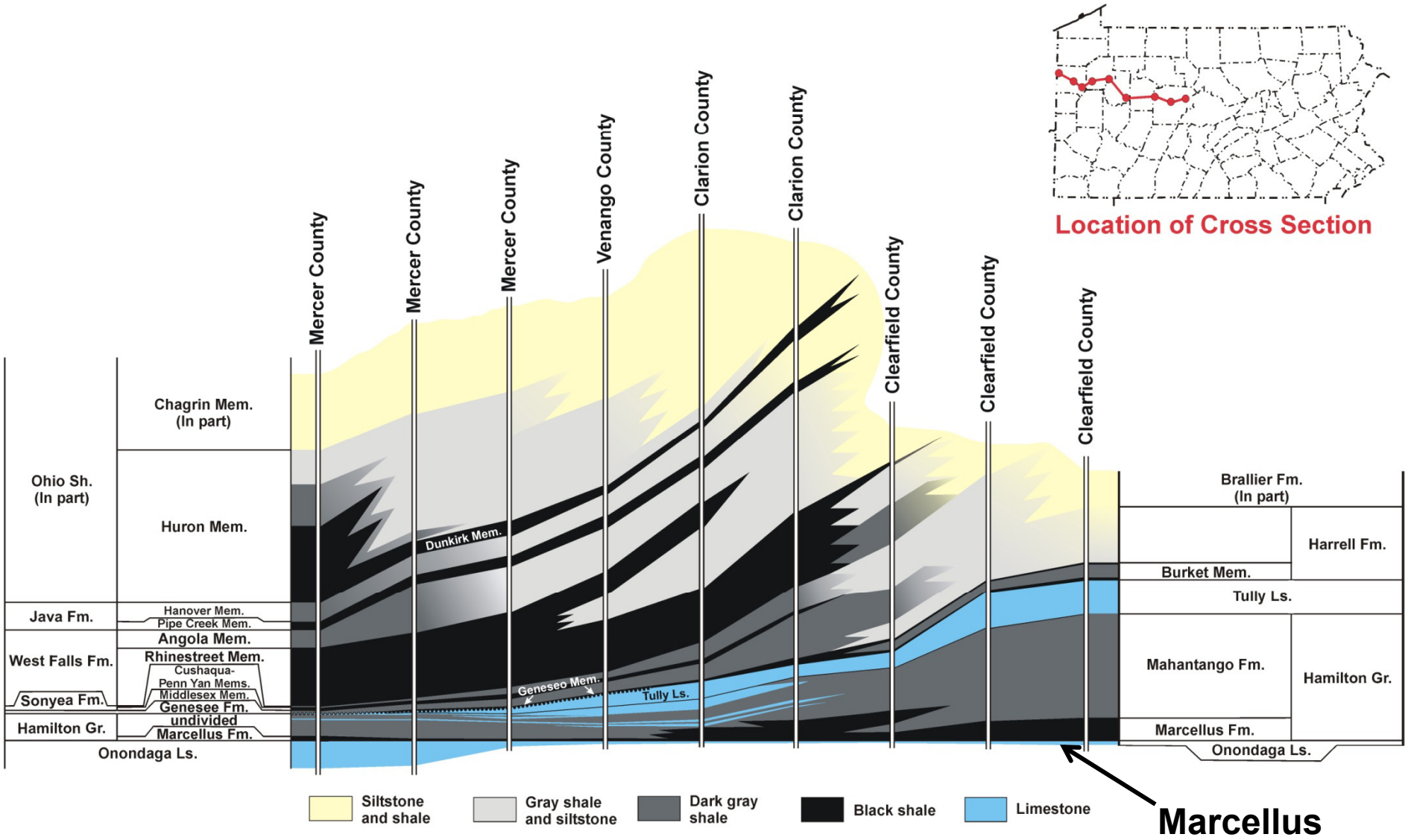
Modified from Piotrowski and Harper, 1979

HAMILTON GROUP STRATIGRAPHY

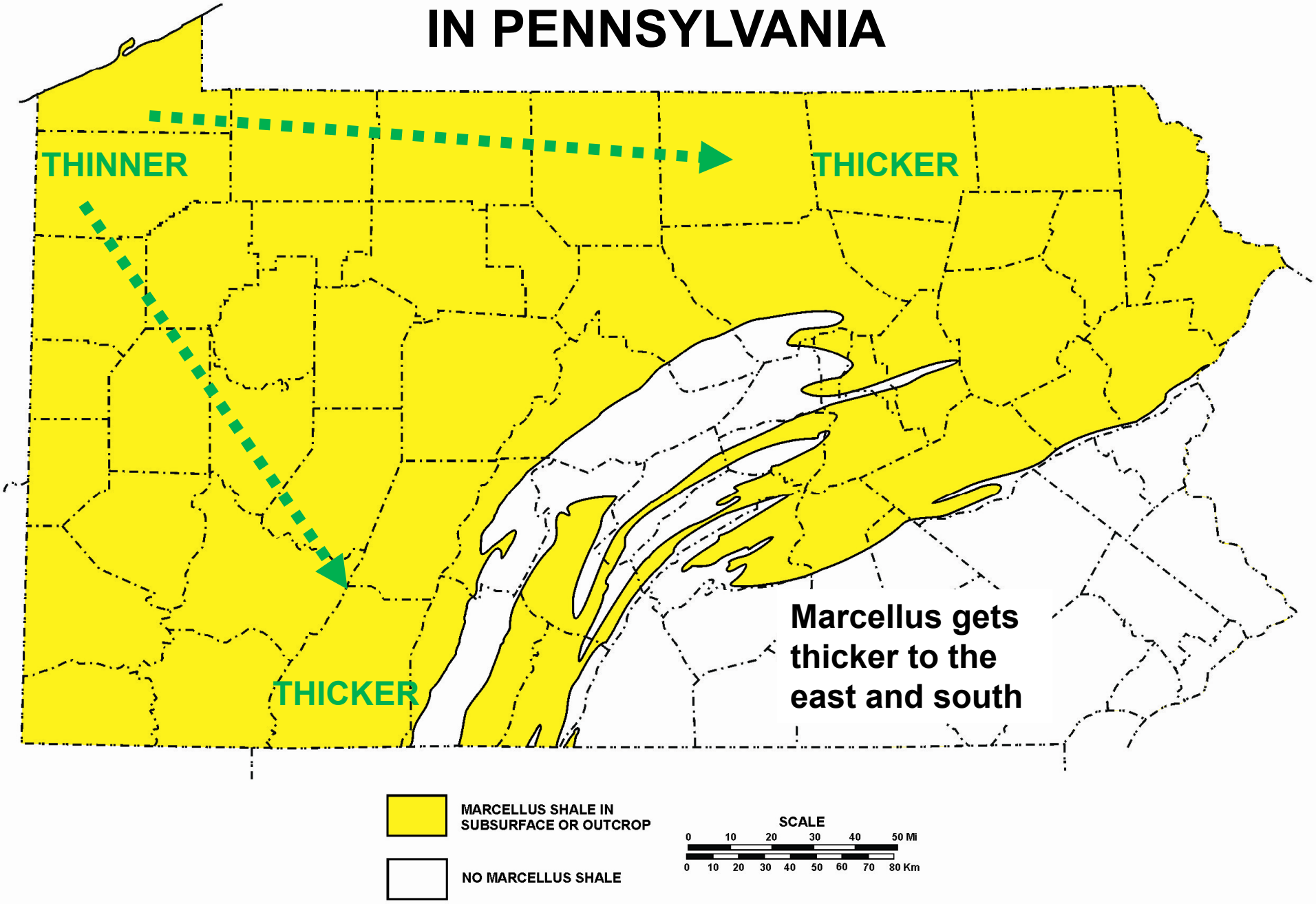
- Marcellus Formation – lowest formation of the Hamilton group with highest organic richness
- Skaneateles, Ludlowville, and Moscow formations – post-Marcellus interval in western and north-central PA, contains less organic-rich shale and limestone
- Mahantango Formation – post-Marcellus interval in central and eastern PA,contains significant siltstones and sandstones

CROSS SECTION OF WESTERN PENNSYLVANIA SHOWING MARCELLUS AND OTHER ORGANIC-RICH SHALES

NOT TO SCALE

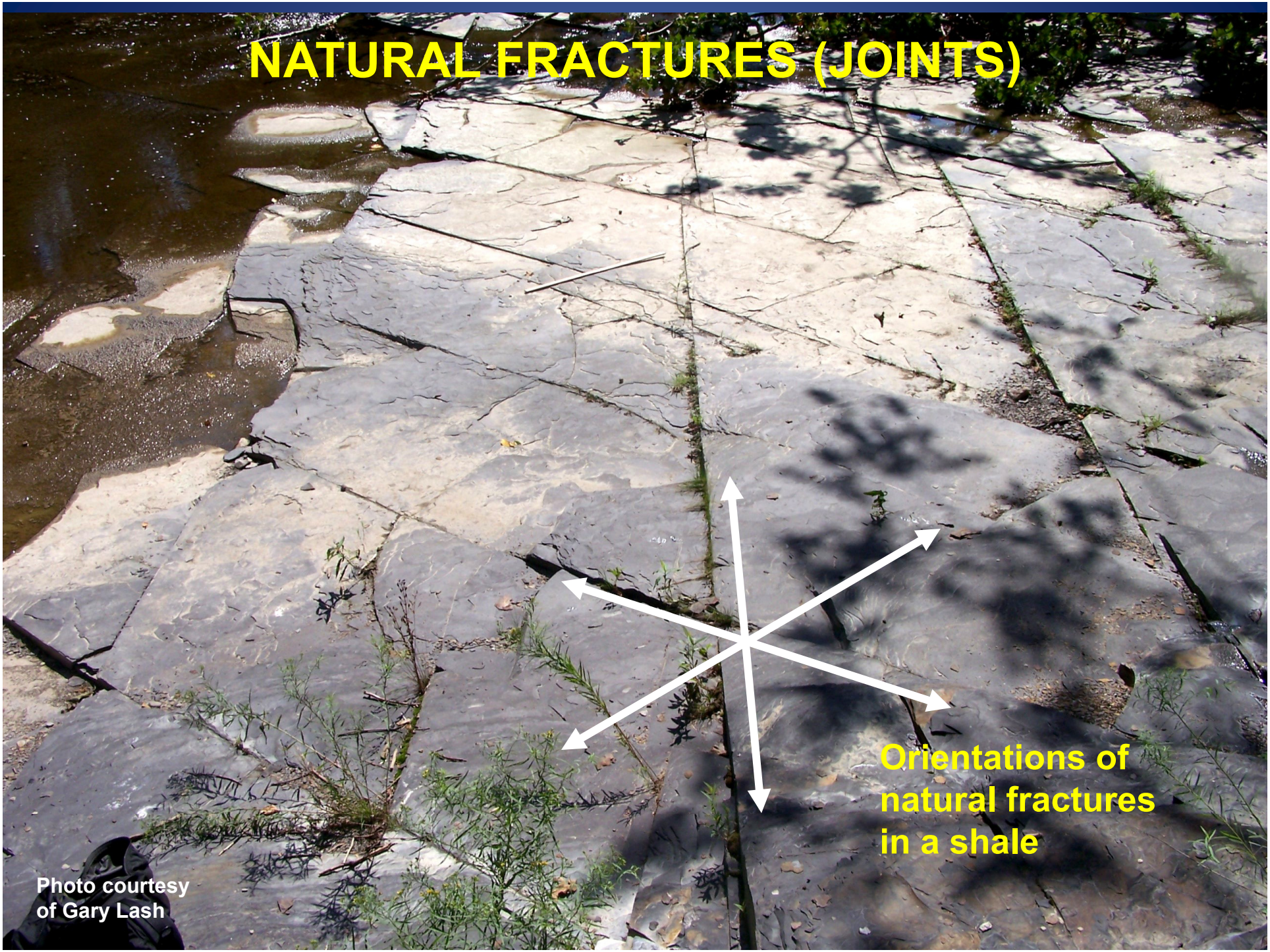


EXTENT OF MARCELLUS FORMATION IN PENNSYLVANIA



THE IMPORTANCE OF JOINTS (NATURAL FRACTURES)

- Geologists have known for centuries about natural fractures, called "joints", that are created as a result of stress and strain on brittle rock
- You can see joints in every exposure of rock along roads and streams – they usually result from a combination of tectonics (mountain building) and erosion (removing the weight of overlying rocks)
- Penn State professor Terry Engelder (2004) recognized a set of joints created prior to the formation of the Allegheny Mountains that are oriented ENE-WSW
- He and others determined that these joints, called J1, were formed by natural hydraulic fracturing as fluids were expelled from the Marcellus and other Devonian organic-rich shales (source rocks) during the emplacement of hydrocarbons in Pennsylvania's oil and gas reservoirs, about 300 million years ago
- J1 joints are approximately perpendicular to J2, a very prominent set of tectonic joints oriented across the grain of the Allegheny Mountains, approximately NW-SE


NATURAL FRACTURES (JOINTS)
Orientations of natural fractures in a shale
Photo courtesy of Gary Lash

ORIENTATIONS OF J1 AND J2 JOINTS

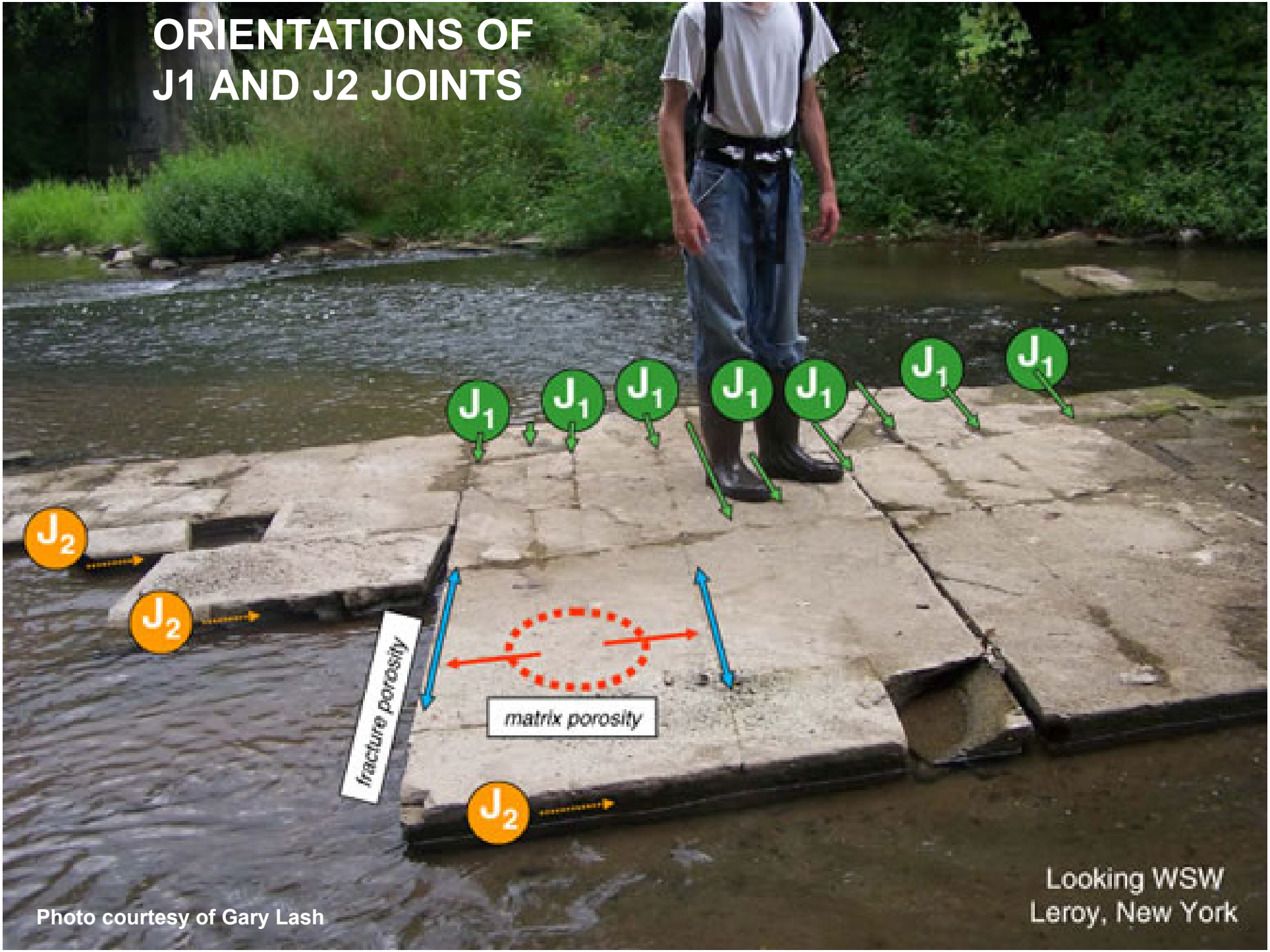
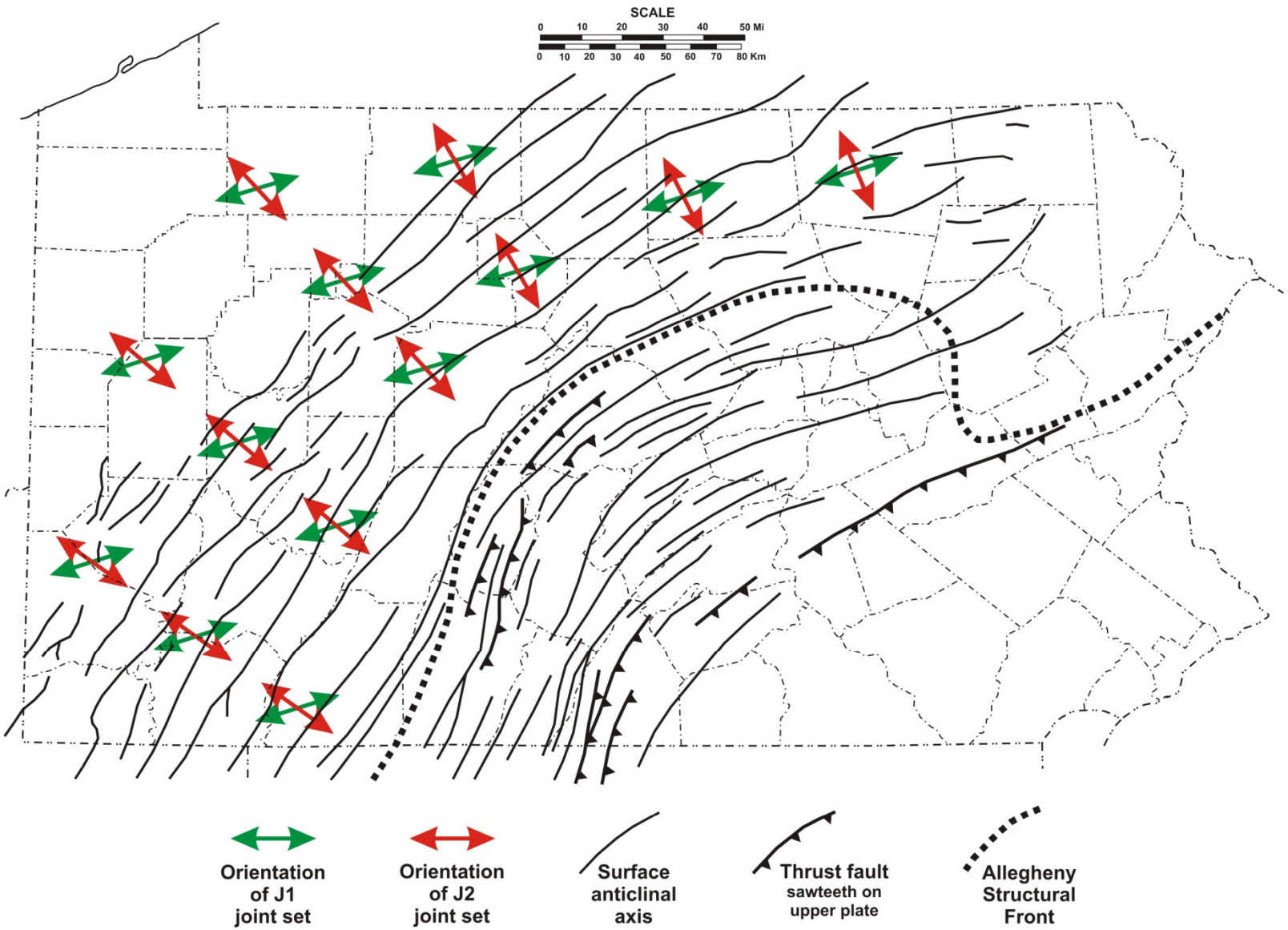


Photo courtesy of Gary Lash

APPROXIMATE ORIENTATIONS OF J1 AND J2 JOINT SETS IN THE MARCELLUS SHALE OF PENNSYLVANIA



SO – WHAT EXACTLY IS THE IMPORTANCE OF JOINTS IN THE MODERN MARCELLUS PLAY?

For the answer, see:

THE MARCELLUS SHALE PLAY IN PENNSYLVANIA

PART 4: DRILLING AND COMPLETION

at

http://www.dcnr.state.pa.ustopogeo/oilandgas/04%20-%20DRILLING%20AND%20COMPLETION.pdf

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