

## Attachment 7

### The Northern Appalachian Coal Basin

The Northern Appalachian Coal Basin is the northernmost of the three basins comprising the Appalachian Coal Region of the eastern United States, and includes parts of the States of Pennsylvania, West Virginia, Ohio, Kentucky, and Maryland (Figure A7-1). The basin trends northeast-southwest and the Rome Trough, a major graben structure, forms the southeastern and southern structural boundaries (Kelafant et al., 1988). The basin is bounded on the northeast, north, and west by outcropping Pennsylvanian-aged sediments (Kelafant et al., 1988). The basin lies completely within the Appalachian Plateau geomorphic province, covering an area of approximately 43,700 square miles (Adams et al., 1984 as cited in Pennsylvania Department of Conservation and Natural Resources, 2002). It consists of six Pennsylvanian age coal units, and contains an estimated 61 trillion cubic feet of coalbed methane (Kelafant et al., 1988). Coal seam depths range from surface outcrops to up to 2,000 feet below ground surface, with most coal occurring at depths shallower than 1,000 feet (Quarterly Review, 1993). Annual coalbed methane production stood at 1.41 billion cubic feet in 2000 (GTI, 2002).

#### 7.1 Basin Geology

The six Pennsylvanian aged coal zones located within the Northern Appalachian Coal Basin are the Brookville-Clarion, Kittanning, Freeport, Pittsburgh, Sewickley, and the Waynesburg. These coal units are contained within the Pottsville, Allegheny, and the Monongahela Groups (Figure A7-3) (Kelafant et al., 1988).

In the Northern Appalachian Basin, the Pottsville stratigraphic group is generally 200 to 300 feet thick, and thins to the north and west into Ohio and Pennsylvania (Kelafant et al., 1988). The coals in this group are interbedded with fluvial and deltaic sands and shales and are capped by marine limestones and shales (Kelafant et al., 1988).

Deposition of this group took place on irregular Mississippian terrain, forming thin and erratic coals (Kelafant et al., 1988).

The Allegheny Group reaches a maximum thickness of 200 to 300 feet in western Maryland and thins westward to about 150 to 200 feet in Ohio. Deposition of this group occurred as cyclothem-type sedimentation, resulting in a complex sequence of lenticular, thin- to massive-bedded subgraywacke, shale, and mudstone interbedded with clays and coal (Kelafant et al., 1988). Due to their alluvial and delta plain depositional environments, Allegheny coals, which include the Brookville/Clarion, Kittanning, and the Freeport, are 2 to 6 feet thick and aerially extensive (Kelafant et al., 1988). The coalbeds decrease in number from the eastern to the western edge of the basin (Kelafant et al., 1988).

The Monongahela Group was deposited primarily in lacustrine and swamp environments. Some of the most important economic coals of the basin were deposited in large lakes, such as the Pittsburgh and Sewickley coals (Kelafant et al., 1988). The Monongahela Group is thickest along the Monongahela River at 400 feet and thins to 250 feet in the southwest along the Ohio River. Shales, mudstones, and freshwater limestones are the major rock types of the Group (Kelafant et al., 1988). The Waynesburg coals are also contained within the Monongahela Group. In general, the coalbeds of the Monongahela Group are laterally extensive.

The total thickness of the Pennsylvanian-aged coal system averages 25 feet; however, better-developed seams within the coal zones can increase in thickness by up to twice the average (Quarterly Review, 1993). Within the Pennsylvanian Coal System, the deepest coal, the Brookville-Clarion, ranges in depth from surface exposures in anticlines to 2,000 feet below ground surface. The Kittanning Group reaches a maximum depth of 2,000 feet and is approximately 800 feet deep in more than half the area in which the group occurs. The distance between the Upper and Lower Kittanning is approximately 100 feet (Kelafant et al., 1988). Freeport coals are at a maximum depth of 1,800 feet in the central portion of the Northern Appalachian Coal Basin. The Upper and Lower Freeport are separated vertically by a distance of 40 to 60 feet (Kelafant et al., 1988). The Pittsburgh coals achieve a maximum depth of 1,200 feet and roughly half of the coals can be found at depths greater than 400 feet (Kelafant et al., 1988). Sewickley coals are deeper than 400 feet with the deepest coals located at 1,200 feet below ground surface (Kelafant et al., 1988). The final and youngest group discussed here, the Waynesburg group, is the shallowest, reaching a maximum depth of 800 feet in the center of the basin. Figures A7-4 through A7-9 (adapted from Kelafant et al., 1988) are isopach maps of sediment cover for the six major coal zones of the Appalachian Coal Basin.

## 7.2 Basin Hydrology and USDW Identification

The Northern Appalachian Basin is situated in the Appalachian Plateaus physiographic province of the region. The primary aquifer in this area is a Pennsylvanian sandstone aquifer underlain by limestone aquifers (National Water Summary, 1984). Water wells are typically 75 to 100 feet in depth in the Pennsylvanian aquifer and commonly produce one to five gallons per minute of water (National Water Summary, 1984). The primary aquifers in the Maryland portion of the basin are Appalachian sedimentary aquifers, which are mostly sandstones, shales, and siltstones with some limestone, dolomite, and coal. Water wells here are typically 30 to 400 feet in depth and usually produce 10 to 100 gallons per minute of water (National Water Summary, 1984).

In Ohio, the primary aquifers are sandstone aquifers, shaly sandstone and carbonate aquifers, and coarse-grained aquifers (comprised of alluvium and glacial outwash) associated with river valleys (National Water Summary, 1984). Water wells within these aquifers typically range from 25 to 300 feet in depth, and common water production rates vary between 1 and 500 gallons per minute (National Water Summary, 1984).

In Pennsylvania, the primary aquifers are sandstone and shale aquifers, with smaller unconsolidated sand and gravel aquifers surrounding river courses (National Water Summary, 1984). Well depths in the sandstone and shale aquifers in Pennsylvania are usually 80 to 200 feet in depth, and the wells typically produce 5 to 60 gallons per minute of water (National Water Summary, 1984).

In West Virginia, the primary aquifer is an Upper Pennsylvanian-aged aquifer consisting of the Dunkard, Monongahela, and Conemaugh Groups (National Water Summary, 1984). This aquifer consists of nearly horizontal beds of shale, sandstone, siltstone, coal, and limestone (National Water Summary, 1984). Water wells typically extend from 50 to 300 feet in depth in this area of West Virginia, and commonly produce 1 to 30 gallons per minute of water (National Water Summary, 1984).

Individual states containing portions of the basin have developed various maps and documents locating underground sources of drinking water (USDWs) and aquifers within their state boundaries, mostly as a part of their respective Underground Injection Control (UIC) Programs. EPA's Regional Office also has information concerning the location of these resources, as not all states within the Northern Appalachian Coal Basin have primacy over their UIC Program. Water quality data from eight historic Northern Appalachian Coal Basin projects show that estimated total dissolved solids (TDS) levels ranged from 2,000 to 5,000 milligrams per liter (mg/L) at depths ranging from 500 to 1,025 feet below ground surface (Zebrowitz et al., 1991), well within EPA's water quality criterion for a USDW of less than 10,000 mg/L of TDS (40 CFR §144.3).

Most states within the Northern Appalachian Basin, including Kentucky, Ohio, and West Virginia have mapped the interface between saline and freshwater aquifers. For Maryland and Pennsylvania, no maps have been identified that define the interface between saline and freshwater aquifers. In Maryland, a deep well drilled in southern Garrett County encountered the fresh/saltwater interface at a depth of 940 feet (Duigon and Smigaj, 1985). Groundwater in Pennsylvania deeper than 450 feet is not considered to be a USDW (Platt, 2001) because of the existence of non-water producing shale from 450 to 1000 feet, and TDS levels in water below this shale that are typically greater than 100,000 mg/L. The following table contains information concerning the relative location of potential USDWs and potential methane-bearing coalbeds in the Northern Appalachian Coal Basin.

As shown in Table A7-1, coalbeds with methane production potential in the Northern Appalachian Basin do occur within USDWs, indicating the potential for impact. West Virginia's interface line between fresh and saline water (Foster, 1980) is based on a qualitative assessment, Ohio's interface line is based on a TDS level of 3,000 mg/L (Sedam and Stein, 1970), and Kentucky's interface line is based on a TDS level of 1,000 mg/L (Hopkins, 1966). In Maryland, the fresh water distinction was probably made based on a TDS level of 1,000 mg/L, as the reference refers to sodium and chloride concentrations of 1,800 mg/L and 2,900 mg/L as "high levels" (Duigon and Smigaj, 1985).

**Table A7-1. Relative Locations of USDWs and Methane-Bearing Coalbeds**

Northern Appalachian Coal Basin, States and Coal Groups	Pennsylvania		West Virginia		Ohio		Kentucky		Maryland	
	Depth to top of Coal (ft)	Depth to Base <sup>3</sup> of Fresh Water (ft)	Depth to top of Coal <sup>2</sup> (ft)	Depth to Base <sup>4</sup> of Fresh Water <sup>1</sup> (ft)	Depth to top of Coal <sup>2</sup> (ft)	Depth to Base <sup>6</sup> of Fresh Water <sup>1</sup> (ft)	Depth to top of Coal <sup>2</sup> (ft)	Depth to Base <sup>5</sup> of Fresh Water <1,000 mg/L TDS (ft)	Depth to top of Coal <sup>2</sup> (ft)	Depth to Base <sup>7</sup> of Fresh Water <sup>1</sup> (ft)
<b>Waynesburg</b>	0 to 800		0 to 800		0 to 400		0 to <400		0 to <400	
<b>Sewickly</b>	0 to 1200		0 to 1200		0 to < 800		0 to <400		0 to <400	
<b>Pittsburgh</b>	0 to 1200		0 to 1200	~ 150 to 500	0 to 800	~ 100 to 500	0 to <400	~ 100 to 500	0 to <400	~ 940
<b>Freepport</b>	0 to 1600	~ 450	0 to 1600	500	0 to <1200	500	0 to <400	500	0 to <400	
<b>Kittanning</b>	0 to 2000		0 to 2000		0 to <1200		0 to <400		0 to <400	
<b>Brookville/Clarion</b>	<400 to 2000		<400 to 2000		< 400 to 1200		<800		<800	

<sup>1</sup> Note: The base of "fresh water" is not necessarily the base of the USDW. Fresh water is within the USDW and the base of fresh water is above the base of the USDW. "Fresh water" is water with <1000 mg/L TDS.

<sup>2</sup> Kelafant et al., 1988

<sup>3</sup> Platt, USEPA Region 3, personal communication 2001

<sup>4</sup> Foster, 1980

<sup>5</sup> Hopkins, 1966 and USGS, 1973

<sup>6</sup> Sedam and Stein, 1970 and USGS, 1971

<sup>7</sup> Duigon, 1985

Therefore, in these states, the depth to the 10,000 mg/L level of TDS in groundwater is potentially and likely deeper than the depths presented above (Table A7-1). This assumption is confirmed by a structure elevation map (Figure A7-6) of the Upper and Lower Freeport Sandstones of the Upper Allegheny Group (Figure A7-3) in Ohio. With the increasing depth of these stratigraphic units toward the basin center, much of the formation waters in these units south of the easternmost counties in Ohio contain TDS levels in excess of 10,000 mg/L (Vogel, 1982). Likewise, the Pittsburgh Group Coals in Pennsylvania range in depth from outcrop to 1,200 feet below ground surface (Figure A7-7). Over this length of “dip”, it is likely that the coals intersect drinking water aquifers before they reach depths where TDS levels exceed the 10,000 mg/L TDS water quality criterion of a USDW.

### 7.3 Coalbed Methane Production Activity

Coalbed methane has been produced in commercial quantities from the Pittsburgh coalbed of the Northern Appalachian Coal Basin since 1932 (Lyons, 1997), after the 1905 discovery of the Big Run Field in Wetzel County, West Virginia (Hunt and Steele, 1991). Coalbed methane production development in the Northern Appalachian Basin has lagged, however, due to insufficient reservoir knowledge, inadequate well completion techniques, and coalbed gas ownership issues revolving around whether the gas is owned by the mineral owner or the oil and gas owner (Zebrowitz et al., 1991). Annual coalbed methane production stood at 1.41 billion cubic feet in 2000 (GTI, 2002). As of October 2002, 185 coalbed methane wells were producing coalbed methane in Pennsylvania (Pennsylvania Department of Conservation and Natural Resources, 2002). Discharge of produced waters has also proven to be problematic (Lyons, 1997) for coalbed methane field operators in the Northern Appalachian Coal Basin.

Some operators in the Northern Appalachian Coal Basin and several test projects are discussed below. As of 1993, O'Brien Methane Production, Inc. had at least 20 wells in southern Indiana County, Pennsylvania (Quarterly Review, 1993). They received a water treatment and discharge permit that allowed O'Brien to discharge produced water into Blacklick Creek. The wells in O'Brien's field were hydraulically fractured with water and sand. Nitrogen was being contemplated for future fracturing. O'Brien's operations have since been assumed by Belden and Blake. BTI Energy, Inc. also had a few coalbed wells in northern Fayette County, Pennsylvania. Two were completed in 1993 and the firm held permits for eight additional wells.

Other projects in the basin included the Lykes/Emerald Mines Project of the United States Bureau of Mines (USBM) and the Penn State University/Carnegie Natural Gas/U.S. Steel Wells Project, both in Greene County, Pennsylvania. Depths to the top of the Pittsburgh coals in Greene County range from 800 to 1,200 feet below ground surface (Kelafant et al., 1988). Hydraulic fracturing fluids included water and sand, and nitrogen foam and sand (Hunt and Steele, 1991). The Christopher Coal Company/Spindler Wells Project, which took place from 1952 to 1959, fractured one well with 12 quarts of

nitroglycerin (Hunt and Steele, 1991). In the Vesta Mines Project of Washington County, Pennsylvania, the USBM used gelled water and sand to complete five wells in the Pittsburgh Seam (Hunt and Steele, 1991).

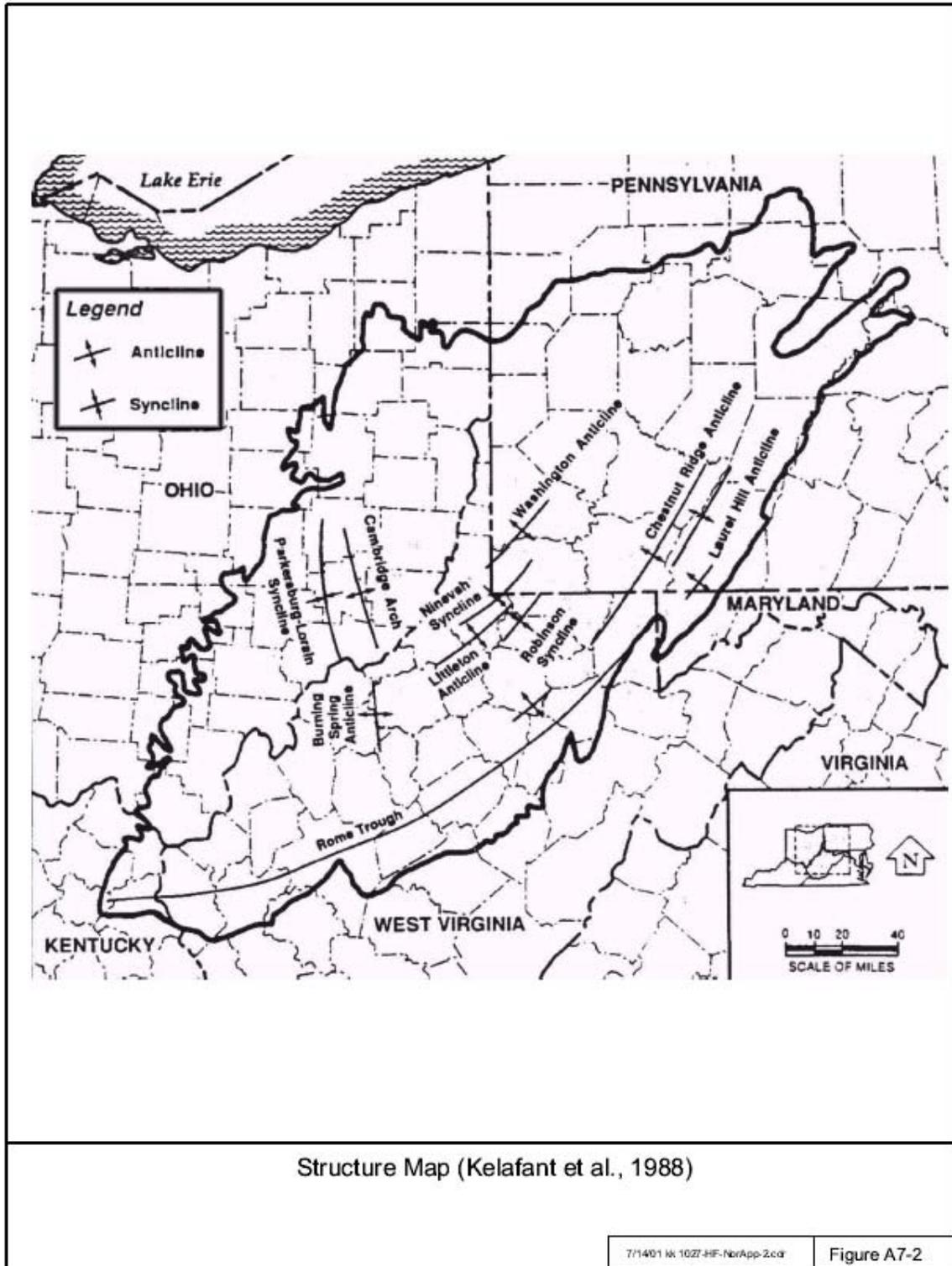
Within the State of Pennsylvania, there have been complaints of methane migrating into water supplies (Markowski, 2001). According to the Pennsylvania Department of Conservation and Natural Resources (2002), none of these complaints were linked specifically to hydraulic fracturing of coalbed methane wells. During a telephone interview (Markowski, 2001), Ms. Markowski stated methane contamination is due to the fact that many coalbed methane wells in southwestern Pennsylvania are completed in abandoned mine shafts. A puncture in the roof of the mineshaft provides a migration pathway for methane into overlying groundwater. These wells are known as gob wells, and are not usually hydraulically fractured or stimulated.

#### **7.4 Summary**

Based on available information, coal seams with methane production potential are located within USDWs throughout the Northern Appalachian Coal Basin, and hydraulic fracturing takes place in this basin. Because most of the coal strata dip, a well's location within the basin determines whether it is within a USDW, and whether the potential for impact exists. For example, in the Pittsburgh Coal Zone in Pennsylvania, the depth to the top of this coal zone varies from outcrop to about 1,200 feet in the very southwestern corner of the state. The approximate depth to the bottom of the USDW is 450 feet. Therefore, production wells operating down to approximately 500 feet could potentially be hydraulically connected to the USDW. However, those wells operating at depths greater than 900 feet would probably not be hydraulically connected to the USDW, unless a fracture extending beyond the coal layers to the shallower aquifer was to occur.

Milici (2002) indicated that the Pittsburgh Coal in Pennsylvania is mined out along its outcrop and the remaining coal resources are deeper (> 450 feet) in the basin. While this situation would greatly minimize the possibility of water quality impacts for this coal zone in Pennsylvania, the potential for contamination from the Pittsburgh coalbeds in other states within the basin still exists (see Table A7-1).

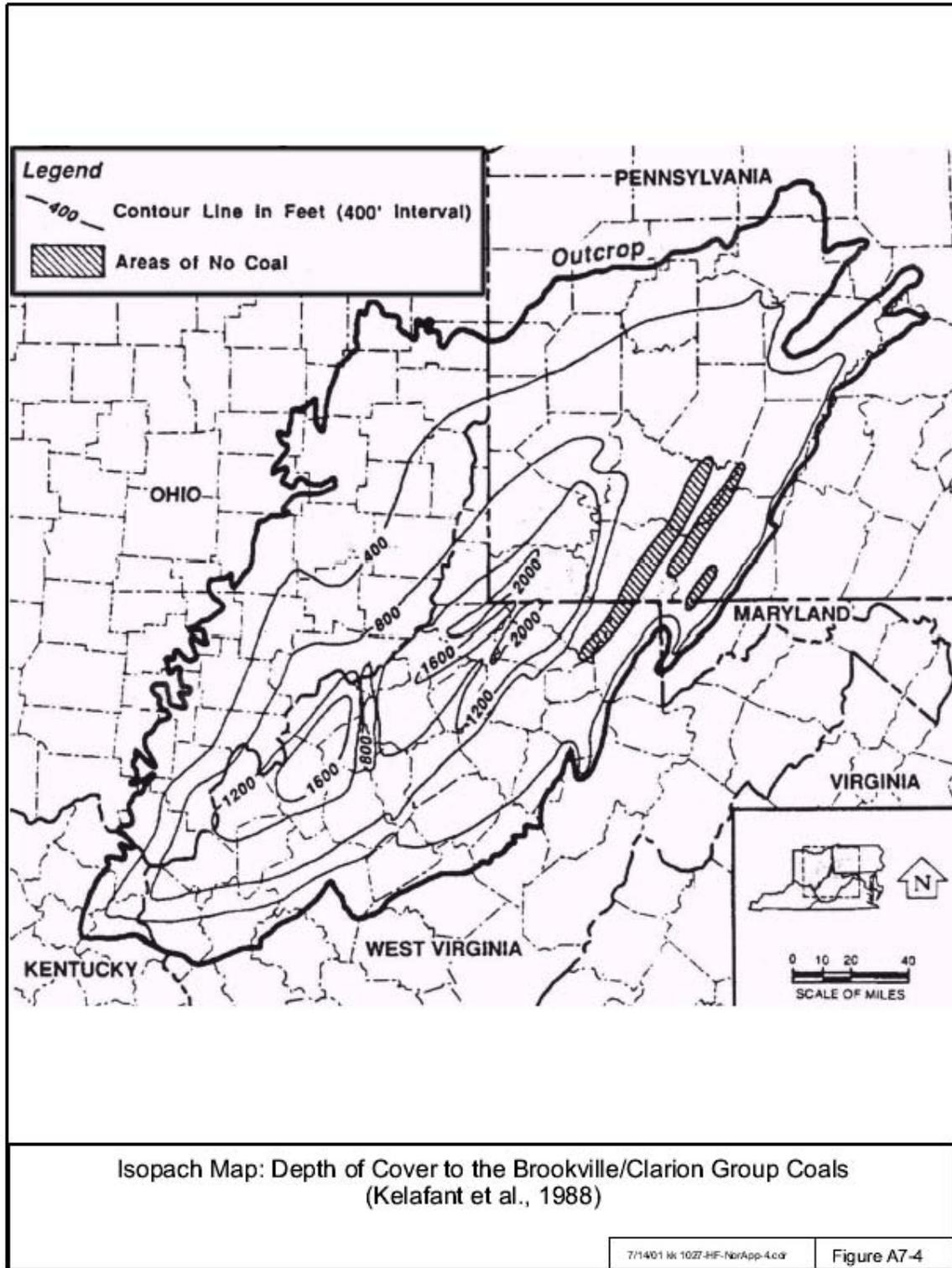


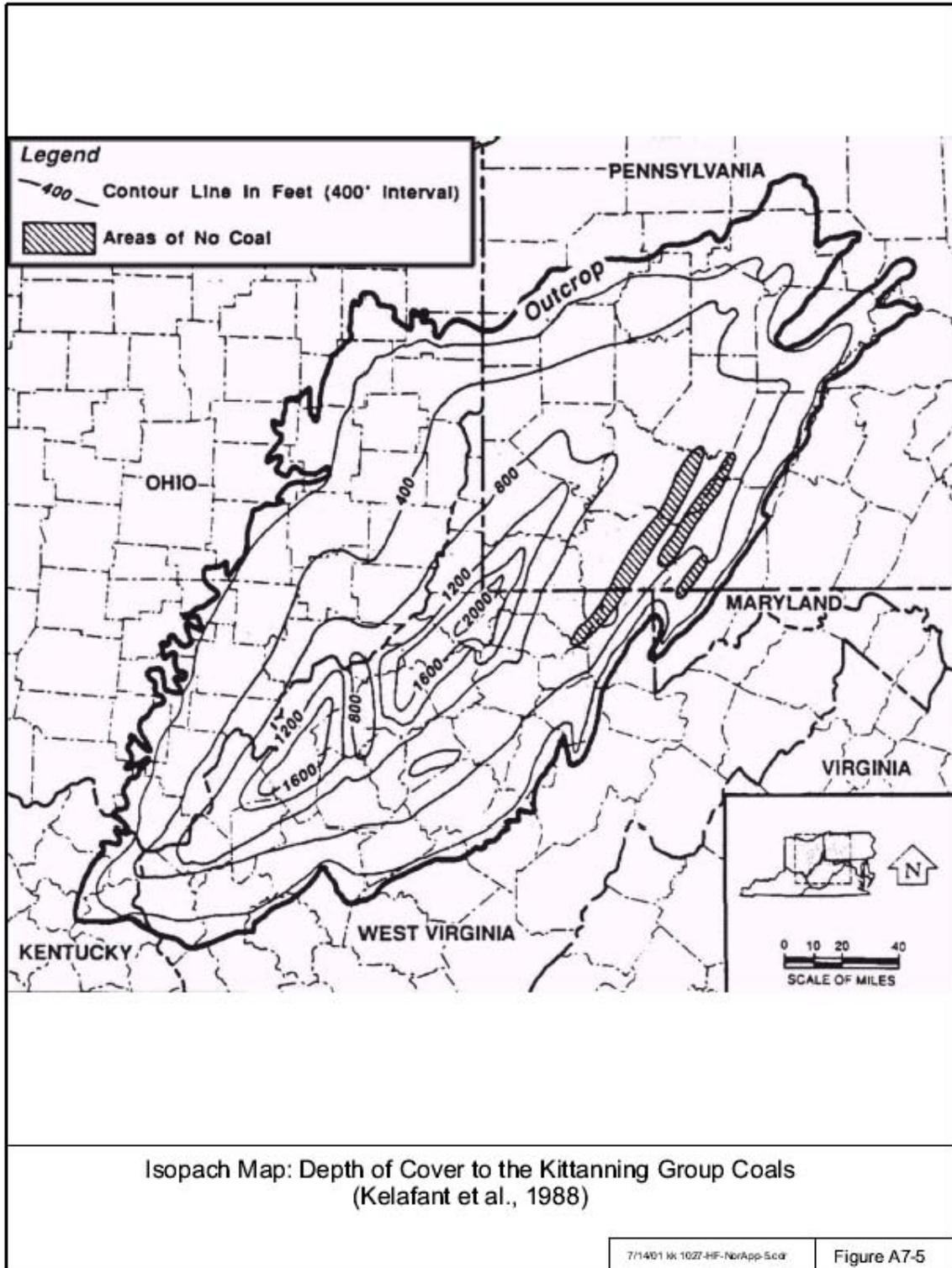


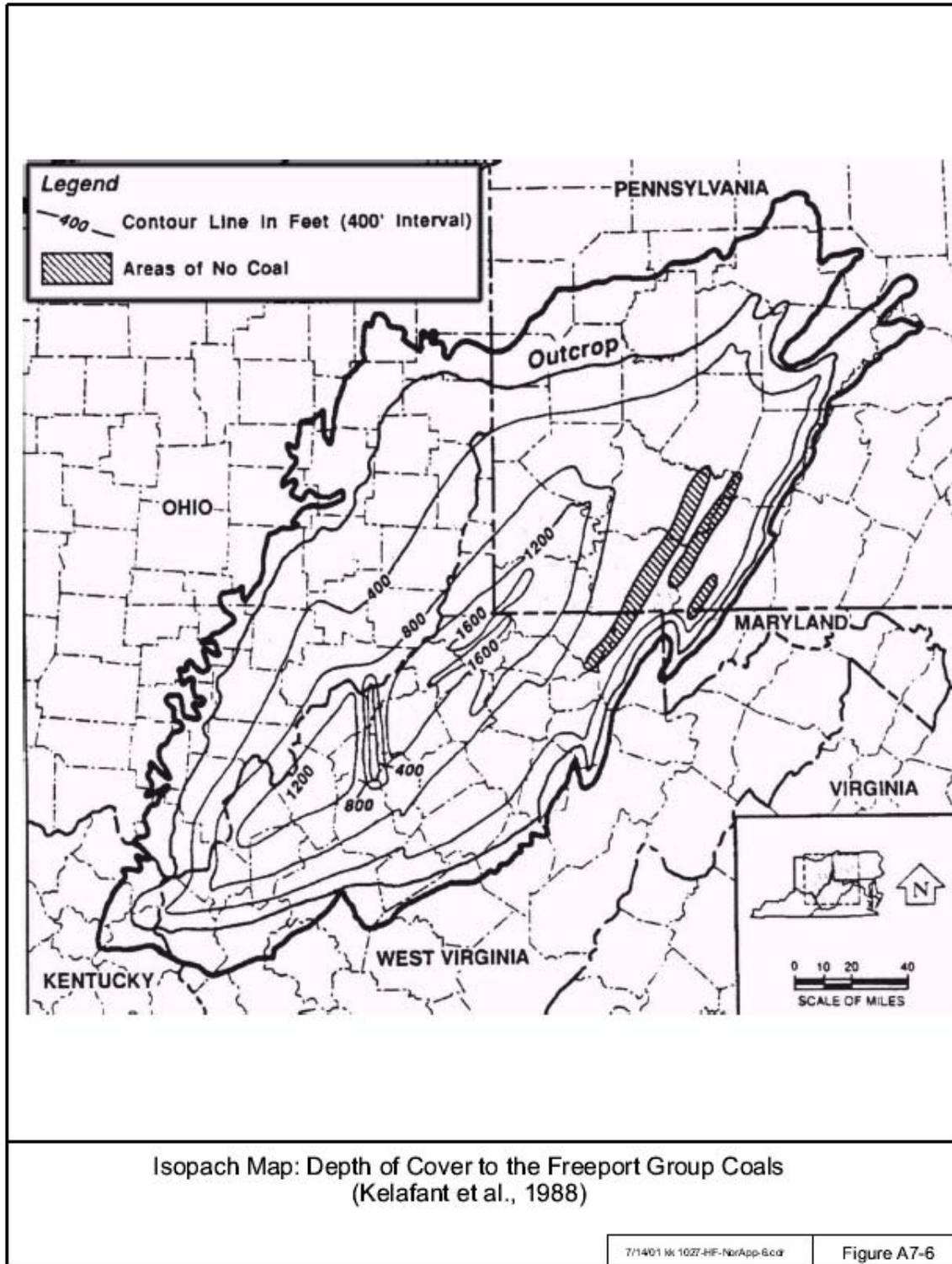
<b>System</b>	<b>Group</b>	<b>Coal Group</b>
<b>Permian</b>	<b>Dunkard</b>	
		<b>Waynesburg</b>
<b>Pennsylvanian</b>	<b>Monongahela</b>	<b>Sewickley</b>
	<b>Conemaugh</b>	<b>Pittsburgh</b>
		<b>Freeport</b>
	<b>Allegheny</b>	<b>Kittanning</b>
	<b>Pottsville</b>	<b>Brookville/Clarion</b>

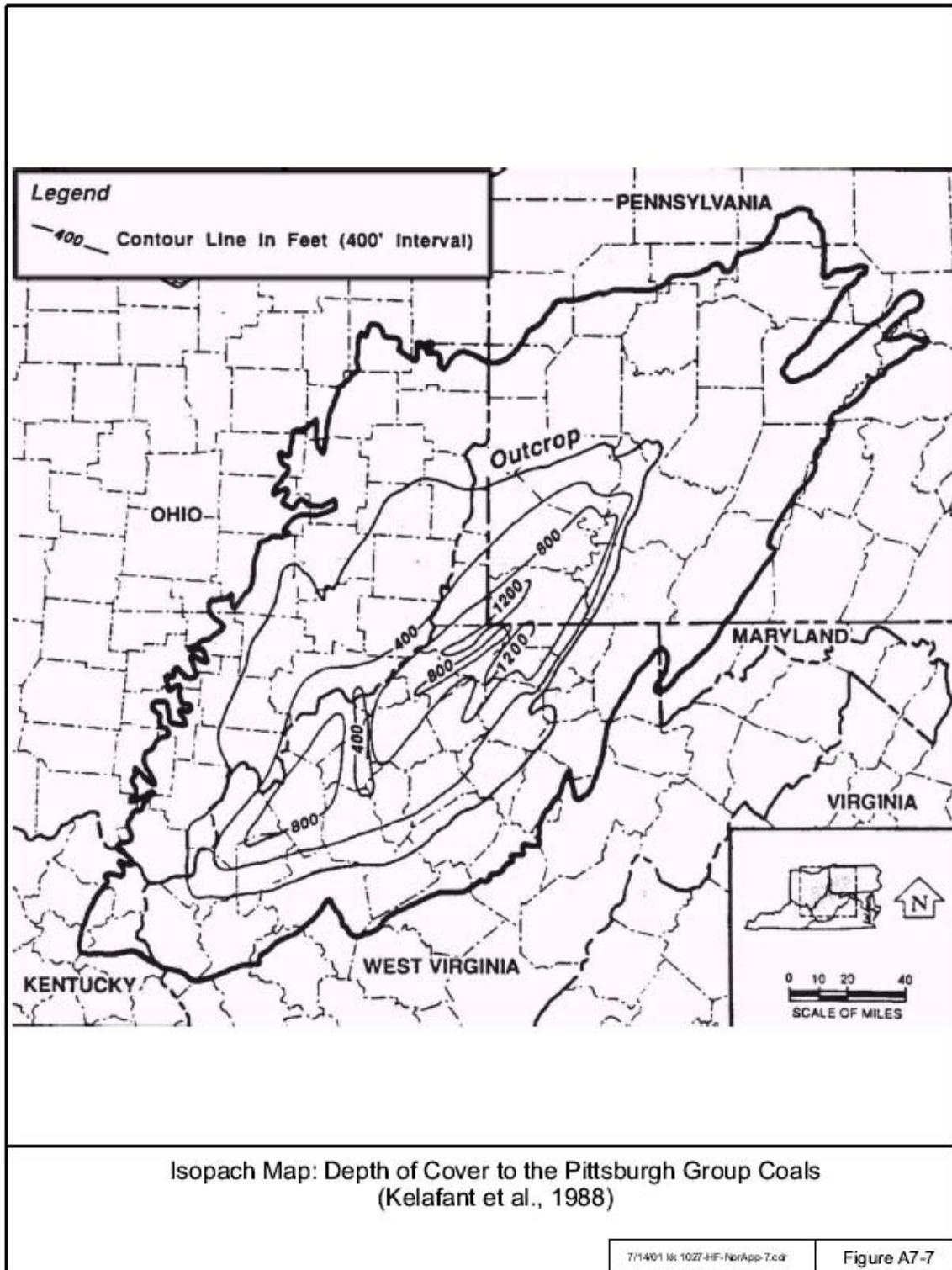
Generalized Stratigraphic Column of the Northern Appalachian Coal Basin  
(Kelafant et al., 1988)

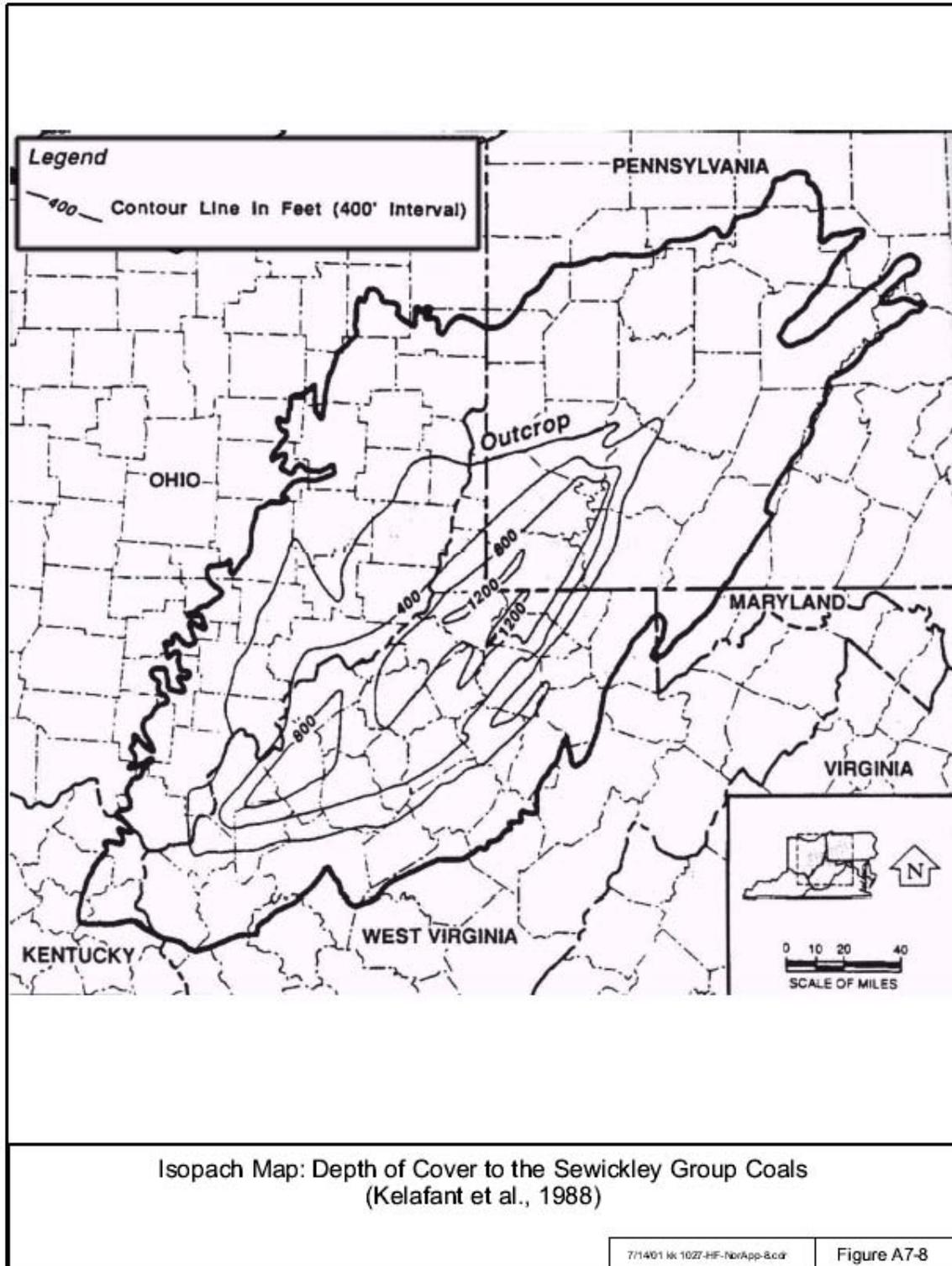
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Figure A7-3

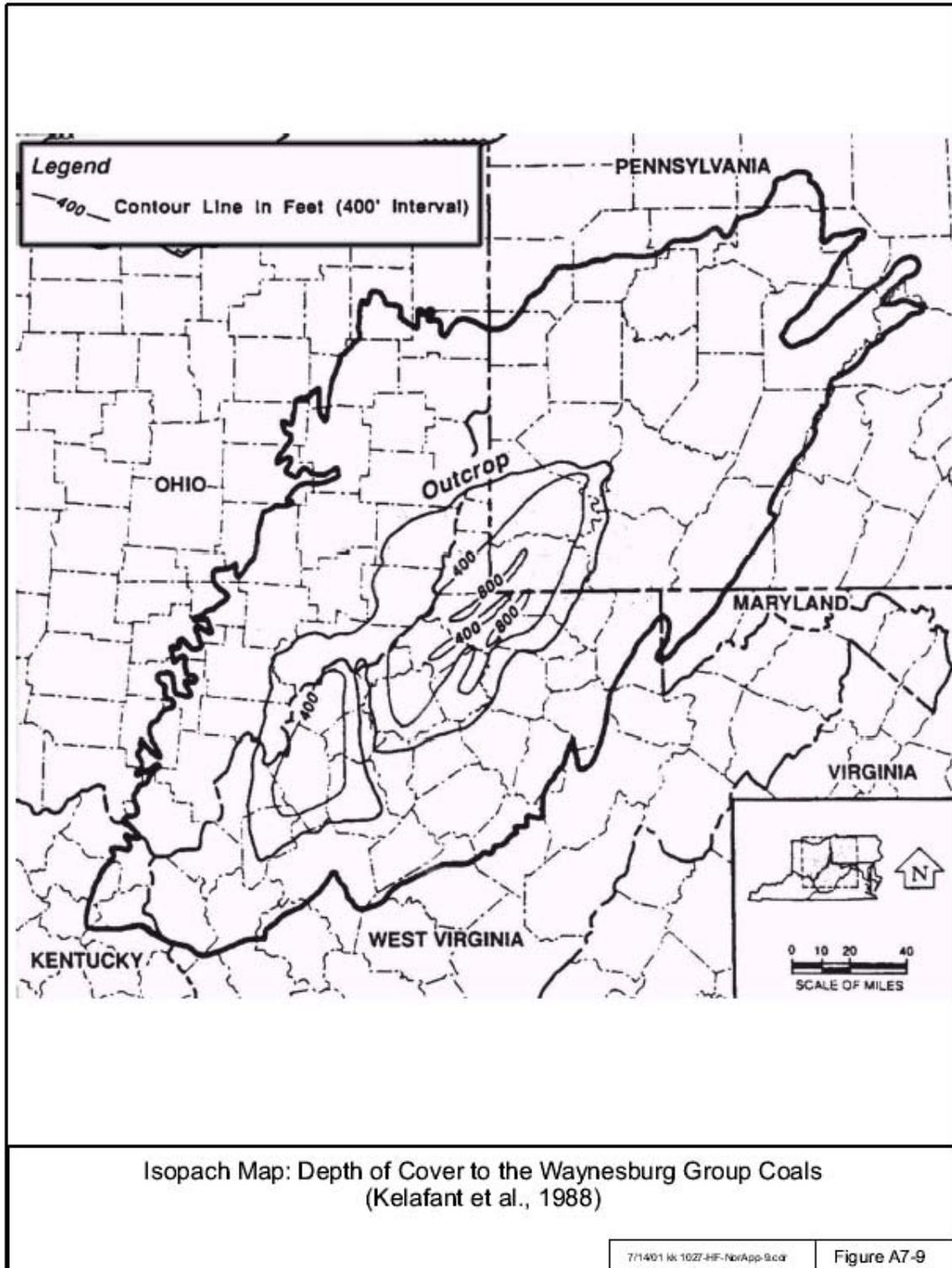












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