Evaluation of Liquid Waste-Storage Potential Based on Porosity Distribution in the Paleozoic Rocks in Central and Southern Parts of the Appalachian Basin

U.S. GEOLOGICAL SURVEY PROFESSIONAL PAPER 1468

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UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1990

DEPARTMENT OF THE INTERIOR

MANUEL LUJAN, JR., *Secretary*

U.S. GEOLOGICAL SURVEY

Dallas L. Peck, *Director*

Library of Congress Cataloging in Publication Data

Lloyd, Orville B.
Evaluation of liquid waste-storage potential based on porosity distribution in the Paleozoic rocks in central and southern parts of the Appalachian Basin.
(U.S. Geological Survey professional paper ; 1468)
Bibliography: p.
Supt. of Docs. no. : I 19.16:1468
1. Liquid-waste disposal in the ground—Appalachian Region—Evaluation. 2. Underground storage—Appalachian Region—Evaluation. 3. Geology, Stratigraphic—Paleozoic. 4. Geology—Appalachian Region. 5. Porosity. I. Reid, Marjorie S. II. Title. III. Series.
TD523.2.L57 1986 628.4′4566 87–600037

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, DC 20402

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[Plates are in pocket]

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UNITS AND CONVERSIONS

For the convenience of readers who prefer inch-pound units rather than the metric (International System) units used in this report, the following factors may be used.

Metric to inch-pound units	Inch-pound to metric units
Length	
1 meter (m) = 39.37 inches (in.) = 3.28 ft = 1.09 yd	1 yard (yd) = 3 feet (ft) = 0.9144 (m) = 0.0009144 km
1 kilometer (km) = 1,000 m = 0.62 mi	1 mile (mi) = 5,280 ft = 1,609 m = 1.609 km
Area	
1 m^2 = 10.758 ft^2	1 ft^2 = 0.0929 m^2
1 km^2 = 0.386 mi^2	1 mi^2 = 2.59 km^2
Volume	
1 m^3 = 35.31 ft^3	1 ft^3 = 0.02832 m^3
1 km^3 = 0.2399 mi^3	1 mi^3 = 4.168 km^3
Additional Abbreviations	
mg/L = milligrams per liter	

Sea Level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)—a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called "Mean Sea Level of 1929."

EVALUATION OF LIQUID WASTE-STORAGE POTENTIAL BASED ON POROSITY DISTRIBUTION IN THE PALEOZOIC ROCKS IN CENTRAL AND SOUTHERN PARTS OF THE APPALACHIAN BASIN

By ORVILLE B. LLOYD, JR., and MARJORIE S. REID

ABSTRACT

This report describes the subsurface distribution of reservoir units in rocks of Cambrian to Mississippian age in the central and southern parts of the Appalachian basin and evaluates their potential for storage of liquid waste.

A potential subsurface reservoir for liquid waste should include the following four characteristics: (1) a significant volume of porous and permeable reservoir rock; (2) surrounding rocks that can prevent escape of waste fluid from reservoir rock; (3) isolation from potable ground water and from the surface environment; and (4) economically feasible drilling depths. The criteria used in this report to determine whether or not these characteristics occur at any study site are as follows: (1) Five-percent porosity is the minimum for reservoir rock (sandstone, dolomite, or limestone) and the volume is significant only when the aggregate thickness of the reservoir rock equals or exceeds 7.5 meters within a 75-meter interval. Rocks that meet these requirements are called potential reservoir intervals. (2) At least 30 meters of confining rock (shale, or evaporite, or some rock with less than 5-percent porosity) should overlie and underlie the reservoir rock. Rocks that meet these requirements are called potential confining intervals. (3) If the top of the reservoir rock is at least 300 meters below sea level, it is considered to be far enough below any potable water supply to preclude accidental penetration by water-well drilling. (4) Rocks more than 2,500 meters below sea level are considered to be too deep for economical use as reservoir rock.

Potential reservoir intervals and potential confining intervals established using these criteria are grouped into six major potential reservoir units composed of dolomite, limestone, and sandstone, and seven major confining units mainly composed of shale, siltstone, and shaly limestone or dolomite.

Major reservoir units cover a median area of 79,450 square kilometers (about one half of the study area) and have a median average area-weighted thickness of 172 meters, of which an estimated 4.5 percent contains potential reservoir rock with a median average thickness-weighted porosity of 8 percent. The median altitude of the top of the potential reservoir intervals is about 1,290 meters below sea level. The median of the area-weighted thickness of overlying potential confining units is 180 meters.

Areas of oil and gas resources, oil and gas wells, faults, tight folds, extensive fracture systems, seismic activity, and the potential for the development of hydraulically induced vertical fractures need to be avoided when subsurface space is considered for injection and storage of liquid waste.

Manuscript approved for publication August 11, 1986.

INTRODUCTION

Large and increasing volumes of waste are produced annually by our highly industrialized society. The disposal of these wastes in the past has caused many serious environmental problems that have prompted the search for waste-management practices that will have the least impact on our environment. As part of this search, the U.S. Geological Survey has made a number of investigations of subsurface rocks to evaluate their potential to accept and store liquid wastes. This report is the result of one of these investigations. As stated by Brown and others (1979), "the U.S. Geological Survey does not advocate that waste be stored in the subsurface, but it does recognize that, in some cases, injection of industrial wastes may be the most environmentally acceptable alternative available to a waste generator or regulator."

The Appalachian basin was selected for investigation because its rocks have potential for the storage of waste based upon recognized permeability and porosity distribution patterns determined from drilling to evaluate the hydrocarbon potential of the basin.

The purpose of this report is to describe the spatial distribution and physical characteristics of the rocks in the central and southern parts of the Appalachian basin with regard to their potential as reservoir or confining units for liquid waste. Available published and unpublished geologic, geophysical, hydrologic, and water-quality data were used to describe the reservoir and confining-unit potential of the rocks. The data are derived primarily from deep oil- and gas-test wells drilled throughout the study area.

The study area includes parts of Kentucky, Maryland, Ohio, Pennsylvania, Tennessee, Virginia, and West Virginia and encompasses about 162,000 km^2 (fig. 1).

Much useful information was derived from previous work regarding the subsurface disposal of liquid wastes in the area. Colton (1961) presented a geologic summary of the entire Appalachian basin and described potential reservoirs for the disposal of liquid radioactive waste primarily on the basis of lithology. The process of, requirements for, and feasibility of subsurface liquid-waste disposal were described for Pennsylvania by Rudd (1972) and for Ohio by Clifford (1975).

Clifford (1975) also described some case histories of liquid-waste disposal wells in Ohio. The Ohio River Valley Water Sanitation Commission (1976) has published a registry of wells used for underground injection of wastewater and an evaluation of the basal sandstone of Cambrian age as a wastewater injection interval in the Ohio River Valley region.

A potential subsurface reservoir for liquid waste should include the following characteristics: (1) a significant volume of porous and permeable reservoir rock containing nonpotable water; (2) surrounding rocks that can prevent escape of waste fluid from the reservoir rock; (3) isolation from the surface environment and from potable ground water; and (4) economically feasible drilling depths. The criteria used in this report to determine whether or not these characteristics occur at any site are as follows: (1) Five-percent porosity was selected as the minimum for reservoir rock (sandstone, dolomite, or limestone), and the volume is considered to be significant only when the aggregate thickness of the reservoir rock equals or exceeds 7.5 meters (m) within a 75 m interval. Rocks that meet these requirements are defined as *potential reservoir intervals* in this report. (2) At least 30 m of confining rock (shale or evaporite or some rock with less than 5-percent porosity) should overlie and underlie the reservoir rock. Rocks that meet these requirements are defined as *potential confining intervals* in this report. (3) If the top of the reservoir rock is 300 m or more below sea level, the reservoir generally contains nonusable ground water and is considered to be far enough below any potable water supply to preclude accidental penetration by water-well drilling. Nonusable ground water is defined as ground water that contains more than 10,000 milligrams per liter (mg/L) dissolved solids (Brown and others, 1979). (4) Rocks more than 2,500 m below sea level are considered to be economically unsuitable for liquid-waste storage because of well-construction and operational costs. In addition, very little data are available for rocks more than 2,500 m below sea level in the study area.

Thus, the potential liquid-waste-storage reservoir environment in the study area can be defined as follows:

> A sandstone, dolomite, or limestone layer containing nonpotable water that lies between about 300 m and 2,500 m below sea level and contains at least 7.5 m of rock with at least 5-percent porosity in a 75 m interval (potential reservoir interval) and is overlain and underlain by at least 30 consecutive meters of shale or evaporite or some rock with less than 5-percent porosity (potential confining interval).

Potential reservoir intervals primarily occur in discrete sections of rock composed of formations, parts of formations, or groups of formations that can be correlated throughout the study area. Six such rock sections are identified and described in this report as *potential reservoir units.* Where the potential confining intervals occur between the potential reservoir units as thick, discrete sections of rock that can be generally correlated throughout the study area, they are referred to as *potential confining units.* Seven potential confining units are identified and described in this report.

ACKNOWLEDGMENTS

Many thanks are due Philip M. Brown for his continued interest, support and encouragement, and critical review of the manuscript even after his retirement from the U.S. Geological Survey.

The Geological Surveys of Kentucky, Maryland, Ohio, Pennsylvania, Tennessee, Virginia, and West Virginia, the Susquehanna River Basin Commission, and the Columbia Gas Corporation provided basic well data and other geologic and hydrologic information used in preparing this report. In addition, Dr. Dennis A. Hodge, State University of New York, Buffalo, New York, provided a preliminary gravity map of West Virginia.

METHODS OF INVESTIGATION

Geologic and hydrologic data from about 550 deep wells that have broad areal distribution were used in this study. The wells were drilled as oil and gas tests. Some were completed as production wells, but most were nonproducers that were plugged and abandoned. Well-completion reports, lithologic logs, sample descriptions, geophysical logs, water-quality reports, and other available and pertinent data obtained for individual wells were analyzed and synthesized during the investigation. Two hundred and eighty-five wells were selected as a key-well network for the area of study (pl. 1). The

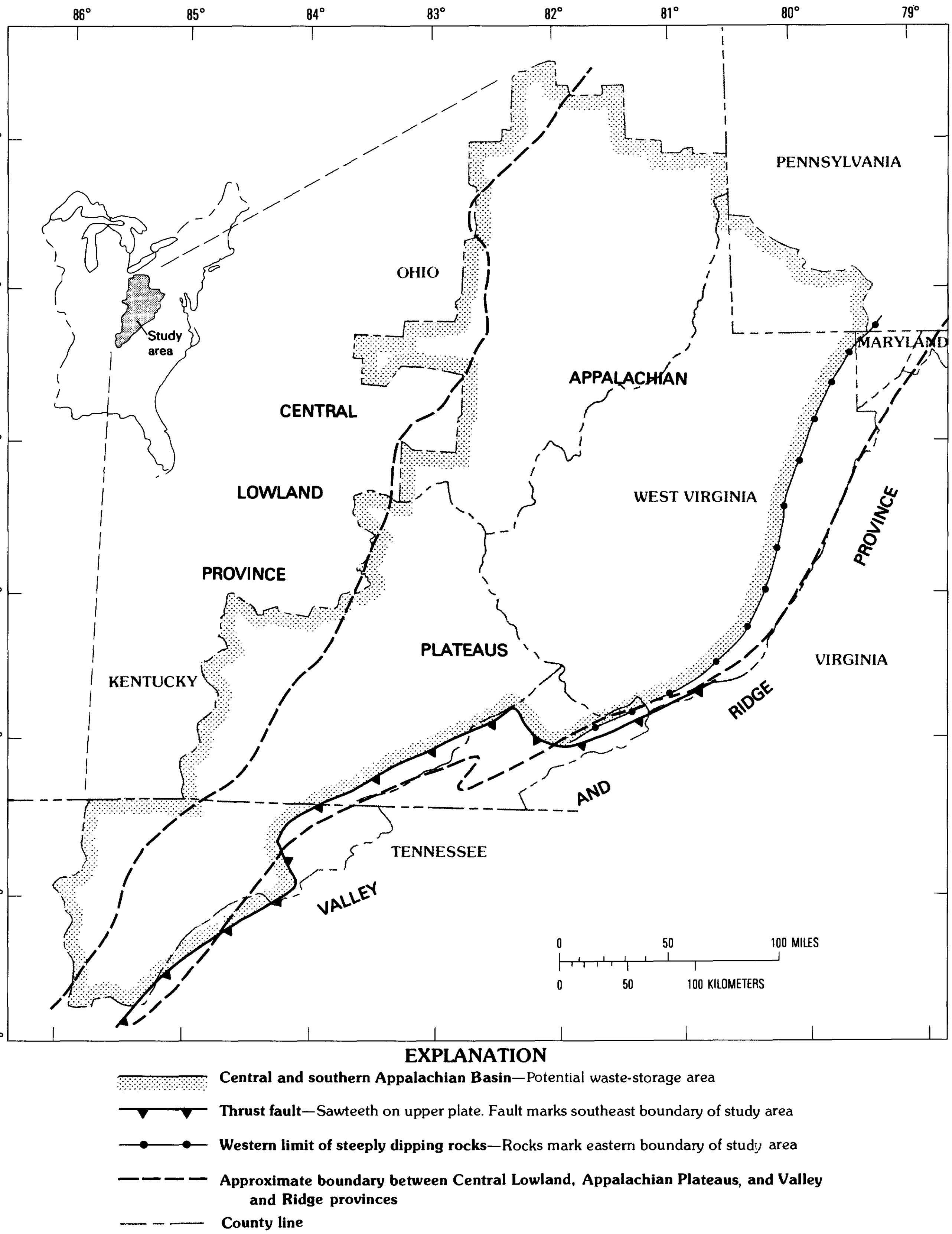


FIGURE 1.—Location of study area.

number of wells selected from a State is approximately proportional to the number of square miles in that State that are included in the study area. Data for these wells are shown in table 1 (in back of report). The data sets for these key wells were the most complete available and provide a representative sample of the subsurface geology in the area. The basic well data were obtained from commercial well-data companies, oil and gas companies, and pertinent State geological surveys.

The data used to correlate and map the altitudes of the tops and thicknesses of the geologic and hydrologic units were derived from geophysical and lithologic logs. In addition, data from geophysical logs of neutron porosity, bulk density, sonic travel time, gamma radiation, spontaneous potential, and resistivity were used to estimate rock porosity and the quality of water contained by the rocks (Schlumberger Well Surveying Corporation, 1958, 1962; Turcan, 1966; Brown, 1971; Schlumberger Limited, 1972, 1974, 1977; Seismograph Service Corporation, 1973; Hilchie, 1978, 1979; MacCary, 1978, 1980, 1983). Wherever possible, cross plots of multiple geophysical logs denoting rock porosity were used to help verify the lithology and estimated porosity of the intervals studied. The concentration of dissolved solids, expressed as sodium chloride in milligrams per liter (mg/L), was calculated for water contained in the most porous and permeable rocks found in the upper part of the sedimentary section (table 2, in back of report). In addition, total dissolved-solids data were obtained from over 300 published brine analyses and water-quality reports and maps (Stout and others, 1932; Price and others, 1937; Hoskins, 1949; Lamborn, 1952; McGrain, 1953; Poth, 1962; Hopkins, 1963, 1966; Price, 1964; Forster, 1980).

For the purposes of this study, porosity data for sandstone, dolomite, and limestone (the most common reservoir rocks for hydrocarbons in the study area) were used as the major indicator of reservoir porosity. Porosity data were used instead of permeability data because available porosity data are abundant, and available permeability data are scarce and spotty by comparison. This approach is based on accounts of a gross correlation between the porosity and permeability of carbonate- and sandstone-reservoir rocks (Archie, 1952, p. 278–298; Levorsen, 1958, p. 128–130). In general, for any given reservoir rock, the log of permeability increased with an increase in percent porosity. Lack of data precludes establishing a quantitative relation between porosity and permeability for the reservoir units throughout the study area. Therefore, the results of this study should be viewed only as a first approximation of evaluating the liquid-waste-storage potential of the rocks in the area.

The characteristics that were compiled for the potential reservoir intervals during the investigation of the geophysical logs of the key wells are (1) altitude of the top, (2) thickness, and (3) dominant rock type or lithology. Also, (4) individual thickness, (5) aggregate thickness, and (6) average thickness-weighted porosity were compiled for the small zones that constitute the reservoir porosity within the intervals. In addition, data were compiled on (7) the thickness and (8) lithology of the confining beds found above and below the potential reservoir intervals. These data are shown in table 3 (in back of report). Some of the characteristics and typical relationships of the individual rock zones with at least 5-percent porosity and potential reservoir and confining intervals are shown in figure 2. The individual rock zones with at least 5-percent porosity are also called reservoir-type zones in this report.

The data for each of the characteristics (except lithology) were ranked according to size and the median value was used as a measure of the central value for each data set. The median is defined as the middle item of a group of items (two or more in this report) that are arranged according to size. With an even number of items, the midpoint is the arithmetic mean of the two central items.

In the case of unit thickness and reservoir porosity, appropriate averages were used to weigh the data with regard to area and thickness, respectively. The average thickness-weighted porosity of the individual porous zones within any potential reservoir interval was obtained by multiplying the thickness and the porosity of each individual porous zone, summing the products and dividing this sum by the aggregate thickness of the individual porous zones. For example, in figure 2 the sum of the products of thickness and porosity for each individual porous zone is 155, and the average thickness-weighted porosity is 155 divided by 16 (the aggregate thickness of the individual porous zones) or about 9.7 percent. Where a number of such values comprised a data set, the median was used to describe the central value of the set and is called *the median average thickness- weighted porosity* in this report.

Average area-weighted thickness for any unit was obtained by preparing a thickness contour map of the unit and estimating the average thickness of an area between two consecutive thickness contours. This value was then multiplied by the proportionate part of the total area of the unit for which this average thickness was representative. The measurements of area were made with a polar planimeter. Such products were calculated for each contour interval until the entire unit area was completed, and the products were summed to obtain the average area-weighted thickness of the unit.

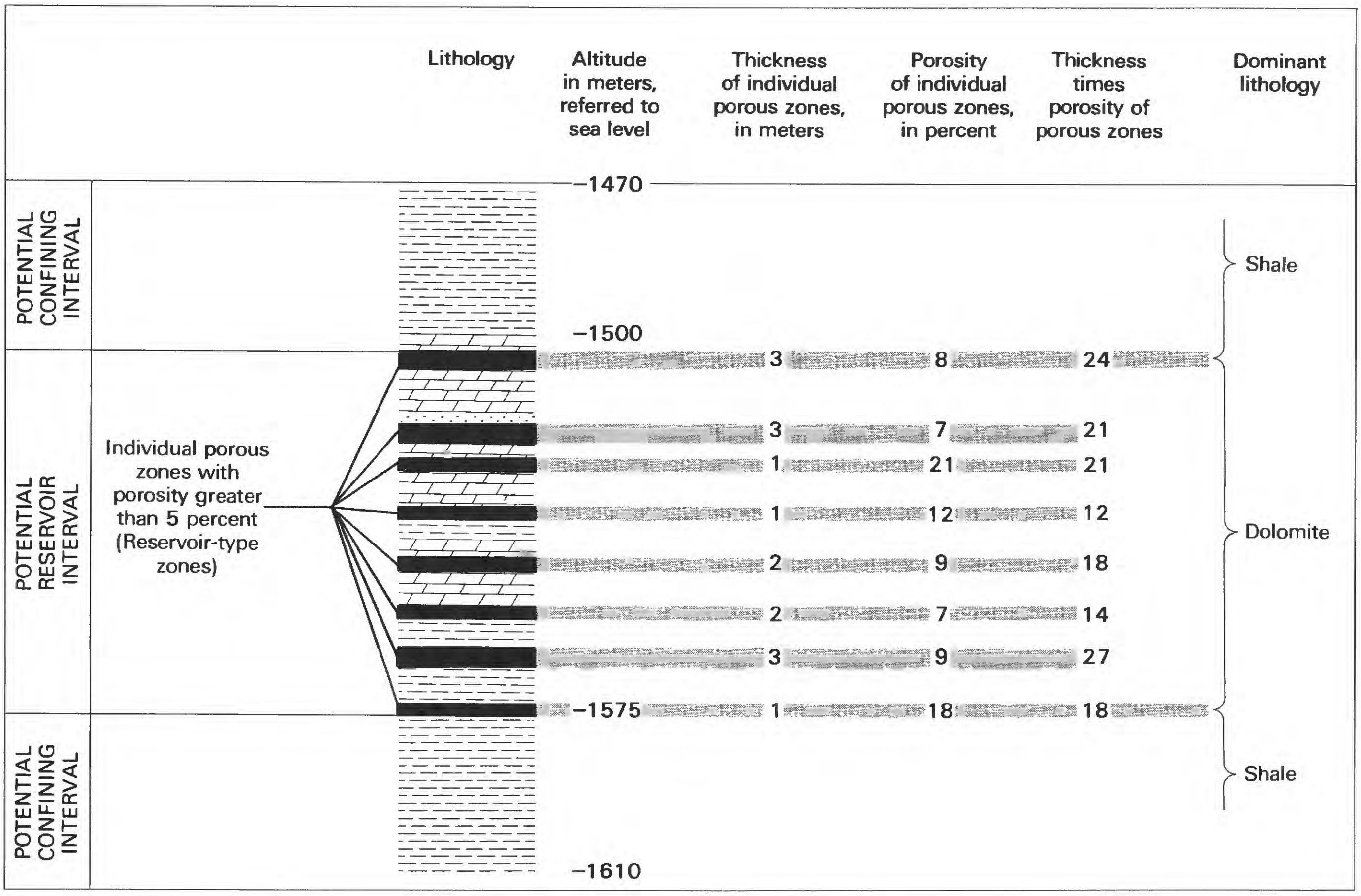


FIGURE 2.—Typical relation between reservoir-type zones, a potential reservoir interval, and potential confining intervals.

The sedimentary section was divided into six potential reservoir units that are designated A through F, oldest through youngest, respectively. These units are successively underlain and overlain by seven potential confining units that are designated Basal, A-B, B-C, C-D, D-E, E-F, and above F, oldest through youngest, respectively.

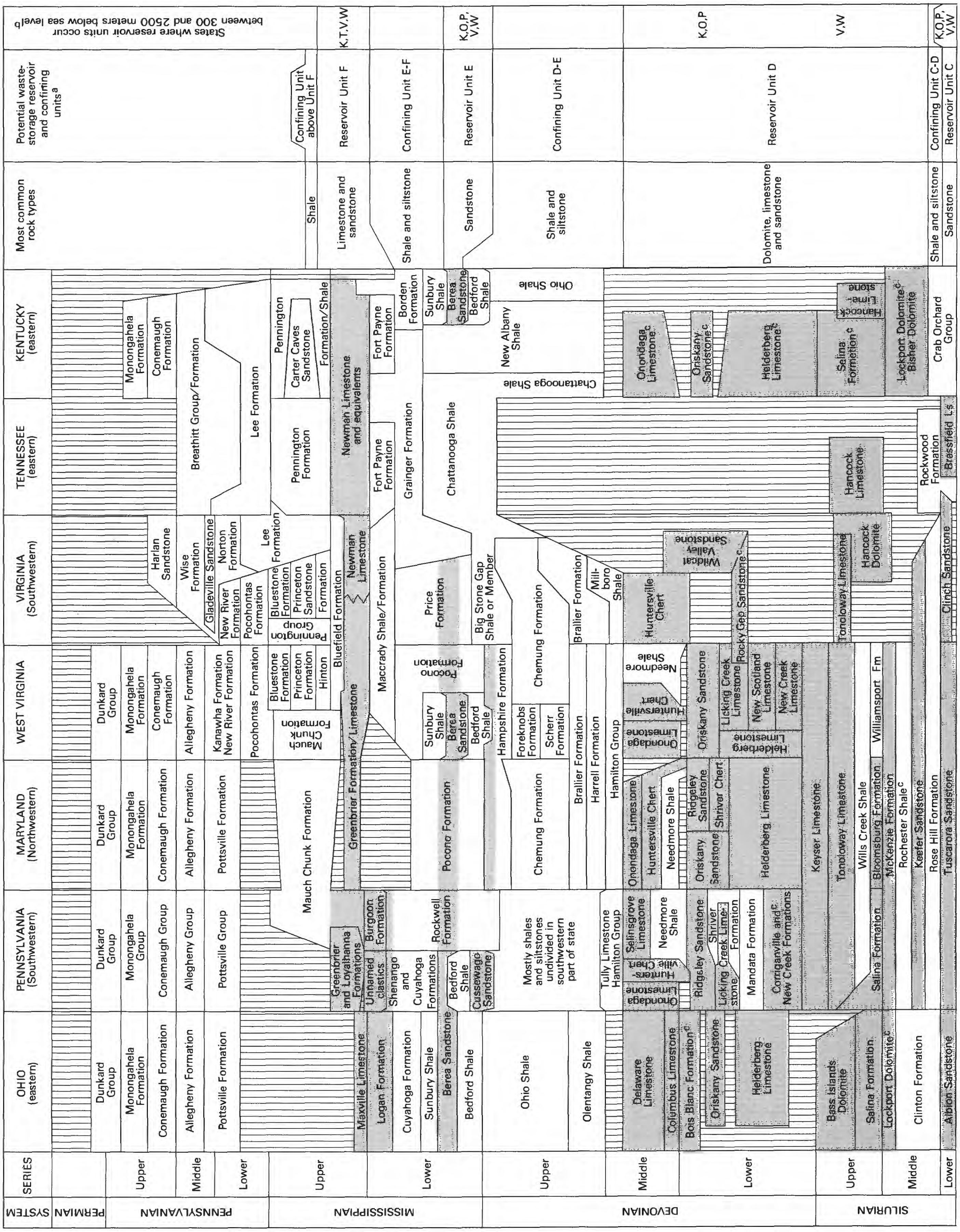
GENERAL GEOLOGY

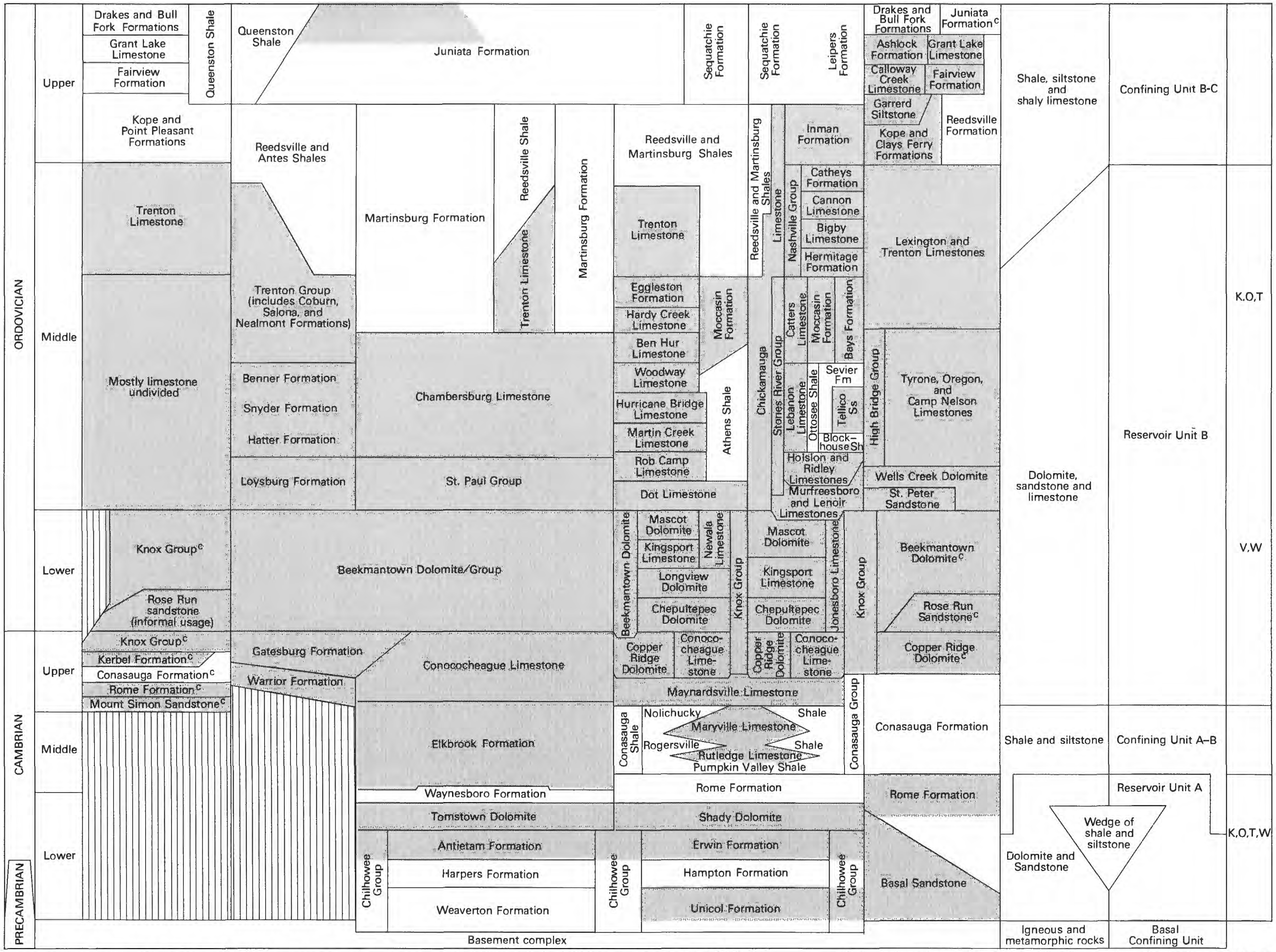
The geologic formations that include the potential reservoir and confining units in the study area are shown in figure 3. These rocks are part of one of the most studied sedimentary basins in the world. Consequently, an extensive literature has been written about the sedimentary, stratigraphic, structural, and tectonic history of the rocks. Colton (1961) and Dennison (1978) gave reviews of the basin geology and presented lists of many of the important reference works. Additional references are listed throughout this report.

The consolidated sedimentary rocks in the study area range in age from Cambrian to Permian. They form a sediment mass composed of sandstone, siltstone, shale, limestone, dolomite, salt, and anhydrite that rests on a basement of Precambrian igneous and metamorphic rocks. The Permian rocks occur at the surface in the north-central part of the area and, generally, are rimmed by successively older rocks on the northwest, east, and southeast, defining a northeast plunging synclinorium (pl. 1). The total thickness of the sedimentary mass in the study area is estimated to range from about 1,500 to 11,000 m or more.

Unconsolidated deposits of Quaternary age directly overlie some of the consolidated sedimentary rocks of Devonian, Mississippian, Pennsylvanian, and Permian age in the central and northwestern part of the study area (pl. 1). These unconsolidated deposits are saturated with freshwater and, therefore, are excluded on the correlation chart (fig. 3) and from further discussion in this report.

FIGURE 3 (on following pages).—Generalized correlation chart of Paleozoic rocks underlying central and southern parts of the Appalachian basin.


SYSTEM
SERIES
OHIO (eastern)
PENNSYLVANIA (Southwestern)
MARYLAND (Northwestern)
WEST VIRGINIA
VIRGINIA (Southwestern)
TENNESSEE (eastern)
KENTUCKY (eastern)
Most common rock types
Potential waste-storage reservoir and confining units[a]
States where reservoir units occur between 300 and 2500 meters below sea level[b]
PERMIAN
PENNSYLVANIAN
MISSISSIPPIAN
DEVONIAN
SILURIAN
Upper
Middle
Lower
Dunkard Group
Monongahela Formation
Monongahela Group
Conemaugh Formation
Conemaugh Group
Allegheny Formation
Allegheny Group
Pottsville Formation
Pottsville Group
Kanawha Formation
New River Formation
Pocohontas Formation
Harlan Sandstone
Wise Formation
Gladeville Sandstone
Norton Formation
Lee Formation
Breathitt Group/Formation
Mauch Chunk Formation
Bluestone Formation
Princeton Formation
Hinton
Pennington Group
Princeton Sandstone
Formation
Bluefield Formation
Pennington Formation
Pennington
Carter Caves Sandstone
Formation/Shale
Greenbrier and Loyalhanna Formations
Maxville Limestone
Greenbrier Formation/Limestone
Newman Limestone
Newman Limestone and equivalents
Logan Formation
Unnamed clastics
Burgoon Formation
Shenango and Cuyahoga Formations
Cuyahoga Formation
Maccrady Shale/Formation
Fort Payne Formation
Grainger Formation
Borden Formation
Sunbury Shale
Rockwell Formation
Pocono Formation
Price Formation
Berea Sandstone
Bedford Shale
Cussewago Sandstone
Chattanooga Shale
Big Stone Gap Shale or Member
Hampshire Formation
Ohio Shale
Mostly shales and siltstones undivided in southwestern part of state
Chemung Formation
Foreknobs Formation
Scherr Formation
New Albany Shale
Olentangy Shale
Brallier Formation
Harrell Formation
Millboro Shale
Tully Limestone
Hamilton Group
Delaware Limestone
Onondaga Limestone
Huntersville Chert
Selinsgrove Limestone
Needmore Shale
Onondaga Limestone[c]
Columbus Limestone
Bois Blanc Formation[c]
Ridgsley Sandstone
Ridgeley Sandstone
Oriskany Sandstone
Oriskany Sandstone[c]
Shriver Formation
Shriver Chert
Licking Creek Limestone
Wildcat Valley Sandstone
Rocky Gap Sandstone[c]
Mandata Formation
Helderberg Limestone
Helderberg Limestone[c]
New Scotland Limestone
New Creek Limestone
Corriganville and New Creek Formations[c]
Keyser Limestone
Bass Islands Dolomite
Tonoloway Limestone
Hancock Limestone
Hancock Dolomite
Salina Formation
Salina Formation[c]
Wills Creek Shale
Bloomsburg Formation
Williamsport Fm
Lockport Dolomite[c]
McKenzie Formation
Rochester Shale[c]
Lockport Dolomite[c]
Bisher Dolomite
Clinton Formation
Keefer Sandstone
Rose Hill Formation
Rockwood Formation
Crab Orchard Group
Albion Sandstone
Tuscarora Sandstone
Clinch Sandstone
Brassfield Ls
Shale
Limestone and sandstone
Shale and siltstone
Sandstone
Shale and siltstone
Dolomite, limestone and sandstone
Shale and siltstone
Sandstone
Confining Unit above Unit F
Reservoir Unit F
Confining Unit E-F
Reservoir Unit E
Confining Unit D-E
Reservoir Unit D
Confining Unit C-D
Reservoir Unit C
K,T,V,W
K,O,P, V,W
K,O,P
V,W
K,O,P, V,W



Note: The nomenclature used in this chart is from many sources and may or may not agree with U.S. Geological Survey usage. Geology adapted from Cardwell and others (1968), Hardeman and others (1966), Harris and Milici (1977), Milici and Smith (1969), Wilson and Sutton (1976), Patchen and others (1985a).

[a]Rocks shallower than confining unit above Unit F are too close to land surface in study area.

[b]K-Kentucky, O-Ohio, P-Pennsylvania, T-Tennessee, V-Virginia, W-West Virginia

[c]Names from Correlation of Stratigraphic Units of North America (COSUNA) project (see Patchen and others 1985a)

The eastern and northeastern boundary of the study area is marked by rocks that dip steeply in rather closely spaced anticlines and synclines which mirror the structure of the adjacent Valley and Ridge province. On the southeastern boundary of the study area, Cambrian clastic and carbonate rocks are exposed at the surface between thrust faults that are located southeast of the Pine Mountain thrust (Harris and Milici, 1977). The trace of the Pine Mountain and associated thrust faults marks the southeastern boundary of the study area (pl. 1).

The rocks have been disrupted in the west-central part of the area by regionally extensive, east and northeast-trending high-angle faults that have been mapped as the Irvine-Paint Creek and Kentucky River fault systems. Analysis of data from oil- and gas-test wells suggest that these faults bound parts of a deep sedimentary trough, the Rome trough, and are vertical extensions of block faults in the basement. The basement faults bound a series of grabens, half grabens, and horsts (Harris, 1975), that have exerted a major control on the lithology and the thickness and distribution of the Lower Cambrian to Lower Ordovician rocks deposited within and on the flanks of the Rome trough (Dever and others, 1977). Although the dominant component of movement in the sedimentary rocks appears to be vertical, an analysis of fracture patterns recognized in Ordovician rocks of the Kentucky River fault system suggests that some lateral movement has occurred. As much as 80 km of right-lateral displacement has been proposed for the igneous and metamorphic rocks in the basement (Dever and others, 1977).

Figure 4 shows a diagrammatic representation of the relation between the sedimentary rock systems in the study area and the potential reservoir and confining units and also displays some typical geophysical log responses for these units. The general distribution of the sedimentary rock systems and the potential reservoir and confining units mapped in the subsurface in the study area are shown on plate 2.

DISTRIBUTION OF ESTIMATED POTENTIAL WASTE-STORAGE ENVIRONMENT

POTENTIAL RESERVOIR AND CONFINING UNITS

The distribution and characteristics of each potential reservoir unit and each potential confining unit are described and illustrated from oldest to youngest in this section. The descriptions are mainly limited to those parts of the units lying between 300 and 2,500 m below sea level. The discussion of the potential confining units includes the identification of rock types and names of the formations or parts of formations that comprise the units. Maps of the distribution and thickness of the confining units, with the exception of the Basal Confining Unit, are included. A map showing the general altitude of the top of the Precambrian basement complex defines the top of the Basal Confining Unit (fig. 5).

Discussion of each potential reservoir unit includes identification of rock types and names of component formations. Maps are presented showing (1) the distribution and altitude of the unit top, and (2) unit thickness and the distribution of identified potential reservoir porosity. Other mappable features associated with the porosity distribution within some of the potential reservoir units, such as the occurrence of porosity in potential Reservoir Unit B near the erosional surface developed on the Cambrian and Ordovician Knox Group and commonly known as the Knox unconformity, are described and illustrated where appropriate. In addition, the characteristics of the potential reservoir intervals, reservoir-type zones, and potential confining intervals are discussed by State. This State by State discussion was pursued to enhance the usefulness of the report on a more local scale.

The data for the statistical summaries given by State in the following discussions and by reservoir unit for the entire area in table 4 were derived from table 3.

BASAL CONFINING UNIT

The Basal Confining Unit is comprised of igneous and metamorphic rocks of Precambrian age that constitute the basement complex upon which the younger sedimentary rocks were deposited. The altitude of the top of this unit ranges from about 1,000 m below sea level in central Ohio to 10,000 m or more below sea level in southwestern Pennsylvania (Harris, 1975; Cardwell, 1977a). The top of this confining unit is deeper than about 2,500 m below sea level in the eastern two-thirds of the study area (fig. 5).

POTENTIAL RESERVOIR UNIT A

Reservoir Unit A overlies Precambrian basement rocks and is confined to the subsurface throughout the study area. The lower part of this unit is composed primarily of fine- to coarse-grained quartz sandstone that contains varying amounts of silt and clay throughout, and orthoclase feldspar near the base. Some shale, siltstone, and carbonate beds are often intercalated with the sandstone. These rocks comprise the Lower Cambrian part of the Chilhowee Group in Tennessee, the basal sandstone (Early Cambrian) in Kentucky, and the Mount Simon Sandstone (Late Cambrian) in Ohio.

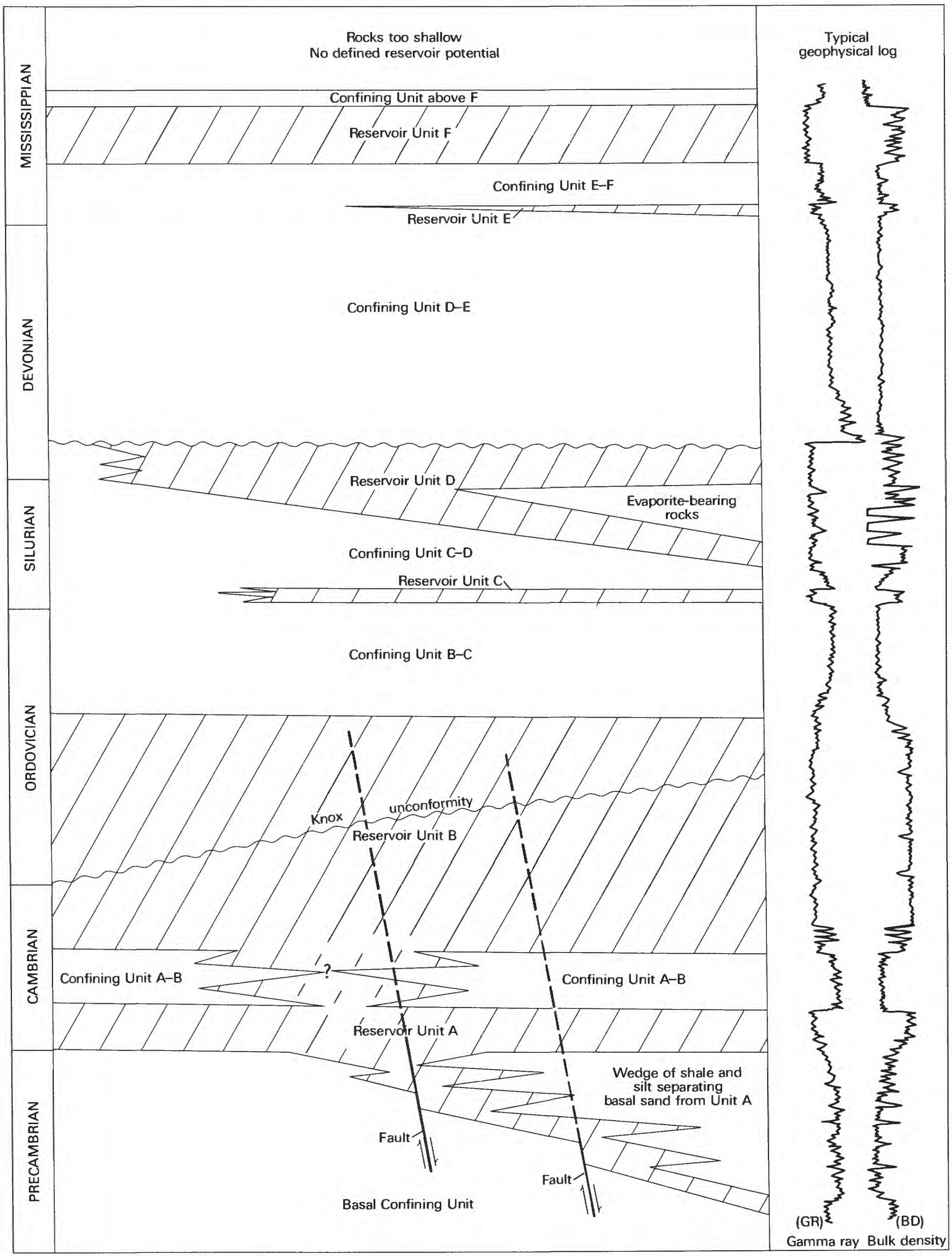


FIGURE 4.—Diagrammatic representation of occurrence and geophysical log response for potential reservoir and confining units.

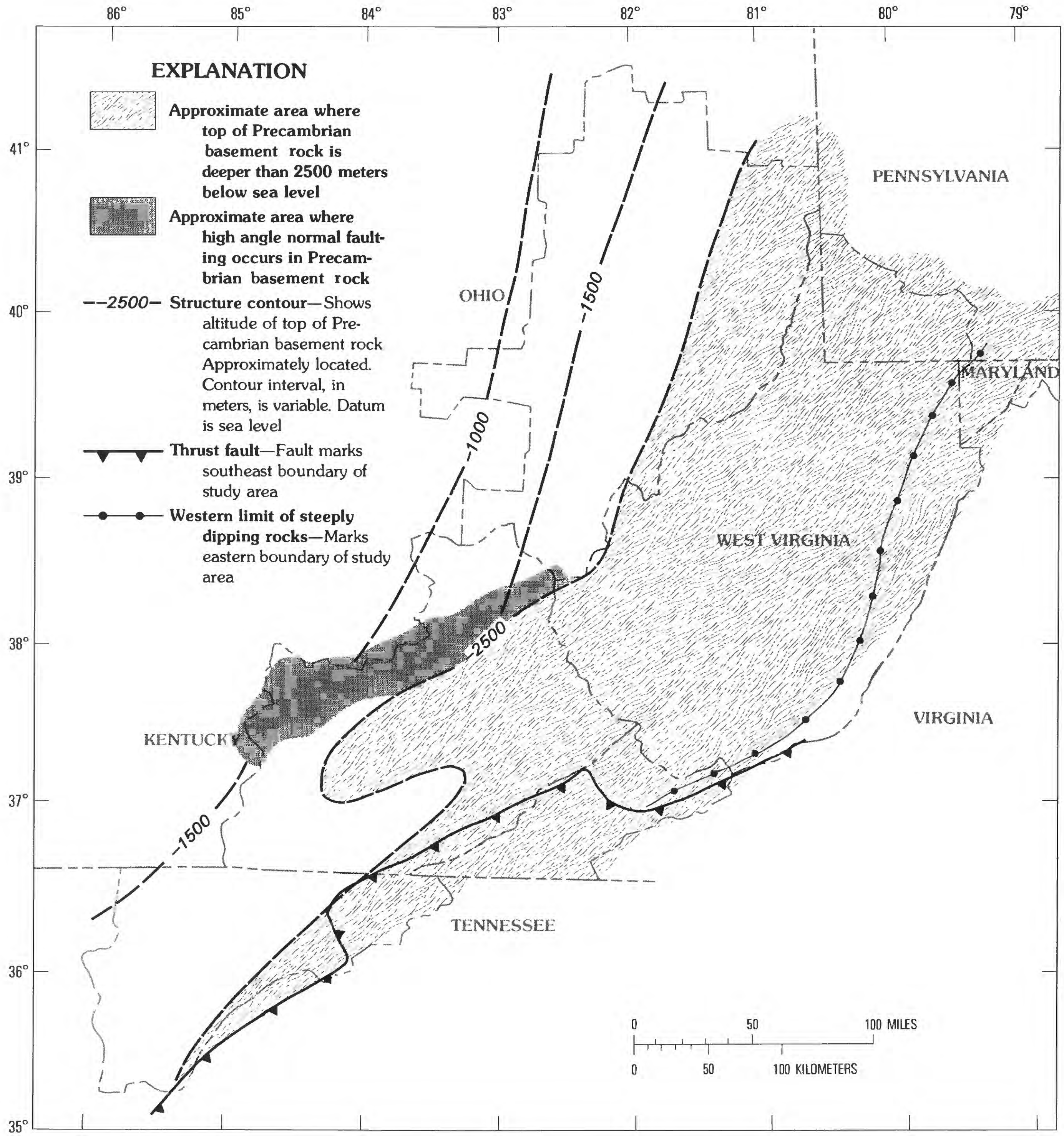


FIGURE 5.—Approximate altitude of the top of the Precambrian basement rocks.

The upper part of Unit A is composed of carbonates and sandstones of the Lower Cambrian part of the Rome Formation and its younger lithostratigraphic equivalents in Ohio (Janssen, 1973). Harris (1964) stated that the Rome Formation rises time-stratigraphically toward the northwest in Kentucky, and Janssen (1973) indicated that it is part of the Upper Cambrian Series in Ohio. Analysis of data from geophysical and lithologic logs of

TABLE 4.—*Summary of characteristics of potential reservoir intervals, individual porous zones, and rock with confining potential for reservoir units*

Intervals	Potential reservoir units					
	A	B	C	D	E	F
POTENTIAL RESERVOIR INTERVALS						
Altitude of interval tops						
Number of data items	32	64	7	51	3	9
Median value, in meters below sea level	1,260	1,224	1,473	1,411	263	388
Range of values, in meters below sea level	1,026–2,145	486–2,353	807–1,813	315–2,327	227–312	313–481
Thickness of intervals						
Number of data items	31	60	7	49	3	9
Median value, in meters	23	82	18	66	69	59
Range of values, in meters	8–402	12–388	8–35	10–239	27–126	9–115
Dominant rock types comprising intervals						
Number of data items	39	71	7	61	4	9
Sandstone, in percent	74	18	100	24	100	33
Limestone, in percent	8	3	--	31	--	67
Dolomite, in percent	18	79	--	45	--	--
INDIVIDUAL RESERVOIR-TYPE POROUS ZONES COMPRISING INTERVALS						
Median thickness of individual zones by interval						
Number of data items	26	63	6	51	3	6
Median value, in meters	2	1.2	4	1.2	1.8	1.7
Range of values, in meters	0.9–9	0.6–4	0.9–8	0.6–5	1.5–2.4	0.9–4
Aggregate thickness of individual zones by interval						
Number of data items	32	64	7	51	3	9
Median value, in meters	12	18	12	13	13	12
Range of values, in meters	8–149	8–122	8–21	8–78	12–23	8–31
Median porosity of individual zones by interval						
Number of data items	26	63	6	51	3	6
Median value, in percent	8	6	6	6	9	6
Range of values, in percent	5–16	5–12	5–10	5–12	7–10	5–10
Average thickness-weighted porosity of individual zones by interval						
Number of data items	32	64	7	51	3	9
Median value, in percent	8	7	7	7	9	5
Range of values, in percent	6–17	6–14	5–11	5–12	9–11	5–10
CONFINING ROCK ABOVE INTERVALS						
Thickness						
Number of data items	31	64	7	45	2	9
Median value, in meters	156	66	96	157	134	64
Range of values, in meters	33–774	31–664	73–148	31–1,551	119–148	31–187
Rock type						
Number of data items	51	78	10	82	5	16
Shale, in percent	37	14	70	38	60	37
Siltstone, in percent	8	--	--	13	40	25
Sandstone, in percent	2	--	--	--	--	19
Limestone, in percent	12	50	--	15	--	19
Dolomite, in percent	41	36	30	22	--	--
Anhydrite, in percent	--	--	--	7	--	--
Salt, in percent	--	--	--	5	--	--
CONFINING ROCK BELOW INTERVALS						
Thickness						
Number of data items	29	55	5	43	3	8
Median value, in meters	1 to basement	64	586	80	217	100
Range of values, in meters	30–254 to basement	33–325	308–789	40–1,036	213–276	30–287
Rock type						
Number of data items	35	79	9	85	4	16
Shale, in percent	6	22	56	27	75	31
Siltstone, in percent	9	1	--	1	25	25
Sandstone, in percent	14	3	--	5	--	7
Limestone, in percent	--	13	44	24	--	37
Dolomite, in percent	14	61	--	28	--	--
Anhydrite, in percent	--	--	--	7	--	--
Salt, in percent	--	--	--	8	--	--
Basement complex rocks, in percent	57	--	--	--	--	--

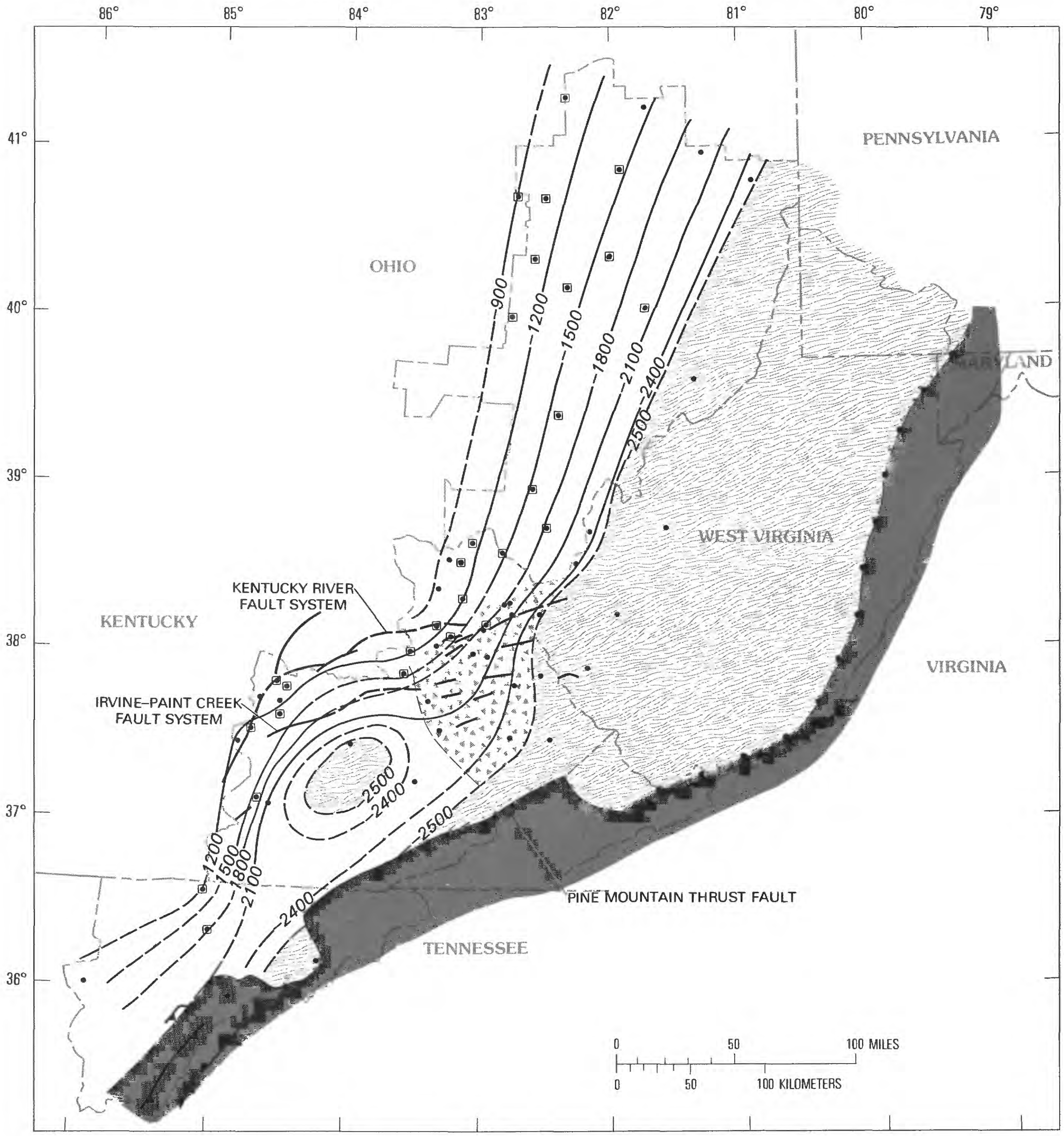


FIGURE 6 (above and facing page).—Areal distribution and altitude of the top of Potential Reservoir Unit A.

EXPLANATION

Approximate area where top of reservoir unit is deeper than 2500 meters below sea level—No defined waste-storage potential

Approximate area where basal sands are too deep to be considered part of the reservoir unit—Decreases chance for waste-storage potential

Approximate area where rocks are thrust faulted or have a steep dip at land surface—No defined waste-storage potential

—*900*— **Structure contour**—Shows altitude of top of reservoir unit. Dashed where approximately located. Contour interval, in meters, is variable. Datum is sea level

Thrust fault—Sawteeth on upper plate. Fault marks southeast boundary of study area

Fault—Dashed where inferred

Western limit of steeply dipping rocks—Marks eastern boundary of study area

• **Data point**

Potential reservoir interval(s) (as defined in text) indicated in wells by porosity calculations made from geophysical logs

key wells indicates that the basal sands are separated from the Rome Formation by a wedge of siltstones and shales in the east-central part of Kentucky.

The top of Unit A occurs at depths greater than 300 m below sea level throughout the study area. It is about 900 m below sea level at the shallowest occurrence along the west boundary in central Ohio and 2,500 m below sea level east of a line drawn from central Columbiana County, Ohio, to central Bell County, Kentucky. In addition, it is deeper than 2,500 m in a small area that centers around parts of Clay, Jackson, Laurel, and Owsley Counties, Kentucky (fig. 6 and pl. 1). Here the top is estimated to be deeper than in the adjacent areas because the upper part of this section is composed of fine-grained sediments that are mapped as part of the overlying confining unit.

In the area where Unit A occurs between 300 m and 2,500 m below sea level, its thickness ranges from less than 50 m in the southwestern part of the area, from Pulaski County, Kentucky, to DeKalb and Warren Counties, Tennessee, to more than 700 m in Johnson County, Kentucky. The thickest parts of Unit A are bounded on the north and south by faults associated with the Kentucky River fault system and the Irvine-Paint Creek fault system, respectively, indicating these rocks were deposited in a graben. North of this faulted area the average thickness of the unit is about 175 m, and to the south it is estimated to be about 75 m (pl. 3*A*). The overall average area-weighted thickness is 144 m. Hydrogeologic sections displaying the depth to and thickness of Unit A, and its relation to the other rocks, are shown on plate 2.

Potential reservoir intervals were identified in Unit A in 28 key wells where both the top of the intervals and the top of the unit lie between 300 m and 2,500 m below sea level in the study area. Thirteen wells are located in Kentucky, 13 in Ohio, and 2 in Tennessee (fig. 6; pl. 3*A*; table 3). A summary of some of the characteristics and distribution of the reservoir porosity found in Unit A is given in table 4.

Data from the wells in Kentucky indicate about 75 percent of the potential reservoir intervals occur in the basal sandstones and 25 percent are found in the Rome Formation. Eighty-four percent of the intervals are found in sandstone, and the remainder are in dolomite and limestone. The median altitude of the top of potential reservoir intervals is about 1,220 m below sea level, and their median thickness is about 25 m. Two intervals occur in two of the 13 wells where reservoir porosity was identified, and one interval occurs in the remaining wells. When evaluated by interval, the median thicknesses of the reservoir-type zones have a median value of 2 m; the aggregate thicknesses of the zones have a median value of about 12 m; the median porosities of the zones range from 6 to 10 percent; and the average thickness-weighted porosities have a median value of 8 percent (table 3). The median thickness of confining intervals that immediately overlie and underlie the potential reservoir intervals is 190 m and less than 1 m to basement rock, respectively. The dominant lithologies constituting the overlying confining rocks are shales and carbonate rocks (43 percent each). The underlying confining rocks are composed of very fine-grained sandstone, siltstone, shale, and igneous or metamorphic basement rocks.

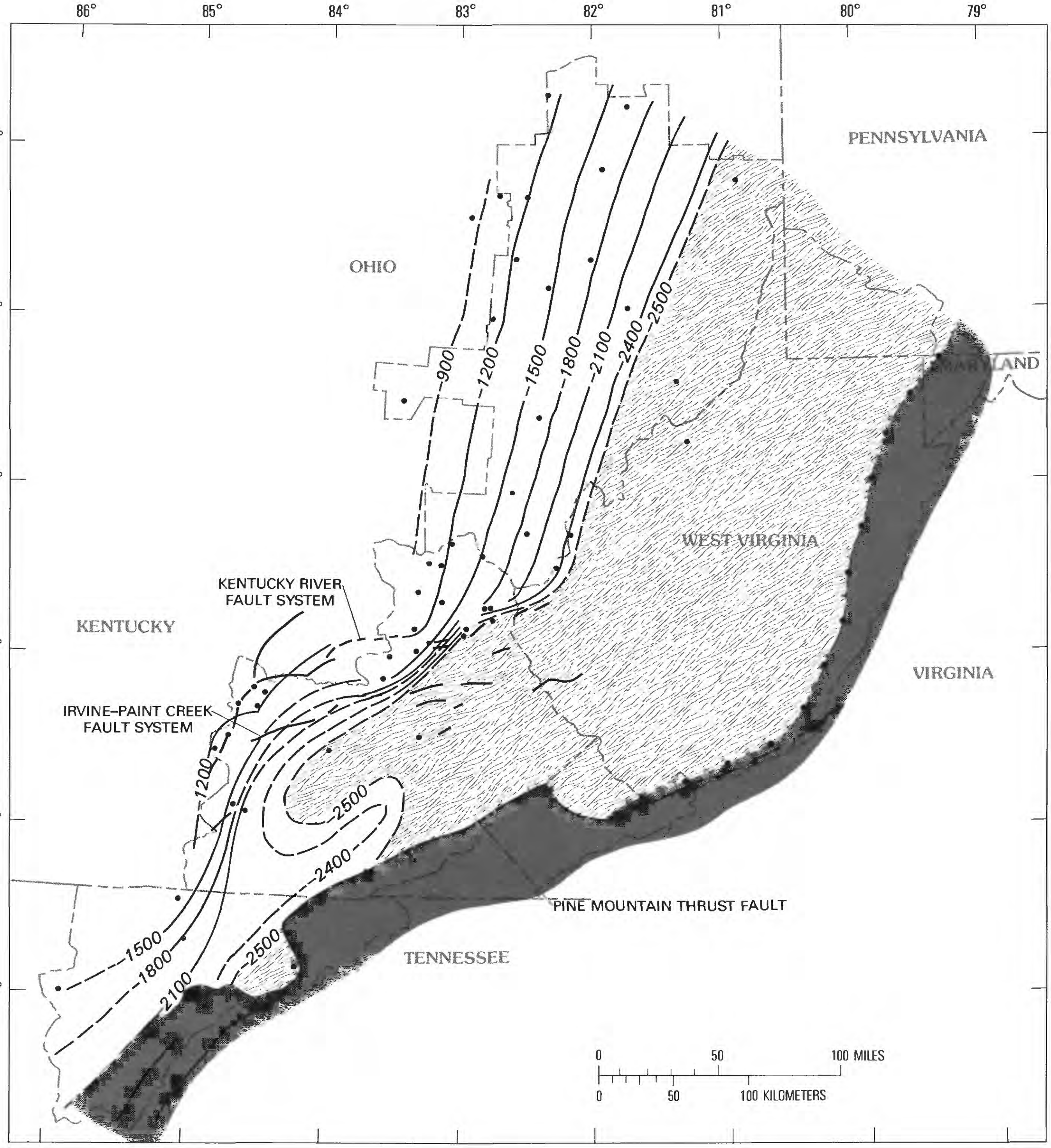


FIGURE 7 (above and facing page).—Areal distribution and altitude of the top of the major sandstone section in Potential Reservoir Unit A.

EXPLANATION

Approximate area where top of reservoir unit is deeper than 2500 meters below sea level—No defined waste-storage potential

Approximate area where rocks are thrust faulted or have a steep dip at land surface—No defined waste-storage potential

—900— **Structure contour**—Shows altitude of top of reservoir unit. Dashed where approximately located. Contour interval, in meters, is variable. Datum is sea level

Thrust fault—Sawteeth on upper plate. Fault marks southeast boundary of study area

Fault—Dashed where inferred

Western limit of steeply dipping rocks—Marks eastern boundary of study area

• **Data point**

In Ohio, 75 percent of the potential reservoir intervals occur in the basal sandstone (Mount Simon Sandstone), and the remainder mainly occur in the Rome Formation. About 67 percent of the intervals occur in sandstone, 27 percent in dolomite, and 6 percent occur in limestone. The median altitude of the top of the potential reservoir intervals is about 1,517 m below sea level, and their median thickness is 21 m. Two intervals occur in two of the 13 wells where potential reservoir porosity was identified, and one occurs in the remaining wells. When evaluated by interval, the median thicknesses of the reservoir-type zones have a median value of 1.8 m; the aggregate thicknesses of the zones have a median value of 9 m; the median porosities of the zones range from 5 to 15 percent; and their average thickness-weighted porosities have a median value of 8 percent (table 3). The median thickness of confining intervals that immediately overlie and underlie the potential reservoir intervals is 81 m and 1 m to basement rock, respectively. The dominant overlying confining rocks are dolomite and shale (in about 69 percent and 26 percent of the cases, respectively), and the dominant underlying confining rocks are basement (80 percent) and carbonate rocks (13 percent).

Potential reservoir intervals primarily occur in the basal sandstone in Unit A in Tennessee. Sixty-seven percent of the reservoir-type zones in the intervals were found in sandstone and 33 percent in dolomite. The median altitude of the top of the potential reservoir intervals is about 1,500 m below sea level, and their median thickness is 22 m. One interval occurs in each of the two wells where reservoir porosity was found. When evaluated by interval, the reservoir-type zones have a median aggregate thickness of about 20 m, and their median average thickness-weighted porosity is 7 percent. The median thickness of confining intervals that immediately overlie and underlie the potential reservoir intervals is 269 m and 6 m to basement rock, respectively. The dominant lithologies constituting the overlying confining rocks are shale (in 50 percent of the cases studied), siltstone (25 percent), and limestone (25 percent). The underlying confining rocks are composed of igneous or metamorphic basement rock.

Because the sandstone in the lower part of Unit A contains the majority of the reservoir-type zones, a separate map showing the altitude of the top and selected wells with estimated thickness of the sandstone has been prepared for comparison purposes (fig. 7). The areal distribution and altitude contours are quite similar to those for Unit A but are shifted to the west. The occurrence of sandstone with greatest thickness is localized near the Irvine-Paint Creek and Kentucky River fault systems from Lincoln County to Boyd County, Kentucky (pl. 1), where the thickness averages about 300 m. The thickness ranges from 573 m and 466 m in wells 147 and 195 in Lawrence and Madison Counties, Kentucky (pl. 1), respectively, to very little, if any, sandstone in well 259 in Pickett County, Tennessee (pl. 1), and averages about 25 m north of and about 50 m south of the faulted area. The values for the altitude of the top and thickness of the potential reservoir intervals are about the same as those for Unit A, 1,285 m and 23 m, respectively, indicating the dominant influence of the sandstones. The median values for the individual and aggregate thickness of the reservoir- type zones found within the intervals are 1.8 m and 11 m, respectively. Porosity of these zones ranges from 5 to 25 percent, and the median average thickness-weighted porosity is 8 percent (table 3).

POTENTIAL CONFINING UNIT A-B

Cambrian siltstones, shales, and shaly carbonate rocks that occur in the Rome Formation or the overlying Conasauga Group or Shale constitute Confining Unit A-B, which overlies Reservoir Unit A (fig. 3). The

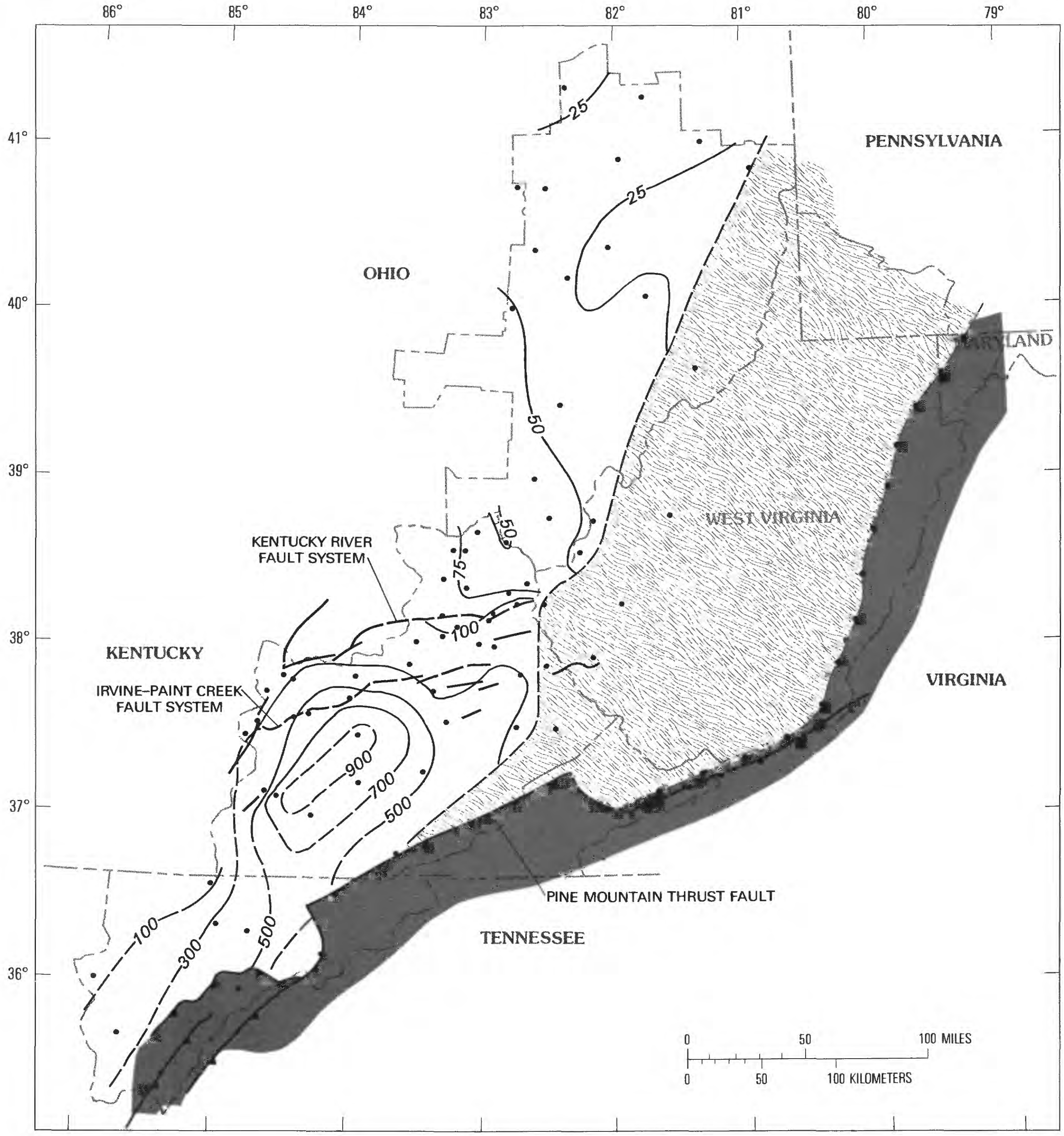


FIGURE 8 (above and facing page).—Thickness of Potential Confining Unit A-B.

EXPLANATION

Approximate area where top of underlying reservoir unit is deeper than about 2500 meters below sea level

Approximate area where rocks are thrust faulted or have a steep dip at land surface

—*300*— **Line of equal thickness of unit, in meters**—Dashed where approximate. Interval is 25 and 200 meters

Thrust fault—Sawteeth on upper plate. Fault marks southeast boundary of study area

Fault—Dashed where inferred

Western limit of steeply dipping rocks— Marks eastern boundary of study area

• **Data point**

average area-weighted thickness of this confining unit is 217 m, but the thickness ranges from 15 m in well 26 in Coshocton County, Ohio, to about 1,066 m in well 207 in Jackson County, Kentucky (pl. 1). The greatest thickness occurs in southeastern Kentucky between the Irvine-Paint Creek fault system and the Pine Mountain thrust fault (fig. 8). These thick sedimentary rocks are components of the Rome Formation and are, in part, the fine-grained equivalents of the thick sandstone mapped in Unit A to the north and northeast. As is the case for the thick sandstone in Unit A, the distribution and great thickness of these fine-grained sedimentary rocks is thought to be controlled by major east- and northeast-trending block faulting in the basement. The average area-weighted thickness of this confining unit is about 400 m in Kentucky and slightly less than 300 m in Tennessee; however, in Ohio it is thin, averaging about 35 m. The overall average area-weighted thickness of the unit is 217 m.

At places where the estimated thickness is less than about 30 m, the confining capacity of the unit may be limited. Geophysical well logs and lithologic descriptions of drill cuttings from wells 26 and 69 in Coshocton and Noble Counties, Ohio, respectively, and well 66 in Wood County, West Virginia (pl. 1), indicate very little if any shale or siltstone occurs between the underlying and overlying potential reservoir units. These data suggest that this unit is ineffective as a confining unit, at least in parts of eastern Ohio and central West Virginia. Hydrogeologic sections displaying the depth to and thickness of Unit A-B and its relation to the other rocks are shown on plate 2.

POTENTIAL RESERVOIR UNIT B

Reservoir Unit B overlies Confining Unit A-B and is found in the subsurface throughout most of the area. Surface exposures of this unit occur north of the Kentucky River fault system in Jessamine County, Kentucky; in the core of the Sequatchie anticline from Sequatchie County to Cumberland County, Tennessee (pl. 1); and east of the Pine Mountain thrust fault in Kentucky, Tennessee, and Virginia. The rocks that comprise this unit are predominately dolomites and limestones that attain an aggregate thickness of about 1,500 m. Some thin carbonate- and silica-cemented quartz sandstones occur in places, and these sandstones attain an aggregate thickness of about 70 m. The carbonate rocks range from Late Cambrian to Middle Ordovician in age. The dolomites are components of the Knox Group and Beekmantown Group or Dolomite, and the limestones comprise the Stones River and Nashville Groups and their stratigraphic equivalents (fig. 3).

The thin sandstones occur at the base of the Middle and Lower Ordovician carbonate rocks (fig. 3). The Middle Ordovician St. Peter Sandstone and equivalents are found in eastern Kentucky and in adjacent parts of Ohio and West Virginia where the units lie on top of an old erosional surface called the Knox unconformity. The thickness averages 10- 15 m and reaches a maximum of about 21 m in three small depositional centers that appear to be associated with the faulting in Powell, Elliott, and Martin Counties, Kentucky (pl. 1) (Freeman, 1953). Rocks that correlate with the Rose Run Sandstone (informal usage in some areas) of Early Ordovician age occur between 300 and 2,500 m below sea level in northeastern Kentucky and parts of eastern and southern Ohio and southwestern West Virginia (Patchen and others, 1985a, b). The southern extent of this sandstone is marked approximately by lat. 37°30′ N., where its distinctive lithologic character changes to that of the overlying and underlying dolomites (Janssen, 1973). This sandstone generally thickens westward and southward from its updip limit in Ohio to over 50 m in several key wells in and near the faulted area in central Kentucky. The average thickness is about 35 m.

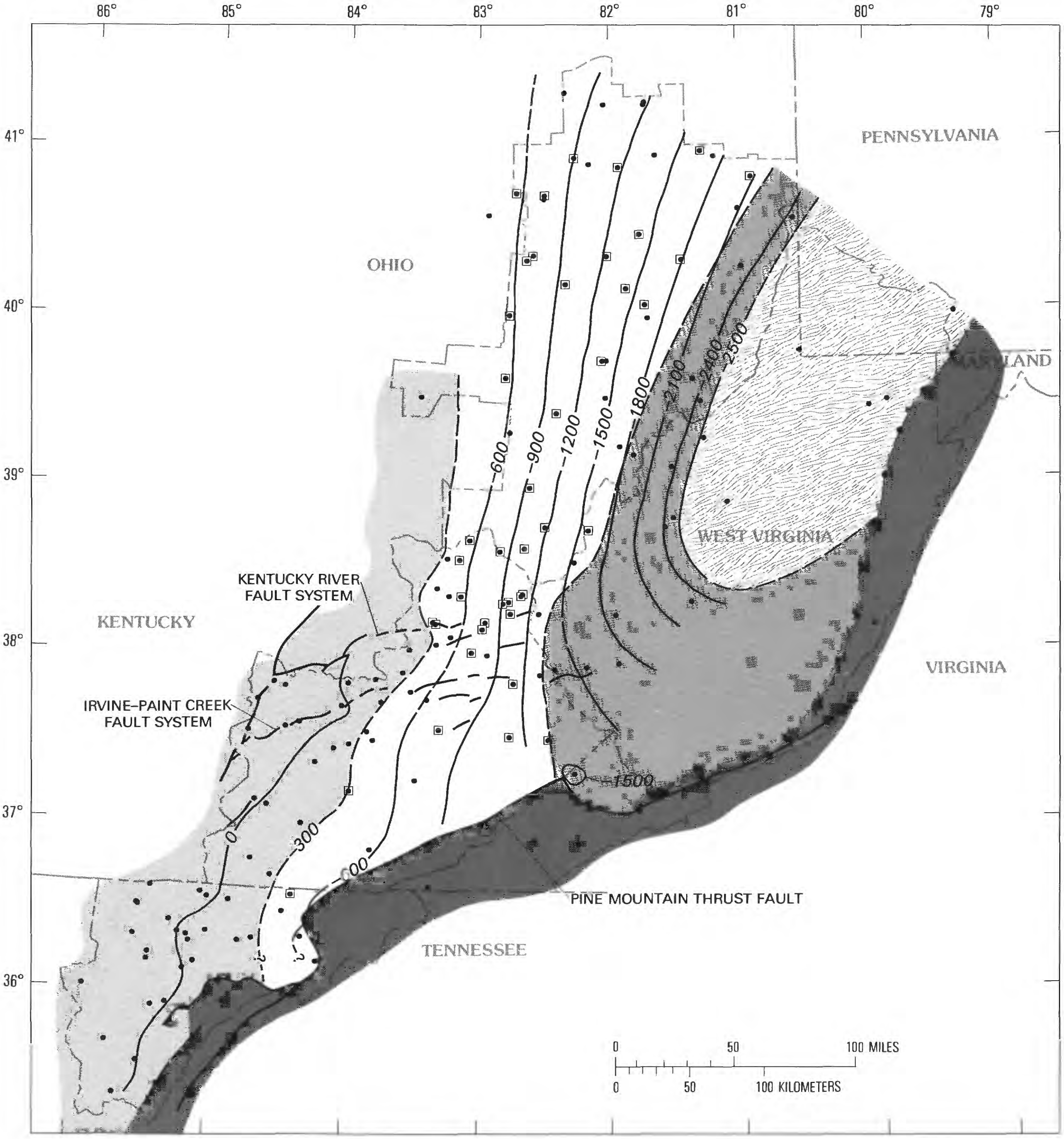


FIGURE 9 (above and facing page).—Areal distribution and altitude of the top of Potential Reservoir Unit B.

EXPLANATION

Approximate area where top of reservoir unit occurs above about 300 meters below sea level—No defined waste-storage potential

Approximate area where top of reservoir unit is deeper than 2500 meters below sea level—No defined waste-storage potential

Approximate area where bottom of unit is deeper than about 2,500 meters below sea level—Decreases chance for waste-storage potential

Approximate area where rocks are thrust faulted or have a steep dip at land surface—No defined waste-storage potential

— —*600*— **Structure contour**—Shows altitude of top of reservoir unit. Dashed where approximately located. Contour interval, in meters, is variable. Datum is sea level

Thrust fault—Sawteeth on upper plate. Fault marks southeast boundary of study area

Fault—Dashed where inferred

Western limit of steeply dipping rocks—Marks eastern boundary of study area

• **Data point**

Potential reservoir interval(s) (as defined in text) indicated in wells by porosity calculations made from geophysical logs

The top of Unit B is deeper than 300 m below sea level throughout most of the area in Ohio, in the eastern two-thirds of Kentucky, and in the northeastern corner of Tennessee (fig. 9). It is deeper than 2,500 m below sea level in southwestern Pennsylvania, in central and northwestern West Virginia, and in a small, adjacent section of southeastern Ohio. Because of the gentle dip and great thickness of this unit, there is a large area between where the base and the top descend below 2,500 m below sea level (fig. 9). At any given place within this area, only some proportionate part of the total thickness of the unit is shallower than 2,500 m below sea level.

Within the defined depth limitations, the thickness of this unit ranges from 195 m in well 1 in Lorain County, Ohio, to 1,469 m in well 244 in McCreary County, Kentucky (pl. 1), respectively, and has an estimated area- weighted average of about 850 m. This average thickness was determined by estimating the unit thickness at 1400 m for the area marked "no data" on plate 3*B* and averaging it (on an area-weighted basis) with the calculated 700 m thickness for the unit throughout the rest of the area. The general thinning of this unit toward the northwest, in Ohio (pl. 3*B*), is in large part caused by the erosion of the rocks lying beneath the Knox unconformity (fig. 3). Figure 10 shows the approximate altitude of the unconformity and the approximate percentage of Unit B found below this feature. A careful comparison of figures 9 and 10 and plate 3*B* indicates that the major part of the reservoir porosity found in Unit B occurs in the rocks below or just above the Knox unconformity. Hydrogeologic sections displaying the depth to and thickness of Unit B and its relation to the other rocks are shown on plate 2.

Potential reservoir intervals were identified in Unit B in a total of 43 wells where both the top of the intervals and the top of the unit lie between 300 m and 2,500 m below sea level in the area (fig. 9; pl. 3*B*; table 3). Nineteen wells are located in Kentucky, 22 in Ohio, 1 in Tennessee, and 1 in West Virginia. Table 4 presents a summary of some of the characteristics and distribution of the reservoir porosity found in Unit B.

Data from the wells in Kentucky indicate that the majority of the potential reservoir intervals are found in rocks below the Knox unconformity. Seventy-five percent of the potential reservoir intervals were found in dolomite, 6 percent in limestone, and 19 percent in sandstone. The median altitude of the top of the potential reservoir intervals in Unit B is about 1,207 m below sea level, and the median thickness of the intervals is 94 m. One to four intervals occur in the wells where reservoir porosity was identified. When evaluated by interval, the median thicknesses of the reservoir-type zones found within the intervals have a median value of 1.2 m; the aggregate thicknesses of the zones have a median value of 21 m; the median porosities of the zones range from 5 to 8 percent; and the average thickness-weighted porosities have a median value of 7 percent (table 3). Confining intervals that immediately overlie and underlie the potential reservoir intervals have a median thickness of about 50 m and 70 m, respectively, and are primarily composed of carbonate rocks.

In Ohio, the majority of the potential reservoir intervals found in Unit B are in rocks that occur below the erosional unconformity. About 85 percent of the potential reservoir porosity occurs in the Knox Group and about 6 percent occurs in the Rose Run sandstone (informal usage). The remainder occurs above the unconformity in the unnamed equivalents of the St. Peter

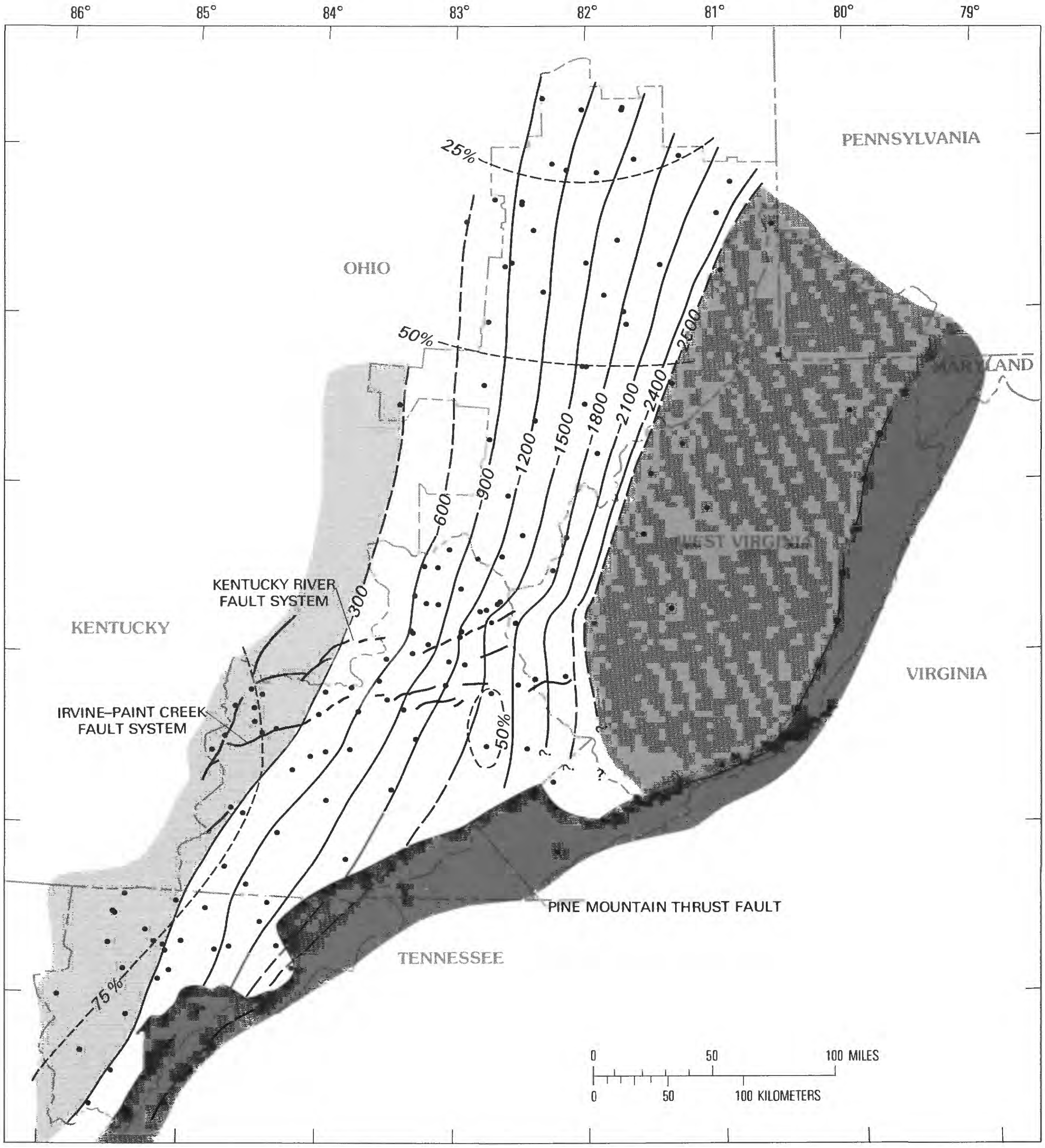


FIGURE 10 (above and facing page).—Areal distribution and altitude of the Knox unconformity on the surface of the Knox Group.

EXPLANATION

Approximate area where unconformity occurs above about 300 meters below sea level

Approximate area where unconformity is deeper than 2500 meters below sea level

Approximate area where rocks are thrust faulted or have a steep dip at land surface

—900— **Structure contour**—Shows altitude of top of unconformity. Dashed where approximately located. Contour interval is 300 and 100 meters. Datum is sea level

Thrust fault—Sawteeth on upper plate. Fault marks southeast boundary of study area

Fault—Dashed where inferred

Western limit of steeply dipping rocks—Marks eastern boundary of study area

—25%— **Line of equal percentage of Reservoir Unit B occurring below the unconformity**

• **Data point**

Sandstone and Wells Creek Dolomite and in overlying Middle Ordovician limestone. The median altitude of the top of the potential reservoir intervals is 1,227 m below sea level, and their median thickness is 70 m. One interval occurs in most of the wells where reservoir porosity was identified. When evaluated by interval, the median thicknesses of the reservoir-type zones have a median value of 1.5 m; the aggregate thicknesses of the zones have a median value of 16 m; the median porosities of the zones range from 5 to 12 percent; and the average thickness-weighted porosities have a median value of 8 percent (table 3). The median thicknesses of confining intervals that immediately overlie and underlie the potential reservoir intervals are 75 m and 56 m, respectively. Dominant lithologies of the overlying confining rocks are limestone (in 56 percent of the studied cases), shale (23 percent), and dolomite (21 percent). Dolomite and shale comprise the underlying confining rocks in 61 and 36 percent of the studied cases, respectively.

All of the four potential reservoir intervals found in Unit B in well 266 in Tennessee occur below the Knox unconformity. The potential reservoir porosity is found in the Copper Ridge Dolomite of the Knox Group of Late Cambrian age and the overlying units of the Knox Group of Early Ordovician age. The median thickness of the potential reservoir intervals is about 104 m, and the median altitude of their top is about 1,107 m below sea level. Four intervals were found in well 266. When evaluated by interval, the median thicknesses of the reservoir-type zones found within the intervals have a median value of 0.7 m; the aggregate thicknesses of the zones have a median value of 10 m; the median porosities of the zones range from 6 to 10 percent; and the average thickness-weighted porosities have a median value of 8 percent (table 3). The median thickness of confining intervals that immediately overlie and underlie the potential reservoir intervals is 85 m and 78 m, respectively. Limestone and dolomite comprise the overlying and underlying confining rocks.

Most of the potential reservoir intervals found in Unit B in well 127 in West Virginia occur in rocks below the erosional unconformity. Thirty-eight percent of the potential reservoir porosity is found in the Conococheaque Limestone, and 46 percent in the Beekmantown Dolomite. The remainder occurs in rocks that overlie the unconformity. Two potential reservoir intervals were found in well 127. Median thickness of the potential reservoir intervals is 86 m, and the median altitude of their top is 1,978 m below sea level. When evaluated by interval, the median thicknesses of the reservoir-type zones that occur within the intervals have a median value of 1 m; the aggregate thicknesses of the zones have a median value of 13 m; the median porosities of the zones range from 6 to 7 percent; and the average thickness-weighted porosities have a median value of 7 percent (table 3). The median thickness of confining intervals that immediately overlie and underlie the potential reservoir intervals is 188 m and 143 m, respectively. Dolomite and limestone constitute the bulk of the potential confining rocks.

POTENTIAL CONFINING UNIT B-C

Confining Unit B-C overlies Reservoir Unit B and is composed of a mixture of very fine-grained sandstone, siltstone, shale, and shaly carbonate rocks that range from Middle Ordovician to Early Mississippian in age. The large range in age is caused by the fact that younger reservoir units that occur in the northern and eastern part of the area thin, pinch out, or change to a silty-shaly facies that forms one confining unit toward the southwest. Therefore, where appropriate, these units are added to and mapped as part of Confining Unit B-C. The index map and diagrammatic cross section of figure

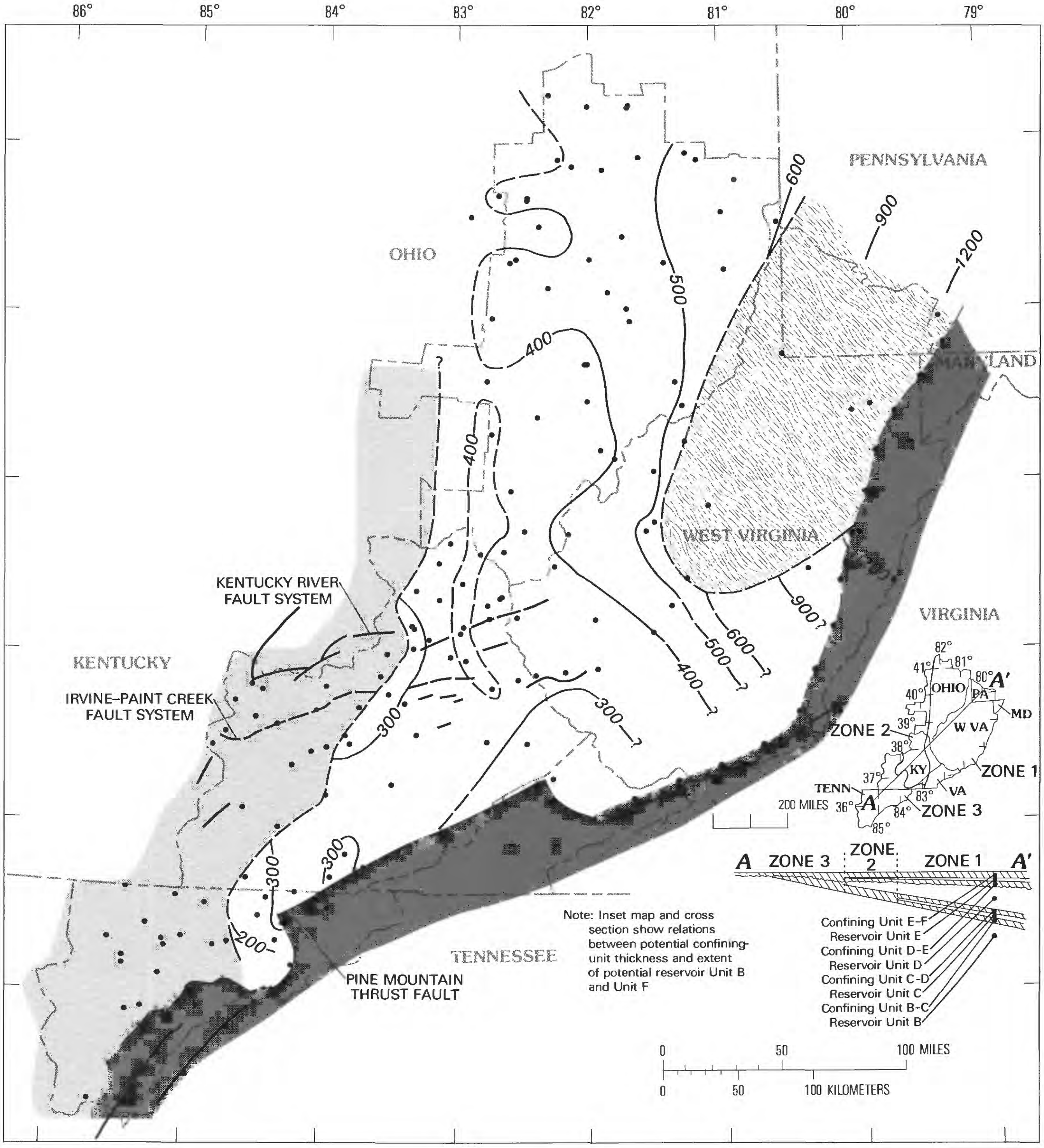


FIGURE 11 (above and facing page).—Thickness of Potential Confining Unit B-C.

EXPLANATION

Approximate area where top of unit occurs above about 300 meters below sea level

Approximate area where top of underlying reservoir unit is deeper than about 2500 meters below sea level

Approximate area where rocks are thrust faulted or have a steep dip at land surface

—*300*— **Line of equal thickness of unit, in meters**—Dashed where approximate. Interval is 300 and 100 meters

Thrust fault—Sawteeth on upper plate. Fault marks southeast boundary of study area

Fault—Dashed where inferred

Western limit of steeply dipping rocks—Marks eastern boundary of study area

• **Data point**

11 shows the areas and the reservoir and confining units that are considered to constitute Unit B-C in three different zones throughout the study area.

Zone one is located east of a line drawn from central Lorain County, Ohio, to western Lee County, Virginia (pl. 1). In this zone, Confining Unit B-C is generally composed of the rocks found between the top of the Trenton Limestone and the base of the Tuscarora Sandstone and includes the Ordovician Martinsburg Formation, Reedsville Shale, Juniata Formation, and their equivalents (fig. 3). The thickness of Confining Unit B-C is contoured and discussed only for the area in which the underlying potential reservoir unit lies between 300 m and 2,500 m below sea level. The confining unit's thickness in zone one ranges from 242 m in well 233 in Wise County, Virginia (pl. 1), to 1,274 m in well 104 in Randolph County, West Virginia (pl. 1), and the average thickness is about 425 m. In general, it thickens from the west and southwest to the east and northeast (fig. 11).

The boundary between zones one and two is marked by the long, narrow 400 m contour closure oriented in a north-south direction in figure 11. This feature results from the abrupt addition of the silty and shaly facies of the Silurian Tuscarora Sandstone and equivalents and the overlying Rose Hill Formation to Confining Unit B-C in zone two. The thickness of the confining unit in zone two ranges from a little over 400 m in the key wells in Licking and Morrow Counties, Ohio, to 227 m in well 191 in Lee County, Kentucky (pl. 1), and averages 325 m.

Zone three begins at the western limit of Reservoir Unit D (see index map in figs. 11 and 14). Any rocks equivalent to Unit D west of this line are included with Confining Unit B-C along with the overlying formations up to the base of Reservoir Unit F. Thus, in zone three, Confining Unit B-C generally includes all the rocks from top of the Middle Ordovician Trenton Limestone to the base of the Mississippian Newman Limestone and its equivalents or, where present, to the base of the Fort Payne Formation (fig. 3). The estimated thickness ranges from less than 200 m in Morgan and Anderson Counties, Tennessee, to 389 m in well 210 in Clay County, Kentucky (pl. 1). The average thickness is about 260 m.

The overall average area-weighted thickness of Confining Unit B-C is 423 m. Hydrogeologic sections displaying the depth to, and thickness of, Unit B-C and its relation to the other rocks are shown on plate 2.

POTENTIAL RESERVOIR UNIT C

Reservoir Unit C overlies Confining Unit B-C and is composed of the Albion and Tuscarora Sandstones and equivalents of Early Silurian age (fig. 3). This unit is confined to the subsurface throughout the study area, and its top ranges from about 400 m below sea level at the western limit of the unit in Ohio to greater than 2,500 m below sea level in northeastern West Virginia and southwestern Pennsylvania (fig. 12). The western limit approximately coincides with the western extent of oil and gas production from this unit in Ohio and Kentucky (DeBrosse and Vohwinkel, 1974; Wilson and Sutton, 1976). As discussed in the previous section, Reservoir Unit C is mapped as part of the underlying Confining Unit B-C (Zone 3) west of this line.

Reservoir Unit C generally thickens from west to east, from 10 m in Ashland, Licking, and Wayne Counties, Ohio, to over 100 m in parts of Barbour, Preston, Randolph, and Upshur Counties, West Virginia (pls. 1, *3C*). Overall, it has an average area-weighted thickness of about 36 m. It is less than 25 m in thickness in the western part, which accounts for about 25 to 30 percent of the total area. The elongate, adjacent thick and thin areas marked by the re-entrants of the 25 m-line of equal thickness in plate *3C* in southwestern West Virginia lie along and appear to be controlled by the eastern and northeastern extension of the block faulting that is so well developed in central Kentucky.

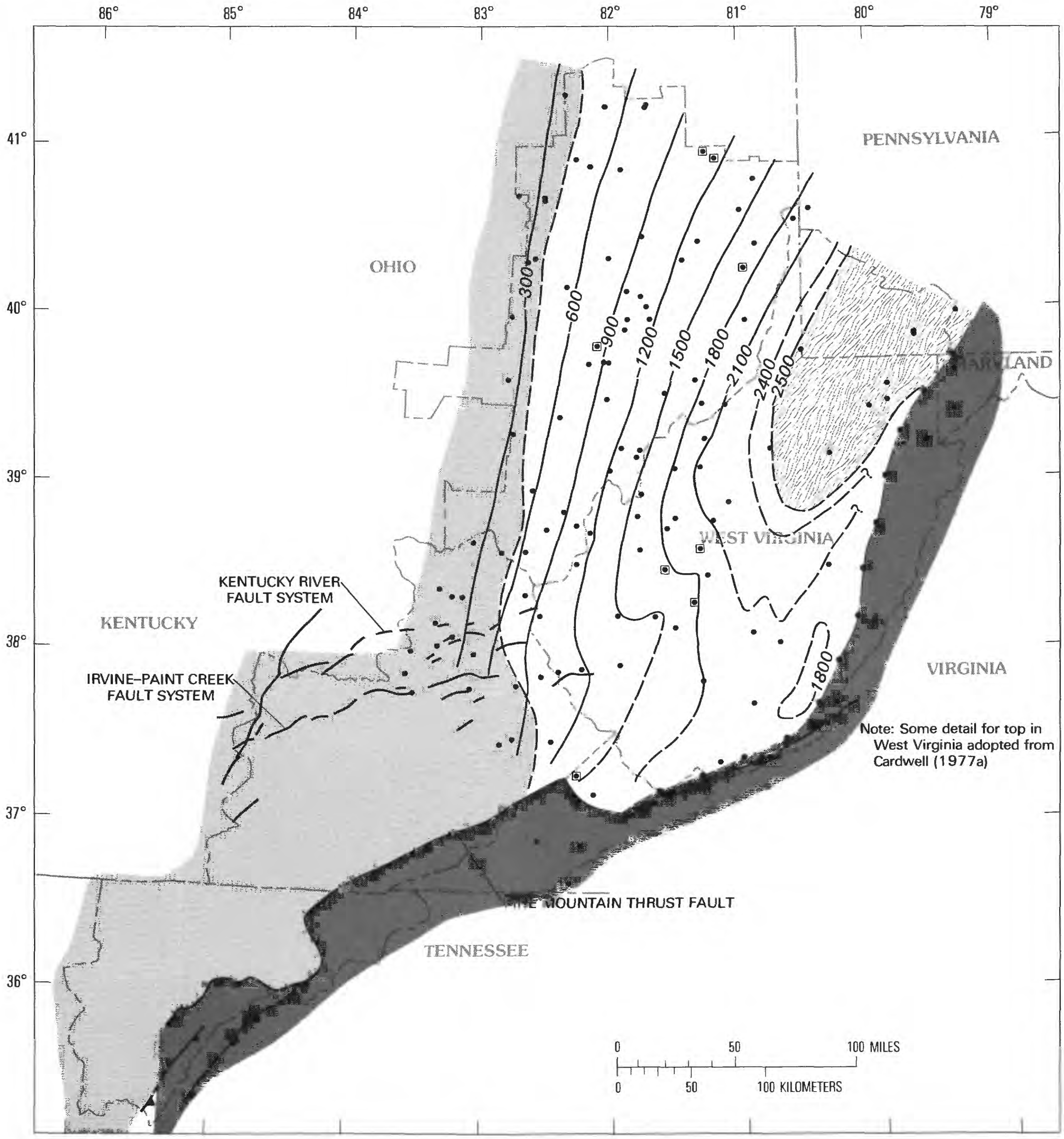


FIGURE 12 (above and facing page).—Areal distribution and altitude of the top of Potential Reservoir Unit C.

EXPLANATION

Dashed line marks approximate western limit of reservoir potential for unit—West of this line the unit is generally a better seal than a reservoir, and has no defined waste-storage potential

Approximate area where top of reservoir unit is deeper than 2500 meters below sea level—No defined waste-storage potential

Approximate area where rocks are thrust faulted or have a steep dip at land surface—No defined waste-storage potential

-300 **Structure contour**—Shows altitude of top of reservoir unit. Dashed where approximately located. Contour interval, in meters, is variable. Datum is sea level

Thrust fault—Sawteeth on upper plate. Fault marks southeast boundary of study area

Fault—Dashed where inferred

Western limit of steeply dipping rocks—Marks eastern boundary of study area

Data point

Potential reservoir interval(s) (as defined in text) indicated in wells by porosity calculations made from geophysical logs

Hydrogeologic sections displaying the depth to and thickness of Reservoir Unit C and its relation to other rocks are shown on plate 2, lines of section *A–A'*, *B–B'*, and *E–E'*.

Potential reservoir intervals were identified in Reservoir Unit C in a total of seven wells where both the top of the intervals and the top of the unit lie between 400 m and 2,500 m below sea level in the study area (fig. 12; pl. 3*C*; table 3). Four wells are located in Ohio, two in West Virginia, and one in Virginia. A summary of some of the characteristics and distribution of reservoir porosity in Reservoir Unit C is given in table 4.

In Ohio, the median altitude of the top of the potential reservoir intervals is 1,110 m below sea level, and their median thickness is about 24 m. One interval was found in each well where reservoir porosity was identified. When evaluated by interval, the median thicknesses of the reservoir-type zones that occur within the intervals have a median value of 5 m; the aggregate thicknesses of the zones have a median value of 11 m; the median porosities of the zones range from 5 to 10 percent; and the average thickness-weighted porosities have a median value of 9 percent (table 3). The median thickness of confining intervals that immediately overlie and underlie the potential reservoir intervals is 78 m and 586 m, respectively. These overlying and underlying confining rocks are composed of shale (60 percent) and limestone (40 percent).

In West Virginia, the median altitude of the top of the potential reservoir intervals is 1,767 m below sea level, and their median thickness is 18 m. One interval occurs in each well where reservoir porosity was identified (table 3). When evaluated by interval, the median thicknesses of the reservoir-type zones found within the intervals have a median value of 6 m; the aggregate thicknesses of the zones have a median value of 12 m; the median porosity of the zones is 6 percent; and the average thickness- weighted porosities have a median value of 6 percent (table 3). Immediate overlying confining intervals have a median thickness of 144 m. Only one of the wells penetrates the underlying confining interval, indicating a thickness of 695 m. The overlying confining rocks are comprised of shale (in 75 percent of the studied cases) and fine-grained sandstone (25 percent). The underlying confining rocks are composed of equal amounts of shale and limestone.

Data from the one well in Virginia (well 222) indicate that the altitude of the top of the potential reservoir interval is 1,473 m below sea level and that the thickness is 20 m. Only one interval was identified. The reservoir-type zones within the interval have a median thickness of 2.4 m and an aggregate thickness of 13 m. The porosity of these zones ranges from 5 to 6 percent, and their average thickness-weighted porosity is 5 percent. The thickness of confining intervals that immediately overlie and underlie the potential reservoir interval is 107 m and 308 m, respectively. Shale comprises the overlying confining rocks and equal amounts of shale and limestone comprise the confining rocks that underlie the interval.

POTENTIAL CONFINING UNIT C-D

Middle Silurian shales, siltstones, very fine-grained sandstones, and a few thin carbonates of the Rose Hill Formation and equivalents constitute Confining Unit C-D (fig. 3) which overlies Reservoir Unit C. Confining Unit C-D thickens from less than 50 m in northern Ohio and from about 100 m near the boundary between Pike County, Kentucky, and Buchanan County, Virginia, to over 150 m in northeastern West Virginia and

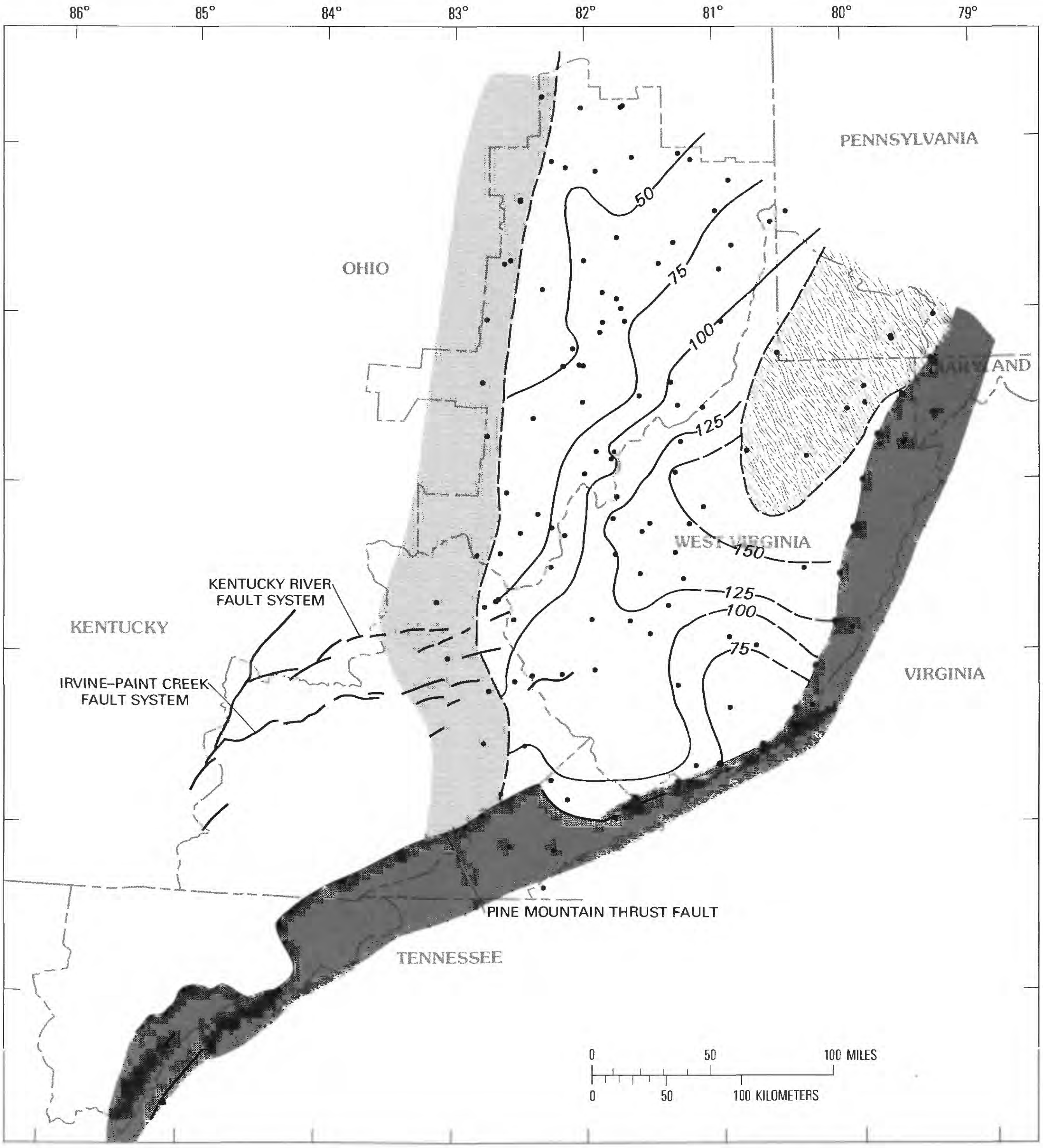


FIGURE 13 (above and facing page).—Thickness of Potential Confining Unit C-D.

EXPLANATION

Dashed line marks approximate western limit of underlying Reservoir Unit C

Approximate area where top of underlying reservoir unit is deeper than 2500 meters below sea level

Approximate area where rocks are thrust faulted or have a steep dip at land surface

100 **Line of equal thickness of unit, in meters**—Dashed where approximate. Interval is 25 meters

Thrust fault—Sawteeth on upper plate. Fault marks southeast boundary of study area

Fault—Dashed where inferred

Western limit of steeply dipping rocks—Marks eastern boundary of study area

• **Data point**

southwestern Pennsylvania (pl. 1). The thinnest occurrence was found in well 4 in Medina County, Ohio, where it is estimated to be 17 m thick; the thickest was found in well 44 in Fayette County, Pennsylvania, where it is about 282 m thick. The average thickness of Unit C-D is about 65 m in Ohio, 178 m in West Virginia, and about 87 m in Kentucky and Virginia (pl. 1). Overall, its average area-weighted thickness is about 92 m where the underlying reservoir unit occurs between 300 m and 2,500 m below sea level (fig. 13).

Hydrogeologic sections displaying the depth to and thickness of Unit C-D and its relation to the other rocks are shown on plate 2.

POTENTIAL RESERVOIR UNIT D

Reservoir Unit D overlies Confining Unit C-D and is composed of the rocks that occur between the base of the Keefer Sandstone and equivalents of Middle Silurian age and the top of the Onondaga Limestone and equivalents of Middle Devonian age (fig. 3). This unit is mostly confined to the subsurface in the study area, but parts of it are exposed near the western boundary in southern Ohio and northern Kentucky. Middle and Lower Devonian limestone and Upper and Middle Silurian limestone and dolomite constitute the bulk of this unit; however, three quartz sandstones are found in the central and northern part of the area.

The Lower Devonian Oriskany Sandstone is the thickest of these sandstones and extends from Garrett County, Maryland (pl. 1), where it is over 75 m thick (Oliver and others, 1971), to its western limit in eastern Ohio and northeastern Kentucky. Its average thickness is about 30 m. The sandstone of the Upper Silurian Williamsport Formation and equivalents is the most restricted of the three sandstones and is found generally in south-central, western, and northeastern West Virginia and in Garrett County, Maryland. Its thickness ranges to slightly over 30 m in southwestern Greenbrier County, West Virginia (pl. 1) and averages about 10 m (Patchen, 1974). The Keefer Sandstone and equivalents are found generally throughout West Virginia and in adjacent parts of Ohio, Kentucky, Virginia, Pennsylvania, and Maryland (Chen, 1977). This sandstone generally thickens from the northwest to over 60 m in southeastern West Virginia and has an average thickness of about 9 m.

The top of Reservoir Unit D is deeper than 300 m below sea level east of a line drawn from central Summit County, Ohio, to central Bell County, Kentucky (fig. 14; pl. 1). The deepest occurrence was found in well 43 in Fayette County, Pennsylvania (pl. 1), where the top is 2,045 m below sea level. The bottom part of the unit is deeper than 2,500 m below sea level in parts of northeastern West Virginia and southwestern Pennsylvania (fig. 14).

Where the top of this unit lies deeper than 300 m below sea level, its thickness ranges from 1,135 m in well 44 in Fayette County, Pennsylvania (pl. 1), to less than 50 m in several wells in south-central Kentucky (pl. 3*D*). The overall average area-weighted thickness of Unit D is about 410 m. The unit appears to have been thickened by reverse faulting along the Burning Springs anticline in parts of Pleasants, Ritchie, Wirt, and Wood Counties, West Virginia (pl. 1). The pronounced thinning toward the west and southwest is caused by erosion and overlap. The Oriskany Sandstone and older rocks are beveled by erosion, and the rocks between the top of the Oriskany and the top of the Onondaga Limestone and its stratigraphic equivalents thin, pinch out, and are overlapped by younger units (Dennison, 1961).

Some of the Upper Silurian rocks (Salina Formation, Wills Creek Shale, and Tonoloway Limestone, see fig. 3) contain evaporite deposits of anhydrite and salt that generally serve as confining beds within this unit (Martens, 1943; Fergusson and Parther, 1968; Clifford, 1973; Norris, 1978). Figure 15 shows the areal extent, altitude of the top, and thickness of the section in which

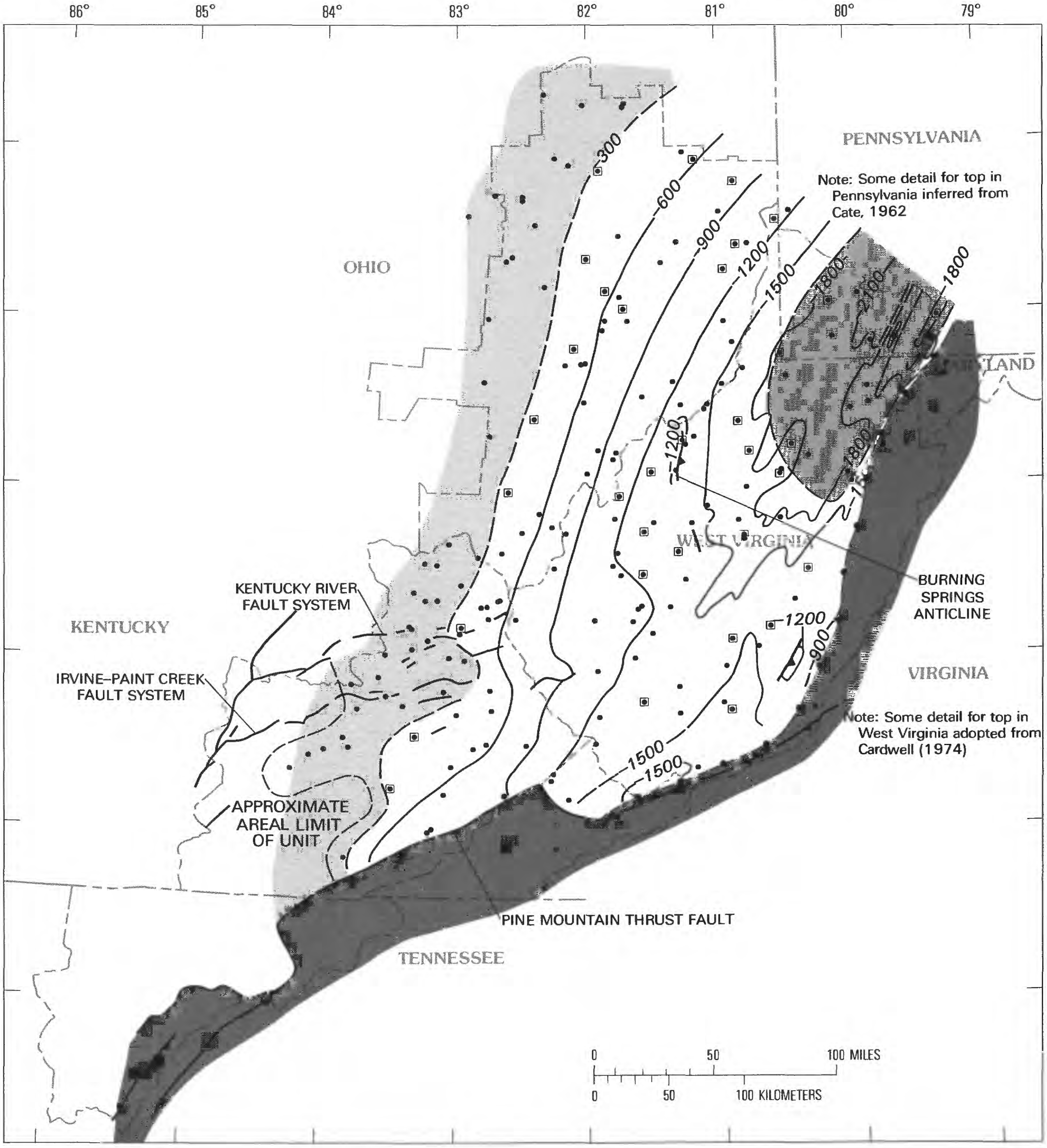


FIGURE 14 (above and facing page).—Areal distribution and altitude of the top of Potential Reservoir Unit D.

EXPLANATION

Approximate area where top of reservoir unit occurs above about 300 meters below sea level—No defined waste storage potential

Approximate area where bottom of reservoir unit is deeper than 2500 meters below sea level

Approximate area where rocks are thrust faulted or have a steep dip at land surface—No defined waste-storage potential

—*900*— **Structure contour**—Shows altitude of top of reservoir unit. Dashed where approximately located. Contour interval is 300 meters. Datum is sea level

Thrust fault—Sawteeth on upper plate. Fault marks southeast boundary of study area

Fault—Dashed where inferred

Western limit of steeply dipping rocks—Marks eastern boundary of study area

Data point

Potential reservoir interval(s) (as defined in text) indicated in wells by porosity calculations made from geophysical logs

evaporates occur. Any reservoir potential within or below this evaporite-bearing interval would be enhanced by additional assurance of confinement. Hydrogeologic sections displaying the depth to and thickness of Unit D and its relation to the other rocks are shown on plate 2, lines of section *A–A'*, *B–B'*, *D–D'*, and *E–E'*.

Potential reservoir intervals were identified in Unit D in a total of 38 wells where both the top of the intervals and the top of the unit lie between 300 m and 2,500 m below sea level in the study area (fig. 14; pl. 3*D*; table 3). Nineteen wells are located in West Virginia, 12 in Ohio, 4 in Pennsylvania, and 3 in Kentucky. Table 4 presents a summary of some of the characteristics and distribution of the reservoir porosity for Unit D.

Data from the wells in West Virginia indicate that about 60 percent of the potential reservoir intervals are found in carbonate rock (dolomite, 33 percent; limestone, 27 percent), and the remaining intervals are found in sandstone and chert. About 70 percent of the potential reservoir porosity occurs above the evaporite-bearing rocks shown in figure 15, and about 25 and 5 percent occurs within and below these rocks, respectively. The median altitude of the top of the potential reservoir intervals is about 1,562 m below sea level, and median thickness of the intervals is 73 m. As many as five potential reservoir intervals were found in one of the wells, but one or two intervals were most common in the other wells where reservoir porosity was identified (table 3). When evaluated by interval, the median thicknesses of the reservoir-type zones found within the intervals have a median value of 1.2 m; the aggregate thicknesses of the zones have a median value of 14 m; the median porosities of the zones range from 5 to 12 percent; and the average thickness-weighted porosities have a median value of 7 percent (table 3). Confining intervals that immediately overlie and underlie the potential reservoir intervals have a median thickness of 276 m and 74 m, respectively. Fine-grained clastic rocks compose about 47 percent of the overlying confining rocks (shale, 33 percent; siltstone, 14 percent), 43 percent is composed of carbonate rocks (limestone, 25 percent; dolomite, 18 percent), and 10 percent is composed of evaporites (anhydrite and salt, 4 and 6 percent, respectively). For the underlying confining rocks, 31 percent is composed of clastic rocks (very fine-grained sandstone, 8 percent; shale, 23 percent), and 56 percent is composed of carbonate rocks (limestone, 33 percent; dolomite, 23 percent), and 13 percent is composed of evaporites (salt, 8 percent; anhydrite, 5 percent).

In Ohio, 36 percent of the identified potential reservoir porosity in Unit D is found above the evaporite-bearing rocks, and 7 and 57 percent occurs within and below these beds, respectively. All the potential reservoir intervals are found in carbonate rocks (dolomite, 64 percent; limestone, 36 percent). The median altitude of the top of the potential reservoir intervals is 681 m below sea level, and their median thickness is 71 m. Two potential reservoir intervals were found in each of 3 wells, and one interval occurred in each of the other 10 wells where reservoir porosity is found. When evaluated by interval, the median thicknesses of the reservoir-type zones that occur within the intervals have a median value of 1.5 m; the aggregate thicknesses of the zones have a median value of 13 m; the median porosities of the zones range from 5 to 9 percent; and the average thickness-weighted porosities have a median value of 8 percent (table 3). Confining intervals that immediately overlie and underlie the potential reservoir intervals have a median thickness of 196 m and 83 m, respectively. The dominant lithologies for the overlying confining rocks are shale (in 34 percent of the studied cases), dolomite (31

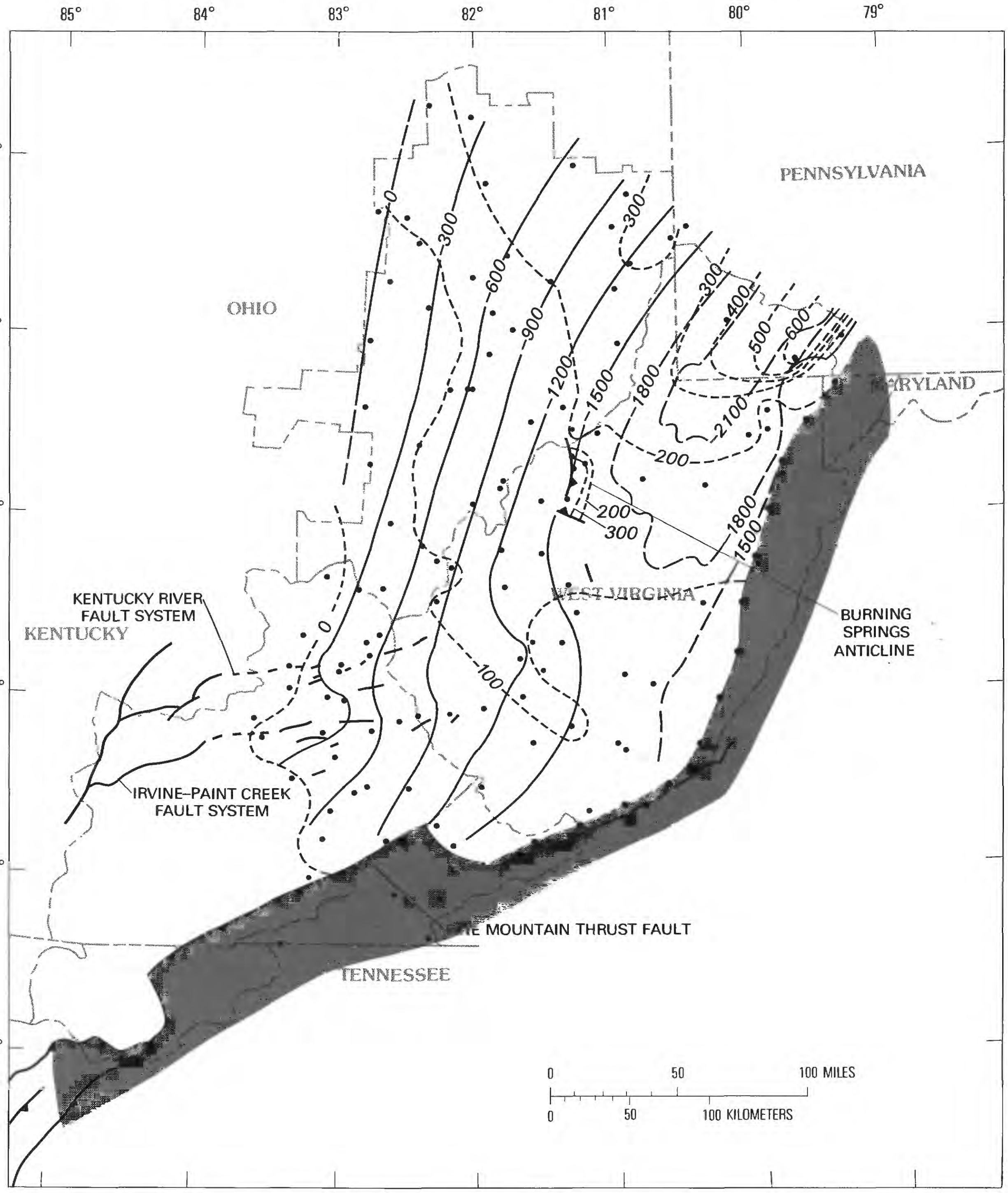


FIGURE 15 (above and facing page).—Areal distribution, altitude of the top, and estimated thickness of evaporite-bearing rocks in Potential Reservoir Unit D.

EXPLANATION

Approximate area where rocks are thrust faulted or have a steep dip at land surface

—*300*— **Structure contour**—Shows altitude of top of evaporite-bearing part of reservoir unit. Dashed where approximately located. Contour interval is 300 meters. Datum is sea level

– –*100*– – **Line of equal thickness of unit, in meters**—Short dashed where approximate. Interval is 100 meters

Thrust fault—Sawteeth on upper plate. Fault marks southeast boundary of study area

Fault—Dashed where inferred

Western limit of steeply dipping rocks—Marks eastern boundary of study area

• **Data point**

percent), and anhydrite (19 percent). The underlying confining rocks are comprised mainly of dolomite (38 percent of the studied cases), shale (28 percent), anhydrite (14 percent), salt (10 percent), and limestone (7 percent).

In Pennsylvania, about 37 percent of the identified potential reservoir porosity in Unit D is found above the evaporite-bearing rocks, and 48 and 15 percent occur within and below these beds, respectively. All the reservoir porosity is found in carbonate rocks (dolomite, 80 percent; limestone, 20 percent). The median altitude of the top of the potential reservoir intervals is about 2,130 m below sea level, and their median thickness is 27 m. Two intervals were found in one of the four wells where potential reservoir porosity was identified. When evaluated by interval, the median thicknesses of the reservoir-type zones that are found within the intervals have a median value of 2.4 m; the aggregate thicknesses of the zones have a median value of 8 m; the median porosities of the zones range from 5 to 9 percent; and the average thickness-weighted porosities have a median value of 6 percent (table 3). The median thickness of overlying and underlying confining intervals is 52 m and 80 m, respectively. Dominant lithologies for the overlying confining rocks are dolomite (43 percent), shale (29 percent), and salt and limestone (14 percent each). The underlying confining rocks are mainly comprised of dolomite (44 percent), shale and limestone (22 percent each).

Potential reservoir intervals were identified in Unit D in three wells in Kentucky. All the intervals occur in dolomite. In well 144, where both evaporite-bearing deposits and potential reservoir porosity were identified in Unit D, about 50 percent of the potential reservoir porosity occurs above the evaporite-bearing rocks, and 12 and 38 percent is found within and below these beds, respectively. All the reservoir intervals identified in Unit D in the Kentucky wells occur in dolomite. The median altitude of the top of the potential reservoir intervals is 378 m below sea level, and their median thickness is 64 m. One interval occurs in each of the three wells in which reservoir porosity was identified. When evaluated by interval, the median thicknesses of the reservoir-type zones that are found within the intervals have a median value of 1 m; the aggregate thicknesses of the zones have a median value of 10 m; the median porosities of the zones range from 6 to 7 percent; and the average thickness-weighted porosities have a median value of 7 percent (table 3). Confining intervals that immediately overlie and underlie the potential reservoir intervals have a median thickness of 202 m and 444 m, respectively. Confining rocks that overlie the potential reservoir intervals are comprised of shale (in 50 percent of the studied cases), siltstone (33 percent), and limestone (17 percent), while the underlying confining rocks are comprised of shale and limestone (50 percent each).

POTENTIAL CONFINING UNIT D-E

Shales, siltstones, very fine-grained sandstones, and some shaly carbonates that range from Middle Devonian to Early Mississippian in age constitute Confining Unit D-E , and overlie Reservoir Unit D (fig. 3). Within the area where Reservoir Unit D occurs between 300 and 2,500 m below sea level, the thickness of Confining Unit D-E ranges from 1,608 m in well 46 in Somerset County, Pennsylvania, to 131 m in well 239 in Knox County, Kentucky (fig. 16; pl. 1). The confining unit has an average thickness of about 1,400 m near the eastern boundary of the area, 300 m in the west and southwest, and an area-weighted average of about 838 m overall. Part of the rock sequence that forms this unit has been repeated in the overthrust area of a reverse fault, causing an apparent thickening along the Burning Springs anticline in parts of Pleasants, Ritchie, Wirt, and Wood Counties, West Virginia (pl. 1). The slight thickening of this unit outlined by the 200-m contour in parts of Breathitt, Lee, Menifee, Powell, and Wolfe Counties, Kentucky (pl. 1), is probably related to the block faulting in central and northeastern Kentucky.

Hydrogeologic sections displaying the depth to and thickness of Confining Unit D-E and its relation to the other rocks are shown on plate 2.

POTENTIAL RESERVOIR UNIT E

Reservoir Unit E overlies Confining Unit D-E and is composed of the sandstones in the Hampshire Formation and equivalents of Late Devonian age and the Cussew-

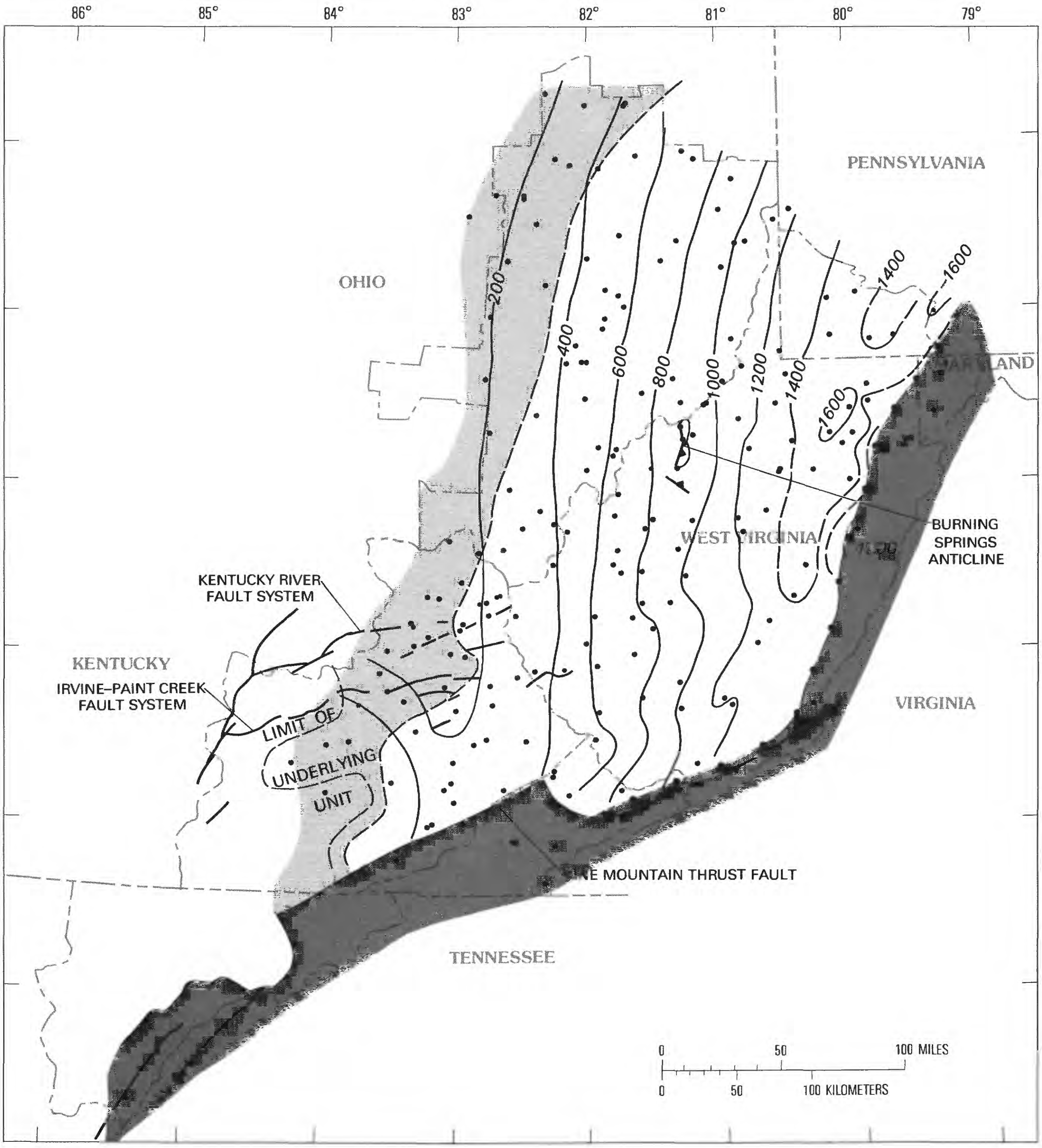


FIGURE 16 (above and facing page).—Thickness of Potential Confining Unit D-E.

EXPLANATION

Approximate area where top of underlying reservoir unit occurs above about 300 meters below sea level

Approximate area where rocks are thrust faulted or have a steep dip at land surface

—*600*— **Line of equal thickness of unit, in meters**—Dashed where approximate. Interval is 200 meters

Thrust fault—Sawteeth on upper plate. Fault marks southeast boundary of study area

Fault—Dashed where inferred

Western limit of steeply dipping rocks—Marks eastern boundary of study area

• **Data point**

ago and Berea Sandstones and equivalents of Early Mississippian age (fig. 3). The top of this unit is deeper than 300 m below sea level in an area that includes the southwestern corner of Pennsylvania, western and southwestern West Virginia and a narrow adjacent strip of Ohio, and southeastern Kentucky and adjacent parts of Virginia (fig. 17). Within this area, the contours on the top of the unit define three major northeast-trending, en echelon lows, and subordinate northwest-, north-, and northeast-trending highs. The deepest occurrence of this unit is found along the axes of the lows in Buchanan County, Virginia, and Wetzel County, West Virginia (pl. 1), where the altitudes of the top are about 900 m and 500 m below sea level, respectively. The shallowest occurrence is found along the axis of the Burning Springs anticline from Pleasants to Wirt Counties, West Virginia (pl. 1), where the top is less than 100 m below sea level (fig. 17).

A study of geophysical and lithologic logs suggested that potential-reservoir sandstone beds have an aggregate thickness of about 8–10 m or more only in the Cussewago Sandstone and equivalents and the Hampshire Formation in southwestern Pennsylvania and adjacent parts of West Virginia and in the Berea Sandstone in southwestern West Virginia and adjacent parts of Ohio and Kentucky (fig. 17). Throughout the remainder of the area, where it lies deeper than 300 m below sea level, the unit is very thin or is composed of siltstone and shale and is not likely to have reservoir potential. Hydrogeologic sections displaying the depth to and thickness of Reservoir Unit E and its relation to the other rocks are shown on plate 2, lines of section *A–A'*, *B–B'*, and *E–E'*.

Potential reservoir intervals were identified in three key wells where the sandstones are about 8 m to 10 m or more in thickness—two in northeastern West Virginia and one in Lawrence County, Kentucky (pl. 1; table 3). The intervals found in the two wells in West Virginia occur in an area where the top of Unit E lies above 300 m below sea level (fig. 17). Because of the paucity of information for this unit, data from these wells were used for comparison purposes.

Data from the West Virginia wells indicate that the reservoir porosity occurs in sandstone of the Hampshire Formation and possible equivalents of the Cussewago Sandstone. The median altitude of the top of the potential reservoir intervals is 245 m below sea level, and their median thickness is 98 m. One interval occurs in each of the two wells where reservoir porosity was found (table 3). When evaluated by interval, the median thicknesses of the reservoir-type zones that are found within the intervals have a median value of 2 m; the aggregate thicknesses of the zones have a median value of 18 m; the median porosities of the zones range from 7 to 10 percent; and the average thickness-weighted porosities have a median value of 9 percent (table 3). Confining intervals that immediately overlie and underlie the potential reservoir intervals have a median thickness of 134 m and 245 m, respectively. Shale and siltstone comprise 67 and 33 percent, respectively, of the overlying confining rocks; and shale comprises 100 percent of the underlying confining rocks.

One potential reservoir interval was found in the Berea Sandstone in well 147 in Lawrence County, Kentucky (pl. 1). The altitude of the top of this interval is 312 m below sea level, and its thickness is 27 m. The reservoir-type zones found within this interval have a median thickness of 1.8 m and an aggregate thickness of 12 m. The porosity of these zones ranges from 6 to 10 percent, and they have an average thickness-weighted porosity of 9 percent. Confining intervals that immediately overlie and underlie the potential reservoir interval are 122+ m and 217 m thick, respectively, and are comprised of about equal amounts of siltstone and shale.

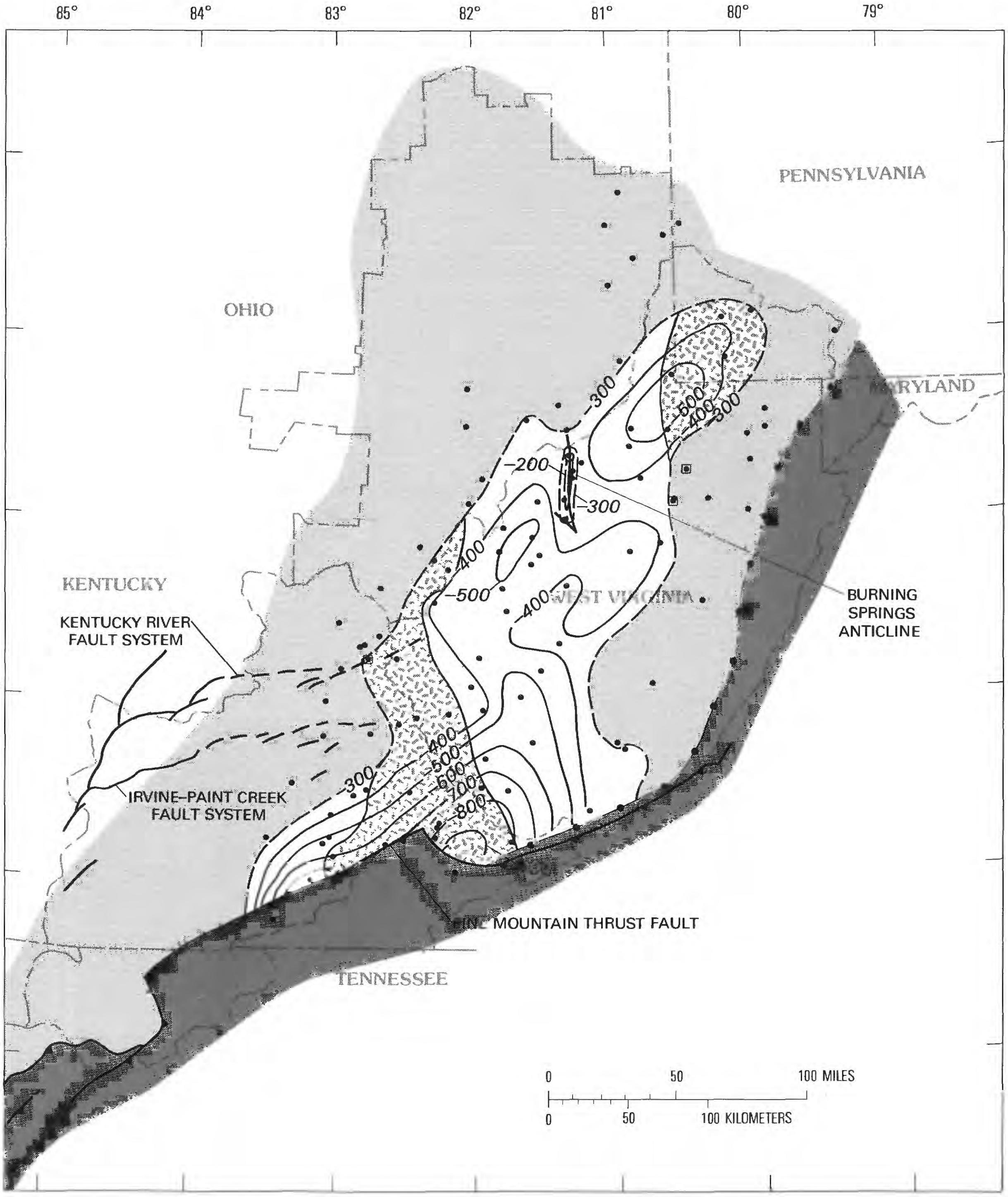


FIGURE 17 (above and facing page).—Areal distribution, altitude of the top, and estimated thickness of Potential Reservoir Unit E.

EXPLANATION

Approximate area where top of reservoir unit occurs above about 300 meters below sea level. Generally no defined waste-storage potential

Approximate area where sandstone in unit is estimated to be 10 meters or more in thickness—Unit may have waste-storage potential

Approximate area where rocks are thrust faulted or have a steep dip at land surface—No defined waste-storage potential

400 **Structure contour**—Shows altitude of top of reservoir unit. Dashed where approximately located. Contour interval is 100 meters. Datum is sea level

Thrust fault—Sawteeth on upper plate. Fault marks southeast boundary of study area

Fault—Dashed where inferred

Western limit of steeply dipping rocks—Marks eastern boundary of study area

Data point

Potential reservoir interval(s) (as defined in text) indicated in wells by porosity calculations made from geophysical logs

POTENTIAL CONFINING UNIT E-F

Primarily, Lower Mississippian shales and siltstones constitute Confining Unit E-F, which overlies Reservoir Unit E (fig. 3). In the two separate areas where the underlying reservoir unit is deeper than 300 m below sea level and potential-reservoir sandstone thickness is about 8 to 10 m or more, the thickness of the confining unit ranges from 77 m in well 128 in Gallia County, Ohio, to 244 m in well 221 in Buchanan County, Virginia (pl. 1). The average thickness of the unit is about 150 m in the southern area and slightly over 100 m in the northern area (fig. 18). The overall average area-weighted thickness of the unit is 140 m.

Hydrogeologic sections displaying the depth to and thickness of Confining Unit E-F and its relation to the other rocks are shown on plate 2, lines of section *A–A'*, *B–B'*, *C–C'*, and *E–E'*.

POTENTIAL RESERVOIR UNIT F

Reservoir Unit F overlies Confining Unit E-F and is composed of the Upper Mississippian Greenbrier Limestone/Formation and equivalents and associated sandstones that occur in the Lower Mississippian Pocono Formation and the Upper Mississippian Mauch Chunk Formation or their respective equivalents (fig. 3). This unit is generally confined to the subsurface except along the eastern and western boundaries of the study area. It occurs within the depth limits defined for the potential waste-storage reservoir environment only in three small areas adjacent to the Pine Mountain thrust fault (fig. 19). These areas appear to be small parts of a larger area that exists beneath the thrust block. The largest and northernmost of these areas is comprised of parts of McDowell County, West Virginia, and Buchanan County, Virginia (pl. 1). The middle area is comprised of parts of Harlan, Leslie, Letcher, and Perry Counties, Kentucky; and the smallest and southernmost area includes parts of Anderson, Campbell, and Morgan Counties, Tennessee (pl. 1). These areas and the area defined by the northeast-trending line of key wells in which porosity zones were identified from Jackson to Marshall Counties, West Virginia (fig. 19; pl. 1; table 3), are aligned along the axes of the deepest lows described for Reservoir Unit E, suggesting that porosity may be structurally controlled.

The deepest occurrence of this unit is found in southern Buchanan County and adjacent parts of Russell County, Virginia (pl. 1), where the top descends to nearly 600 m below sea level. Where the top is deeper than 300 m below sea level within the study area, the thickness of the unit ranges from 150 m in well 273 in Anderson County, Tennessee, to about 244 m in well 235 in Harlan County, Kentucky (pls. 1, 3*E*). The average area-weighted thickness is about 200 m. Hydrogeologic sections displaying the depth to and thickness of Unit F and its relation to the other rocks are shown on plate 2, lines of section *A–A'*, *B–B'*, *C–C'*, and *E–E'*.

Potential reservoir intervals were identified in a total of eight wells in Unit F where both the top of the intervals and the top of the unit lie between 300 m and 2,500 m below sea level in the study area (fig. 19; pl. 3*E*; table 3). Three wells are located in Virginia, two in West Virginia, two in Tennessee, and one in Kentucky. Table 4 presents a summary of some of the characteristics and distribution of the reservoir porosity identified in Reservoir Unit F.

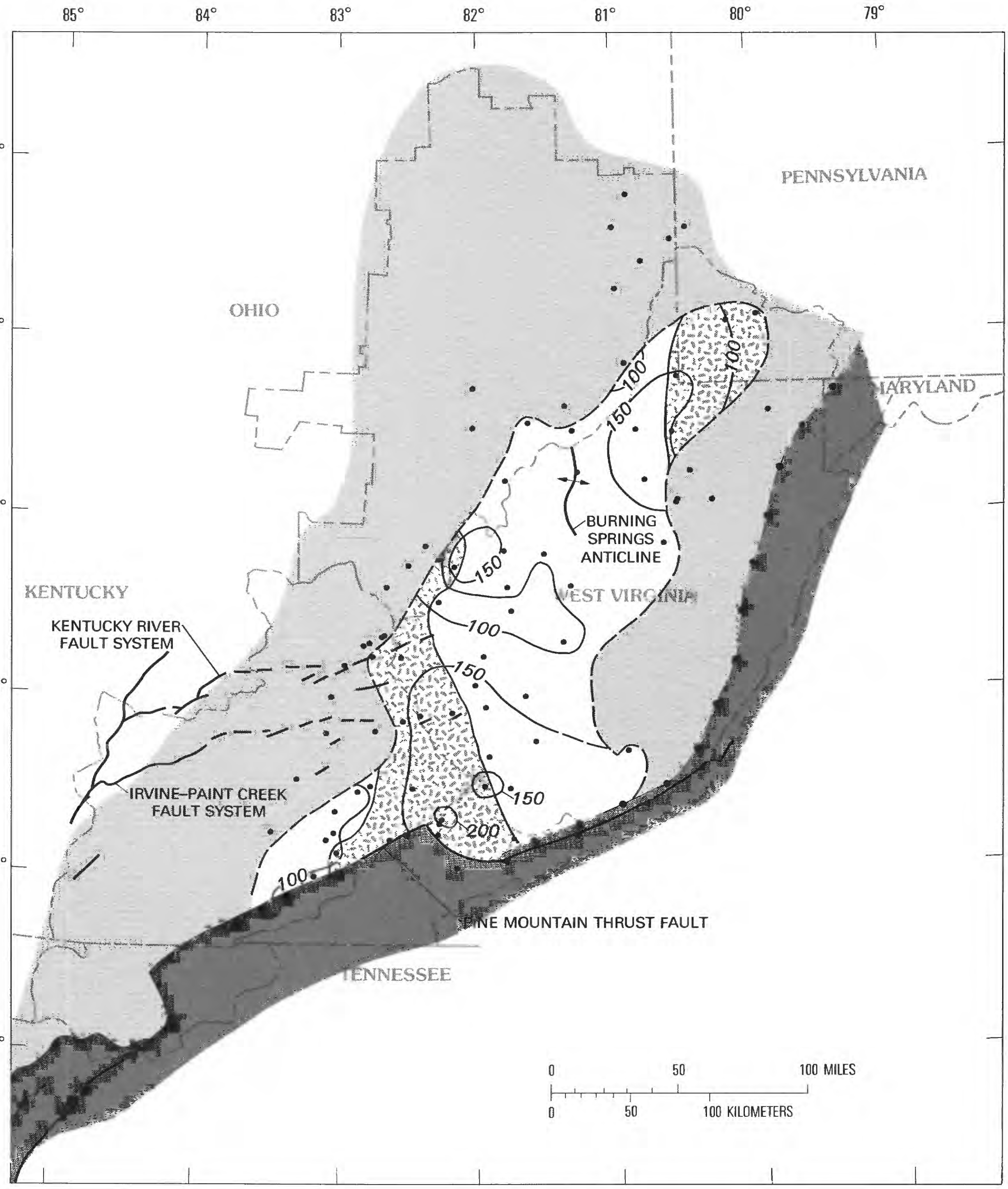


FIGURE 18 (above and facing page).—Thickness of Potential Confining Unit E-F.

EXPLANATION

Approximate area where top of underlying reservoir unit occurs above about 300 meters below sea level

Approximate area where sandstone in underlying reservoir unit is estimated to be 10 meters or more in thickness

Approximate area where rocks are thrust faulted or have a steep dip at land surface

—*150*— **Line of equal thickness of unit, in meters**—Dashed where approximate. Interval is 250 meters

Thrust fault—Sawteeth on upper plate. Fault marks southeast boundary of study area

Fault—Dashed where inferred

Western limit of steeply dipping rocks—Marks eastern boundary of study area

• **Data point**

In Virginia, 50 percent of the potential reservoir intervals are found in the Newman Limestone and 50 percent occur in overlying sandstones. The median altitude of the top of the potential reservoir intervals is 428 m below sea level, and their median thickness is 51 m. Two potential reservoir intervals occur in one of the three wells where reservoir porosity was identified. When evaluated by interval, the median thicknesses of the reservoir-type zones that are found within the intervals have a median value of 2 m; the aggregate thicknesses of the zones have a median value of 12 m; the median porosities of the zones range from 5 to 10 percent; and the average thickness-weighted porosities of the zones have a median value of 6 percent (table 3). The median thickness of confining intervals that immediately overlie and underlie the potential reservoir intervals is 79 m and 144 m, respectively. Shale, siltstone, very fine-grained sandstone (29 percent each), and limestone (13 percent) constitute the overlying confining rocks; and siltstone (38 percent), limestone, shale (25 percent each), and very fine-grained sandstone (12 percent) constitute the underlying confining rocks.

In West Virginia, all of the potential reservoir intervals are found in sandstone. The median altitude of the top of the potential reservoir intervals is 332 m below sea level, and their median thickness is 10 m. One interval occurs in each of the two key wells where reservoir porosity was identified. When evaluated by interval, the median aggregate thicknesses of the reservoir-type zones that are found within the intervals have a median value 10 m, and the average thickness-weighted porosities have a median value of 5 percent (table 3). Confining intervals that immediately overlie and underlie the potential reservoir intervals have a median thickness of 58 m and 146 m, respectively. Shale (in 50 percent of the studied cases), siltstone, and very fine-grained sandstone (25 percent each) compose the overlying confining rocks, and equal amounts of limestone and shale compose the underlying confining rocks.

Data from the wells in Tennessee indicate that the potential reservoir intervals occur in the Newman Limestone of Late Mississippian age. The median altitude of the top of the potential reservoir intervals is 448 m below sea level, and their median thickness is 87 m. One interval occurs in each of the two key wells where reservoir porosity was identified. When evaluated by interval, the median thicknesses of the reservoir-type zones that are found within the intervals have a median value of 1.5 m; the aggregate thicknesses of the zones have a median value of 12 m; the median porosities of the zones range from 5 to 6 percent; and the average thickness-weighted porosities have a median value of 6 percent (table 3). Confining intervals that immediately overlie the potential reservoir intervals have a median thickness of 109 m. The underlying confining rocks are 31 m thick in the one well where they were penetrated. Limestone and shale comprise 67 and 33 percent, respectively, of the overlying confining rocks, and equal amounts of shale and limestone comprise the underlying confining rocks.

One potential reservoir interval was found in well 234 in Harlan County, Kentucky (pl. 1). The interval occurs in sandstone. The altitude of the top of the interval is 370 m below sea level, and the thickness is 96 m. The reservoir-type zones within the interval have a median thickness of 1.5 m and an aggregate thickness of 31 m. The porosity of these zones ranges from 5 to 7 percent, and they have a median average thickness- weighted porosity of 5 percent. The thickness of the confining intervals that immediately overlie and underlie the potential reservoir interval is 88 m and 44 m, respectively. These confining rocks consist of equal amounts of shale and siltstone.

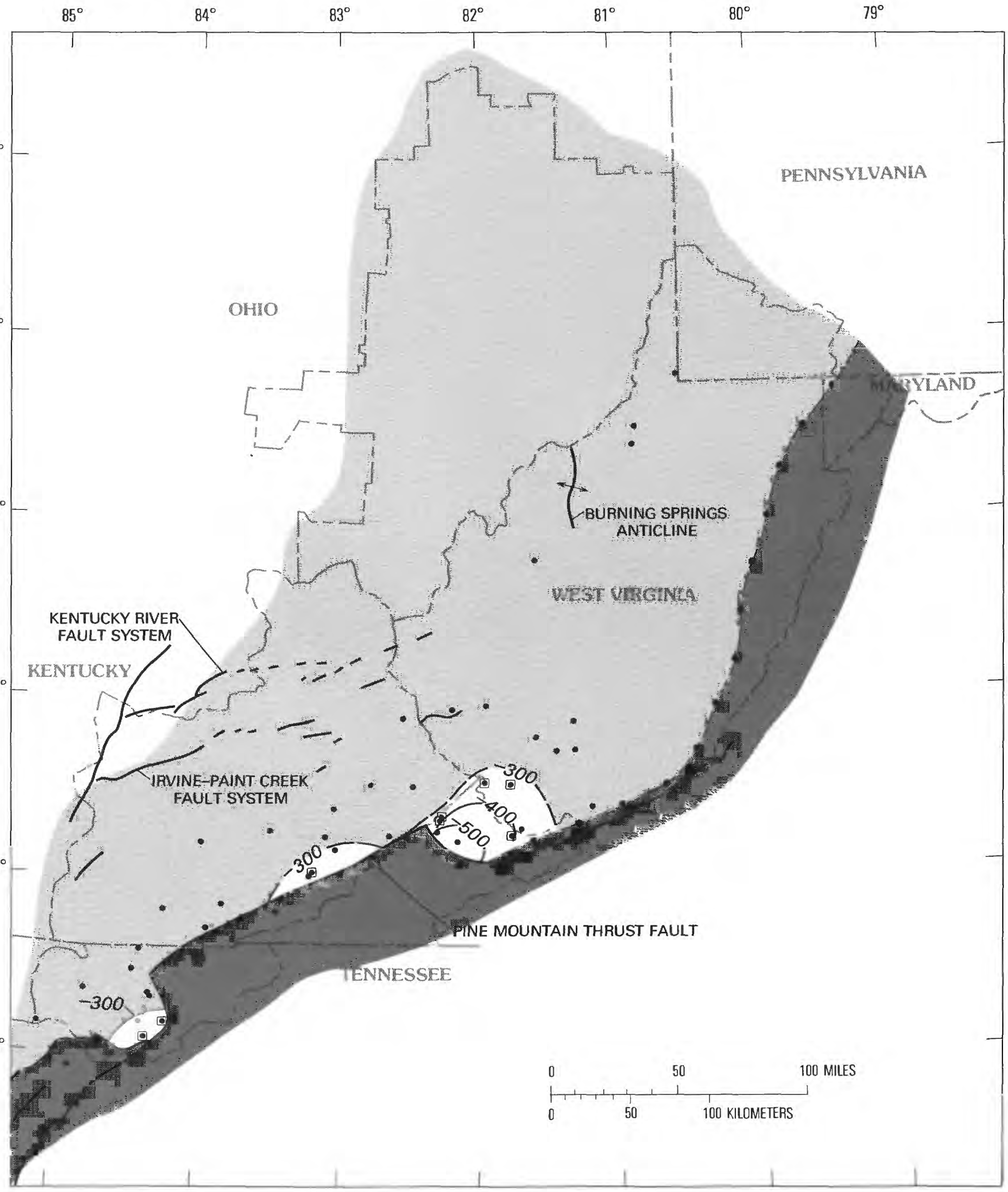


FIGURE 19 (above and facing page).—Areal distribution and altitude of the top of Potential Reservoir Unit F.

EXPLANATION

- **Approximate area where top of reservoir unit occurs above about 300 meters below sea level**—No defined waste-storage potential
- **Approximate area where rocks are thrust faulted or have a steep dip at land surface**—No defined waste-storage potential
- *300* **Structure contour**—Shows altitude of top of reservoir unit. Dashed where approximately located. Contour interval is 100 meters. Datum is sea level
- **Thrust fault**—Sawteeth on upper plate. Fault marks southeast boundary of study area
- **Fault**—Dashed where inferred
- **Western limit of steeply dipping rocks**—Marks eastern boundary of study area
- **Data point**
- **Potential reservoir interval(s) (as defined in text) indicated in wells by porosity calculations made from geophysical logs**

POTENTIAL CONFINING UNIT ABOVE UNIT F

The confining unit that overlies Reservoir Unit F is composed of Upper Mississippian shales and siltstones. In the areas where the top of Unit F is deeper than 300 m below sea level, this overlying confining unit ranges in thickness from 115 m in well 273 in Anderson County, Tennessee, to about 30 m in wells 272 in Anderson County, Tennessee, 222 in Dickenson County, Virginia, and 229 in McDowell County, West Virginia (pl. 1). The average area-weighted thickness of this unit is about 50 m (fig. 20).

Hydrogeologic sections displaying the depth to and thickness of the Confining Unit above Unit F and its relation to the other rocks are shown on plate 2, lines of section *A–A'*, *B–B'*, *C–C'*, and *E–E'*.

SUMMARY AND COMPARISON OF THE POTENTIAL RESERVOIR UNITS

Several of the physical characteristics that were derived from the key-well data were chosen to summarize and compare the units regarding their regional reservoir potential. These characteristics are listed as column headings in table 5, and the value for each is listed for each unit. The values and some of the derivations of the characteristics are discussed below.

A study of figures 6–19, plate 3, and column 1 in table 5, indicates that Units A, B, C, and D are the most widespread, occurring over areas that range from 77,300 to 96,400 km^2. Units E and F have very restricted distributions by comparison, occupying only 16 and 5 percent, respectively, of the average area covered by the other units. The average area-weighted thicknesses listed in column 2 range from 850 m for Unit B to 36 m for Unit C. The thickness of 58 m of Unit E is an area-weighted average for the isolated northern and southern parts of the unit that contain potential reservoir sands with an aggregate thickness of about 8–10 m or more.

Column 3 indicates that Reservoir Unit B has an estimated total volume of about 82,000 km^3, which is about twice that of Unit D and about seven times that of Unit A. Although Unit C has a large areal distribution, it is thin and only has a volume that is slightly over 2,900 km^3. Units E and F have small volumes, 794 and 860 km^3, respectively, and this is a reflection of their small areal distribution.

The values in column 4 were derived for each unit by multiplying the number of potential reservoir intervals found per well by the median of the aggregate thicknesses of rock with reservoir porosity found in the potential reservoir intervals and taking the product as a percentage of the average area-weighted thickness of the unit. The number of potential reservoir intervals per well in a given unit was determined by dividing the number of potential reservoir intervals that were found in the unit by all wells for which porosity calculations were made for the unit. This determination was made by using only the wells and intervals that occur in the area where the appropriate unit lies between 300 and 2,500 m below sea level with the exception of Unit E. Altitudes for the top of potential reservoir intervals in Unit E are as shallow as 227 m below sea level. The estimated percentage of unit volume that contains reservoir porosity ranges from 1.4 percent in Unit E to 4.9 percent in Unit A.

The median average thickness-weighted porosity of the reservoir-type zones found within the potential reservoir intervals is low, ranging from 5 percent in Unit F to 9 percent in Unit E (column 5).

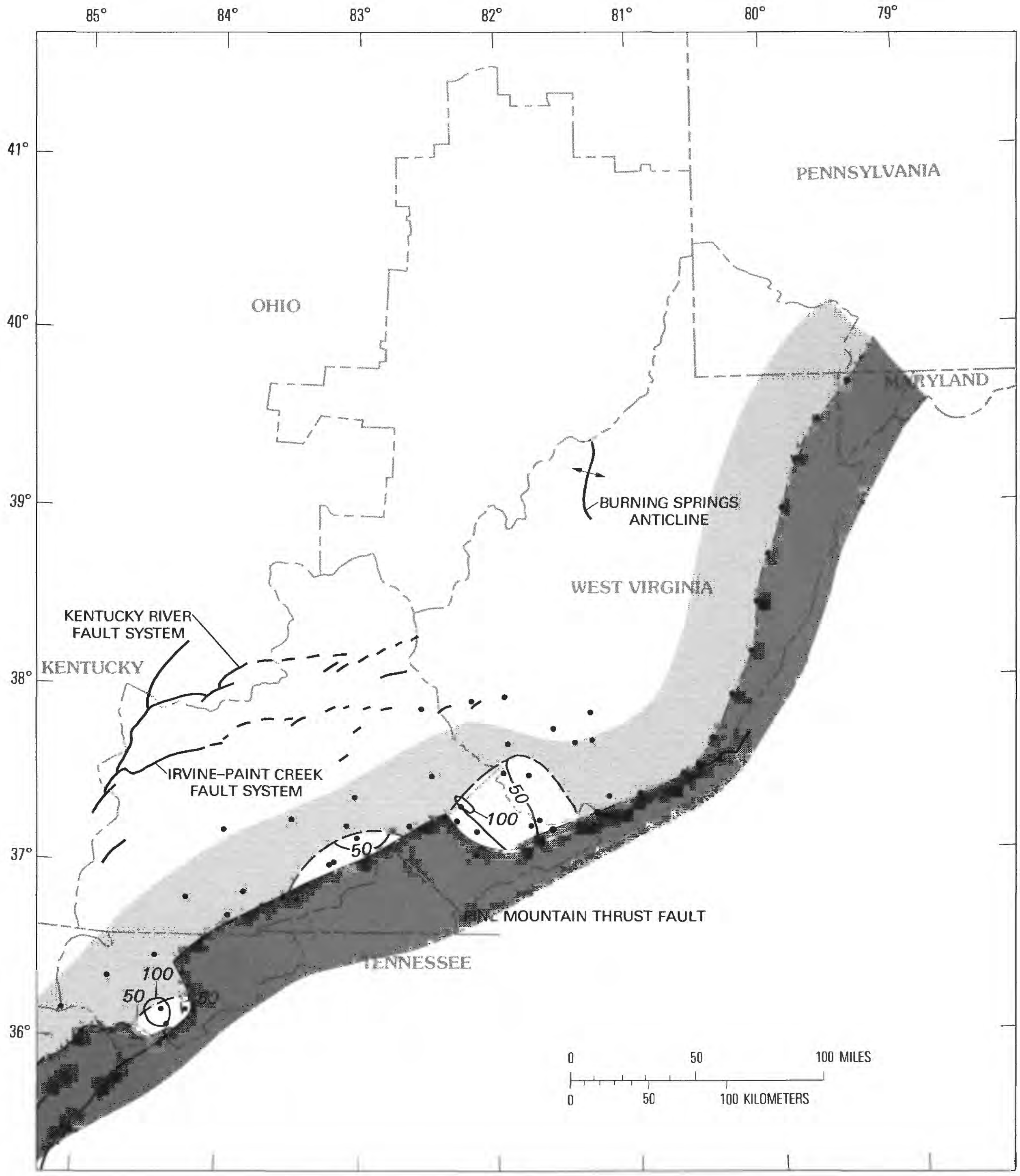


FIGURE 20 (above and facing page).—Thickness of Potential Confining Unit above Unit F.

EXPLANATION

Approximate area where top of underlying reservoir unit occurs above about 300 meters below sea level

Approximate area where rocks are thrust faulted or have a steep dip at land surface

50 **Line of equal thickness of unit, in meters**—Dashed where approximate. Interval is 50 meters

Thrust fault—Sawteeth on upper plate. Fault marks southeast boundary of study area

Fault—Dashed where inferred

Western limit of steeply dipping rocks—Marks eastern boundary of study area

• **Data point**

A relative reservoir-volume index was devised and used to rank the units regarding their potential reservoir pore volume. This index is listed in column 6 and is the product of the physical characteristics of the reservoir rocks listed in columns 1, 2, 4, and 5. An index is used because the regional nature of this appraisal and the attendant limited amount and distribution of data preclude determining the actual total reservoir pore volume in any potential reservoir unit. According to the index, Unit B has the largest amount of reservoir pore volume. It has nearly three times as much as Units A and D and 14, 58, and 98 times as much as Units C, F, and E, respectively.

The median depth to the top of the potential reservoir intervals listed in column 7 is one of the most important economic factors that must be considered if and when plans are made to use the reservoir pore volume in any of the units. The values in this column indicate two distinct groups of data. The interval depths for Units A, B, C, and D range from 1,224 m (Unit B) to 1,582 m (Unit C) and average about 1,370 m, while those for Units E and F average about 325 m. This four-fold difference in mean depth will be a major factor in well-construction cost estimates.

The potential for liquid waste confinement within a reservoir is one of the major safety factors that must be determined when considering the use of any reservoir unit for liquid-waste storage. For the purposes of this study, the confining ability of shales and evaporites and rocks with porosity less than 5 percent is assumed to be directly proportional to their thickness. Setting all other differences aside, the data listed in column 8 (table 5) are used as one of the indicators of the confinement potential that must be associated with each of the reservoir units to insure their operational worth. When the values in the subcolumns titled "Above" and "Below" in column 8 are ranked separately and the two ranking numbers for each unit are added together and these sums are ranked, the order of potential for confinement listed from best to worst, is A, C, D, E, F, and B (C, D, and E have the same sum value). These data are derived partly from the low-porosity zones that separate the potential reservoir intervals found within the reservoir units, and partly from the major confining units that separate the reservoirs. In order that the major confining units receive full consideration for their confinement role, their thicknesses (column 9) above and below the reservoir units were added together and the sums were assigned to the appropriate intervening reservoir units as another indicator of confinement potential. These values were then ranked and the ranking number for each reservoir unit was added to the appropriate ranking number that resulted from the previously described analysis of the data in column 8. The resulting order of potential for confinement, listed from best to worst, is A, E, D, C, B, and F.

To rank the overall reservoir potential of the units on a regional basis with the available data, columns 6 and 7 (table 5) and the last ranking given for potential of confinement were used to represent the major physical, economic, and safety characteristics, respectively. Table 6 illustrates the rankings and the overall evaluation.

From this evaluation viewpoint, Unit A has the best reservoir potential, followed by B, E, D, F, and finally C, which has the worst. Obviously, there could be other viewpoints depending on the emphasis given the various data which would be determined by the dictates of judgment and the local situation. It should be kept in mind that these are average values calculated for the entire region and that geologic and hydrologic conditions can change drastically over very short lateral and vertical distances. Thus, detailed studies of local conditions are essential in all cases where the deep subsurface reservoir rocks are to be used for the storage of liquid wastes.

TABLE 5.—*Regional physical characteristics of potential reservoir and confining units*

Potential Reservoir Unit (PRU)	Columns 1: Area where top of PRU occurs between 300 m and 2,500 m below sea level (km²)	2: Average area-weighted thickness (m)	3: Volume Column 1 times Column 2, divided by 1,000 (km³)	4: Estimated percent of unit thickness with reservoir porosity (percent)	5: Median thickness-weighted porosity, in percent, for Column 4, taken from table 4 (percent)	6: Relative reservoir volume index (a product of Columns 1, 2, 4 and 5 divided by 1,000 (km³)	7: Median altitude, top of potential reservoir intervals (m)	8: Median thickness of rock with confining potential immediately overlying and underlying potential reservoir intervals — Above (m)	8: Below (m)	9: Potential confining unit and average area-weighted thickness (m)
										Below A is Basement
A	77,300	144	11,131	4.9	8	44	1,260	156	1 to basement	
										A–B, 217
B	96,400	850	81,940	1.7	7	98	1,224	66	64	
										B–C, 423
C	81,600	36	2,938	3.3	7	6.8	1,473	96	586	
										C–D, 92
D	95,300	410	39,073	1.5	7	41	1,411	157	80	
										D–E, 838
E	13,700 n(4,250)† s(9,450)	58 n(31)† s(70)	794 n(132)† s(662)	1.4	9	1.0	263††	134	217	
										E–F, 140
F	4,300	200	860	3.9	5	1.7	388	64	100	
										50 Above F

†Numbers in parentheses are subdivisions of total showing contribution of northern (n) and southern (s) areas where reservoir potential sands are 10 m or more in thickness

††Because of a paucity of data, intervals with tops shallower than 300 m below sea level were used to determine interval characteristics for Unit E.

OTHER PHYSICAL FACTORS THAT AFFECT THE POTENTIAL FOR THE SUBSURFACE STORAGE OF LIQUID WASTE

Up to this point, the evaluation of reservoir potential has been based on the occurrence and distribution of defined potential reservoir and confining intervals where they occur between about 300 m and 2,500 m below sea level. Other important factors that must be considered include (1) the occurrence and distribution of valuable resources, particularly oil and gas; (2) the density and distribution of oil and gas wells; (3) the distribution of major structural complexities, such as tight folding and faulting; (4) the distribution of seismic activity; and (5) the potential for the development of hydraulically induced vertical fractures. Problems that may be caused by the incompatability of the physical and chemical natures of liquid waste and any potential liquid-waste reservoir environment were not considered in this evaluation because they are beyond the scope of this report.

TABLE 6.—*Ranking of liquid waste-storage reservoir potential for Reservoir Units*

Potential Reservoir Unit	Index of major physical characteristics (Column 6, table 5)	Index of major economic characteristics (Column 7, table 5)	Index of major safety characteristics	Overall reservoir potential; the sum of the preceeding columns (the lower the point total the better the potential)
A	3	4	1	8
B	1	3	5	9
C	4	6	4	14
D	2	5	3	10
E	6	1	2	9
F	5	2	6	13

OIL AND GAS RESOURCES

Oil and gas are probably the most valuable resources in the study area. The economic and energy value of the past and estimated future production of these resources will play a major role in any decision to store liquid wastes in the subsurface. The very fact that the storage

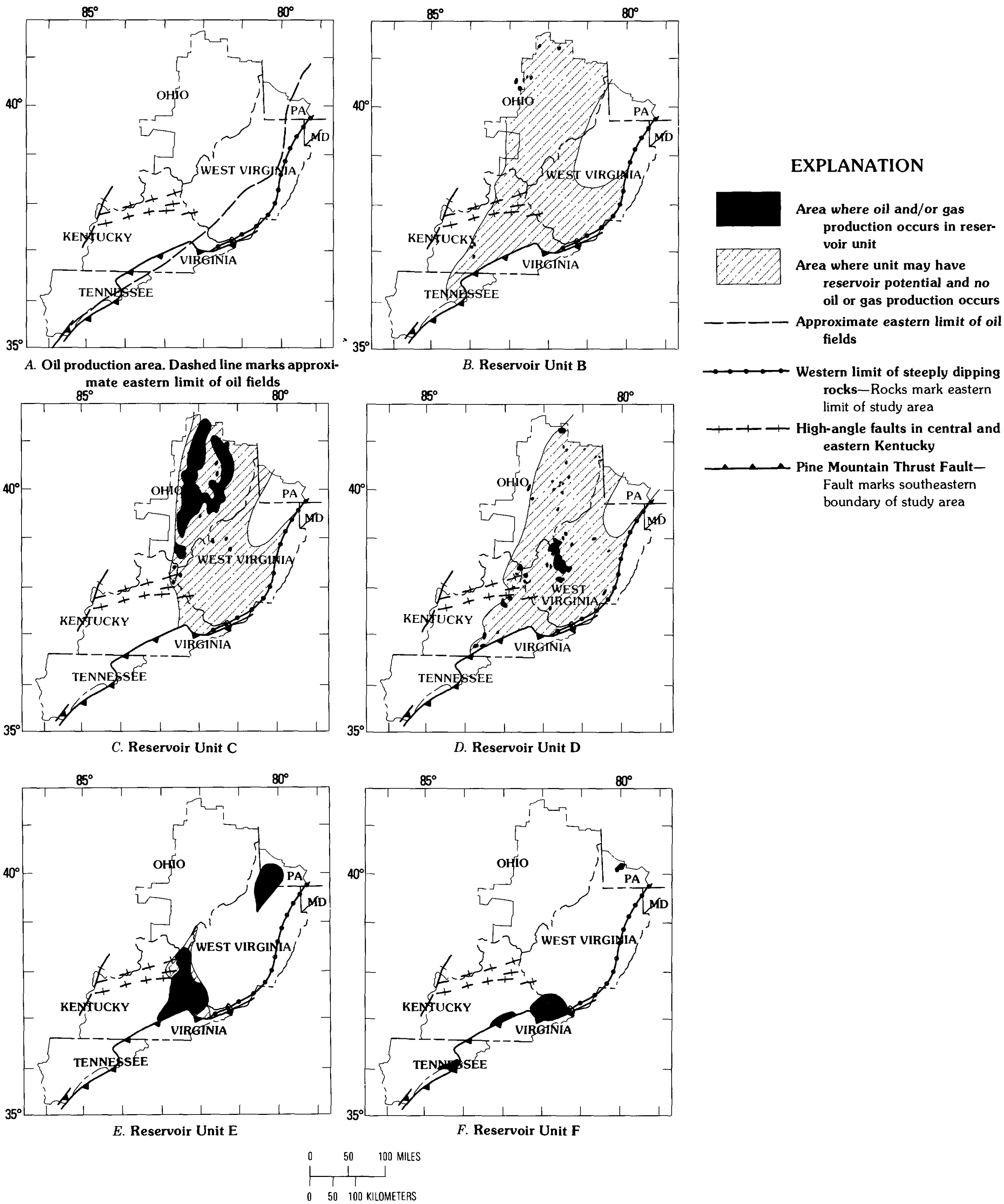


FIGURE 21.—Distribution of oil and gas production from Potential Reservoir Units B through F.

of oil and gas and liquid wastes have the same general reservoir and confinement requirements may introduce an element of competition for the appropriate kinds of subsurface space in the future (McKelvey, 1972). However, at present it is generally accepted that rocks saturated with oil and gas will be set aside for the development of these resources. Thus, a brief discussion of oil and gas distribution follows so that at least major producing areas can be recognized and avoided. The information was taken from publications by LeVan (1962), Wilson and Sutton (1973, 1976), DeBrosse and Vohwinkel (1974), DeWitt (1975), DeWitt and others (1975), Harris (1975), Miller (1975), Cardwell (1977b), and Piotrowski and others (1979).

Oil and gas producing areas within the potential reservoir units described in the preceding sections of this report are shown in figure 21. Producing areas are shaded black. No significant oil and gas fields have been discovered in the sandstones and dolomites that constitute Potential Reservoir Unit A in the study area. Thus, Unit A is not shown in figure 21. However, significant amounts of oil and gas have been produced from all the other units at various places. Oil production has occurred west of the dashed line drawn through the area from Pennsylvania through Tennessee (fig. 21*A*). Gas production has occurred from different horizons throughout the study area.

Scattered production from some of the rocks that constitute Potential Reservoir Unit B occurs in central and northern Ohio and in northeastern and central Kentucky where this unit lies between about 300 m and 2,500 m below sea level (fig. 21*B*). In Ohio, the Knox Group (Patchen and others, 1985a) appears to be the important producing horizon, and in Kentucky the important producing horizons are the Rose Run Sandstone, the Knox Group (Patchen and others, 1985b), the St. Peter Sandstone, and the Trenton Limestone. In addition, hydrocarbons have been produced from Potential Reservoir Unit C in about 50 percent of the study area in Ohio and from a few small fields in northeastern Kentucky and west-central West Virginia in the remainder of the study area (fig. 21*C*).

Production of oil and gas is more widespread in Potential Reservoir Unit D than in any other unit in the study area (fig. 21*D*). The largest oil- and gas-producing fields are found in Jackson and Kanawha Counties, West Virginia. The important producing horizons throughout the study area are found in the Huntersville Chert, Oriskany Sandstone, Williamsport Formation, Lockport Dolomite, and the Keefer Sandstone.

Oil and gas have been produced from Potential Reservoir Units E and F practically everywhere they occur between about 300 and 2,500 m below sea level (fig. 21*E*, *F*). Thus, it appears that oil and gas resources are more abundant in the youngest and shallowest units. However, these data in part are biased by the fact that the overwhelming amount of exploratory drilling has been limited to the shallower rocks to reduce expense and technology requirements. Many reserves may be discovered in the deeper parts of the basin.

OIL AND GAS WELLS

The location and number of old and new hydrocarbon exploration and development wells throughout the study area is an important factor that must be considered when assessing the confinement potential of rocks associated with any reservoir unit. Such holes penetrate confining units and, if not cased, maintained, or plugged properly, can provide avenues of escape for any fluid in the reservoir units. It is very difficult to find data on the location and number of the oldest wells in the area because of incomplete record keeping during the earliest oil and gas exploration and development in the Appalachian Plateaus. This may seriously hamper the use of shallower units, at least, for liquid-waste storage. The Geological Survey of the appropriate State should be consulted for data on the occurrence and distribution of oil and gas reserves and wells as part of any process to select specific subsurface sites for liquid-waste disposal.

MAJOR STRUCTURAL COMPLEXITIES

Just as drilled wells can serve as man-made avenues for fluid escape from reservoir rocks, faults and tightly folded, steeply dipping rocks exposed at land surface can serve as natural breaches that preclude proper confining conditions. In addition, faults and tight folds (separately or in combination) can complicate the reservoir-confining unit geometry and make it difficult to predict the effect of subsurface fluid injection without a great deal of expensive exploratory drilling. The following discussion outlines the occurrence and distribution of the major faults and folds in the study area.

Thrust faults have been mapped at land surface along the southeastern border of the study area (fig. 22). Subsurface thrust faults have been mapped or inferred from deep-well and geophysical data east of the dotted line (A) drawn in figure 22 from northern West Virginia to southern Tennessee (fig. 22; and Bayer, 1982). These thrust faults form an acute angle with the horizontal or nearly horizontal rock bedding planes and, thus, generally traverse great horizontal distances before they cross any significant vertical section of rock. The larger part of their surface area is believed to be confined to shales or shaly rocks, and much of the movement probably occurred as bedding-plane slippage. Because of

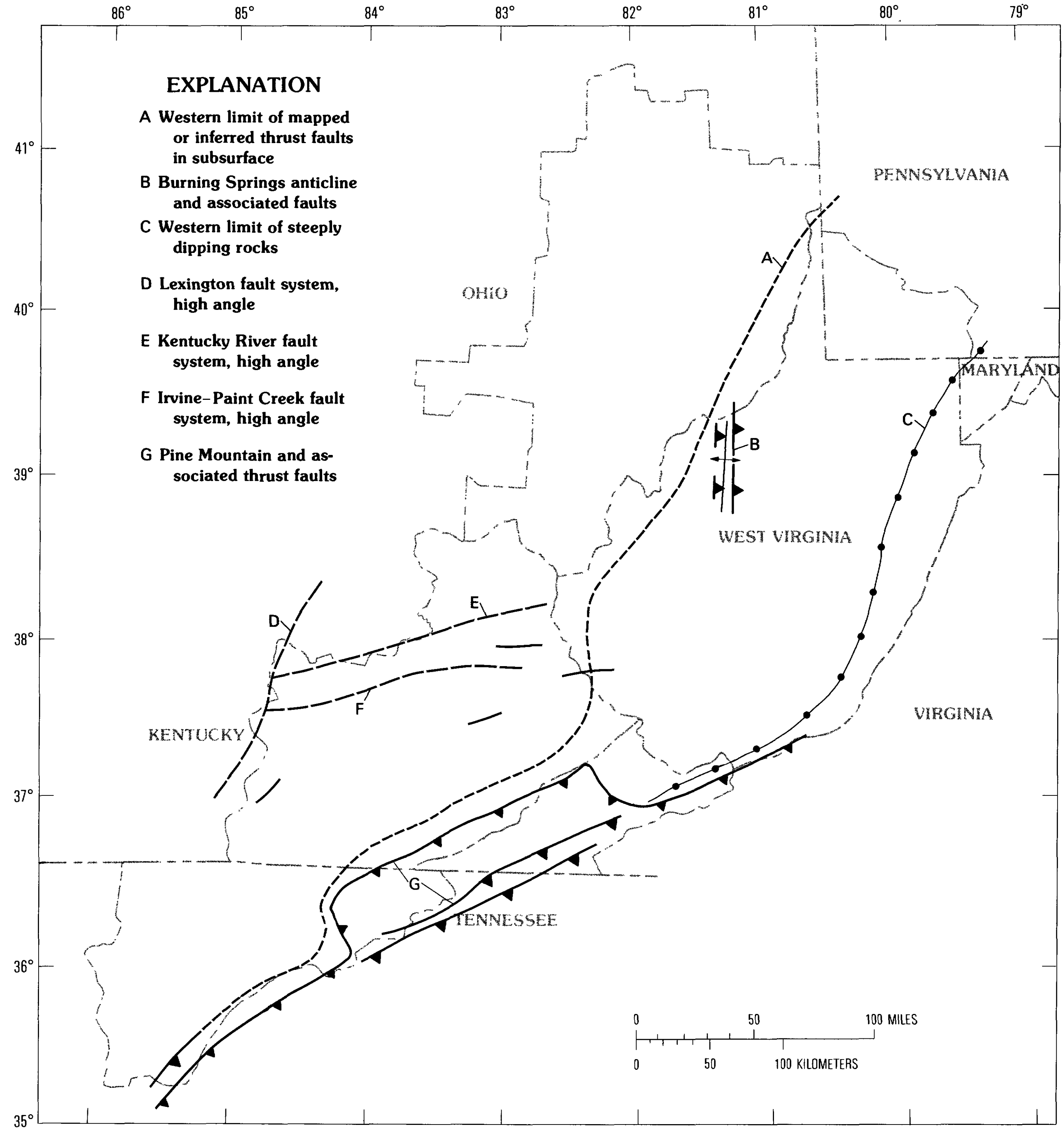


FIGURE 22.—Approximate location of major fault and fold structures.

their nature, the low-angle thrust faults probably serve less to breach the confining beds and more to distort the rock geometry. On the other hand, the high-angle faults (D, E, and F, fig. 22) that are mapped in central and eastern Kentucky and adjacent parts of West Virginia are nearly vertical and cut directly across all the sedimentary rocks. Therefore, the high-angle faults may act as more efficient conduits than thrust faults for the escape of fluids from deep reservoir rocks.

Tightly folded, steeply dipping (rock bedding planes that are nearly perpendicular to a horizontal plane at land surface) rock is mapped along the eastern border of the study area (C, fig. 22) from just north of the Pine Mountain overthrust block (G, fig. 22) in southwestern Virginia to southwestern Pennsylvania. This folded rock area and the major faulted areas are shown in the illustrations (figs. 5–20; pl. 3) that illustrate the top or thickness of the reservoirs and confining units.

SEISMIC ACTIVITY

Seismic activity (earthquakes), caused by rock movement along faults to relieve stress, is an important factor that must be considered when attempting to evaluate the integrity of any potential injection-well installation and the confining ability of any rocks subjected to such movement. Obviously, the areas most prone to seismic activity should be avoided. Figure 23 shows the approximate location of seismic events that have occurred in the area from 1776 to present, and table 7 lists the location, number, and some intensities of earthquakes that occurred at each site (Stover and others, 1979a, b, c, 1980a, b, 1981). The areas that were free from earthquakes during this time are northwestern Tennessee, southwestern and northwestern Kentucky, central and eastern Ohio, central and eastern West Virginia, and Garrett County, Maryland. According to Algermissen (1969), most of the study area lies in a zone where only minor earthquake damage can be expected to occur (fig. 23). Moderate damage can be expected along the southeastern border of the area southeast of the dashed line drawn in figure 23, from southern West Virginia to southern Tennessee. It must be remembered that these data are historical and, thus, are subject to varying precision and accuracy, and they have been collected only for a very short period of geologic time. Therefore, these data can be used as a guide but cannot be used to predict the exact location, magnitude, and intensity of future earthquakes.

At places, a strong, positive correlation exists between seismic activity and subsurface liquid injection. Sun (1982) gave a concise review of cases and references that support this correlation. In all such cases, it appears that the increased pressure in the fluid-filled pores of the rock, caused by the liquid injection, triggered impending stress release along preexisting faults.

The stresses in the rock associated with one or more known or unknown, active or potentially active, faults could be balanced such that only a small increase in pore pressure would allow movement along the fault(s). Such effects could occur, at least on a local scale, in the study area. Raleigh and others (1972) suggested that small-scale injection tests in conjunction with seismic studies could be made in the rock within the area of interest to try to determine whether or not any large-scale waste-injection operation would cause seismic activity.

Even though the evidence indicates the study area is subject to regional compression, it is highly probable that at least local areas of extension occur. With this in mind, it is important to note that Hubbert and Willis (1957) predicted, and Wolff and others (1975) demonstrated, that vertical hydraulic fractures will develop in areas of extension where the well-face injection pressure is raised to about two-thirds of the overburden pressure. Raleigh and others (1972) have suggested that small-scale hydraulic fracturing tests could be made in the rock within the area of interest to try to determine (1) the critical well-face injection pressure at which hydraulic fractures will occur and (2) the orientation of the resulting fractures.

HYDRAULIC FRACTURES

Injection of liquids in the subsurface can cause hydraulic fracturing of rocks. In fact, this mechanism has been used extensively on a controlled basis by oil and gas companies in the Appalachian basin to increase permeability and well yield in "tight" oil and gas reservoirs.

From studies of the ages, orientations, and types of faults, and of the hydraulic fracturing results in the Appalachian basin, Zoback and Zoback (1981) indicated that the present study area is now subject to a regional compressive stress field with the greatest principal stress axis oriented horizontally in a general east-west direction. In addition, they indicated that the area is characterized by a combination of thrust and strike-slip faults that form when the least principal stress axis is oriented vertically and horizontally, respectively.

Potential for the development of vertical hydraulic fractures that can breech confining units exists wherever the least principal stress axis is oriented in the horizontal plane. The amount of well-face injection pressure needed to cause vertical fractures depends on whether the area is under compression (maximum principal stress axis is horizontal) or extension (maximum principal stress axis is vertical).

SUMMARY AND CONCLUSIONS

The central and southern parts of the Appalachian basin are underlain by consolidated sedimentary rocks that range from Cambrian to Permian in age and include

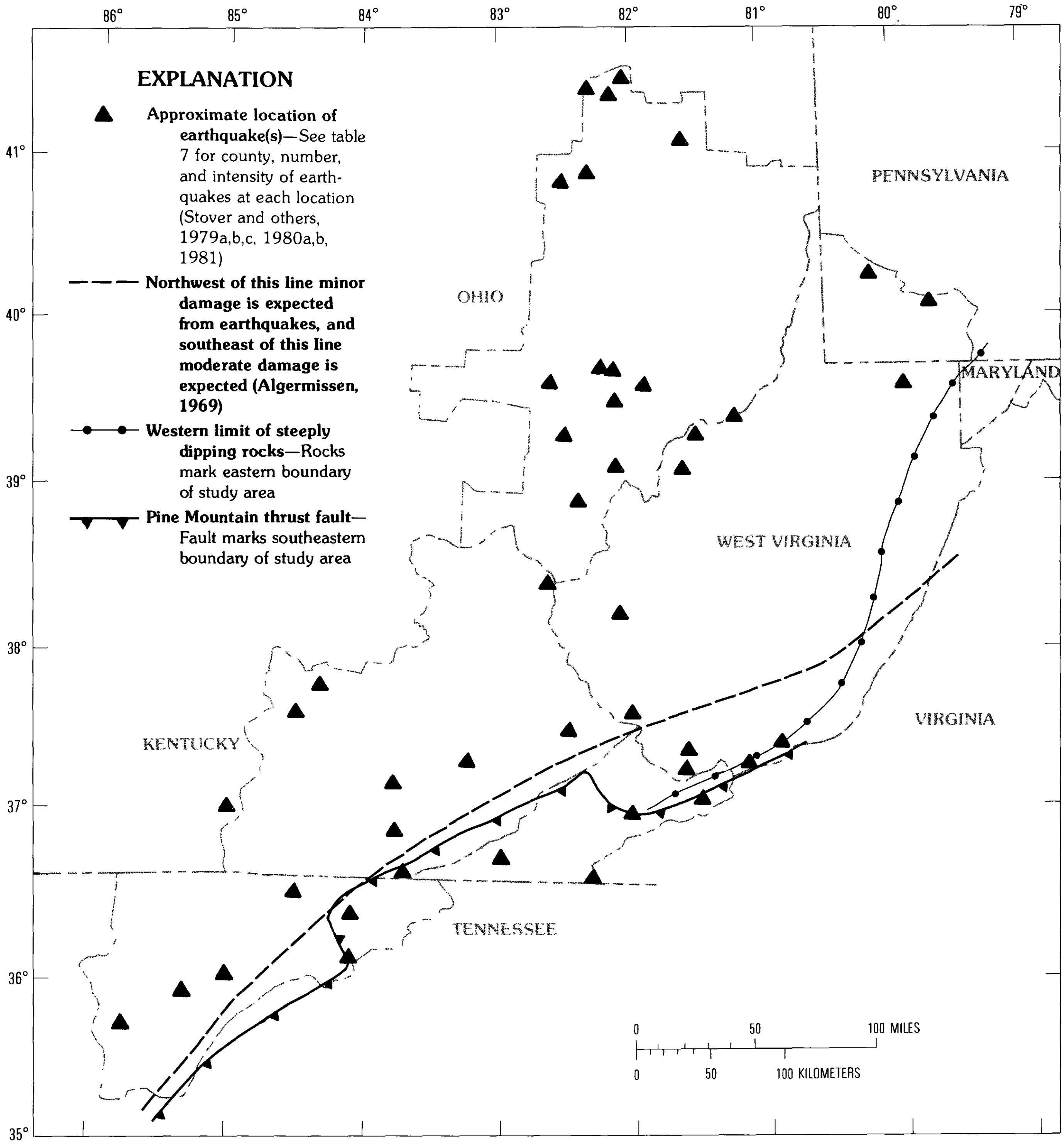


FIGURE 23.—Distribution of earthquakes from 1776 to 1980, and location of damage-risk zones.

dolomite, limestone, evaporites, sandstone, siltstone, and shale. The collective thickness of these deposits ranges from about 1,500 m on the western border of the area to a maximum of about 11,000 m on the eastern and northeastern border. The rocks have been folded into a northeast-plunging synclinorium so that the younger rocks are exposed at land surface in the central and northeastern parts of the area and the older rocks crop

TABLE 7.—*Earthquakes in central and southern parts of the Appalachian basin*

[Data for this table taken from Stover and others (1979a, b, c, 1980a, b, 1981). Date abbreviations: JAN—January, FEB—February, MAR—March, APR—April, AUG—August, SEPT—September, OCT—October, NOV—November, DEC—December. Intensity: MM, stands for Modified Mercalli Intensity Scale of 1931. Abridged version taken from Lessing (1974)]

Date Year Month Day	County	Latitude (North)	Longitude (West)	Epicenter Depth (kilometer)	Magnitude Gutenberg-Richter Scale	Intensity MM
			Kentucky			
1779 -- --	Russell	37.0	85.0*	--	--	--
1817 DEC 12	do.	37.0	85.0*	--	--	--
1827 JULY 05	do.	37.0	85.0*	--	--	--
1834 NOV 20	do.	37.0	85.0*	--	--	V
1846 MAR 23	do.	37.0	85.0*	--	--	V*
1854 FEB 13	Clay	37.2	83.8	--	--	IV*
1854 FEB 13	do.	37.2	83.8*	--	--	IV*
1854 FEB 13	do.	37.2	83.8*	--	--	IV*
1854 FEB 28	Garrard	37.6	84.5	--	--	IV
1883 MAY 23	Boyd	38.4	82.6	--	--	IV
1883 MAY 23	do.	38.4	82.6	--	--	IV
1898 JUNE 06	Madison	37.8	84.3	--	--	III
1898 JUNE 26	do.	37.8	84.3	--	--	III*
1954 JAN 01	Perry	37.3	83.2	--	--	IV
1954 JAN 02	Bell	36.6	83.7	--	--	VI
1957 JAN 25	do.	36.6	83.7	--	--	IV
1958 OCT 23	Pike	37.5	82.5	--	--	--
1976 JAN 19	Knox	36.88	83.82	005	4.0	VI
			Ohio			
1776 -- --	Morgan	39.6	81.9	--	--	VI
1850 OCT 01	Lorain	41.4	82.3	--	--	IV
1872 JULY 23	do.	41.4	82.1	--	--	III
1886 MAY 03	Athens	39.5	82.1	--	--	V*
1901 MAY 17	Vinton	39.3	82.5	--	--	V
1902 JUNE 14	Washington	39.4	81.2	--	--	IV
1926 NOV 05	Meigs	39.1	82.1	--	--	VII
1927 FEB 17	Richland	40.8	82.5	--	--	IV
1928 SEPT 09	Lorain	41.5	82.0	--	--	V
1932 JAN 21	Summit	41.1	81.5	--	--	V
1940 MAY 31	do.	41.1	81.5	--	--	II
1940 JUNE 16	Ashland	40.9	82.3	--	--	IV
1940 JULY 28	do.	40.9	82.3	--	--	III
1940 AUG 15	do.	40.9	82.3	--	--	III
1940 AUG 19	do.	40.9	82.3	--	--	III
1952 JUNE 20	Perry	39.72	82.09	013	--	VI
1953 MAY 07	do.	39.7	82.2*	--	--	IV
1967 APR 08	Hocking	39.64	82.56	007	4.5	V
1975 FEB 16	Gallia	39.86	82.38	000	4.4	IV
			Pennsylvania			
1885 SEPT 26	Washington	40.3	80.1*	--	--	III*
1965 OCT 08	Fayette	40.1	79.7	--	--	--
			West Virginia			
1824 JULY 15	Wood	39.3	81.5*	--	--	IV
1933 JUNE 15	Mingo	37.57	81.97	005	--	--
1957 MAR 07	Monogalia	39.6	79.9*	--	--	III*
1957 MAR 13	do.	39.6	79.9*	--	--	III*
1965 APR 26	McDowell	37.33	81.60	005	--	--
1967 DEC 16	do.	37.36	81.60	002	3.5	--
1969 NOV 20	Mercer	37.45	80.93	003	4.3	VI
1970 AUG 11	Lincoln	38.23	82.05	010	--	IV
1972 SEPT 12	Monongalia	39.6	79.9*	--	--	III*
1974 OCT 20	Wood	39.09	81.59	011	--	V
1976 MAY 06	Monogalia	39.6	79.9*	--	--	IV
1976 JUNE 19	McDowell	37.34	81.60	001	4.7	V
1976 JULY 03	do.	37.32	81.13	001	--	--
			Virginia			
1854 NOV 22	Tazwell	37.1	81.7*	--	--	III
1859 MAR 22	do.	37.1	81.5*	--	--	IV*
1921 JULY 15	Scott	36.6	82.3	--	--	V
1949 SEPT 16	Lee	36.7	83.0*	--	--	III*
1949 SEPT 17	do.	36.7	83.0*	--	--	IV*
1977 OCT 23	Russell	36.97	82.04	005	--	--
			Tennessee			
1913 MAR 28	Union	36.2	83.7	--	--	VII
1918 JUNE 22	Anderson	36.1	84.1	--	--	IV*
1920 DEC 24	Cumberland	36.0	85.0	--	--	V
1948 FEB 10	Campbell	36.4	84.1	--	--	V*
1967 OCT 18	Scott	36.5	84.5	--	--	--
1974 JAN 11	Warren	35.7	85.8*	--	--	II
1975 MAY 14	White	35.95	85.25	005	--	II

*Number assigned by original compiler from available data.

out in the peripheral and southwestern parts. The rocks are deformed by tight folds on the east and northeast boundary, southeastward-dipping thrust faults in the southeast, and basement-controlled, high angle normal and strike-slip (?) faults in central and eastern Kentucky.

Many of the sedimentary rocks have reservoir and confining characteristics that constitute potential for the emplacement and storage of liquid waste. Quantification of these characteristics was carried out mainly by a study of the rock lithology and the porosity distribution in the rocks. A potential waste-storage reservoir environment in these rocks is defined as:

> A sandstone, dolomite, or limestone layer containing nonpotable water that lies between about 300 m and 2,500 m below sea level and contains at least 7.5 m of rock with at least 5-percent porosity within a section no more than 75 m thick (potential reservoir interval) and is overlain and underlain by at least 30 consecutive meters of shale or evaporite or some rock with less than 5-percent porosity (potential confining beds).

This environment, as defined, was found in rocks that range from Cambrian to Mississippian in age. About two-thirds of the potential reservoir intervals occur in carbonate rocks and the remainder occur in sandstones. The potential reservoir intervals are grouped into six larger units called potential-reservoir units (designated A through F, oldest to youngest). These reservoir units are separated by seven confining beds called potential-confining units (designated Basal, A-B, B-C, C-D, D-E, E-F, and Above F).

The Basal Confining Unit is composed of Precambrian igneous and metamorphic rocks that form the basement on which the younger units were deposited. Potential Reservoir Unit A overlies the Basal Confining Unit, is composed mainly of sandstone and dolomite, occurs between 300 m and 2,500 m below sea level over a 77,300 km^2 area, and has an average area-weighted thickness of 144 m. About 5 percent of the unit was estimated to contain defined reservoir porosity. One potential reservoir interval occurs in each of the 28 wells where reservoir porosity was identified. The median altitude to the top of the potential reservoir intervals within the unit is 1,260 m below sea level, and their median thickness is 23 m. When evaluated by interval, the median thicknesses of the reservoir-type zones that are found within the intervals have a median value of 2 m, the aggregate thicknesses of the zones have a median value of 12 m, the median porosities of the zones range from 5 to 16 percent, and the average thickness-weighted porosities of the zones have a median value of 8 percent (table 4). Unit A is overlain by Potential Confining Unit A-B which has an average area-weighted thickness of 217 m.

Potential Reservoir Unit B overlies Potential Confining Unit A-B, is composed mainly of dolomite, limestone, and sandstone, occurs between 300 m and 2,500 m below sea level over a 96,400 km^2 area, and has an average area-weighted thickness of 850 m. About 2 percent of the unit was estimated to contain defined reservoir porosity. An average of about 2 potential reservoir intervals occur in each of the 43 wells where reservoir porosity was identified. Median altitude to the top of the potential reservoir intervals within the unit is 1,224 m below sea level, and their median thickness is 82 m. When evaluated by interval, the median thicknesses of the reservoir-type zones that are found within the intervals have a median value of 1.2 m, the aggregate thicknesses of the zones have a median value of 18 m, the median porosities of the zones range from 5 to 12 percent, and the average thickness-weighted porosities have a median value of 7 percent (table 4). About 85 percent of the reservoir porosity occurs below the Knox unconformity on the surface of the Knox Group. Unit B is overlain by Potential Confining Unit B-C which has an average area-weighted thickness of 423 m.

Potential Reservoir Unit C overlies Potential Confining Unit B-C, is composed of sandstone, occurs between 400 m and 2,500 m below sea level over a 81,600 km^2 area, and has an average area-weighted thickness of 36 m. About 3 percent of the unit was estimated to contain defined reservoir porosity. One potential reservoir interval occurs in each of the eight wells where reservoir porosity was identified. Median altitude of the top of the potential reservoir intervals within the unit is 1,582 m below sea level, and their median thickness is 18 m. When evaluated by interval, the median thickness of the reservoir-type zones that are found within the intervals have a median value of 4 m, the aggregate thicknesses of the zones have a median value of 12 m, the median porosities of the zones range from 5 to 10 percent, and the average thickness-weighted porosities have a median value of 7 percent (table 4). Unit C is overlain by Potential Confining Unit C-D which has an average area-weighted thickness of 92 m.

Potential Reservoir Unit D overlies Potential Confining Unit C-D, is composed of dolomite, limestone, sandstone, and some interlayered evaporites in the middle part of the unit, occurs between 300 m and 2,500 m below sea level over a 95,300 km^2 area, and has an average area-weighted thickness of 410 m. About 2 percent of the unit was estimated to contain reservoir porosity. At least one potential reservoir interval was found in 38 wells, and two occurred in about half the wells where reservoir porosity was identified. The median altitude to the top of the potential reservoir intervals within the unit is 1,411 m below sea level, and their median thickness is 66 m. When evaluated by interval, the median thicknesses of the reservoir-type zones that are found within the intervals have a median value of 1.2 m, the aggregate thicknesses of the zones have a median value of 13 m, the median porosities of the zones range from 5 to 12 percent, and the average thickness-weighted porosities have a median value of 7 percent (table 4). About 52 percent of the reservoir porosity occurs in rocks that lie above the evaporite-bearing section, 17 percent within the section, and 31 percent below. Unit D is overlain by Potential Confining Unit D-E which has an average area-weighted thickness of 838 m.

Potential Reservoir Unit E, which overlies Potential Confining Unit D-E, is composed of sandstone and siltstone, and is separated into a northern and southern part where the aggregate thickness of sandstone in the unit is about 8 to 10 m or more. Collectively, these two parts of the unit occur between 300 m and 2,500 m below sea level over a 13,700 km^2 area, and have an average area-weighted thickness of 58 m. About 1.4 percent of the unit was estimated to contain reservoir porosity. One potential reservoir interval occurs in each of the three key wells where reservoir porosity was identified. The median altitude of the top of the potential reservoir intervals is slightly above 300 m below sea level, and their median thickness is 69 m. When evaluated by interval, the thicknesses of the reservoir-type zones that are found within the intervals have a median value of 1.8 m, the aggregate thicknesses of the zones have a median value of 13 m, the median porosities of the zones range from 7 to 10 percent, and the average thickness-weighted porosities have a median value of 9 percent (table 4). Unit E is overlain by Potential Confining Unit E-F which has an average area-weighted thickness of 140 m.

Potential Reservoir Unit F overlies Potential Confining Unit E-F, is composed of sandstone and limestone, and occurs in three small areas adjacent to the Pine Mountain thrust fault that lie between 300 m and 2,500 m below sea level and constitute an aggregate surface area of 4,300 km^2. The average area-weighted thickness of the unit is 200 m. About 4 percent of the unit was estimated to contain defined reservoir porosity. One potential reservoir interval occurs in each of the eight wells where reservoir porosity was identified. The median altitude of the top of the potential reservoir intervals found in the unit is 388 m below sea level, and their median thickness is 59 m. When evaluated by interval, the median thicknesses of the reservoir-type zones that are found within the intervals have a median value of 1.7 m, the aggregate thicknesses of the zones have a median value of 12 m, the median porosities of the zones range from 5 to 10 percent, and the average thickness-weighted porosities have a median value of 5 percent (table 4). The confining unit that overlies Unit F has an average area-weighted thickness of about 50 m.

When all the unit factors listed are categorized into physical, economic, and safety characteristics, and the regional reservoir potential of the units is ranked according to these attributes, the resulting unit order from greatest reservoir potential to least is A, B, E, D, F, and C.

Other important factors that must be considered when assessing liquid waste-storage potential include (1) the occurrence and distribution of valuable resources, particularly oil and gas; (2) the density and distribution of oil and gas wells; (3) the distribution of major structural complexities, such as tight folding and faulting; (4) the distribution of seismic activity; and (5) the potential for the development of hydraulically induced fractures. These factors, separately or in combination, generally can decrease the potential for waste storage, and knowledge of their influence will be required when selecting any specific subsurface site to be considered for injection and storage of liquid wastes.

Oil and gas resources occur at various horizons in the study area. Significant amounts of oil and gas have been produced from about 5, 30, 10, 90, and 90 percent of the areas where units B, C, D, E, and F, respectively, occur between about 300 m and 2,500 m below sea level. The occurrence of these resources appears to be most common in the younger, shallower units. However, this may be illusionary since most of the exploratory and development drilling has been limited to the shallower units. Detailed information on the distribution of oil and gas production and exploratory wells can be obtained from the pertinent State Geological Surveys.

Steeply dipping rocks and thrust faults occur in the eastern part of the area, high-angle faults occur in central and eastern Kentucky, and seismic events have occurred in each State in the study area. Accordingly, when deep-well, liquid-waste injection is proposed or planned, pilot tests may be needed to help determine whether or not tectonic stress in any particular area and on any rock is such that increased pore pressure caused by fluid injection will trigger earthquakes. Pilot tests also may be made to help determine the critical well-face injection pressure at which hydraulic fracturing occurs and to determine the orientation of the resulting fractures.

SELECTED REFERENCES

Algermissen, S.T., 1969, Seismic risk studies in the United States: Fourth World Conference on Earthquake Engineering, Santiago, Chile, January 13–18, 1969, Proceedings, v. 1, p. 14–27.

American Association of Petroleum Geologists, 1970, Geological highway map of the mid-Atlantic region: American Association of

Petroleum Geologists, U.S. Geological Highway Map Series, Map 4, approximate scale 1:2,000,000, 1 sheet.

______ 1976, Geological highway map of the northeastern region: American Association of Petroleum Geologists, U.S. Geological Highway Map Series, Map 10, approximate scale 1:2,000,000, 1 sheet.

______ 1978, Geological highway map of the Great Lakes region: American Asssociation of Petroleum Geologists, U.S. Geological Highway Map Series, Map 11, approximate scale 1:2,000,000, 1 sheet.

______ 1985a, Correlation of stratigraphic units of North America, Northern Appalachian region: Tulsa, Oklahoma, The American Association of Petroleum Geologists, 1 sheet.

______ 1985b, Correlation of stratigraphic units of North America, Southern Appalachian region: Tulsa, Oklahoma, The American Association of Petroleum Geologists, 1 sheet.

Archie, G.E., 1952, Classification of carbonate reservoir rocks and petrophysical considerations: American Association of Petroleum Geologists Bulletin, v. 36, no. 2, p. 278–298.

Bayer, K.C., 1982, Map showing approximate eastern limit of commercial oil and gas fields in relation to structural features and physiographic provinces in the Appalachian region: U.S. Geological Survey Oil and Gas Investigation Chart OC–121, scale 1:2,500,000, 1 sheet.

Brown, D.L., 1971, Techniques for quality-of-water interpretations from calibrated geophysical logs, Atlantic Coastal Plain: Ground Water, v. 9, no. 4, 14 p.

Brown, P.M., Brown, D.L., Reid, M.S., and Lloyd, O.B., Jr., 1979, Evaluation of the geologic and hydrologic factors related to the waste-storage potential of Mesozoic aquifers in the southern part of the Atlantic Coastal Plain, South Carolina, and Georgia: U.S. Geological Survey Professional Paper 1088, 37 p.

Cardwell, D.H., 1974, Oriskany and Huntersville gas fields of West Virginia: West Virginia Geological and Economic Survey, Mineral Resources Series, no. 5, 151 p.

______ 1977a, West Virginia gas development in Tuscarora and deeper formations: West Virginia Geological and Economic Survey, Mineral Resources Series, no. 8, 34 p.

______ 1977b, Oil and gas fields of West Virginia: West Virginia Geological and Economic Survey, Mineral Resources Series, no. 7, 171 p.

Cardwell, D.H., Erwin, R.B., and Woodard, H.P., 1968, Geologic Map of West Virginia: West Virginia Geological and Economic Survey, scale 1:250,000, 2 sheets.

Cate, A.S., 1962, Subsurface structure of the plateau region of north-central and western Pennsylvania on top of the Oriskany Formation: Pennsylvania Geological Survey, 4th series, revision of plate 3, Bulletin G 27, approximate scale 1:300,000, 1 sheet.

Chen, Ping-fan, 1977, Lower Paleozoic stratigraphy, tectonics, paleogeography, and oil/gas possibilities in the central Appalachians (West Virginia and adjacent states) Part 1, Stratigraphic maps: West Virginia Geological and Economic Survey, Report of Investigation RI–26–1, 141 p.

Clifford, M.J., 1973, Silurian rock salt of Ohio: Ohio Department of Natural Resources, Division of Geological Survey, Report of Investigations 90, 42 p.

______ 1975, Subsurface liquid-waste injection in Ohio: Ohio Department of Natural Resources, Division of Geological Survey, Information Circular 43, 27 p.

Colton, G.M., 1961, Geologic summary of the Appalachian basin, with reference to the subsurface disposal of radioactive waste solutions: U.S. Geological Survey Trace Elements Investigations Report TEI–791, 121 p.

DeBrosse, T.A., and Vohwinkel, J.C., 1974, Oil and gas fields of Ohio: Ohio Department of Natural Resources, Division of Geological Survey, map, scale 1:500,000, 1 sheet.

Dennison, J.M., 1961, Stratigraphy of Onesquethaw Stage of Devonian in West Virginia and bordering states: West Virginia Geological Survey Bulletin 22, 87 p.

______ 1978, Stratigraphy and sedimentary tectonics of the Appalachian basin: American Association of Petroleum Geologists Short Course Notes printed for Eastern Section meeting, October 17, 1978, 46 p.

Dever, G.R., Jr., Hoge, H.P., Hester, N.C., and Ettensohn, F.R., 1977, Stratigraphic evidence for Late Paleozoic tectonism in northeastern Kentucky: Kentucky Geological Survey, Field Trip Guide Book, Eastern Section, American Association of Petroleum Geologists, October 9, 1976, 80 p.

DeWitt, Wallace, Jr., 1975, Oil and gas data from the Upper Paleozoic rocks in the Appalachian basin: U.S. Geological Survey Miscellaneous Investigations Series Map I–917–A, scale 1:2,500,000, 4 sheets.

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, 4 sheets.

Fergusson, W.B., and Parther, B.A., 1968, Salt deposits in the Salina Group in Pennsylvania: Pennsylvania Geological Survey, 4th Series, Mineral Resources Report M 58, 41 p.

Forster, J.B., 1980, Fresh and saline groundwater of West Virginia: West Virginia Geological and Economic Survey, map, scale 1:250,000, 4 sheets.

Freeman, L.B., 1953, Regional subsurface stratigraphy of Cambrian and Ordovician in Kentucky and vicinity: Kentucky Geological Survey Series IX, Bulletin 12, 352 p.

Hardeman, W.D., Miller, R.A., and Swingle, G.D., 1966, Geologic map of Tennessee: Tennessee Department of Conservation, Division of Geology, scale 1:250,000, 4 sheets.

Harris, L.D., 1964, Facies relations of exposed Rome Formation and Conasauga Group of northeastern Tennessee with equivalent rocks in the subsurface of Kentucky and Virginia: U.S. Geological Survey Professional Paper 501–B, p. 25–29.

______ 1975, Oil and gas data from the Lower Ordovician and Cambrian rocks of the Appalachian basin: U.S. Geological Survey Miscellaneous Investigation Series Map I–917–D, scale 1:2,500,000, 3 sheets.

Harris, L.D., and Milici, R.C., 1977, Characteristics of thin-skinned style of deformation in the southern Appalachians, and potential hydrocarbon traps: U.S. Geological Survey Professional Paper 1018, 40 p.

Hilchie, D.W., 1978, Applied openhole log interpretation for geologists and engineers: Douglas W. Hilchie, Incorporated, Golden, Colorado, 309 p.

______ 1979, Old electric log interpretation: Douglas W. Hilchie, Incorporated, Golden Colorado, 161 p.

Hopkins, H.T., 1963, The effect of oil field brines on the potable ground water in the upper Big Pitman Creek basin, Kentucky: Kentucky Geological Survey Series X, Report of Investigations 4, 36 p.

______ 1966, Fresh-saline water interface map of Kentucky: Kentucky Geological Survey Series X, map, scale 1:500,000.

Hoskins, H.A., 1949, Interpretations of salt water analyses: Appalachian Geological Society Bulletin, v. 1, 10 p.

Hubbert, M. King, and Willis, E.G., 1957, Mechanics of hydraulic fracturing: American Institute of Mining, Metallurgical and Petroleum Engineers Transactions, v. 210, p. 153–166.

Janssen, Adriaan, 1973, Stratigraphy of the Cambrian and Lower Ordovician rocks in Ohio: Ohio Department of Natural Resources, Division of Geological Survey, Bulletin 64, 197 p.

King, P.B., 1969, Tectonic map of North America: U.S. Geological Survey Map, scale 1:5,000,000, 2 sheets.

Lamborn, R.E., 1952, Additional analyses of brines from Ohio: Ohio Department of Natural Resources, Division of Geological Survey, Report of Investigations 11, 56 p.

Lessing, Peter, 1974, Earthquake history of West Virginia: West Virginia Geological and Economic Survey, Environmental Geology Bulletin 12, 13 p.

LeVan, D.C., 1962, Wells drilled for oil and gas in Virginia prior to 1962: Virginia Division of Mineral Resources, Mineral Resources Report 4, 47 p.

Levorsen, A.I., 1958, Geology of petroleum: San Francisco, California, W.H. Freeman and Company, 703 p.

MacCary, L.M., 1978, Interpretation of well logs in a carbonate aquifer: U.S. Geological Survey Water-Resources Investigations Report 78–88, 30 p.

______ 1980, Use of geophysical logs to estimate water-quality trends in carbonate aquifers: U.S. Geological Survey Water-Resources Investigations Report 80–57, 23 p.

______ 1983, Geophysical logging in carbonate aquifers: Ground Water, v. 21, no. 3, p. 334–342.

McDowell, R.C., Grabowski, G.J., Jr., and Moore, S.L., 1981, Geologic Map of Kentucky: Eleventh Kentucky Geological Survey, map, scale 1:250,000, 4 sheets.

McGrain, Preston, 1953, Miscellaneous analyses of Kentucky brines: Kentucky Geological Survey Series IX, Report of Investigations 7, 16 p.

McKelvey, V.E., 1972, Underground space—an unappraised resource, *in* Underground waste management and environmental implications: American Association of Petroleum Geologists Memoir 18, p. 1–5.

Martens, J.H.C., 1943, Rock salt deposits of West Virginia: West Virginia Geological Survey, Bulletin 7, 67 p.

Maryland Geological Survey, 1968, Geologic map of Maryland, scale 1:250,000, 1 sheet.

Milici, R.C., 1980, Relationship of regional structure to oil and gas producing areas in the Appalachian basin: U.S. Geological Survey Miscellaneous Investigation Series Map I–917–F, scale 1:2,500,000, 5 sheets.

Milici, R.C., and Smith, J.W., 1969, Stratigraphy of the Chickamauga Supergroup in its type area, *in* Precambrian-Paleozoic Appalachian problems: Georgia Geological Survey Bulletin 80, 35 p.; *reprinted as* Tennessee Division of Geology Report of Investigations 24, 32 p.

Miller, R.L., 1975, Oil and gas data from the Upper and Middle Ordovician rocks in the Appalachian basin: U.S. Geological Survey Miscellaneous Investigation Series Map I–917–C, scale 1:2,500,000, 3 sheets.

Norris, S.E., 1978, Hydrological environment of the Silurian salt deposits in parts of Michigan, Ohio, and New York: U.S. Geological Survey Open-File Report 78–684, 31 p.

North American Geologic Map Committee, 1965, Geologic Map of North America: U.S. Geological Survey Map, scale 1:5,000,000, 2 sheets.

Ohio Department of Natural Resources, Division of Geological Survey, 1965, Geologic Map of Ohio: scale 1:500,000, 1 sheet.

Ohio River Valley Water Sanitation Commission (ORSANCO), 1976, Evaluation of the Ohio Valley Region basal sandstone as a wastewater injection interval: Cincinnati, Ohio, Ohio River Valley Water Sanitation Commission, 30 p.

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 Geological Survey, 4th series, Progress Report 182, approximate scale 1:1,200,000, 7 sheets.

Patchen, D.G., 1974, Stratigraphy and petrography of the Upper Silurian Williamsport Sandstone, West Virginia: West Virginia Geological and Economic Survey, Report of Investigations 23, 16 p., *reprint from the* 1973 Proceedings of the West Virginia Academy of Science 45, no. 3, p. 250–265.

Patchen, D.G., Avery, K.L., and Erwin, R.B., 1985a, Correlation of stratigraphic units of North America (COSUNA) project, Northern Appalachian region: Tulsa, Oklahoma, The American Association of Petroleum Geologists, 1 sheet.

______ 1985b, Correlation of stratigraphic units of North America (COSUNA) project, Southern Appalachian region: Tulsa, Oklahoma, The American Association of Petroleum Geologists, 1 sheet.

Pennsylvania Topographic and Geological Survey, 1960, Geologic map of Pennsylvania: Pennsylvania Geological Survey, 4th series, scale 1:250,000, 2 sheets.

Piotrowski, R.G., Cozart, C.L., Heyman, Louis, Harper, J.A., and Abel, K.D., 1979, Oil and gas development in Pennsylvania in 1978: Pennsylvania Geological Survey, 4th series, Progress Report 192, 61 p.

Poth, C.W., 1962, The occurrence of brine in western Pennsylvania: Pennsylvania Geological Survey, 4th series, Bulletin M 47, 53 p.

Price, P.H., 1964, Appalachian connate water: West Virginia Geological and Economic Survey Bulletin 28, 42 p.

Price, P.H., Hare, C.E., McCue, J.B., and Hoskins, H.A., 1937, Salt brines of West Virginia: West Virginia Geological Survey, v. VIII, 203 p.

Raleigh, C.B., Healy, J.H., and Bredehoeft, J.D., 1972, Faulting and crustal stress at Rangely, Colorado, *in* Flow and fracture in rocks: American Geophysical Union Monograph 16, p. 275–284.

Rudd, Neilson, 1972, Subsurface liquid waste disposal and its feasibility in Pennsylvania: Pennsylvania Geological Survey, 4th series, Environmental Geology Report EG 3, 103 p.

Schlumberger Limited, 1972, Log interpretation—principles, v. 1: Houston, Texas, 113 p.

______ 1974, Log interpretation—applications, v. 2: Houston, Texas, 116 p.

______ 1977, Log interpretation charts: Houston, Texas, 83 p.

Schlumberger Well Surveying Corporation, 1958, Introduction to Schlumberger well logging (Schlumberger Document 8): Houston, Texas, 176 p.

______ 1962, Log interpretation chart book: Houston, Texas, 80 p.

Seismograph Service Corporation, Birdwell Division, 1973, Geophysical well log interpretation manual: Tulsa, Oklahoma, 186 p.

Stout, Wilber, Lamborn, R.W., and Schaaf, Downs, 1932, Brines of Ohio: Ohio Geological Survey, 4th series, Bulletin 37, 123 p.

Stover, C.W., Reagor, B.G., and Algermissen, S.T., 1979a, Seismicity map of the State of Ohio: U.S. Geological Survey Miscellaneous Field Studies Map MF–1142, scale 1:1,000,000, 1 sheet.

______ 1979b, Seismicity map of the State of Kentucky: U.S. Geological Survey Miscellaneous Field Studies Map MF–1144, scale 1:1,000,000, 1 sheet.

______ 1979c, Seismicity map of the State of Tennessee: U.S. Geological Survey Miscellaneous Field Studies Map MF–1157, scale 1:1,000,000, 1 sheet.

______ 1980a, Seismicity map of the State of West Virginia: U.S. Geological Survey Miscellaneous Field Studies Map MF–1226, scale 1:1,000,000, 1 sheet.

______ 1980b, Seismicity map of the State of Virginia: U.S. Geological Survey Miscellaneous Field Studies Map MF–1257, scale 1:1,000,000, 1 sheet.

______ 1981, Seismicity map of the State of Pennsylvania: U.S. Geological Survey Miscellaneous Field Studies Map MF–1280, scale 1:1,000,000, 1 sheet.

Sun, R.J., 1982, Selection and investigation of sites for the disposal of radioactive wastes in hydraulically induced subsurface fractures: U.S. Geological Survey Professional Paper 1215, 87 p.

Turcan, A.N., Jr., 1966, Calculation of water quality from electrical logs—theory and practice: Department of Conservation, Louisiana Geological Survey and Louisiana Department of Public Works, Water Resources Pamphlet 19, 23 p.

U.S. Environmental Protection Agency, 1980, Part 146—Underground injection control program, criteria and standards: Federal Register, v. 45, no. 123, p. 42,500–42,503.

Virginia Department of Conservation and Economic Development, Division of Mineral Resources, 1963, Geologic Map of Virginia: scale 1:500,000, 1 sheet.

Vlissides, S.D., and Quirin, B.A., 1964, Oil and gas fields of the United States: U.S. Geological Survey Map, scale 1:2,500,000, 2 sheets.

Wilson, E.N., and Sutton, D.G., 1973, Oil and gas map of Kentucky, sheet 3, east-central part: Kentucky Geological Survey Series X, scale 1:250,000, 1 sheet.

______ 1976, Oil and gas map of Kentucky, sheet 4, eastern part: Kentucky Geological Survey Series X, scale 1:250,000, 1 sheet.

Wolff, R.G., Bredehoeft, J.D., Keys, W.S., and Shuter, Eugene, 1975, Stress determination by hydraulic fracturing in subsurface waste injection: American Water Works Association Journal, v. 67, no. 9. p. 519–523.

Zoback, M.D., and Zoback, M.L., 1981, State of stress and intraplate earthquakes in the United States: Science, v. 213, no. 3, July, p. 96–104.

BASIC DATA

This section contains tables that display data for the key wells that were used for the descriptions and interpretations found in this report.

TABLE 1.—*Record of key wells*

Well number: The number is that assigned to identify the well in the study area (see pl. 1 for well location).

Well name: The operator and land owner names and identification number are given for each well.

Coordinate location: Location is given in degrees (°), minutes (′), and seconds (″) of Latitude (Lat.) north of the equator, and Longitude (Long.) west of the meridian that passes through the earth poles and Greenwich, England.

Elevation of GL: GL stands for ground level and the value is given in meters (m) above sea level.

Total depth: The total depth of the well is given in meters (m) below ground level.

Rock system at total depth: The alphabetical letters stand for the rock system and series that was found in the well at total depth. Precambrian (Pre€); Cambrian (€), Ordovician (O), Silurian (S), Devonian (D), Mississippian (M), represent the Paleozoic rock systems. Lower (L), Middle (M), and Upper (U) represent the divisions of the systems or series and prefix the system letters.

Data source: Geophysical logs (G), lithologic or sample or core descriptions or logs (L), and the appropriate State Geological Survey oil and gas well files (SF).

Potential reservoir units A–F depth to tops and thicknesses: Depth to top is in meters below sea level, and (-) indicates top in meters above sea level; WNDE, Well not deep enough; NPAR, Not present as a reservoir; UTS, Unit too shallow; UTD, Unit too deep; UTSOA, Unit too shallow or absent; ND, No data; PD, Poor data; ?, Questionable; +, Well not deep enough to fully penetrate unit; --, No determination made; FR, Fault repeated; A, Unit is absent.

Remarks: QWC, Water quality calculated from geophysical logs; QW-DST, Water quality data from State Geological Survey files on analyses made on samples collected during drill stem tests; S, Well included in cross section(s); NPAR, Not present as a reservoir.

TABLE 1.—*Record of key wells*

				Coordinate location						Potential Reservoir Unit A	
Well number	Well name	County	State	Lat.	Long.	Elev of GL (m)	Total depth (m)	Rock system at total depth	Data source	Depth to top (m)	Thickness (m)
1	East Ohio Gas Co., A. Born #1	Lorain	Ohio	41°17′50″	82°19′16″	258	1,399	Pre€	G, L	1,024	114
2	Great Basins Petroleum Co., R.J. Maurer Investment Co. #1	do	do	41°13′54″	82°01′27″	268	1,515	M–L€	G	WNDE	--
3	Wiser Oil Co., Divoky #2	Medina	do	41°14′00″	81°42′00″	381	1,846	U€	G	WNDE	--
4	Wiser Oil Co., Frank L Smith #1A	do	do	41°13′43″	81°42′07″	361	2,146	Pre€	GL	1,469	171
5	Sunshine Petroleum Corp., R.L. Jones #1	Ashland	do	40°54′46″	82°14′48″	349	1,474	U€	G, SF	WNDE	--
6	M&G Oil Co., K.F. & M.G. Cehrs #4	do	do	40°52′39″	82°08′36″	303	1,576	U€	G, L	WNDE	--
7	Great Lakes Gas Corp., Alonzo Drake, Jr. #1	Wayne	do	40°51′37″	81°54′20″	349	2,102	Pre€	G, L, SF	1,475	221
8	East Ohio Gas Co., Knight #3	Summit	do	40°55′59″	81°37′07″	342	1,970	LO	G, L, SF	WNDE	--
9	Belden and Blake & Co., B. Westfall	Stark	do	40°57′12″	81°15′46″	346	2,426	U–M€	G, L	1,986	91+
10	East Ohio Gas Co., L.&L. Frederick Comm.	do	do	40°54′53″	81°10′13″	340	2,380	U€	G, SF	WNDE	--
11	Management Control Corp. Frank Murray #3	Columbiana	do	40°47′10″	80°52′13″	360	3,122	U€	G, L	2,474	284+
12	Pan American Petroleum Corp., A.C. Windbigler #1	Morrow	do	40°40′50″	82°41′20″	422	1,490	Pre€	G, L	918	140
13	Tri-State Producing Co., Scott #2	Richland	do	40°41′17″	82°28′50″	442	1,677	Pre€	G	1,095	132
14	Tri-State Producing Co., J. & A.R. Hooks #1	do	do	40°40′48″	82°28′41″	423	1,417	U€	G	WNDE	--
15	United Producing Co., Inc., Orrie & Erma Myers #3	Morrow	do	40°34′13″	82°54′43″	308?	1,250	Pre€	G, L	769	144
16	David Cantway, Palos Verdes #1 (Cunningham)	Knox	do	40°31′11″	82°23′15″	378	1,762	U€	G, L	WNDE	--
17	Kin-Ark Oil Co., Levi S. Erb #1	Holmes	do	40°27′43″	81°44′50″	340	2,082	U€	G, L,SF	WNDE	--
18	Management Control Corp., John O. McAllister #1	Carroll	do	40°36′23″	80°59′07″	340	2,766	LO	G, L	WNDE	--
19	St. Joe Petroleum Corp., R.J. Ashcroft #1	Beaver	Pa.	40°36′06″	80°26′02″	341	2,313	UO	G, L, SF	WNDE	--
20	Humble Oil & Refining Co., Sarah K. Minesinger #1	Hancock	W.Va.	40°32′24″	80°33′23″	317	3,166	LO	G, L, SF	WNDE	--
21	Belden Oil & Gas Co., J. Carney #1	Jefferson	Ohio	40°24′55″	80°46′20″	324?	1,517	LD	G, SF	WNDE	--
22	Floyd A. Gearhart Howard S. Miser #1	do	do	40°24′17″	80°51′40″	341	2,100	UO	G, L, SF	WNDE	--
23	Sanford E. McCormick, Roy Birney #1	Harrison	do	40°15′43″	80°57′59″	339	3,103	LO	G, L	WNDE	--
24	Atlas Mineral Corp., John G. Scalia #1	Tuscarawas	do	40°25′10″	81°18′25″	272	1,646	UO	G, SF	WNDE	--
25	Stocker & Sitler, Huebner Unit #2	do	do	40°18′14″	80°25′29″	367	2,506	LO	G, L	WNDE	--
26	Bob Tatum Edwin L. Lee #1	Coshocton	do	40°19′25″	82°00′09″	314	2,124	U€	G, L	1,618	186
27	Ohio Fuel Gas Co., G.D. Larimore, #3	Knox	do	40°19′30″	82°33′52″	364	1,637	Pre€	G	1,097	155
28	Lake Shore Pipeline Co., Gordon Dixon #1	do	do	40°18′18″	82°36′27″	371	1,295	U€	G, SF	WNDE	--
29	Lake Shore Pipeline Co., Lucille Crowley #1	Licking	do	40°09′24″	82°19′15″	322	1,826	Pre€	G, L, SF	1,337	161
30	Ashland Oil & Refining Co., C.S. Schmelzer #1	do	do	39°58′44″	82°44′25″	326	1,464	Pre€	G, L	991	143
31	Worthington Oil Co., Inc., Columbia & Southern Electric Co.	Muskingum	do	40°08′21″	81°51′35″	241	2,046	U€	G, SF	WNDE	--
32	Ballard & Cordell, D. Welker #1	do	do	40°06′00″	81°45′10″	261	1,353	LS	L	WNDE	--
33	Lake Shore Pipeline Co., William Marshall #1	Guernsey	do	40°02′10″	81°43′00″	303	2,628	Pre€	G, L, SF	2,037	200
34	Golden Cycle Corp., M. & C. Vessels #1	do	do	39°57′49″	81°41′19″	312	2,240	LO	G, SF	WNDE	--
35	Kewanee Oil Company, Dorothy Mikolojcik #1	Muskingum	do	39°57′52″	81°51′32″	289	1,349	UO	G	WNDE	--
36	Oxford Oil Company, T.E. Corder #1	do	do	39°54′18″	81°52′59″	261	1,297	UO	L, SF	WNDE	--
37	Natural Gas Co. of West Virginia, E. A. Mobley #1	Belmont	do	39°57′22″	80°57′25″	358	2,404	UO	L	WNDE	--
38	Oxford Oil Company, Gilbert Dangel #1	Monroe	do	39°50′20″	80°53′57″	399	1,921	LD	G, L	WNDE	--

TABLE 1.—*Record of key wells*—Continued

Well number	Potential Reservoir Unit B Depth to top (m)	Potential Reservoir Unit B Thickness (m)	Potential Reservoir Unit C Depth to top (m)	Potential Reservoir Unit C Thickness (m)	Potential Reservoir Unit D Depth to top (m)	Potential Reservoir Unit D Thickness (m)	Potential Reservoir Unit E Depth to top (m)	Potential Reservoir Unit E Thickness (m)	Potential Reservoir Unit F Depth to top (m)	Potential Reservoir Unit F Thickness (m)	Remarks
1	750	195	363	9	–35	357	UTS	--	UTS	--	Unit C, NP; S
2	967	238+	544	12	–163	654	UTS	--	UTS	--	QWC
3	1,152	?	692	17	216	442	UTS	--	UTS	--	
4	1,152	284	677	18	213	440	UTS	--	UTS	--	
5	902	220+	490	21	124	322	UTS	--	UTS	--	QWC
6	984	287+	565	10	193	324	UTS	--	UTS	--	
7	1,169	272	711	10	312	353	UTS	--	UTS	--	
8	1,362	264+	854?	53?	400	462	UTS	--	UTS	--	
9	1,611	342	1,066	22	514	524	UTS	--	UTS	--	QWC
10	1,704	336+	1,151	31	575	528	UTS	--	UTS	--	QWC
11	2,009	448	1,415	18	767	602	–143	20	UTS	--	
12	574	311	205	21	–103	278	A	--	UTS	--	Unit C, NPAR; S
13	747	317	369	11	49	271	UTS	--	UTS	--	Unit C, NPAR; S
14	757	232+	367	9	59	267	UTS	--	UTS	--	
15	416	308	NPAR	--	–205	245	A	--	UTS	--	
16	?	?	?	?	127	247	UTS	--	UTS	--	Poor log for Units B and C
17	1,413	326+	932	18	514	341	UTS	--	UTS	--	QWC
18	2,056	367+	1,486	26	891	543	–2	12	UTS	--	
19	WNDE	--	1,908	52	1,197	633	12	18	UTS	--	QWC
20	2,409	436+	1,773	40	1,100	611	98	48	UTS	--	QWC
21	WNDE	--	WNDE	--	1,118	75+	69	13	UTS	--	
22	WNDE	--	1,700	20	1,046	589	UTS	--	UTS	--	
23	2,281	479+	1,705	21	1,066	579	86	9	UTS	--	QWC
24	WNDE	--	1,312	23	788	471	UTS	--	UTS	--	
25	1,774	360+	1,255	34	748	454	UTS	--	UTS	--	
26	1,221	383?	774	15	415	299	UTS	--	UTS	--	QWC
27	719	344	341	19	62	225	UTS	--	UTS	--	Unit C, NPAR; S
28	684	237+	303	18	27	238	UTS	--	UTS	--	Unit C, NPAR
29	936	373	523	10	229	245	UTS	--	UTS	--	S
30	583	357	209	22	–24	197	UTS	--	UTS	--	Unit C, NPAR; S
31	1,426	377+	971	14	575	323	UTS	--	UTS	--	
32	WNDE	--	1,045	24	625	347	UTS	--	UTS	--	
33	1,568	438	1,101	15	667	340	UTS	--	UTS	--	QWC; S
34	1,610	315+	1,149	22	714	361	UTS	--	UTS	--	
35	WNDE	--	1,017	11	617	347	UTS	--	UTS	--	
36	WNDE	--	990	22	605	289	UTS	--	UTS	--	
37	WNDE	--	1,990	48	1,302	558	UTS	--	UTS	--	
38	WNDE	--	WNDE	--	1,443	78+	268	62	UTS	--	

TABLE 1.—*Record of key wells*—Continued

				Coordinate location						Potential Reservoir Unit A	
Well number	Well name	County	State	Lat.	Long.	Elev of GL (m)	Total depth (m)	Rock system at total depth	Data source	Depth to top (m)	Thickness (m)
39	Occidental Petroleum Corp., John Burley #1	Marshall	W.Va.	39°45′47″	80°31′48″	434	5,033	U€	G, L, SF	WNDE	--
40	John T. Galey Samuel Cooper #1	Washington	Pa.	40°04′32″	80°09′30″	347	2,480	LD, US ?	G, L	WNDE	--
41	PNG-SNEE-Eberly Dugne Duvall #1	do	do	40°06′19″	79°56′45″	387	2,663	US	G, L. SF	WNDE	--
42	A.J. Fox et al., G.W. Gordon #1	Greene	do	39°51′35	80°08′52	425	2,639	LD, US ?	G, L, SF	WNDE	--
43	Amoco Production Co., Francis R.Griffin #1	Fayette	do	39°50′02″	79°50′39″	368	2,652	LD, US ?	G, L, SF	WNDE	--
44	Snee & Eberly et al., Leo F. Heyn #1	do	do	39°51′02″	79°39′38″	704	3,527	LS	G, L, SF	WNDE	--
45	William E. Snee and Eberly, E.C. Ricks #1	do	do	39°50′37″	79°39′11″	769	3,670	UO	G, L, SF	WNDE	--
46	Amoco Production Co., Leonard Svetz #1	Somerset	Pa.	39°58′40″	79°20′02″	748	6,541	U€	G, L, SF	WNDE	--
47	Snee & Eberly-NY State Nat. Gas, USA Collier #1	Garrett	Md.	39°40′18″	79°16′00″	870?	2,684	LD	L	WNDE	--
48	Texas Eastern Gas Transmission, Bowman-Seibert #2	do	do	39°37′59″	79°21′12″	729	3,541	UO	L	WNDE	--
49	Texas Eastern Transmission Corp., U.S.A. Savage River #1	do	do	39°37′17″	79°17′14″	813	2,481	LD	G	WNDE	--
50	Snee & Eberly Collier Unit #1	do	do	39°37′20″	79°18′40″	731	2,242	LD	G	WNDE	--
51	New York State Natural Gas Corp., (N–247) John Shaw #2	do	do	39°24′01″	79°22′00″	747	2,183	LS	G	WNDE	--
52	Phillips Petroleum Co., H.G. Walls #A–1	Preston	W.Va.	39°27′57″	79°52′11″	557	4,448	MO	G, L, SF	WNDE	--
53	Phillips Petroleum Corp. Clifford J. May #A–1	Monongalia	do	39°33′51″	79°52′23″	665	3,373	LS	G, L, SF	WNDE	--
54	Phillips Petroleum Corp., R.R. Finch #A–1	Marion	do	39°25′57″	80°00′42″	409	5,215	LO	G, L, SF	WNDE	--
55	Truman Smith-Smith Oil & Gas #1 Charles R. & Goldie Stoneking	Wetzel	do	39°37′31″	80°29′03″	322	2,346	LD	L, SF	WNDE	--
56	Consolidated Gas Supply Corp., L.G. Robinson	do	do	39°27′31″	80°34′10″	386	1,696	U–MD	G, SF	WNDE	--
57	Quaker State Oil Refining Corp., C.D. Cottrill #1	Tyler	do	39°22′03″	80°51′06″	292	2,078	LD	G,SF	WNDE	--
58	Dee Drilling Company, P.A. Walking #1	do	do	39°28′12″	80°49′59″	274	873	U–MD	G	WNDE	--
59	Mobay Chemical Corp., H. Emch and A. Pyles #1	Wetzel	do	39°40′40″	80°49′20″	410	2,142	LD	G, SF	WNDE	--
60	Sam W. Jack Drilling, A.R.A. Salt Test Well #1, N.Am. Coal	Monroe	Ohio	39°35′30″	80°58′15″	198	1,996	US	G	WNDE	--
61	Clifford L. Sayre (FMC) #1 Benjamin (E&R Wells)	Tyler	W.Va.	39°27′28″	81°05′45″	197	1,979	US	L	WNDE	--
62	F.M.C. Corp. (Benj. #5) EARL & Rosalene Wells #5	Pleasants	do	39°27′37″	81°05′50″	217	1,976	US	L	WNDE	--
63	F.M.C. Corp., #10 FMC Corp.	do	do	39°27′42″	81°06′29″	203	2,401	UO	G, SF	WNDE	--
64	Consolidated Gas Supply Corp., P.B. Case	Ritchie	do	39°16′58″	81°11′55″	334	2,383	US	G	WNDE	--
65	Hope Natural Gas Company,Jessie Powell	do	do	39°14′20″	81°15′30″	307	1,771	LD	G, L, SF	WNDE	--
66	Hope Natural Gas Company, Power Oil Company	Wood	do	39°15′22″	81°16′16″	317	4,063	Pre€	G, L, SF	UTD	--
67	Commonwealth Gas Corp., William C. Kerns #1	Pleasants	do	39°19′46″	81°17′16″	327	2,092	US	G, L, SF	WNDE	--
68	Guernsey Petroleum Corp., Carl Matheny Unit #2	Washington	Ohio	39°28′14″	81°17′30″	195	2,819	MO	G, L, SF	WNDE	--
69	Amerada Petroleum Corp., B. Ullman #1	Noble	do	39°36′36″	81°20′50″	312	3,488	Pre€	G, L	2,922	243
70	Berry Holding Company Cecil F. Offenberger #1	Washington	do	39°31′45″	81°34′32″	289	1,849	UO	G, L	WNDE	--
71	Columbia Gas Transmission Corp., Denver B. Kittle	Morgan	do	39°29′34″	82°01′10″	260	1,988	LO	G	WNDE	--
72	Columbia Gas Transmission Corp., George Campbell, et al.	do	do	39°42′49″	82°00′38″	313	1,906	LO	G, L	WNDE	--
73	Buckeye Management Co. & Columbia Gas Trans. Corp., H.V. Thomas #1	Perry	do	39°42′50″	82°02′21″	277	1,887	LO	G, L	WNDE	--
74	Quaker State Oil Refining Corp., D.M. & M.J. Potts #1	do	do	39°48′23″	82°05′57″	242	1,082	LS	G, SF	WNDE	--
75	Pure Oil Company, J.C. Kiener #1	do	do	39°42′27″	82°09′43″	308	1,106	UO	G, L, SF	WNDE	--
76	Clark Oil & Refining Corp., Rosa Thomas Heirs #1	Fairfield	do	39°36′36″	82°46′30″	333	1,149	U€	G, L, SF	WNDE	--

TABLE 1.—*Record of key wells*—Continued

Well number	Potential Reservoir Unit B		Potential Reservoir Unit C		Potential Reservoir Unit D		Potential Reservoir Unit E		Potential Reservoir Unit F		Remarks
	Depth to top (m)	Thickness (m)	Depth to top (m)	Thickness (m)	Depth to top (m)	Thickness (m)	Depth to top (m)	Thickness (m)	Depth to top (m)	Thickness (m)	
39	3,461	1,134^{+}	2,677	74	1,871	675	527	32	259	102	S
40	WNDE	--	WNDE	--	1,918	212^{+}	374	120	UTS	--	S
41	WNDE	--	WNDE	--	1,986	286^{+}	315	136	UTS	--	
42	WNDE	--	WNDE	--	2,007	204^{+}	395	122	UTS	--	S
43	WNDE	--	WNDE	--	2,045	234^{+}	UTS	--	UTS	--	
44	WNDE	--	2,719	99^{+}	1,302	1,135	UTS	--	UTS	--	
45	WNDE	--	2,747	149^{+}	1,590	930	UTS	--	UTS	--	S
46	4,080	1,707^{+}	2,771	102	1,788	797	-23	203	UTS	--	QWC
47	WNDE	--	WNDE	--	1,655	116^{+}	UTS	--	A	--	
48	WNDE	--	2,653	143	1,430	1,098	UTS	--	A	--	
49	WNDE	--	WNDE	--	1,572	91^{+}	UTS	--	A	--	
50	WNDE	--	WNDE	--	1,393	?	UTS	--	A	--	
51	WNDE	--	1,376	69^{+}	395	821	UTS	--	A	--	
52	3,708	177^{+}	2,628	138	1,728	713	-126	37	UTS	--	
53	WNDE	--	2,615	88^{+}	1,665	782	-390	126	UTS	--	
54	3,581	1,219^{+}	2,651	95	1,779	700	-4	67	UTS	--	QWC
55	WNDE	--	WNDE	--	1,917	107^{+}	ND	--	UTS	--	No logs for Unit E part of section
56	WNDE	--	WNDE	--	WNDE	--	502	53	UTS	--	QWC
57	WNDE	--	WNDE	--	1,665	110^{+}	482	--	219	99	
58	WNDE	--	WNDE	--	WNDE	--	525	25	249	105	Unit E, NPAR is present as silt and shale;QWC;S
59	WNDE	--	WNDE	--	1,622	107^{+}	NPAR	--	UTS	--	
60	WNDE	--	WNDE	--	1,530	265^{+}	--	--	UTS	--	
61	WNDE	--	WNDE	--	1,464	318^{+}	NPAR	--	UTS	--	
62	WNDE	--	WNDE	--	1,467	237^{+}	NPAR	--	UTS	--	
63	WNDE	--	2,119	49	1,438	568	NPAR	--	UTS	--	S
64	WNDE	--	WNDE	--	1,445	600^{+}	398	--	UTS	--	QWC
65	WNDE	--	WNDE	--	1,362	102^{+}	346	4	UTS	--	
66	2,603	871?	2,021	27	907	985	NPAR	--	UTS	--	QWC
67	WNDE	--	WNDE	--	1,021	740	56	--	UTS	--	
68	2,423	198^{+}	1,871	49	1,262	444	312	3	UTS	--	
69	2,249	657	1,721	45	1,149	466	266	1	UTS	--	QWC;S
70	WNDE	--	1,503	39	1,008	401	302	3	UTS	--	QWC
71	1,409	316^{+}	990	40	623	299	127	42	UTS	--	QWC
72	1,344	247^{+}	929	31	563	308	81	40	UTS	--	
73	1,308	299^{+}	900	29	540	300	UTS	--	UTS	--	
74	WNDE	--	803	12	470	290	UTS	--	UTS	--	
75	WNDE	--	757	12	435	271	UTS	--	UTS	--	
76	573	241^{+}	NPAR	--	2	172	UTS	--	UTS	--	

TABLE 1.—*Record of key wells*—Continued

Well number	Well name	County	State	Coordinate location Lat.	Coordinate location Long.	Elev of GL (m)	Total depth (m)	Rock system at total depth	Data source	Potential Reservoir Unit A Depth to top (m)	Potential Reservoir Unit A Thickness (m)
77	Kewanee Oil, E.A. Hopkins #1	Fayette	Ohio	39°29′25″	83°25′00″	294	1,435	Pre€	G, L	611	176
78	Well Supervision, Inc.,Brown #1	Vinton	do	39°17′32″	82°44′21″	190	1,241	U€	G, L	WNDE	--
79	Ralph Halbert George & Ina Woods #1	Jackson	do	38°57′57″	82°35′35″	262	1,926	Pre€	G, L	1,484	147
80	E.J. Dunigan, Jr.,M.E. & H. Hockman #1	Hocking	do	39°23′54	82°23′22	296	1,980	Pre€	G, L	1,522	160
81	Ohio Fuel Gas Co., Alfred B. and J.B. Windom #1	Meigs	do	39°04′25″	82°00′20″	220	1,467	UO	G, L	WNDE	--
82	Hunting Oil Co., Inc., Earl W. and Phyllis H. Cleek R# 1–A	do	do	38°56′19″	81°45′52″	183	1,761	UO	G, L, SF	WNDE	--
83	Sinclair-Prairie Oil, No. 1, W.T. Longworth	do	do	39°09′19″	81°48′21″	250	2,276	MO	L	WNDE	--
84	Carl E. Smith Inc., Herman C. Buckley #2	Athens	do	39°12′37″	81°54′57″	198	2,283	U€	G, SF	WNDE	--
85	Quaker State Oil Refining Corp., Barber & Fowler #1	do	do	39°11′29″	81°46′53″	222	1,698	UO	G, L	WNDE	--
86	Exxon Company, U.S.A., Howard Deem #1	Wood	W.Va.	39°04′50″	81°30′30″	211	4,043	Pre€	G	3,530	172
87	United Fuel Gas Company, Cora L. Brown et al.	Wirt	do	39°05′09″	81°19′02″	324	2,501	LS	G, L, SF	WNDE	--
88	Pennzoil United, Inc., W.B. Maxwell	Doddridge	do	39°11′45″	80°46′29″	303	2,871	UO	G, L, SF	WNDE	--
89	Halbert and Prough, Guy Simmons NO. 1–A	Gilmer	do	38°59′19″	80°48′15″	246	2,408	U–MS	G, SF	WNDE	--
90	Allegheny Land and Mineral Co., J.T. Lovett	Lewis	do	39°03′35″	80°32′56″	375	2,210	LD	G	WNDE	--
91	Hope Natural Gas Co., J.L.J. Bailey	do	do	39°04′30″	80°32′16″	351	2,140	LD	G, L, SF	WNDE	--
92	Consolidated Gas Supply Corp., J. Boring	Harrison	do	39°13′59″	80°26′42″	359	2,225	LD	G, SF	WNDE	--
93	Hope Natural Gas Co., C.S. Gribble	do	do	39°09′30″	80°19′47″	339	3,051	UO	L, SF	WNDE	--
94	Consolidated Gas Supply Corp., L.E. Bond	Upshur	do	39°04′15″	80°17′56″	382	2,203	U–MD	G, SF	WNDE	--
95	Hope Natural Gas Co., B.L. Martin	do	do	39°02′21″	80°16′18″	474	1,433	U–MD	G, L, SF	WNDE	--
96	Monitor Petroleum Corp., Junior Phillips #1	Barbour	do	39°00′31″	80°01′03″	684	2,472	LD	G, SF	WNDE	--
97	G.L. Cabot No. 1 O. Shockey et al.	do	do	39°03′47″	80°01′42″	620	2,441	LD	L	WNDE	--
98	Hope Natural Gas Co., James E. Sayers	do	do	39°13′12″	80°03′59″	482	1,389	U–MD	G, L, SF	WNDE	--
99	Industrial Gas Associates, Lewis M. Stout #1	Taylor	do	39°17′05″	80°09′32″	360	2,421	MD	G, SF	WNDE	--
100	Consolidated Gas Supply Corp., Blanche Swisher	do	do	39°17′12″	79°59′14″	460	1,356	U–MD	G, SF	WNDE	--
101	Consolidated Gas Supply Corp., W.W. Nester	Tucker	do	39°12′51″	79°46′12″	556	2,652	LS	G, L	WNDE	--
102	Columbian Fuel Corp., U.S.A. #Q–1	Preston	do	39°14′16″	79°34′24″	662	3,020	U–MO	G, L, SF	WNDE	--
103	Cities Service Oil Company, USA T–1	Tucker	do	39°13′28″	79°35′00″	621	2,129	LS	G, L, SF	WNDE	--
104	Hope Natural Gas Co., West Virginia Board of Control	Randolph	do	38°42′26″	79°58′09″	620	3,999	MO	G, L, SF	WNDE	--
105	Cramon Stanton Inc., Pardee & Curtin Lumber Co. #1	Webster	do	38°30′10″	80°21′45″	495	2,647	UO	G, L, SF	WNDE	--
106	Hope Natural Gas Co., West Virginia & Pittsburgh Railroad Co.	do	do	38°19′47″	80°27′06″	768	2,270	LD	G, L, SF	WNDE	--
107	J.C. Baker & Sox, Inc., J.C. Baker and Son, No. 1	Braxton	do	38°47′59″	80°33′14″	268	2,187	LD	G, SF	WNDE	--
108	Consolidated Gas Supply Corp., Lafayette Mick	Gilmer	do	38°53′56″	80°37′26″	373	716	LM	G, SF	WNDE	--
109	Consolidated Gas Supply Corp., I.N. Brown #11889	Braxton	do	38°50′07″	80°39′05″	336	1,422	U–MD	G, SF	WNDE	--
110	Consolidated Gas Supply Corp., I.N. Brown #11329	do	do	38°49′09″	80°38′59″	432	753	LM	G, SF	WNDE	--
111	Consolidated Gas Supply Corp., F.J. Dobbins	do	do	38°42′28″	80°49′39″	446	2,059	LD	G, SF	WNDE	--
112	Hope Natural Gas Co., Ed L. Boggs	do	do	38°41′08″	80°49′44″	322	1,932	LD	L, SF	WNDE	--
113	Westrans Petroleum Inc., William J. Mohr Heirs #1	Gilmer	do	38°47′22″	80°52′05″	288	2,081	LD	G, L, SF	WNDE	--
114	Exxon Company U.S.A., Gainer Lee et al. #1	Calhoun	do	38°52′57″	81°06′07″	367	6,164	Pre€	G, SF	UTD	--

TABLE 1.—*Record of key wells*—Continued

	Potential Reservoir Unit B		Potential Reservoir Unit C		Potential Reservoir Unit D		Potential Reservoir Unit E		Potential Reservoir Unit F		
Well number	Depth to top (m)	Thickness (m)	Depth to top (m)	Thickness (m)	Depth to top (m)	Thickness (m)	Depth to top (m)	Thickness (m)	Depth to top (m)	Thickness (m)	Remarks
77	87	466	NPAR	--	2	172	UTS	--	UTSOA	--	
78	676	374+	330	20	94	175	UTS	--	UTS	--	Unit C, NPAR; S
79	938	476	543	23	312	178	UTS	--	UTS	--	QWC
80	1,045	445	664	16	357	236	UTS	--	UTS	--	QWC
81	WNDE	--	1,206	32	814	294	280	10	UTS	--	
82	WNDE	--	1,540	23	1,101	333	436	1	UTS	--	
83	1,850	176+	1,390	48	958	339	--	--	UTS	--	
84	1,676	406+	1,249	37	845	305	280	3	UTS	--	
85	WNDE	--	1,415	32	967	344	UTS	--	UTS	--	
86	2,382	884	1,850	27	1,309	418	485	--	UTS	--	
87	WNDE	--	2,132	42+	1,146	831	182	--	UTS	--	QWC
88	WNDE	--	2,488	70	1,654	677	399	10	UTS	--	QWC; S
89	WNDE	--	WNDE	--	1,641	517+	NPAR	--	UTS	--	
90	WNDE	--	WNDE	--	1,694	137+	261	73	UTS	--	
91	WNDE	--	WNDE	--	1,673	115+	250	76	UTS	--	
92	WNDE	--	WNDE	--	1,734	130+	224	134	UTS	--	QWC; S
93	WNDE	--	2,631?	81+?	1,811	656	UTS	--	UTS	--	
94	WNDE	--	WNDE	--	WNDE	--	235	236	UTS	--	QWC; S
95	WNDE	--	WNDE	--	WNDE	--	UTS	--	UTS	--	
96	WNDE	--	WNDE	--	1,674	110+	-74	142	UTS	--	
97	WNDE	--	WNDE	--	1,726	94+	UTS	--	UTS	--	
98	WNDE	--	WNDE	--	WNDE	--	UTS	--	UTS	--	
99	WNDE	--	WNDE	--	do	--	UTS	--	UTS	--	
100	WNDE	--	WNDE	--	WNDE	--	33	256	UTS	--	QWC
101	WNDE	--	1,981	110+	732	1,070	A	--	A	--	
102	WNDE	--	1,469	147	716	629	UTS	--	UTS	--	QWC
103	WNDE	--	1,446	59+	686	640	A	--	A	--	
104	2,454	920+	1,067	113	131	750	A	--	A	--	QWC; S
105	WNDE	--	2,040	96	1,355	567	-89	25	UTS	--	
106	WNDE	--	WNDE	--	1,402	100+	UTS	--	UTS	--	
107	WNDE	--	WNDE	--	1,757	161+	NPAR	--	UTS	--	QWC
108	WNDE	--	WNDE	--	WNDE	--	NPAR	--	UTS	--	
109	WNDE	--	WNDE	--	WNDE	--	400	8	UTS	--	
110	WNDE	--	WNDE	--	WNDE	--	WNDE	--	UTS	--	
111	WNDE	--	WNDE	--	1,551	60+	NPAR	--	UTS	--	QWC
112	WNDE	--	WNDE	--	1,536	75+	NPAR	--	UTS	--	
113	WNDE	--	WNDE	--	1,668	121+	454	2	UTS	--	
114	2,865	1,585	2,246	37	1,529	562	NPAR	--	UTS	--	S

TABLE 1.—*Record of key wells*—Continued

Well number	Well name	County	State	Coordinate location Lat.	Coordinate location Long.	Elev of GL (m)	Total depth (m)	Rock system at total depth	Data source	Potential Reservoir Unit A Depth to top (m)	Potential Reservoir Unit A Thickness (m)
115	Jogruss Oil Corp., Allen Beard, G.F. Dillon #2	Roane	W.Va.	38°46′29″	81°12′54″	258	2,438	UO	G, SF	WNDE	--
116	United Fuel Gas Co., United Fuel Gas Fee	do	do	38°36′30″	81°19′04″	278	2,242	LS	G, L, SF	WNDE	--
117	United Fuel Gas Co., U.F.G. Co. Fee	Clay	do	38°27′12″	81°15′54″	348	2,482	UO	G, L, SF	WNDE	--
118	Harry Holtom, Bruen #1	Kanawha	do	38°29′06	81°35′10	239	1,991	UO	G, SF	WNDE	--
119	Exxon Corp., Walter W. McCoy et al., #1	Jackson	do	38°43′45″	81°34′18″	278	5,387	Pre€	G, SF	3,737	366?
120	United Fuel Gas Co., J.W. Heinzman	Roane	do	38°47′02″	81°30′23″	251	2,760	MO	L	WNDE	--
121	Pennzoil United, Inc., L.G. Helmick #1	Jackson	do	38°52′40″	81°33′57″	324	851	D	G	WNDE	--
122	South Penn Oil Co., Nellie Sayre King No. 1	do	do	38°48′18″	81°47′50″	234	1,913	LS	G, L, SF	WNDE	--
123	Commonwealth Gas Corp., Frank Hardy #3	Putnam	do	38°36′04″	81°46′38″	256	1,996	UO	G	WNDE	--
124	G.L. Cabot No. 1 Hatfield Campbell Creek Coal	do	do	38°31′01″	81°48′37″	181	1,423	LD	L	WNDE	--
125	United Fuel Gas Co., Gladys Bailey et al.	do	do	38°28′29″	81°44′53″	236	1,681	US	G, SF	WNDE	--
126	Cyclops Corp., E. Kingery Unit #1	Cabell	do	38°31′25″	82°15′48″	199	2,607	Pre€	G, L, SF	2,267	114
127	United Fuel Gas Company, Grover Arrington No. 1	Mason	do	38°42′53″	82°09′32″	182	2,632	Pre€	G, L	2,297	135
128	Columbia Gas Transmission Corp., John Bane	Gallia	Ohio	38°45′10″	82°15′50″	167	1,246	UO	G, SF	WNDE	--
129	Quaker State Oil Refining Corp., R.L. & F.F. Cook	do	do	38°50′06″	82°21′49″	180	1,084	UO	G, L, SF	WNDE	--
130	J. Stanley Goldberg, A.J. Payne #1	Lawrence	do	38°43′51″	82°29′04″	183	2,134	Pre€	G	1,776	157
131	East States Gas Producing Co., Cambria Clay # 1–A	do	do	38°36′20″	82°38′35″	221	1,607?	U€	G, L	WNDE	--
132	Earlougher Eng. Co., U.S.S. Chemical Div., U.S. Steel Corp., #1	Scioto	do	38°35′32″	82°49′17	166	1,712	Pre€	G, L	1,421	114
133	Commonwealth Gas Corp., D.P. Newell Jr. & Sr., #1	Greenup	Ky.	38°38′21″	83°03′05″	318	1,583	Pre€	G, L, SF	1,131	126
134	Ashland Oil and Refining Co., Dewey Wolfe #1	Lewis	do	38°32′09″	83°07′50″	336	1,549	Pre€	G, L, SF	1,080	114
135	Ralph Thomas, Daisey Adams #1	do	do	38°32′43″	83°12′59″	169	1,277	Pre€	G	1,021	75
136	United Carbon Co., Fred Felty #1	Greenup	do	38°25′00″	82°57′02″	215	1,276	LO	G, L, SF	WNDE	--
137	United Fuel Gas Co., Alice Shepherd #1	Lewis	do	38°22′48″	83°17′27″	277	1,387	Pre€	G, L, SF	1,052	50
138	Carter Development Co., Oscar Coleman #4	Carter	do	38°20′00″	83°12′10″	262	1,093	U€	G, L	--	--
139	United Fuel Gas Co., Lloyd Stamper et al.	do	do	38°19′40″	83°07′20″	258	1,550	Pre€	G, L, SF	1,187	96
140	Pennzoil Co., Fannie Mays No. 1	Rowan	do	38°10′17″	83°19′40″	275	1,022	U€	G, L, SF	WNDE	--
141	Pennzoil Co., Carmia Jones No. 1	do	do	38°09′55″	83°18′16″	364	1,521	Pre€	G, L, SF	1,110	38
142	United Fuel Gas Co., J.O. Litton	Elliott	do	38°05′40″	83°11′50″	292	1,644	Pre€	G, L, SF	1,256	31
143	Monitor Petroleum Corp., Cecil Ison #1	do	do	38°08′07″	82°57′38″	206	2,946	M–L€	G, L, SF	1,898	482
144	Inland Gas Co., Everett McDavid	Carter	do	38°10′25″	82°56′48″	241	3,042	L€	G, L	1,832	357
145	Inland Gas Co., Coalton Tract Fee #538	do	do	38°17′24″	82°48′00″	237	2,216	Pre€	G, L, SF	1,678	137
146	Inland Gas Co., Inc., Coalton Tract Fee #533	Boyd	do	38°17′50″	82°45′45″	258	2,924	Pre€	G, L, SF	1,801	166
147	Inland Gas Co., Inc., W.P. & Roberta Young	Lawrence	do	38°13′37″	82°44′40″	264	3,875	Pre€	G, L, SF	2,140	302
148	Inland Gas Co., Inc. L.O. White heirs	Boyd	do	38°20′07″	82°40′17″	196	2,340	L€	G, L, SF	WNDE	--
149	Inland Gas Co., Inc., #551 Eva Smallridge	do	do	38°20′17″	82°39′43″	214	2,572	M–L€	G, L, SF	1,922	177
150	Exxon Corp., Jay P. Smith #1	Wayne	W.Va.	38°13′19″	82°32′03″	181	4,458	Pre€	G, SF	2,546	355
151	United Fuel Gas Co., Mineral Tract #1	do	do	38°04′56″	82°25′03″	328	718	UD	G	WNDE	--
152	United Fuel Gas Co., UFG Co. Mineral Tract #23	Lincoln	do	38°03′40″	82°00′13″	366	1,225	U–MD	G	WNDE	--

TABLE 1.—*Record of key wells*—Continued

Well number	Potential Reservoir Unit B		Potential Reservoir Unit C		Potential Reservoir Unit D		Potential Reservoir Unit E		Potential Reservoir Unit F		Remarks
	Depth to top (m)	Thickness (m)	Depth to top (m)	Thickness (m)	Depth to top (m)	Thickness (m)	Depth to top (m)	Thickness (m)	Depth to top (m)	Thickness (m)	
115	WNDE	--	2,095	36	1,447	503	ND	--	UTS	--	No log for Unit E part of section; S
116	WNDE	--	1,921	39+	1,356	433	390	--	UTS	--	Unit E, NPAR
117	WNDE	--	1,914	24	1,357	414	NPAR	--	UTS	--	QWC
118	WNDE	--	1,718	22	1,224	362	ND	--	UTS	--	No log for Unit E part of section; S
119	2,420	1,224	1,841	23	1,301	401	482	2	239	119	QWC
120	WNDE	--	1,895	35	1,337	414	475	6	UTS	--	
121	WNDE	--	WNDE	--	WNDE	--	502	1	UTS	--	QWC
122	WNDE	--	1,637	42+	1,173	334	497	5	UTS	--	
123	WNDE	--	1,687	26	1,220	343	498	3	UTS	--	
124	WNDE	--	WNDE	--	1,166	60+	481	6	UTS	--	
125	WNDE	--	WNDE	--	1,187	253+	450	5	UTS	--	QWC
126	1,539	684	1,118	29	813	226	414	3	UTS	--	QWC
127	1,593	660	1,162	25	823	289	363	15	UTS	--	
128	WNDE	--	1,028	24	710	243	316	9	UTS	--	QWC
129	WNDE	--	873	18	579	223	228	4	UTS	--	QWC
130	1,180	524	771	16	500	190	UTS	--	UTS	--	
131	1,032	543+	685	17	418	176	162	24	UTS	--	QWC
132	827	545	493	18	275	135	UTS	--	UTS	--	Unit C, NPAR; S
133	541	531	NPAR	--	53	101	UTS	--	UTS	--	QWC; S
134	427	593	NPAR	--	20	85	UTS	--	UTSOA	--	QWC
135	341	592	NPAR	--	-73	96	UTS	--	UTSOA	--	QWC
136	723	336+	NPAR	--	215	102	17	35	UTS	--	
137	381	578	NPAR	--	-29	12	UTS	--	UTSOA	--	QWC
138	478	352+	NPAR	--	49	38	--	--	UTSOA	--	QWC
139	564	566	NPAR	--	115	66	--	--	UTS	--	QWC; S
140	374	372+	NPAR	--	-26	32	UTS	--	A	--	QWC
141	304	721	NPAR	--	-8	36	UTS	--	UTS	--	QWC; S
142	468	706	NPAR	--	103	58	--	--	UTS	--	QWC; S
143	873	884	NPAR	--	308	162	--	--	UTS	--	QWC
144	917	803	NPAR	--	377	126	141	64	UTS	--	QWC
145	908	693	NPAR	--	411	134	183	36	UTS	--	QWC
146	1,047	687	678	44?	471	133	230	34	UTS	--	QW–DST
147	1,174	850	NPAR	--	552	180	311	29	UTS	--	QWC
148	1,128	697	757?	40?	526	153	269	25	UTS	--	
149	1,122	731	773	17	540	158	280	35	UTS	--	QWC
150	1,395	1,000	987	27	679	215	372	18	UTS	--	QWC
151	WNDE	--	WNDE	--	WNDE	--	--	--	UTS	--	QWC
152	WNDE	--	WNDE	--	392	--	392	6	UTS	--	

TABLE 1.—*Record of key wells*—Continued

Well number	Well name	County	State	Coordinate location Lat.	Coordinate location Long.	Elev of GL (m)	Total depth (m)	Rock system at total depth	Data source	Potential Reservoir Unit A Depth to top (m)	Potential Reservoir Unit A Thickness (m)
153	Exxon Corp. U.S.A. Douglas McCormick #1	Lincoln	W.Va.	38°13′02″	81°56′24″	224	5,829	Pre€	G, SF	3,424	224?
154	Owens, Libbey-Owens Gas Dept. Bull Creek Coal Land Co.	Boone	do	38°13′10″	81°39′22″	297	1,830	UO	L, SF	WNDE	--
155	Columbia Gas Trans Corp., Black Band Coal & Coke Co.	Kanawha	do	38°16′24″	81°37′04″	304	1,683	US	G, SF	WNDE	--
156	Columbian Carbon Co., Susan Hogue et. al.	do	do	38°17′43	81°35′10	334	1,741	MS	G, L, SF	WNDE	--
157	Union Oil Co. of California, Chelyon Coal & Land Co.	do	do	38°08′29″	81°30′57″	429	2,461	U–MO	G, SF	WNDE	--
158	Columbia Gas Transmission Corp., Sally Dickenson Todd	do	do	38°17′45″	81°22′25″	378	3,227	LO	G	WNDE	--
159	Shell Oil Co., Foulke Meadow River Lands #1	Fayette	do	38°06′40″	80°55′52″	625	2,592	LS	G, L, SF	WNDE	--
160	Columbia Gas Trans. Corp., Westvaco Co #1	Greenbrier	do	38°03′39″	80°43′57″	1,060	3,087	UO	G, SF	WNDE	--
161	Rotary Development Corp., New Gauley Coal Corp.	Nichols	do	38°10′56″	80°38′47″	776	2,388	US	G, L, SF	WNDE	--
162	Tidewater Oil Co., U.S. Forest Service	Pocahontas	do	38°09′10″	80°00′41″	1,065	3,633	MO	G, L, SF	WNDE	--
163	United Fuel Gas, J.R. Damron	Greenbrier	do	37°41′39″	80°19′30″	866	2,141	UO	G, L, SF	WNDE	--
164	Columbia Gas, E.M. Thompson	do	do	39°57′45″	80°37′40″	876	1,034	UD	L	WNDE	--
165	Ashland Oil & Refining Co., Bewind-White Coal Mining #1	Fayette	do	37°56′20″	80°58′11″	902	2,845	LS	G, SF	WNDE	--
166	Columbia Gas Trans. Corp., F.W. Sawyers et al.	Raleigh	do	37°43′56″	80°58′57″	857	2,682	MS	G	WNDE	--
167	Anchor Petroleum Co., Elizabeth Ball #1	Summers	do	37°41′32″	80°55′30″	571	2,521	UO	G, L, SF	WNDE	--
168	Phillips Petroleum Co., Beaver #A–1	Raleigh	do	37°40′28″	81°18′09″	621	2,144	LD	G, L	WNDE	--
169	Owens Libbey-Owens, No. 2 W. Pocahontas	Wyoming	do	37°39′43″	81°25′54″	614	2,100	LD	L, SF	WNDE	--
170	Columbia Gas Trans; Corp., Dickenson Properties, Inc.	Raleigh	do	37°49′48″	81°18′41″	548	2,395	UO	G, L, SF	WNDE	--
171	Consolidated Gas Supply Corp., Loup Creek Colliery Div. II	Wyoming	do	37°44′25″	81°34′41″	477	2,067	MS	G, SF	WNDE	--
172	Consolidated Gas Supply Corp., Federal Coal Company	Boone	do	37°59′57″	81°38′59″	392	2,002	MS	G, SF	WNDE	--
173	Southeastern Oil & Gas Co., C.C. Chambers #3	Logan	do	37°55′19″	81°55′53″	364	2,286	MO	G, L, SF	WNDE	--
174	United Fuel Gas, Mingo and Wyoming Land & Coal Co.	Mingo	do	37°39′08″	81°54′40″	472	1,777	LD	G, L, SF	WNDE	--
175	Columbia Gas Trans., Mineral Tract #10	do	do	37°54′19″	82°10′15″	285	5,972	Pre€	G, L, SF	3,213	208?
176	United Fuel Gas Co., F.D. Caldwell et al. #42	Wayne	do	37°53′29″	82°23′42″	210	2,408	U€	G, L, SF	WNDE	--
177	United Fuel Gas Co., Jasper James et al.	Martin	Ky.	37°51′25″	82°31′19″	197	4,015	M–L€	G, L, SF	2,536	171
178	U.S. Signal, #1 Elkhorn City Coal Corp.	Johnson	do	37°48′09″	82°43′20″	217	4,440	Pre€	G, L, SF	2,460	129
179	United Fuel Gas Co., S.W. McGuire	Floyd	do	37°41′19″	82°42′53″	264	794	MD	G, SF	WNDE	--
180	Kentucky-West Virginia Gas Co., Lark Howard	Magoffin	do	37°39′30″	82°58′57″	338	835	MS	L	WNDE	--
181	CNG Producing Co., Fred Howard #AA–2	do	do	37°47′36″	83°04′11″	302	822	LS	G, SF	WNDE	--
182	Cumberland Petroleum Co., #44 L.C. Bailey	do	do	37°51′17″	83°03′27″	310	1,545	LO	L	WNDE	--
183	Columbia Gas Trans. Corp., J.H. Evans	Johnson	do	37°58′21″	82°55′10″	282	3,048	M–L€	G, L, SF	1,957	722
184	Monitor Petroleum Corp., Freddy Ison #1	Morgan	do	37°59′14″	83°02′24″	247	3,052	M–L€	G, L, SF	1,851	508
185	Ashland Oil & Refining Co., Lee Clay Products Co., #1	do	do	38°02′40″	83°18′24″	237	1,755	Pre€	G, L, SF	1,280	165
186	Exxon Company, U.S.A., Orville Banks #1	Wolfe	do	37°42′31″	83°22′04″	313	3,756	Pre€	G, L, SF	1,997	212
187	Howard Atha et al., Dewey Tyra No. 1	do	do	37°45′53″	83°29′29″	315	1,463	U€	G, L, SF	WNDE	--
188	United Fuel Gas, Frank Brown	Menifee	do	38°00′34″	83°30′47″	299	1,789	Pre€	G, L, SF	1,180	143
189	Monitor Petroleum Corp., Campbell #1	do	do	37°52′24″	83°33′05″	341	2,069	Pre€	G, L, SF	1,474	228
190	A.H. Carpenter, Maloney #1	Powell	do	37°49′56″	83°45′41″	206	984	U€	G, SF	WNDE	--

TABLE 1.—*Record of key wells*—Continued

	Potential Reservoir Unit B		Potential Reservoir Unit C		Potential Reservoir Unit D		Potential Reservoir Unit E		Potential Reservoir Unit F		
Well number	Depth to top (m)	Thickness (m)	Depth to top (m)	Thickness (m)	Depth to top (m)	Thickness (m)	Depth to top (m)	Thickness (m)	Depth to top (m)	Thickness (m)	Remarks
153	1,868	1,431	1,487	26	1,088	280	444	5	UTS	--	S
154	WNDE	--	1,495	19	1,068	308	–	–	UTS	--	
155	WNDE	--	WNDE	--	1,120	259⁺	ND	--	UTS	--	No Logs for Unit E&F parts of section; S
156	WNDE	--	WNDE	--	1,143	264⁺	NPAR	–	UTS	--	
157	WNDE	--	1,719	28	1,310	300	456	8	UTS	--	
158	2,295	551⁺	1,798	31	1,324	356	390	27	UTS	--	QWC
159	WNDE	--	1,917	47+	1,454	384	UTS	–	UTS	--	QWC
160	WNDE	--	1,957	55⁺	1,480	401	104	3	UTS	--	QWC
161	WNDE	--	WNDE	--	1,460	149⁺	–188	4	UTS	--	
162	1,644	920⁺	547	92	UTS	--	A	–	A	--	
163	WNDE	--	1,180	90	566	544	NPAR	–	UTS	--	
164	WNDE	--	WNDE	--	WNDE	--	UTS	–	UTS	--	
165	WNDE	–	WNDE	--	1,463	322	UTS	–	UTS	--	
166	WNDE	--	WNDE	--	1,553	267	247	10	UTS	--	Unit E mostly silt and shale
167	WNDE	--	1,883	55	1,533	294	322	71?	UTS	--	QWC
168	WNDE	--	WNDE	--	1,459	59⁺	NPAR	--	103	114	
169	WNDE	–	WNDE	--	WNDE	--	A	--	218	204	
170	WNDE	--	1,801	28	1,421	283	NPAR	--	71	245	QWC
171	WNDE	–	WNDE	--	1,365	221⁺	544	4	242	136	QWC
172	WNDE	–	WNDE	--	1,337	255	560	2	UTS	--	QWC
173	1,707	211⁺	1,374	22	1,010	243	390	3	145	87	
174	WNDE	–	WNDE	--	1,272	30⁺	658	8	UTS	--	
175	1,526	1,465	1,205	24	858	227	360	28	119	42	S
176	1,430	768?	1,066	32	737	206	355	31	UTS	--	
177	1,347	1,052	985	12	656	217	326	37	133	53	
178	1,104	1,012	NPAR	--	492	201	239	23	UTS	--	QWC; S
179	WNDE	--	NPAR	--	529	1⁺	UTS	–	UTS	--	QWC
180	WNDE	--	NPAR	--	330	166	UTS	--	UTS	--	
181	WNDE	--	NPAR	--	222	141	62	18	UTS	--	QWC
182	883	352⁺	NPAR	--	ND	--	ND	–	ND	--	No log data for upper units
183	802	917	NPAR	--	141	235	UTS	--	UTS	--	
184	689	996	NPAR	--	221	133	49	23	UTS	--	QWC; S
185	330	843	NPAR	–	59	49	UTS	--	UTS	--	
186	607	1,110	NPAR	--	224	68	NPAR	–	UTS	--	
187	388	756⁺	NPAR	--	71	38	NPAR	--	UTS	--	
188	235	811	NPAR	–	–57	22	UTS	–	A	--	QWC; S
189	234	942	NPAR	–	–5	32	UTS	–	UTS	--	QWC
190	112	665⁺	NPAR	–	–117	11	A	--	A	--	S

TABLE 1.—*Record of key wells*—Continued

Well number	Well name	County	State	Coordinate location: Lat.	Coordinate location: Long.	Elev of GL (m)	Total depth (m)	Rock system at total depth	Data source	Potential Reservoir Unit A: Depth to top (m)	Potential Reservoir Unit A: Thickness (m)
191	The Wider Oil Co., No. 1 WD & WH	Lee	Ky.	37°41′37″	83°42′49″	293	954	LO	G, SF	WNDE	--
192	South Central Petroleum, No. 1, James Hall	Powell	do	37°48′30″	83°57′30″	230	1,914	M–L€	L, SF	WNDE	--
193	Texaco, Inc., Tipton #1	Estill	do	37°40′20″	84°00′21″	194	2,078	M–L€	G, L, SF	WNDE	--
194	Texas West Bay Co., W.J. Hamilton #1	Madison	do	37°35′03	84°19′27	301	2,098	M–L€	G	WNDE	--
195	Texaco, Inc., B.E. Perkins #1	do	do	37°47′01″	84°25′56″	286	1,956	Pre€	G, L, SF	1,184	466+
196	Texaco Inc., No 1 Park Wolfinbarger	Jessamine	do	37°49′08″	84°30′30″	293	1,851	Pre€	G, L, SF	1,008	526
197	Texaco Inc., Leonard Kirby #1	Garrard	do	37°43′02″	84°37′56″	293	1,751	Pre€	G, L, SF	1,088	335
198	Clinton Oil Co., George and Cristine Hale #1–V	do	do	37°42′09″	84°29′02″	208	1,688	L€	G, SF	1,187	288+
199	Patrick Petroleum Co., C.C. Broaddus & E.C. Tussey	do	do	37°37′20″	84°29′09″	286	1,548	L€	G, SF	1,209	48+
200	L. & M. Gas Co., C.B. Causey #1	do	do	37°33′44″	84°25′32″	282	1,675	M–L€	G, L, SF	WNDE	--
201	Rome Oil and Gas Co., Foster-Morrow Unit #1	Lincoln	do	37°32′10″	84°42′02″	310	1,762	M–L€	G, L, SF	1,328	119+
202	The California Co., A.R. Spears #1	do	do	37°27′20″	84°47′20″	343	1,864	Pre€	G, L, SF	1,235	174
203	Amerada Hess Corp., Hirstel Daulton #1	Pulaski	do	37°07′21″	84°38′52″	318	2,050	Pre€	G, L, SF	1,618	104
204	Amerada Hess Petrol. Corp., Ray Edwards, et al. #1	do	do	37°05′14″	84°33′37″	288	2,703	Pre€	G, L, SF	2,358	41
205	Kin Ark Oil Co., Burgess Abney #1	Rockcastle	do	37°20′43″	84°12′15″	344	838	LO	G, L, SF	WNDE	--
206	Ferguson and Bosworth, Martha Bond #1	Jackson	do	37°25′23″	84°03′51″	433	955	LO	G, L, SF	WNDE	--
207	Monitor Petroleum Corp., Stanley Neeley #1	do	do	37°27′13″	83°56′51″	410	3,111	L€	G, L, SF	2,610	88+
208	Monitor Petroleum Corp., #1 Brandenburg Minerals–R. Newman	Lee	do	37°31′36″	83°48′49″	267	952	LO	G, L, SF	WNDE	--
209	Petroleum Exploration Corp., No. 3 J.C. Botner	Owsley	do	37°28′08″	83°46′38″	303	1,156	LO	L	WNDE	--
210	Algonquin Petroleum Co., Hubbard #1	Clay	do	37°10′15″	83°56′31″	360	1,948	M–L€	G, L, SF	WNDE	--
211	United Fuel Gas Co., Fordson Coal Co., No. 28	Leslie	do	37°13′45″	83°27′30″	356	2,875	Pre€	G, SF	2,378	131
212	United Fuel Gas Co., S.W. Williams	Breathitt	do	37°32′18″	83°17′04″	229	3,392	Pre€	G, L, SF	2,163	61
213	Ashland Oil Eastern Kentucky Realty Co.	Knott	do	37°21′11″	83°01′10″	495	1,166	MS	G, SF	WNDE	--
214	Cities Service Oil Co., Kelley " A" #1	do	do	37°14′04″	83°01′23″	343	963	UD	G, SF	WNDE	--
215	Kentucky–West Virginia Gas Co., R.D. Baker No. 6877	Perry	do	37°11′38″	83°04′25″	465	1,229	MS	G, L, SF	WNDE	--
216	Kentucky-West Virginia Gas Co., W.J. Caudill	Letcher	do	37°07′10″	82°59′59″	540	1,284	UD	G, SF	WNDE	--
217	Weaver Oil & Gas Corp., et al., Weaver #1 (Potter) Tr. 5–348	do	do	37°11′12″	82°37′35″	469	1,527	MS	G, SF	WNDE	--
218	Kentucky-West Virginia Gas Co., Marion Hunter	Knott	do	37°27′35″	82°51′14″	322	1,204	UO	G, SF	WNDE	--
219	Signal Oil and Gas Co., Hall #1	Floyd	do	37°29′35″	82°45′29″	206	3,962	Pre€	G, SF	2,417	143
220	Signal Oil and Gas Co., Stratton #1	Pike	do	37°28′55″	82°27′47″	359	3,801	Pre€	G, L, SF	2,615	132
221	Columbia Gas Trans. Corp., The Pittston Co., #21 well	Buchanan	Va.	37°18′06″	82°15′01″	496	1,756	LD	G	WNDE	--
222	Columbia Gas Trans. Corp., B. Mullins	Dickenson	do	37°16′44″	82°15′32″	462	2,853	LO	G, L	WNDE	--
223	United Fuel Gas Co., The Pittston Co., #7 well	do	do	37°12′58″	82°16′48″	477	1,366	UD	G, SF	WNDE	--
224	Columbia Gas Trans. Corp., John W. Pabst, et al.	Buchanan	do	37°09′56″	82°08′31″	509	2,225	LS	G, L	WNDE	--
225	Penn-Ohio Gas Co., Clinchfield Coal Co. #1	Russell	do	37°01′46″	82°08′46″	631	1,878	UD	L, SF	WNDE	--
226	Consolidated Gas Supply Corp., Rose L. Dennis	McDowell	W.Va.	37°29′28″	81°56′39″	414	1,789	US	G, SF	WNDE	--
227	United Fuel Gas Co., Warren Simpson Coal & Land Corp., #13	do	do	37°28′46″	81°45′25″	405?	1,179	UD	G, SF	WNDE	--
228	Phillips Petroleum Co., Wilson #1	Mercer	do	37°21′07″	81°11′19″	794	2,763	UO	G, L, SF	WNDE	--

TABLE 1.—*Record of key wells*—Continued

Well number	Potential Reservoir Unit B		Potential Reservoir Unit C		Potential Reservoir Unit D		Potential Reservoir Unit E		Potential Reservoir Unit F		Remarks
	Depth to top (m)	Thickness (m)	Depth to top (m)	Thickness (m)	Depth to top (m)	Thickness (m)	Depth to top (m)	Thickness (m)	Depth to top (m)	Thickness (m)	
191	213	447+	NPAR	--	-38	24	A	--	UTS	--	
192	45	1,020	NPAR	--	UTS	--	A	--	A	--	QWC
193	-40	1,175	NPAR	--	A	--	NPAR	--	UTS	--	QWC;S
194	-85	1,331	NPAR	--	A	--	A	--	A	--	
195	-149	981	NPAR	--	A	--	A	--	A	--	
196	-226	1,035	NPAR	--	A	--	A	--	UTS	--	QWC
197	-204	1,090	NPAR	--	A	--	A	--	UTS	--	QWC
198	-212	1,091	NPAR	--	A	--	A	--	UTS	--	QWC
199	-223	1,145	NPAR	--	A	--	A	--	UTS	--	QW-DST
200	-181	1,218	NPAR	--	A	--	A	--	UTS	--	QWC; S
201	-174	1,214	NPAR	--	A	--	A	--	A	--	QWC
202	-211	1,156	NPAR	--	A	--	A	--	A	--	
203	-55	1,304	NPAR	--	A	--	A	--	A	--	QWC
204	46	1,415	NPAR	--	A	--	A	--	UTS	--	QW-DST; S
205	100	393+	NPAR	--	-122	3	A	--	UTS	--	
206	158	361+	NPAR	--	-124	12	A	--	UTS	--	QWC
207	230	1,314	NPAR	--	-83	42	A	--	UTS	--	
208	305	378+	NPAR	--	19	15	A	--	UTS	--	QWC
209	401	452+	NPAR	--	67	52	UTSOA	--	UTS	--	
210	300	1,123	NPAR	--	A	--	--	--	-142	53	QWC
211	753	1,104	NPAR	--	380	56	290	8	105	89	S
212	780	1,054	NPAR	--	353	75	237	17	UTS	--	QWC
213	WNDE	--	NPAR	--	529	105	342	39	124	140	QWC
214	WNDE	--	NPAR	--	WNDE	--	495	15	UTS	--	
215	WNDE	--	NPAR	--	664	87	522	18	277	158	
216	WNDE	--	NPAR	--	WNDE	--	584	22	315	173	
217	WNDE	--	NPAR	--	897	133	611	32	265	212	QWC
218	WNDE	--	NPAR	--	557	157	315	50	UTS	--	
219	1,094	1,040	NPAR	--	581	162	341	25	192	40	S
220	1,390	1,058	1,120	25	874	148	532	32	217	157	S
221	WNDE	--	WNDE	--	1,224	32+	759	27	312	203	
222	1,739	647+	1,462	34	1,227	140	752	25	334	230	S
223	WNDE	--	WNDE	--	WNDE	--	843	27	500	167	
224	WNDE	--	1,654	58+	1,441	137	--	--	577	181	S
225	WNDE	--	WNDE	--	WNDE	--	971	85?	596	268	
226	WNDE	--	WNDE	--	1,309	62+	746	104	315	241	QWC
227	WNDE	--	WNDE	--	WNDE	--	739	20	340	210	QWC
228	WNDE	--	1,897	68	1,561	239	385	2	-167	340	

TABLE 1.—*Record of key wells*—Continued

Well number	Well name	County	State	Coordinate location: Lat.	Coordinate location: Long.	Elev of GL (m)	Total depth (m)	Rock system at total depth	Data source	Potential Reservoir Unit A: Depth to top (m)	Potential Reservoir Unit A: Thickness (m)
229	United Fuel Gas Co., New River & Pocahontas Coal Co. #27	McDowell	W.Va.	37°13′30″	81°41′11″	658	1,470	UD	G, L, SF	WNDE	--
230	United Fuel Gas Co., New River & Pocahontas Consol. Coal Co. #34	Tazewell	Va.	37°11′25″	81°44′40″	879	1,739	UD	G, SF	do	--
231	Gulf Oil Corp., W.R. Price #1	Russell	do	36°52′30″	82°14′14″	672	5,182	Pre€	G, L, SF	3,893	64
232	Tidewater-Wolfs Head, E.D. Smith #1	Scott	do	36°38′56	82°19′02	444	2,201	UO	G, L, SF	WNDE	--
233	Columbia Gas Trans. Corp., Pennsylvania-Virginia Corp.	Wise	do	36°53′44″	82°34′00″	1,052	2,547	MO	G, L, SF	WNDE	--
234	Ray Resources Corp., Georgia Pacific Corp. #154	Harlan	Ky.	36°59′41″	83°09′53″	517	1,475	MS	G	WNDE	--
235	Ray Resources Corp., Georgia Pacific Corp. #153	do	do	36°58′18″	83°11′26″	500	1,621	M–UO	G	WNDE	--
236	Shell Oil Company, L.S. Bales No. 1	Lee	Va.	36°37′03″	83°21′15″	421	2,444	U€	G, L, SF	WNDE	--
237	Columbian Carbon Well #1410 Kentenia Corp. #1	Harlan	Ky.	36°46′30″	83°24′58″	564	1,471	MS	G, L, SF	WNDE	--
238	United Fuel Gas Co., James Knuckles #2	Bell	do	36°44′56″	83°39′44″	451	3,058	L€	G, L, SF	2,540	64+
239	Petroleum Exploration Co., No. 2 Abe Carnes	Knox	do	36°49′27″	83°47′44″	320	1,988	U€	G, SF	WNDE	--
240	Weaver Oil & Gas Corp., et al., Jack Stewart et al. #1	Whitley	do	36°41′11″	83°54′34″	344	923	LS	G, SF	WNDE	--
241	Freida Roach-American Petrol. Co., Josephine Vermillion #1	do	do	36°35′31″	84°09′41″	330	734	S	G	WNDE	--
242	Graham-Michaelia Drilling Co., Oscar White #1	do	do	36°47′47″	84°12′20″	330	405	UM	G, SF	WNDE	--
243	Howard Sober, Inc., Cumberland Minerals Co., Inc., #3 O&G	Laurel	do	36°58′33″	84°18′03″	354	2,238	M–L€	G, L, SF	WNDE	--
244	Sam Day & Co., Stearns No. 1	McCreary	do	36°40′17″	84°31′17″	387	1,100	LO	G, SF	WNDE	--
245	Jerome Goldberg, Lewis Turpin #1	Wayne	do	36°46′16″	84°40′34″	282	1,129	U€	G, SF	WNDE	--
246	El Pameo, C.C. Sherrill #1	Clay	Tenn.	36°36′00″	85°25′01″	314	612	LO	G	WNDE	--
247	Perry Fulk, No. 1A Della Bronstetter	do	do	36°29′39″	85°30′29″	169	358	LO	L	WNDE	--
248	Midwestern Petroleum Corp., No. 5 Wesley Flatt	do	do	36°28′50″	85°29′34″	176	399	LO	L	WNDE	--
249	Bradfield and Bartle, Grady Pigg No. 1	Jackson	do	36°18′25″	85°32′10″	299	581	LO	G, L, SF	WNDE	--
250	C.A. Perry & Sons, Inc., Verble #1	Putnam	do	36°12′15″	85°25′55″	392	305	MO	G	WNDE	--
251	Stanolind Oil & Gas Co., No. 1 Hyder	do	do	36°09′30″	85°25′30″	326	649	LO	L	WNDE	--
252	Marine Carrier Inc., (Bob Stuard) Dr. J.R. Billings No. 1	Overton	do	36°23′50″	85°15′50″	327	597	LO	G	WNDE	--
253	Petroten, Inc., No. 1, O. Allred	do	do	36°19′32″	85°12′05″	272	570	LO	L	WNDE	--
254	Ratliff Farms, Koppers & Abston Units #1	do	do	36°18′30″	85°08′13″	575	869	LO	G	WNDE	--
255	Jervian Corp., No. 1 Brier Hill	do	do	36°16′35″	85°07′05″	558	920	LO	L	WNDE	--
256	C.G. Collins & Western Reserves Oil Co., Plateau Properties "A"	Putnam	do	36°06′30″	85°09′40″	588	1,104	LO	G	WNDE	--
257	Perry Fulk Oil Co., No. 1 Walker Trustees	Fentress	do	36°09′14″	85°04′59″	568	1,017	LO	L	WNDE	--
258	Monitor Petroleum Corp., Gernt Estate #8	do	do	36°20′05″	84°59′50″	531	2,380	Pre€	G, L	1,778	55
259	Associated Oil & Gas Exploration Co., Sells #1	Pickett	do	36°34′15″	85°02′31″	270	1,773	Pre€	G, L	1,199	29
260	Lee Ratner, Davis #1	Fentress	do	36°32′25″	84°59′45″	274	570	LO	G	WNDE	--
261	Petroleum Development Corp., Koppers West #1	do	do	36°31′25″	84°50′15″	507	1,055	LO	G, SF	WNDE	--
262	Red Feather Gas & Oil Co., No. B-1 Carson Hull	do	do	36°20′50″	84°45′40″	432	488	UO	L	WNDE	--
263	Riley Oil Co., Louise Lanham #1	Morgan	do	36°17′10″	84°45′10″	450	2,445	M–L€	G, L	WNDE	--
264	Ben E. Tate, Trustee, Baker-Pemberton #1	do	do	36°18′05″	84°39′12″	471	1,682	U€	G, L	WNDE	--
265	Martin Shurin, Jr. L.J. West #1	Scott	do	32°27′23″	84°25′48″	485	1,857	U€	G, L	WNDE	--
266	Howard Atha, Ketchen Coal Company, No. 1	do	do	36°33′57″	84°22′26″	356	2,303	M–L€	G, L	WNDE	--

TABLE 1.—*Record of key wells*—Continued

Well number	Potential Reservoir Unit B: Depth to top (m)	Potential Reservoir Unit B: Thickness (m)	Potential Reservoir Unit C: Depth to top (m)	Potential Reservoir Unit C: Thickness (m)	Potential Reservoir Unit D: Depth to top (m)	Potential Reservoir Unit D: Thickness (m)	Potential Reservoir Unit E: Depth to top (m)	Potential Reservoir Unit E: Thickness (m)	Potential Reservoir Unit F: Depth to top (m)	Potential Reservoir Unit F: Thickness (m)	Remarks
229	WNDE	--	WNDE	--	WNDE	--	789	8	355	242	
230	WNDE	--	WNDE	--	WNDE	--	821	12	421	215	
231	153; 2,256 FR	570; 1,214 FR	1,979	34	1,759	116	--	--	--	--	S
232	WNDE	--	1,657	85	1,593	15	1,017	3	UTS	--	
233	803	688^{+}	468	93	262	125	UTS	--	UTS	--	
234	WNDE	--	NPAR	--	842	51	712	5	370	238	
235	WNDE	--	NPAR	--	840	48	--	--	366	244	
236	–173	2,193^{+}	A	--	A	--	A	--	A	--	Younger units faulted out
237	WNDE	--	NPAR	--	848	28	768	7	365	219	
238	881	1,316	NPAR	--	547	18	272	5	99	132	
239	580	1,086^{+}	NPAR	--	298	18	A	--	26	141	S
240	WNDE	--	NPAR	--	A	--	A	--	216	142	QWC
241	WNDE	--	NPAR	--	PD	--	A	--	UTS	--	
242	WNDE	--	NPAR	--	PD	--	A	--	–76	151^{+}	
243	271	1,460	NPAR	--	A	--	A	--	UTS	--	
244	242	469^{+}	NPAR	--	A	--	A	--	UTS	--	
245	196	650^{+}	NPAR	--	ND	--	ND	--	ND	--	No logs for upper units
246	–17	315^{+}	NPAR	--	A	--	A	--	A	--	S
247	–69	258^{+}	NPAR	--	A	--	A	--	A	--	
248	–73	297^{+}	NPAR	--	A	--	A	--	A	--	
249	–137	435^{+}	NPAR	--	A	--	A	--	UTS	--	Bottom of Unit F exposed at land surface; S
250	–131	44^{+}	NPAR	--	A	--	A	--	UTS	--	
251	–65	389^{+}	NPAR	--	A	--	A	--	UTS	--	
252	–10	281^{+}	NPAR	--	A	--	A	--	UTS	--	S
253	7	292^{+}	NPAR	--	A	--	A	--	UTS	--	
254	34	259^{+}	NPAR	--	A	--	A	--	UTS	--	
255	41	322^{+}	NPAR	--	A	--	A	--	UTS	--	
256	–14	528^{+}	NPAR	--	A	--	A	--	UTS	--	
257	86	364^{+}	NPAR	--	A	--	A	--	–385	254	
258	28	1,366	NPAR	--	A	--	A	--	UTS	--	QWC; S
259	–69	1,235	NPAR	--	A	--	A	--	UTS	--	S
260	–35	331^{+}	NPAR	--	A	--	A	--	UTS	--	
261	87	461^{+}	NPAR	--	A	--	A	--	UTS	--	
262	WNDE	--	NPAR	--	A	--	A	--	–208	209	
263	187	1,389	NPAR	--	A	--	A	--	UTS	--	QWC; S
264	270	941^{+}	NPAR	--	A	--	A	--	UTS	--	
265	427	946^{+}	NPAR	--	A	--	A	--	2	189	
266	415	1,310	NPAR	--	A	--	A	--	–12	174	QWC; S

TABLE 1.—*Record of key wells*—Continued

				Coordinate location						Potential Reservoir Unit A	
Well number	Well name	County	State	Lat.	Long.	Elev of GL (m)	Total depth (m)	Rock system at total depth	Data source	Depth to top (m)	Thickness (m)
267	Dr. Paul Fletcher, American Assoc. Mining Co. #1	Claiborne	Tenn.	36°30′10″	83°55′15″	442	1,068	MS	G, L, SF	WNDE	–
268	Moore and Weaver, Meredith #1	Campbell	do	36°25′38″	84°15′48″	426	1,166	MO	G, SF	WNDE	–
269	Columbian Carbon, No. 1 East Tenn. Iron & Coal	do	do	36°19′13″	84°18′34″	435	1,162	MO	L	WNDE	–
270	Petroleum Development Corp., Koppers #7	do	do	36°18′25	84°17′45	472	2,026	LO	G, SF	WNDE	–
271	Atlantic Richfield, Sanford Heirs, No. 1	Anderson	do	36°10′10″	84°10′05″	272	3,517	Pre€	G, L, SF	3,037	177
272	National Energy Corp., Browning & Welch, Briceville #1	do	do	36°09′11″	84°12′11″	347	1,060	MO	G, L, SF	WNDE	–
273	Columbian Carbon, #1 Tenn. Mining & Manufacturing	do	do	36°09′17″	84°22′40″	424	987	UO	L	WNDE	–
274	Geo, Inc. Windrock #3–#1	do	do	36°05′07″	84°19′50″	308	899	LM	G	WNDE	–
275	National Energy Corp., Coal Creek Mining & Manufac. Co. #1	do	do	36°04′30″	84°20′09″	306	889	UM	G, SF	WNDE	–
276	Ladd Petroleum Corp., T.J. Kemmer #1	Cumberland	do	35°56′30″	84°49′15″	715	3,091	Pre€	G, SF	2,254	106
277	Shell Oil Co. Guy Peterson #1	do	do	35°55′00″	84°51′18″	798	1,647	LO	G, L	WNDE	–
278	Kingwood, No. 1 Harrison	do	do	35°52′55″	85°06′25″	591?	1,130	LO	L	WNDE	–
279	Mt. Carmel Drilling Co., E.C. Wall #1	White	do	35°54′39″	85°16′18″	485	493	U–MO	G, SF	WNDE	–
280	Triangle Oil, Lem Spiva No. 1	do	do	35°53′26″	85°23′18″	339	688	LO	G, L, SF	WNDE	–
281	Amoco Production Co., R.S. Driver #1	DeKalb	do	36°00′15″	85°54′11″	234	1,931	Pre€	G, L	1,377	46
282	Continental Tennessee, Inc., Walker-Flynt-Arnold Unit #1	Warren	do	35°40′24″	85°43′30″	286	2,001	Pre€	G, SF	NPAR?	–
283	Godfrey L. Cabot, Inc., No. 1 Rocky River	VanBuren	do	35°34′15″	85°29′35″	548	1,544	U€	L	WNDE	–
284	Magnolia Petroleum Co., W.H. Patterson #1	Grundy	do	35°22′30″	85°39′30″	577	1,345	U€	G, L	WNDE	–
285	Weaver Oil & Gas Corp., Pope Estate #1	Sequatchie	do	35°26′09″	85°20′20″	233	2,258	M–L€	G, L	WNDE	–

TABLE 1.—*Record of key wells*—Continued

Well number	Potential Reservoir Unit B Depth to top (m)	Potential Reservoir Unit B Thickness (m)	Potential Reservoir Unit C Depth to top (m)	Potential Reservoir Unit C Thickness (m)	Potential Reservoir Unit D Depth to top (m)	Potential Reservoir Unit D Thickness (m)	Potential Reservoir Unit E Depth to top (m)	Potential Reservoir Unit E Thickness (m)	Potential Reservoir Unit F Depth to top (m)	Potential Reservoir Unit F Thickness (m)	Remarks
267	WNDE	--	NPAR	--	A	--	A	--	127	375	
268	597	140+	NPAR	--	A	--	A	--	--	--	
269	724?	?	NPAR	--	A	--	A	--	177	184	
270	636	914+	NPAR	--	A	--	A	--	216	189	
271	-272; 635; 1,002 FR	848+; 249 1,438 FR	NPAR	--	A	--	A	--	A	--	Younger units faulted out; S
272	--	--	NPAR	--	A	--	A	--	373	216	
273	WNDE	--	NPAR	--	A	--	A	--	365	150	S
274	WNDE	--	NPAR	--	A	--	A	--	359	152	
275	WNDE	--	NPAR	--	A	--	A	--	367	122+	
276	-35	1,749	NPAR	--	A	--	A	--	UTS	--	
277	-210	1,058+	NPAR	--	A	--	A	--	UTS	--	QWC
278	153	386+	NPAR	--	A	--	A	--	UTS	--	S
279	WNDE	--	NPAR	--	A	--	A	--	UTS	--	
280	WNDE	--	NPAR	--	A	--	A	--	UTS	--	Bottom of Unit F is at land surface
281	-240	1,564	NPAR	--	A	--	A	--	A	--	S
282	-209	1,414	NPAR	--	A	--	A	--	UTS	--	Bottom of Unit F is at land surface
283	-8	1,004+	NPAR	--	A	--	A	--	UTS	--	S
284	-34	798+	NPAR	--	A	--	A	--	UTS	--	QWC; S
285	149	1,425	NPAR	--	A	--	A	--	A	--	

TABLE 2.—*Approximate sodium chloride concentration of ground water from various depths in selected key wells*

[C, data calculated from geophysical logs; D, data from drill stem test; minus sign in depth column indicates altitude in meters above sea level]

Well Number	Depth below sea level, in meters	Concentration of total dissolved solids as NaCl, in milligrams per liter
	Kentucky	
133	-108	26,000–C
133	823	160,000–C
135	603	42,500–C
135	151	75,000–C
137	666	14,000–C
138	-95	21,000–C
139	-37	55,000–C
139	417	65,000–C
140	690	57,000–C
141	-97	22,000–C
142	740	56,000–C
143	108	41,000–C
144	397	113,000–C
145	1,211	250,000–C
146	1,303	330,000–D
147	331	67,500–C
149	284	175,000–C
178	689	203,000–C
179	150	70,000–C
181	245	127,000–C
184	70	35,000–C
188	370	78,000–C
188	498	88,000–C
189	621	117,000–C
193	336	11,000–C
196	1,036	200,000–C
197	109	do.
198	1,205	181,000–C
199	1,213	158,000–D
200	51	25,000–C
201	1,389	108,000–C
203	194	22,000–C
203	1,048	32,600–C
203	1,109	42,500–C
204	360	48,000–C
204	1,182	119,000–D
206	-258	5,000–C
206	-70	140,000–C
208	592	40,700–C
210	638	111,000–C
212	1,159	55,000–C
212	1,353	152,000–C
213	127	14,400–C
213	173	56,200–C
217	-16	12,400–C
217	106	16,500–C
240	80	106,000–C

TABLE 2.—*Approximate sodium chloride concentration of ground water from various depths in selected key wells*—Continued

Well Number	Depth below sea level, in meters	Concentration of total dissolved solids as NaCl, in milligrams per liter
	Ohio	
2	178	26,000–C
2	469	45,000–C
5	431	88,000–C
9	1,876	199,000–C
10	658	40,000–C
12	-75	55,000–C
12	146	76,000–C
17	-16	38,000–C
23	90	5,200–C
26	3	28,000–C
28	50	54,000–C
29	1,471	55,000–C
30	3	30,000–C
30	1,113	260,000–C
33	760	23,000–C
68	305	39,000–C
69	145	65,000–C
69	3,160	95,000–C
71	673	115,000–C
71	1,738	205,000–C
79	493	66,000–C
80	23	23,000–C
80	1,669	74,000–C
128	1,050	34,000–C
129	26	43,000–C
131	178	105,000–C
131	1,224	129,000–C
132	1,522	142,000–C
	Pennsylvania	
19	17	40,000–C
46	-18	30,000–C
	Tennessee	
258	-25	25,000–C
258	397	45,000–C
258	462	75,000–C
263	-118	40,000–C
265	-333	17,000–C
271	-525	22,500–C
284	-170	180,000–C
	West Virginia	
20	-39	16,000–C
54	362	8,000–C
56	343	19,000–C
58	303	44,000–C
59	379	7,000–C
64	242	75,000–C
66	1,006	190,000–C
87	1,272	37,000–C

TABLE 2.—*Approximate sodium chloride concentration of ground water from various depths in selected key wells*—Continued

Well Number	Depth below sea level, in meters	Concentration of total dissolved solids as NaCl, in milligrams per liter
	West Virginia—Continued	
88	211	11,000–C
92	3	5,000–C
92	227	22,000–C
95	362	23,000–C
95	417	13,500–C
100	40	85,000–C
104	320	4,500–C
107	1,833	80,000–C
111	222	76,000–C
116	1,404	37,000–C
117	1,405	107,000–C
119	156	84,000–C
119	336	91,000–C
121	119	38,000–C
121	159	100,000–C
125	451	9,200–C
126	163	20,000–C
150	374	140,000–C
151	190	30,000–C
158	-169	23,000–C
159	-156	16,000–C
160	13	18,000–C
167	310	38,000–C
170	-132	24,000–C
170	89	75,000–C
171	21	6,500–C
171	335	13,000–C
172	116	18,000–C
172	343	20,000–C
226	320	13,000–C
227	354	5,500–C
227	750	38,000–C
228	613	77,000–C

TABLE 3.—*Some characteristics of potential reservoir intervals, individual porous zones and rock with confining potential in selected key zones*

Top of Interval: Defined as potential reservoir interval mainly where top of unit and interval occurs between about 300 and 2,500 m below sea level.

Rock Type: SS, sandstone; SLT, siltstone; SH, shale; DOL, dolomite; LS, limestone; ANHYD, anhydrite; B, basement; where preceded by "+" basement lies below the specified thickness of rock type(s) listed immediately before the plus sign; SALT, halite salt; CHRT, chert.

Column Letter Headings:
N, number of items in sample.
M, median value.
R, range of values.

Geophysical Logs Used for Porosity Calculations

Log type abbreviations:
BD, bulk density; N, neutron; R, resistivity; S, borehole sonic; x, cross plot; +, no overlap of logs and no cross plot possible.

Miscellaneous:
TD, total well depth; --, no data available.

Well number	Top of interval, in meters below sea level	Thickness of interval, in meters	Dominant rock type for interval	Data for individual zones with estimated rock porosity equal to or greater than 5 percent within the indicated interval.								Data for rock with confining potential that lies immediately above and below the indicated interval.				Geophysical logs used for porosity calculations
				Thickness of individual zones, in meters			Aggregate thickness of individual zones, in meters	Porosity of individual zones, in percent			Average thickness-weighted porosity of individual zones, in percent	Above		Below		
				N	M	R		N	M	R		Thickness in meters	Rock type	Thickness in meters	Rock type	
POTENTIAL RESERVOIR UNIT F																
Kentucky																
234	370	96	SS	16	1.5	0.6–5	31	16	5	5–7	5	88	SH, SLT	44	SLT, LS	BD
Tennessee																
272	466	115	LS	9	0.9	0.6–5	13	9	5	5–6	6	31	LS	30	LS, SH	BD
275	431	59	LS	6	1.8	0.6–3	10	6	6	5–11	7	187	LS, SH	1 to TD	--	BD
Virginia																
221	313	42	SS	3	4	2.4–8	14	3	5	5–6	5	116	SLT, SH	66	LS, SLT	BD
222	388	17	SS	1	–	--	17	1	--	--	5	94	SH, SS	64	SLT, SS	BD
222	468	79	LS	5	2	0.6–5	11	5	9	5–9	8	64	SLT, SS	223	SH, SLT	BD
230	481	60	LS	6	1.2	0.6–2.1	8	6	10	6–15	10	51	LS	287	LS, SH	BD
West Virginia																
226	315	12	LS	1	--	–	12	1	--	--	5	53	SH, SLT	159	SH, LS	BD
227	348	9	LS	1	--	--	9	1	--	--	5	62	SH, SS	133	LS,SH	BD
POTENTIAL RESERVOIR UNIT E																
Kentucky																
147	312	27	SS	7	1.8	0.6–3	12	7	9	6–10	9	122+	SH, SLT	217	SH, SLT	BD
West Virginia																
90	263	69	SS	5	2.4	1.5–4	13	5	10	9–15	11	148	SH	213	SH	BD
92	227	126	SS, SLT	11	1.5	0.3–5	23	11	7	5–15	9	119	SH, SLT	276	SH	BD
POTENTIAL RESERVOIR UNIT D																
Kentucky																
144	378	126	DOL	13	0.9	0.6–2.4	15	13	6	5–10	7	202	SH	426	SH, LS	N ×BD
211	383	49	DOL	9	1.5	0.9–2.7	15	9	7	5–20	10	145	SH, SLT	444	SH, LS	R
212	355	64	DOL	5	0.9	0.6–6	10	5	6	5–9	6	351	SH, SLT, LS	640	SH, LS	N+R
Ohio																
7	315	70	LS	7	5	0.6–8	30	7	9	5–12	9	435	SH	127	DOL, ANHYD SALT	N
7	609	31	DOL	6	3	0.6–13	21	6	7	6–10	9	91	DOL, SH, ANHYD	537	SH	N
10	999	82	DOL	20	1.2	0.6–7	40	20	6	5–13	7	337	DOL, ANHYD	73	SH,DOL	N+BD
11	776	82	LS	9	0.6	0.3–2.4	8	9	6	5–10	7	884	SH, SLT	85	LS	N×BD
22	1,047	79	LS	9	2.1	0.6–7	31	9	6	5–9	7	128	SH	411	ANHYD, DOL, SALT	N+BD
22	1,536	53	DOL	6	4	0.9–14	30	6	6	5–11	7	489	ANHYD, DOL, SALT	88	SH, DOL	N+BD
23	1,311	81	DOL	6	1.2	0.6–3	10	6	7	5–13	8	45	DOL ANHYD	81	DOL, SALT	N×BD
23	1,587	25	DOL	6	0.6	0.6–3	8	6	6	5–7	6	112	DOL	78	SH	N×BD
26	447	31	DOL	10	0.6	0.6–4	13	10	6	5–13	7	443	SH	63	ANHYD, DOL, SH	N×BD
31	586	66	LS	10	0.6	0.3–1.8	9	10	5	5–8	6	502	SH, SLT	221	DOL	BD
33	745	43	LS	3	3	1.8–4	9	3	7	5–7	6	46	LS	151	ANHYD, DOL	N
74	479	77	LS	7	2.4	0.6–4	14	7	9	6–11	8	438	SH	46	DOL	BD
74	617	111	DOL	10	0.9	0.6–3	13	10	7	5–23	8	46	DOL	79	DOL, SH	BD

TABLE 3.—*Some characteristics of potential reservoir intervals, individual porous zones and rock with confining potential in selected key zones*—Continued

Well number	Top of interval, in meters below sea level	Thickness of interval, in meters	Dominant rock type for interval	Data for individual zones with estimated rock porosity equal to or greater than 5 percent within the indicated interval. Thickness of individual zones, in meters			Aggregate thickness of individual zones, in meters	Porosity of individual zones, in percent			Average thickness-weighted porosity of individual zones, in percent	Data for rock with confining potential that lies immediately above and below the indicated interval. Above		Below		Geophysical logs used for porosity calculations
				N	M	R		N	M	R		Thickness in meters	Rock type	Thickness in meters	Rock type	
POTENTIAL RESERVOIR UNIT D—Continued																
Ohio—Continued																
79	323	76	DOL	5	1.2	0.9–2.4	8	5	8	5–14	8	269	SH	60	LS	N×BD
80	521	57	DOL	8	1.5	0.6–4	13	8	8	6–9	8	77	ANHYD, DOL, SH	509	SH	N×BD
82	1,321	105	DOL	8	4	1.2–20	35	8	8	6–10	9	31	DOL	149$^+$	SH, SLT	N
Pennsylvania																
40	1,927	28	LS	5	2.4	1.8–10	20	5	9	7–10	8	34	SH	41	LS	BD
44	2,327	10	DOL	2	4	1.8–6	8	2	6	5–6	5	687	SALT, DOL	383	SH, DOL	BD
45	2,131	27	DOL	3	4	0.6–4	9	3	6	6–8	7	40$^+$	DOL,SH	358	DOL,SH SALT	BD
46	2,014	19	DOL	4	1.8	1.8–2.1	8	4	5	5–5	5	67	LS	80	LS, DOL	BD
46	2,152	29	DOL	5	0.9	0.6–5	8	5	6	5–8	6	37	DOL	55	DOL	BD
West Virginia																
20	1,105	55	LS	4	4	1.5–8	16	4	6	5–7	6	801	SH	42	LS	N×BD
20	1,201	42	LS	5	1.5	1.5–5	12	5	5	5–6	6	42	LS	355	DOL, SH, SALT, ANHYD	N×BD
39	2,283	30	DOL	9	0.6	0.6–3	9	9	6	5–9	7	80	DOL, SALT	119	DOL, SALT	S
52	2,072	160	DOL	11	1.8	0.6–4	20	11	10	6–20	11	256	DOL, LS	80	DOL, SH	N+BD
53	1,668	48	CHRT	5	5	0.6–22	36	5	8	7–10	8	1,551	SH, SLT	260	LS, SH	N×BD
57	1,673	80	SS	12	0.6	0.3–1.8	9	12	6	5–9	7	1,358	SH, SLT	30 to TD	–	BD
66	941	139	LS, SS	33	1.2	0.3–18	78	33	6	5–15	8	1,148	SH	41	SH, LS	N
66	1,220	151	LS, SS	18	1.8	0.6–9	55	18	6	5–8	6	41	SH, LS	40	SH, LS	N
66	1,411	73	LS, SS	12	1.8	0.3–7	22	12	5	5–6	6	40	SH, LS	89	LS	N
66	1,572	173	DOL	14	1.2	0.6–2.1	18	14	8	5–12	8	89	LS	69	DOL, SH	N
66	1,815	53	DOL	3	2.1	2.1–15	19	3	7	7–8	8	69	DOL, SH	1,036	SH, LS	N
86	1,314	158	LS, SS	12	0.9	0.3–5	14	12	8	5–17	11	800	SH	73	DOL, LS	BD
88	1,677	72	SS	7	0.9	0.9–6	12	7	5	5–7	6	490	SH	61	LS	BD
88	1,889	62	DOL	9	0.6	0.6–1.2	8	9	7	5–16	8	40	DOL, LS	104	DOL, SALT, LS, ANHYD	BD
90	1,708	79	SS	10	0.9	0.3–4	12	10	5	5–8	6	1,162	SH, DOL, SALT	–	–	BD
92	1,748	29	SS, LS	6	0.9	0.3–3	9	6	6	5–9	7	956	SH, SLT	87 to TD	SS, LS	BD
96	1,679	22	SS	4	2.4	0.6–5	10	4	6	5–7	6	395	SH	47	SS	N×BD
105	1,357	86	SS	13	0.9	0.6–3	13	13	5	5–7	6	1,248	SH	62	LS	BD
105	1,662	110	DOL	20	0.6	0.6–1.5	13	20	5	5–12	7	157	DOL, LS	88	DOL	BD
111	1,562	51$^+$	LS, SS	6	1.2	0.9–5	11	6	6	5–8	7	1,328	SH, SLT	0.6 to TD	–	BD
118	1,495	78	DOL	7	5	1.2–6	29	7	7	5–12	7	15$^+$	–	148	SH	BD
119	1,306	44	SS, CHRT	5	5	1.5–9	24	5	6	5–7	6	983	SH, SLT	72	LS	N×BD
119	1,422	50	LS	6	1.5	0.9–5	12	6	12	7–19	12	72	LS	76	DOL	N×BD
159	1,526	35	LS	7	0.6	0.6–1.8	8	7	5	5–7	5	52	LS	64	LS	N×BD
161	1,468	132$^+$	SS, LS, DOL	17	0.9	0.6–6	21	17	12	5–20	11	1,276	SH, SLT	9 to TD	–	R
167	1,707	124	DOL	17	0.9	0.3–5	19	17	7	5–15	9	50	DOL, ANHYD	91	SH, SS	BD
171	1,366	100	LS, DOL	11	3	0.9–14	51	11	7	5–12	7	819	SH, SLT	40	DOL	BD
POTENTIAL RESERVOIR UNIT C																
Ohio																
9	1,070	18	SS	3	5	1.8–5	12	3	10	8–12	10	96	DOL, SH	556	SH	N×BD
10	1,151	30	SS	4	5	3–9	21	4	9	7–9	8	73	SH, DOL	789	SH, LS	N+BD
23	1,690	35	SS	7	0.9	0.6–3	10	7	5	5–7	6	78	SH	586	SH, LS	N×BD
74	807	8	SS	1	–	–	8	1	–	–	11	79	DOL, SH	24$^+$	–	BD

TABLE 3.—*Some characteristics of potential reservoir intervals, individual porous zones and rock with confining potential in selected key zones*—Continued

Well number	Top of interval, in meters below sea level	Thick-ness of interval, in meters	Dominant rock type for interval	Data for individual zones with estimated rock porosity equal to or greater than 5 percent within the indicated interval.								Data for rock with confining potential that lies immediately above and below the indicated interval.				Geophy-sical logs used for porosity calcula-tions
				Thickness of individual zones, in meters			Aggregate thick-ness of individual zones, in meters	Porosity of individual zones, in percent			Average thickness-weighted porosity of indivi-dual zones, in percent	Above		Below		
				N	M	R		N	M	R		Thick-ness in meters	Rock type	Thick-ness in meters	Rock type	
POTENTIAL RESERVOIR UNIT C—Continued																
Virginia																
222	1,473	20	SS	4	2.4	2.1–6	13	4	5	5–6	5	107	SH	308	SH, LS	BD
West Virginia																
118	1,721	18	SS	2	8	1.5–15	16	2	6	5–7	7	148	SH	9 to TD	–	BD+S
158	1,813	15	SS	2	4	1.2–7	8	2	6	5–6	6	141	SH	695	SH, LS	BD+S
POTENTIAL RESERVOIR UNIT B																
Kentucky																
133	709	204	DOL	33	0.9	0.3–5	38	33	8	5–18	8	39	LS	35	DOL	N×BD
133	949	98	DOL	24	0.9	0.3–2.1	21	24	6	5–18	7	35	DOL	86	SH, LS	N×BD
134	664	315	DOL	54	0.6	0.3–7	56	54	6	5–20	9	576	LS, SH	115	DOL, SH	BD
139	748	148	DOL	14	1.2	0.6–6	20	14	6	5–11	7	329	LS, SH	37	DOL	N+R
139	936	139	DOL	14	0.6	0.6–1.8	13	14	5	5–8	6	37	DOL	189	DOL, SH	N+R
140	486	257+	DOL	35	0.9	0.3–11	45	35	8	5–16	9	71	LS	–	–	BD
141	600	141	DOL	20	1.8	0.6–5	45	20	7	5–15	7	36	DOL	86	DOL	BD
141	828	114	DOL	9	1.8	0.6–3	17	9	7	5–11	6	86	DOL	185	DOL, SH	BD
142	713	388	DOL	47	0.9	0.3–5	57	47	6	5–11	7	80	LS	156	DOL, SH	N
143	1,316	29	DOL	3	1.2	0.6–6	8	3	5	5–8	7	82	DOL	227	DOL	N×BD
144	1,224	129	DOL	15	1.5	0.6–9	37	15	7	5–13	7	33	LS	110	DOL	N×BD
145	1,167	169	DOL	16	0.9	0.6–3	23	16	6	5–14	7	49	LS	35	DOL	N×BD
145	1,372	70	DOL	8	1.2	0.6–2.1	11	8	6	5–7	6	35	DOL	41	DOL	N×BD
146	1,286	63	SS, DOL	11	0.9	0.3–5	17	11	5	5–7	6	34	LS	34	DOL	N×BD
146	1,504	42	DOL	7	0.9	0.6–2.4	8	7	7	5–8	7	31	DOL	57	DOL	N×BD
147	1,486	37	SS	9	0.9	0.6–11	23	9	6	5–8	6	48	DOL	36	DOL	N×BD
147	1,622	96	DOL	10	0.6	0.3–2.4	10	10	6	5–16	9	31	DOL	89	DOL	N×BD
148	1,375	40	SS	8	1.2	0.3–9	21	8	7	5–8	8	38	LS	33	DOL	N×BD
148	1,447	203	DOL, SS	28	0.6	0.3–4	32	28	7	5–15	8	33	DOL	45	DOL	N×BD
148	1,695	62	DOL	7	0.6	0.6–3	8	7	5	5–7	6	45	DOL	138	DOL, SH	N×BD
149	1,403	271	DOL, SS	48	0.6	0.3–5	48	48	8	5–24	9	47	LS	61	DOL	N×BD
178	1,717	40	DOL, SS	3	3	2.4–4	9	3	7	6–10	8	110	LS	305	DOL	BD×S
184	1,175	17	SS	5	0.9	0.3–3	8	5	5	5–9	7	171	LS, DOL	34	SS, DOL	BD×S
210	490	67	LS	7	3	1.5–7	18	7	7	6–10	7	37	LS	55	LS	N
210	611	152	DOL	18	2.4	0.6–17	78	18	7	5–10	8	55	LS	35	DOL	N
210	779	81	DOL	7	1.5	0.3–14	25	7	6	5–8	6	35	DOL	110	DOL	N
210	1,190	65	DOL	7	1.5	0.9–1.5	9	7	7	5–11	7	72	DOL	70	DOL	N
212	1,605	37	DOL	5	1.8	0.6–11	18	5	6	5–7	6	52	DOL	65	DOL	N
212	1,707	94	DOL	16	1.2	0.6–5	24	16	6	5–9	6	65	DOL	325	SLT, SH LS	N
219	1,166	54	LS	8	0.6	0.6–5	12	8	6	5–24	10	480	SH, LS	84	LS	BD
219	1,679	172	DOL	13	1.2	0.9–7	29	13	7	5–23	10	46	DOL	79	DOL	BD
220	1,938	92	DOL	12	1.2	0.3–5	21	12	8	6–23	14	48	DOL	45	DOL	BD
Ohio																
5	1,069	47+	DOL	9	0.6	0.3–6	14	9	8	5–10	8	52	LS	6 to TD	–	N
7	1,387	12	DOL	2	4	3–5	9	2	9	8–10	8	164	LS	60	LS	N
9	1,872	78	SS, DOL	4	3	0.6–5	12	4	6	5–13	10	193	LS	37	SH, DOL	N×BD
11	2,353	30	SS	5	1.5	1.2–2.4	8	5	6	5–7	6	41	DOL	132	DOL, SH	N×BD
12	757	124	DOL	12	2.4	0.6–22	52	12	7	5–13	10	162	LS	53	SH, DOL	N
13	949	32	DOL	4	1.5	0.9–5	9	4	6	7–9	7	642	SH, LS	52	DOL	N
13	1,033	28	DOL	5	1.5	0.9–2.1	8	5	5	5–8	6	52	DOL	43	DOL, SH	N
17	1,650	82	DOL	7	1.5	1.2–3	13	7	7	6–15	8	66	LS	6 to TD	–	N+BD

TABLE 3.—*Some characteristics of potential reservoir intervals, individual porous zones and rock with confining potential in selected key zones*—Continued

Well number	Top of interval, in meters below sea level	Thickness of interval, in meters	Dominant rock type for interval	Data for individual zones with estimated rock porosity equal to or greater than 5 percent within the indicated interval.								Data for rock with confining potential that lies immediately above and below the indicated interval.				Geophysical logs used for porosity calculations
				Thickness of individual zones, in meters			Aggregate thickness of individual zones, in meters	Porosity of individual zones, in percent			Average thickness-weighted porosity of individual zones, in percent	Above		Below		
				N	M	R		N	M	R		Thickness in meters	Rock type	Thickness in meters	Rock type	
							POTENTIAL RESERVOIR UNIT B—Continued									
							Ohio—Continued									
25	2,043	70	DOL	7	1.8	1.2–2.1	12	7	5	5–9	6	66	LS, SH	22 to TD	--	N×BD
26	1,450	111	DOL	10	0.9	0.6–5	18	10	5	5–9	6	70	LS	58	DOL	N×BD
27	930	107	DOL	9	2.1	0.3–1.3	42	9	8	5–13	9	66	LS, SH	85	DOL, SH	N
28	886	33+	DOL	1	--	--	33	1	--	--	7	182	LS	2.7 to TD	--	N×BD
29	1,158	34	DOL	8	1.8	0.6–2.1	10	8	6	5–6	6	108	do	40	SH, DOL	N
29	1,232	67	DOL	8	1.2	0.9–2.4	11	8	7	5–11	7	40	SH, DOL	54	SH, DOL	N
30	779	156	DOL	13	2.1	0.9–25	55	13	6	5–10	7	36	LS, SH	64	DOL, SH	BD
31	1,671	14	DOL	4	1.8	0.6–3	8	4	8	7–11	8	193	LS	34	DOL	BD
32	1,719	52	DOL	6	0.6	0.6–13	17	6	5	5–8	7	34	DOL	31 to TD	--	BD
33	1,904	81	DOL	8	1.2	0.6–10	21	8	6	5–9	8	49	DOL	64	DOL	N
73	1,551	42	SS	6	0.9	0.6–4	8	6	7	5–12	9	651	SH, LS	14 to TD	--	N×BD
76	770	41	DOL	7	2.4	0.9–5	25	7	8	5–15	9	80	LS	4 to TD	--	N
79	1,186	41	SS, DOL	5	1.2	0.6–9	14	5	12	9–14	12	40	DOL	34	DOL	N×BD
79	1,260	153	DOL	23	3	0.6–33	106	23	7	5–10	7	34	DOL	79	SH, DOL	N×BD
80	1,201	263	DOL	39	1.8	0.6–16	122	39	6	5–13	7	112	LS	77	DOL	N×BD
130	1,381	297	DOL	39	0.9	0.3–4	40	39	6	5–14	8	175	LS	219	DOL, SH	N+BD
131	1,223	162+	SS	20	0.9	0.6–4	21	20	6	5–24	10	664	SH, LS	12 to TD	--	N×BD
132	1,011	201	DOL	30	0.9	0.6–5	36	30	8	5–28	9	625	LS, SH	44	DOL	N×BD
							Tennessee									
266	800	107	DOL	8	0.6	0.6–2.4	9	8	6	5–11	6	89	LS	91	LS	N×BD
266	998	136	DOL	9	0.6	0.3–11	13	9	9	5–35	10	91	LS, DOL	80	LS, DOL	N×BD
266	1,311	101	DOL	11	0.9	0.6–1.5	10	11	7	5–13	8	55	LS, DOL	47	LS, DOL	N×BD
266	1,216	40	SS, DOL	8	1.2	0.6–1.2	8	8	6	5–15	7	81	DOL	76	DOL	N×BD
							West Virginia									
127	1,815	124	DOL	11	0.9	0.6–3	16	11	6	5–8	6	172	LS	52	DOL, SS	N
127	2,142	47	DOL	8	0.9	0.6–4	10	8	7	6–11	8	204	LS	234	DOL	N
							POTENTIAL RESERVOIR UNIT A									
							Kentucky									
133	1,222	11	SS	4	1.8	0.9–2.7	8	4	14	6–17	13	84	DOL	24	SH+B	N×BD
134	1,168	23	SS	2	9	4–15	19	2	16	14–18	17	40	DOL	3	SH+B	BD
139	1,264	9	SS	1	--	--	9	1	--	--	10	189	DOL, SH	8	SH+B	N+R
141	1,126	21	SS	2	5	3–6	9	2	8	7–9	8	185	DOL, SH	0	B	BD
142	1,257	27	SS	5	0.9	0.6–6	9	5	6	5–8	6	156	DOL, SH	2.1	SH+B	N
144	2,145	43	SS	2	7	2.8–11	13	2	12	10–14	13	160	DOL, SH	202	SS, DOL	N×BD
188	1,180	90	SS, LS	7	4	0.9–7	24	7	11	7–13	11	223	SH, LS	37	SH	N×BD
189	1,475	113	SS	13	1.2	0.6–9	28	13	7	5–12	7	347	SH, LS	49	SLT, SS	BD
195	1,185	17	SS	3	4	2.7–4	11	3	10	8–10	9	460	SH, LS	52	SH, SLT	BD×S
195	1,254	366	SS	45	1.2	0.6–2.7	64	45	6	5–14	7	52	SH, SLT	30	SH+B	BD×S
196	1,026	12	SS	1	--	--	12	1	--	--	12	303	SH, DOL	47	SS, DOL	N×BD
196	1,084	402	SS, LS	57	2.1	0.6–8	149	57	8	5–14	9	47	SS, DOL	30	SS, SLT	N×BD
199	1,209	8	SS	1	--	--	8	1	--	--	7	273	SLT, SH	23+	SLT, SH	S
201	1,336	91+	SS	12	1.5	0.6–3	20	12	7	5–12	8	361	SLT, SH	20 to TD	SLT, SH	BD
203	1,618	89	SS, DOL	4	2.4	0.6–6	11	4	6	5–8	6	384	SH, LS	15	SLT+B	BD
							Ohio									
1	1,102	35	SS	5	5	2.1–5	20	5	8	7–9	8	774	SH, LS	1.5	SLT	N
7	1,475	64	DOL, LS	4	2.0	0.3–4	8	4	6	6–8	7	12	SH	126	DOL	N
7	1,665	25	SS	7	0.9	0.6–2.4	8	7	6	6–7	6	126	DOL	5	SH+B	N
12	1,037	21	SS	1	--	--	21	1	--	--	11	37	DOL, SH	0	B	N

TABLE 3.—*Some characteristics of potential reservoir intervals, individual porous zones and rock with confining potential in selected key zones*—Continued

Well number	Top of interval, in meters below sea level	Thickness of interval, in meters	Dominant rock type for interval	Data for individual zones with estimated rock porosity equal to or greater than 5 percent within the indicated interval.								Data for rock with confining potential that lies immediately above and below the indicated interval.				Geophysical logs used for porosity calculations
				Thickness of individual zones, in meters			Aggregate thickness of individual zones, in meters	Porosity of individual zones, in percent			Average thickness-weighted porosity of individual zones, in percent	Above		Below		
				N	M	R		N	M	R		Thickness in meters	Rock type	Thickness in meters	Rock type	
							POTENTIAL RESERVOIR UNIT A—Continued									
							Ohio—Continued									
13	1,212	14	SS	4	2.1	0.9–3	8	4	6	6–7	7	81	DOL	0.9	SH+B	N
26	1,783	17	SS	6	1.2	0.9–1.8	8	6	8	5–9	7	158	DOL	16	SH+B	N×BD
27	1,231	27	SS	3	5	2.1–15	22	3	8	7–14	12	56	DOL	0	B	N
29	1,468	32	SS	6	3	1.5–5	18	6	8	6–13	9	105	DOL	0	B	N
30	1,033	97	DOL, SS	12	0.9	0.6–4	17	12	12	5–18	13	33	DOL	4	SLT+B	N×BD
33	2,049	18	DOL	1	--	--	17	1	--	--	6	64	DOL	254	DOL, SS +B	N
79	1,601	19	SS	5	1.5	1.2–2.7	9	5	15	6–16	14	91	DOL	11	SH+B	N×BD
80	1,541	48	DOL	6	1.5	0.6–5	15	6	5	5–8	6	77	DOL	67	DOL	N×BD
80	1,657	16	SS	5	1.2	0.9–3	8	5	10	7–10	9	67	DOL	10	SH+B	N×BD
130	1,897	18	SS	4	1.8	0.9–5	9	4	8	6–8	7	219	DOL, SH	18	SLT+B	N+BD
132	1,517	16	SS, DOL	2	4	0.9–8	9	2	10	7–14	13	175	DOL, SH	2.1	SLT+B	N×BD
							Tennessee									
258	1,802	18	SS	1	--	--	18	1	--	--	7	460	SH, SLT	11	SH+B	N×S
259	1,201	27	DOL, SS	3	5	3–15	23	3	7	6–8	7	78	LS, SH	0	B	N
							POTENTIAL RESERVOIR UNIT A (BASAL SANDS ONLY)									
							Kentucky									
133	1,222	11	SS	4	1.8	0.9–2.7	8	4	14	6–17	13	84	DOL	24	SH+B	N×BD
134	1,168	23	SS	2	9	4–15	19	2	16	14–18	17	40	DOL	3	SH+B	BD
139	1,264	9	SS	1	--	--	9	1	--	--	10	189	DOL, SH	8	SH+B	N+R
141	1,126	21	SS	2	5	3–6	9	2	8	7–9	8	185	DOL, SH	0	B	BD
142	1,257	27	SS	5	0.9	0.6–6	9	5	6	5–8	6	156	DOL, SH	2.1	SH+B	N
144	2,390	371	SS	33	1.2	0.6–4	52	33	11	6–25	12	202	SS, DOL	34 to TD	SS, SH	N×BD
145†	1,880	32	SS	7	1.8	0.6–5	15	7	12	6–15	12	197	DOL, SH	30	SH+B	N×BD
146†	2,077	93	SS	9	0.9	0.6–4	11	9	8	5–10	8	62	SH	40	SS, SLT	N×BD
188†	1,307	156	SS	20	1.8	1.5–8	57	20	11	7–15	11	37	SH	11+	SH	N×BD
189	1,475	113	SS	13	1.2	0.6–9	28	13	7	5–12	7	347	SH, LS	49	SLT, SS	BD
195	1,185	17	SS	3	4	2.7–4	11	3	10	8–10	9	460	SH, LS	52	SH, SLT	BD×S
195	1,254	366	SS	45	1.2	0.6–2.7	64	45	6	5–14	7	52	SH, SLT	30	SH+B	BD×S
199	1,209	8+	SS	1	--	--	8	1	--	--	7	273	SLT, SH	23	SLT,SH	S
							Ohio									
1	1,102	35	SS	5	5	2.1–5	20	5	8	7–9	8	774	SH, LS	1.5+	SLT	N
7	1,665	25	SS	7	0.9	0.6–2.4	8	7	6	6–7	6	126	DOL	5	SH+B	N
12	1,037	21	SS	1	--	--	21	1	--	--	11	37	DOL, SH	0	B	N
13	1,212	14	SS	4	2.1	0.9–3	8	4	6	6–7	7	81	DOL	1	SH+B	N
26	1,783	17	SS	6	1.2	0.9–1.8	8	6	8	5–9	7	158	DOL	16	SH+B	N×BD
27	1,231	27	SS	3	5	2.1–15	22	3	8	7–14	12	56	DOL	0	B	N
29	1,468	32	SS	6	3	1.5–5	18	6	8	6–13	9	105	DOL	0	B	N
79	1,601	19	SS	5	1.5	1.2–2.7	9	5	15	6–16	14	91	DOL	11	SH+B	N×BD
130	1,897	18	SS	4	1.8	0.9–5	9	4	8	6–8	7	219	DOL, SH	18	SLT+B	N+BD
132	1,517	16	SS, DOL	2	4	0.9–8	9	2	10	7–14	13	175	DOL, SH	2.1	SLT+B	N×BD
							Tennessee									
258	1,802	18	SS	1	–	--	18	1	--	–	7	460	SH, SLT	11	SH+B	N×S
259	1,201	27	DOL, SS	3	5	3–15	23	3	7	6–8	7	78	LS, SH	0	B	N

†Basal sands are separated from Unit A primarily by shale and siltstone.

☆U.S. GOVERNMENT PRINTING OFFICE: 1990-773-047/06059