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

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DONALD PAUL HODEL, Secretary

GEOLOGICAL SURVEY

Dallas L. Peck, Director

For additional information
write to:

District Chief
U.S. Geological Survey
Post Office Box 2857
Raleigh, North Carolina 27602
Telephone: (919) 856-4510

Copies of this report can be
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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 feet = 1.09 yards	1 yard (yd) = 3 feet (ft) = 0.9144 (m) = 0.0009144 km
1 kilometer (km) = 1,000 m = 0.62 mile	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 miles	1 mi^3 = 4.168 km^3

Additional Abbreviations

mg/L = milligrams per liter

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."

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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 Plateaus province 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 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 the National Geodetic Vertical Datum of 1929 (NGVD of 1929), 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 NGVD of 1929 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 <u>units</u> 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 NGVD of 1929. 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.

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 are described for Pennsylvania by Rudd (1972) and for Ohio by Clifford (1975).

Clifford (1975) also describes 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

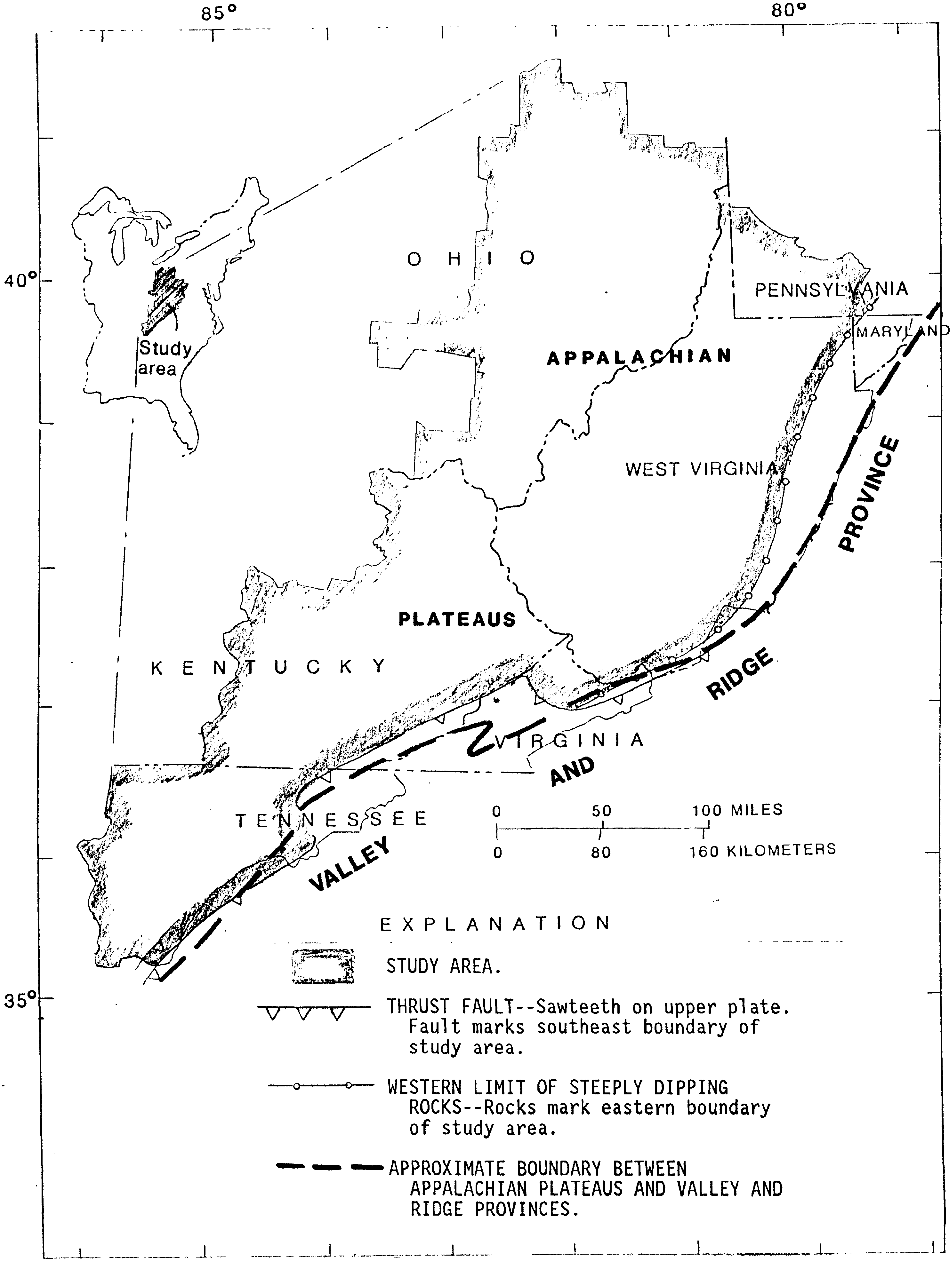

Figure 1.--Location of study area.

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 NGVD of 1929, 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 NGVD of 1929 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 NGVD of 1929 in the study area.

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

> A sandstone, dolomite, or limestone layer containing nonpotable water that lies between about 300 m and 2,500 m below NGVD of 1929 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 and potential confining intervals established in the study basin using this definition are grouped into six major potential reservoir units and seven major potential confining units.

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 (fig.2). The 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). 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 claculated 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 other, 1932; Price and others, 1937; Hoskins, 1949; Lamborn, 1952; McGrain, 1953; Poth, 1962; Hopkins, 1963, 1966; Price, 1964; and 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 3. 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 weight 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 3 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.

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 table 4. These rocks are part of one of the most studied sedimentary basins in the world.

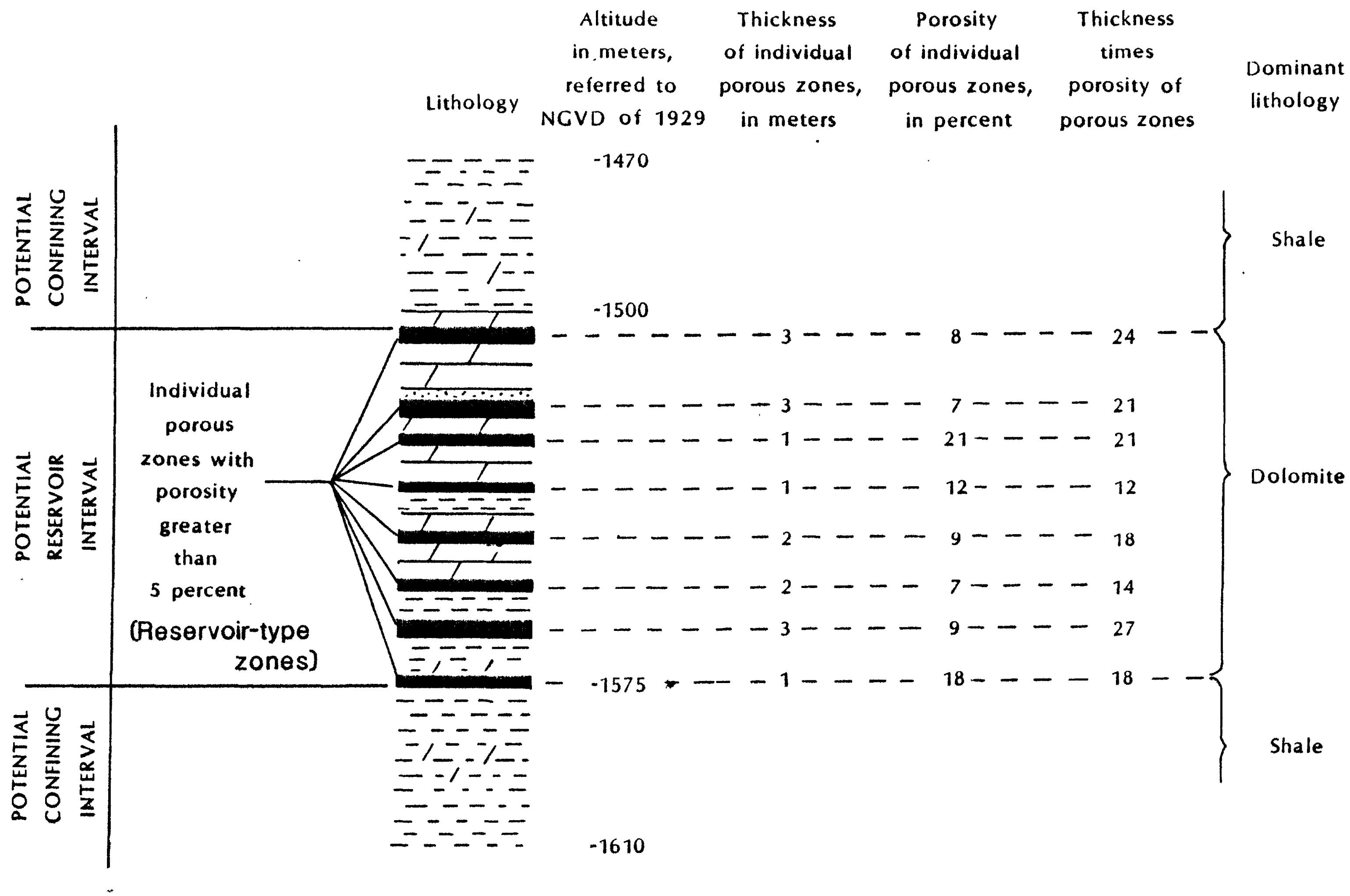

Figure 3.--Typical relation between reservoir-type zones, a potential reservoir interval and potential confining intervals.

Consequently, an extensive literature has been written about the sedimentary, stratigraphic, structural, and tectonic history of the rocks. Colton (1961) and Dennison (1978) give reviews of the basin geology and present lists of many of the important reference works. Additional references are listed throughout this report.

The consolidated sedimentary rocks in the study area range from Cambrian to Permian in age. 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 (fig. 4). 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 (fig. 4). These unconsolidated deposits are saturated with freshwater and, therefore, are excluded on the correlation chart (table 4) and from further discussion in this report.

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 (fig. 4).

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 5 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 in figures 6-10.

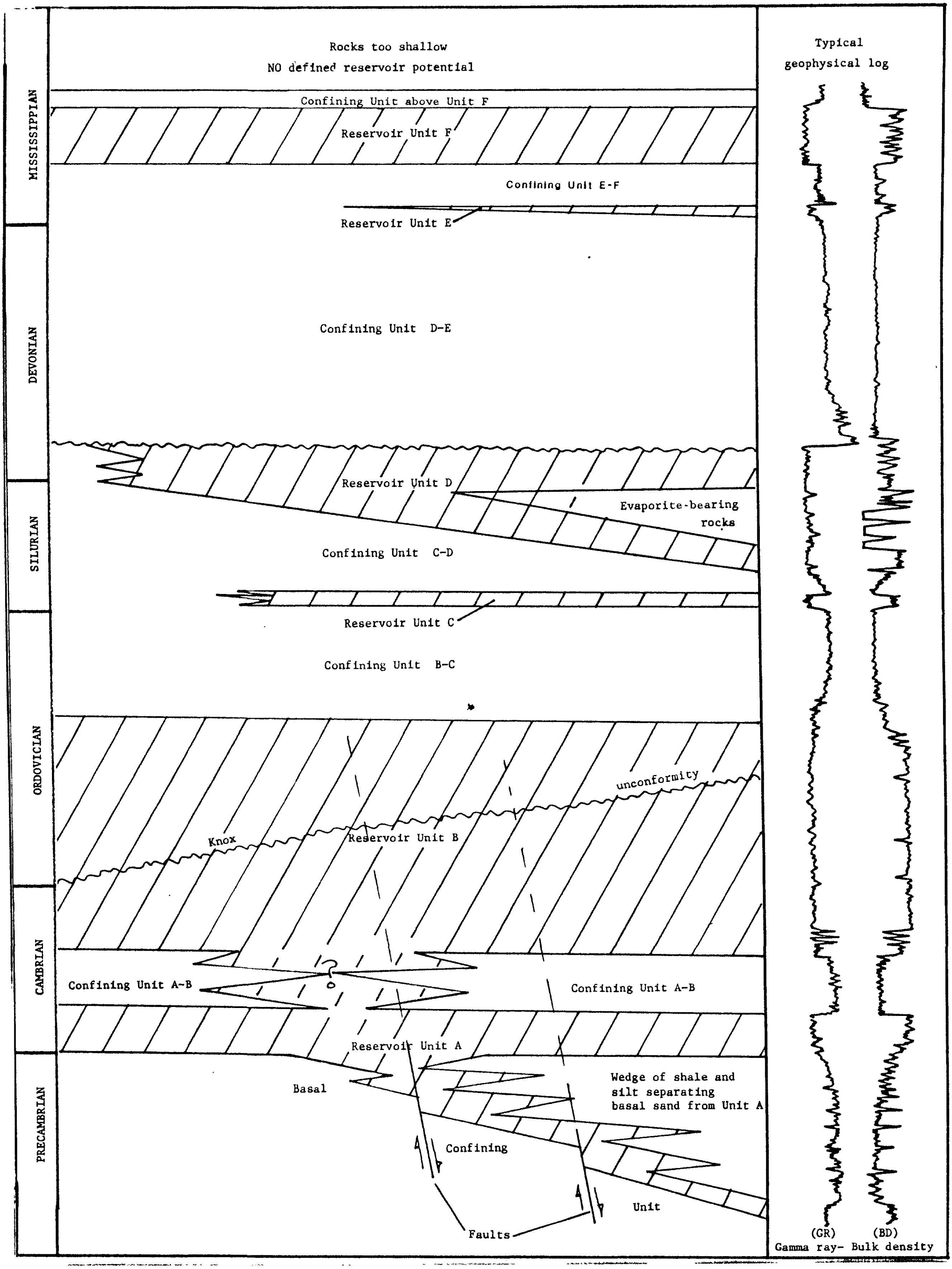

Figure 5.--Diagrammatic representation of occurrence and geophysical log response for potential reservoir and confining units.

DISTRIBUTION OF ESTIMATED POTENTIAL WASTE-STORAGE ENVIRONMENT

Potential Reservoir and Confining Units

The distribution and characteristics of each potential reservoir and 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 NGVD of 1929. The discussion of the 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.

Discussion of each 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 reservoir units, such as the occurrence of porosity in Reservoir Unit B near the erosional surface and developed on the Cambrian and Ordovician Knox Group 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 5 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 NGVD of 1929 in central Ohio to 10,000 m or more below NGVD of 1929 in southwestern Pennsylvania (Harris, 1975; Cardwell, 1977a). The top of this confining unit is deeper than about 2,500 m below NGVD of 1929 in the eastern two-thirds of the study area (fig. 11).

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.

Table 5.--Summary of characteristics of potential reservoir intervals, individual porous zone 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 NGVD of 1929	1,260	1,224	1,473	1,411	263	388
Range of values, in meters below NGVD of 1929	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	-	-	-	-	-

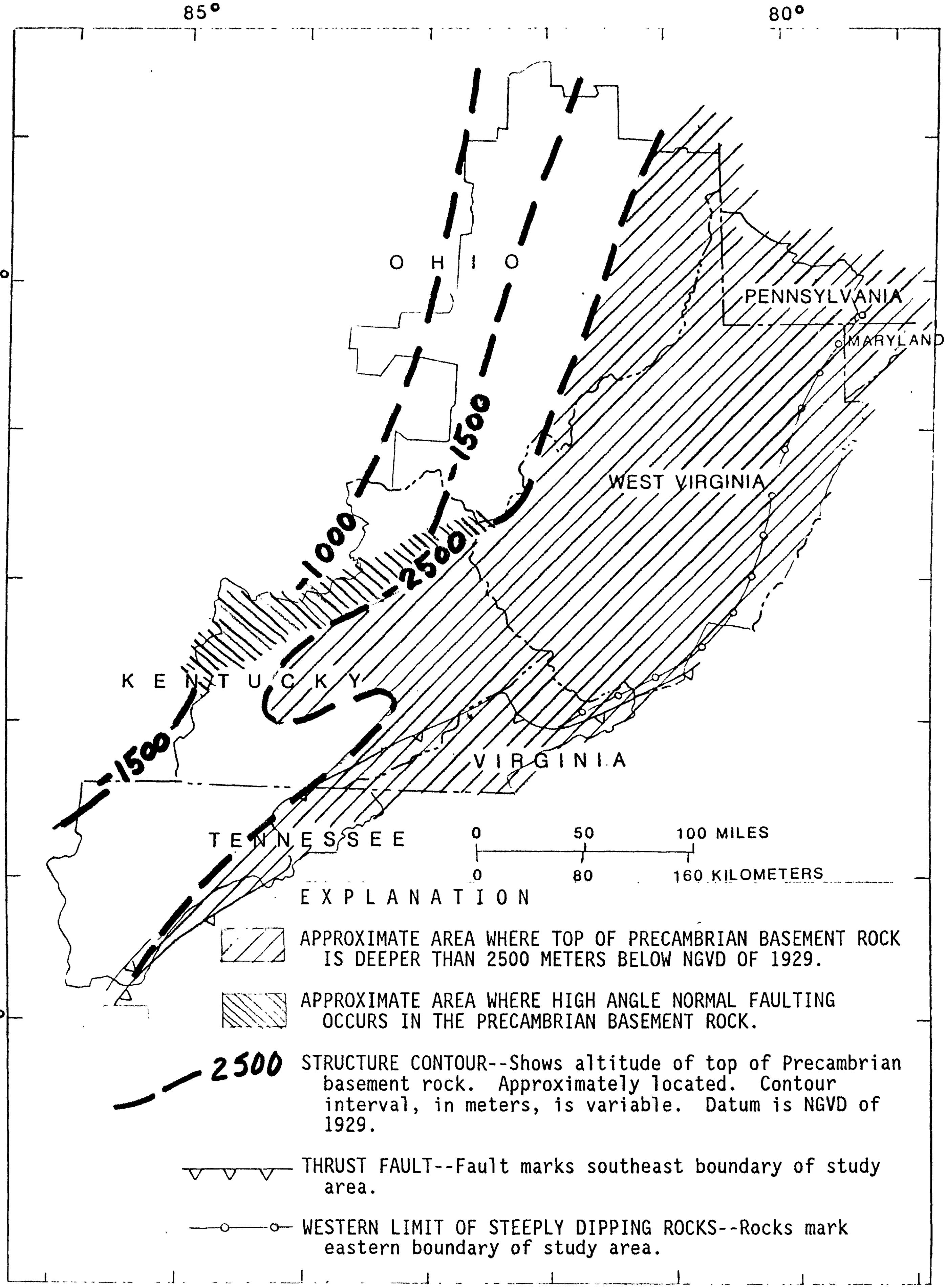

Figure 11.--Approximate altitude of the top of the Precambrian basement rocks.

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) states that the Rome Formation rises time-stratigraphically toward the northwest in Kentucky, and Janssen (1973) indicates it is part of the Upper Cambrian Series in Ohio. Analysis of data from geophysical and lithologic logs of 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 NGVD of 1929 throughout the study area. It is about 900 m below NGVD of 1929 at the shallowest occurrence along the west boundary in central Ohio and 2,500 m below NGVD of 1929 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. 12). 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 NGVD of 1929, 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 (fig. 13). 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 in figures 6 through 10.

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 NGVD of 1929 in the study area. Thirteen wells are located in Kentucky, 13 in Ohio, and 2 in Tennessee (figs. 12 and 13, and table 3). A summary of some of the characteristics and distribution of the reservoir porosity found in Unit A is given in table 5.

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 NGVD of 1929, 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 basement.

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 NGVD of 1929, 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 NGVD of 1929, 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 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. 14). 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, 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, respectively, to very little if any sandstone in well 259 in Pickett County, Tennessee, 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).

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 (table 4). The 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. The greatest thickness occurs in southeastern Kentucky between the Irvine-Paint Creek fault system and the Pine Mountain thrust fault (fig. 15). 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, 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 in figures 6 through 10.

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, 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 (table 4).

The thin sandstones occur at the base of the Middle and Lower Ordovician carbonate rocks (table 4). 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 to 15 m and reaches about 21 m in three small depositional centers that appear to be associated with the faulting in Powell, Elliott, and Martin Counties, Kentucky (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 NGVD of 1929 in northeastern Kentucky and parts of eastern and southern Ohio and southwestern West Virginia (Patchen and others, 1985 a, b). The southern extent of this sandstone is marked approximately by latitude 37 30 North, 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.

The top of Unit B is deeper than 300 m below NGVD of 1929 throughout most of the area in Ohio, in the eastern two-thirds of Kentucky, and the northeastern corner of Tennessee (fig. 16). It is deeper than 2,500 m below NGVD of 1929 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 NGVD of 1929 (fig. 16). 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 NGVD of 1929.

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, 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 figure 17 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 (fig. 17), is in large part caused by the erosion of the rocks lying beneath the Knox unconformity (table 4). Figure 18 shows the approximate altitude of the unconformity and the approximate percentage of Unit B found below this feature. A careful comparison of figures 16, 17, and 18 indicates that the major part of the reservoir porosity found in Unit B occurs in the rocks below or just above the unconformity. Hydrogeologic sections displaying the depth to and thickness of Unit B and its relation to the other rocks are shown in figures 6 through 10.

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 NGVD of 1929 in the area (figs. 16 and 17, and table 3). Nineteen wells are located in Kentucky, 22 in Ohio, one in Tennessee, and one in West Virginia. Table 5 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 NGVD of 1929, 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 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 NGVD of 1929, 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 NGVD of 1929. 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 Conoccocheaque 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 NGVD of 1929. 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.

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 19 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. 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 (table 4). 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 NGVD of 1929. The confining unit's thickness in zone one ranges from 242 m in well 233 in Wise County, Virginia, to 1,274 m in well 104 in Randolph County, West Virginia, and the average thickness is about 425 m. In general, it thickens from the west and southwest to the east and northeast (fig. 19).

The boundary between zones one and two is marked by the long, narrow 400 m-contour closure oriented in a north-south direction on figure 19. 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, and averages 325 m.

Zone three begins at the western limit of Reservoir Unit D (see index map on figure 19 and figure 23). 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 (table 4). 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. 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 in figures 6 through 10.

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 (table 4). This unit is confined to the subsurface throughout the study area, and its top ranges from about 400 m below NGVD of 1929 at the western limit of the unit in Ohio to greater than 2,500 m below NGVD of 1929 in northeastern West Virginia and southwestern Pennsylvania (fig. 20). 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 (fig. 21). 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 on figure 22 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.

Hydrogeologic sections displaying the depth to and thickness of Reservoir Unit C and its relation to other rocks are shown in figures 6, 7, and 10.

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 300 m and 2,500 m below NGVD of 1929 in the study area (figs. 20 and 21, and 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 5.

In Ohio, the median altitude of the top of the potential reservoir intervals is 1,110 m below NGVD of 1929 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 NGVD of 1929, 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). Immediately 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 composed 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 NGVD of 1929 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.

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 (table 4) 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 southwestern Pennsylvania. 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. Overall, its average area-weighted thickness is about 92 m where the underlying reservoir unit occurs between 300 m and 2,500 m below NGVD of 1929 (fig. 22).

Hydrogeologic sections displaying the depth to and thickness of Unit C-D and its relation to the other rocks are shown in figures 6 through 10.

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 (table 4). 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, 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, 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 NGVD of 1929 east of a line drawn from central Summit County, Ohio, to central Bell County, Kentucky (fig. 23). The deepest occurrence was found in well 43 in Fayette County, Pennsylvania, where the top is 2,045 m below NGVD of 1929. The bottom part of the unit is deeper than 2,500 m below NGVD of 1929 in parts of northeastern West Virginia and southwestern Pennsylvania (fig. 23).

Where the top of this unit lies deeper than 300 m below NGVD of 1929, its thickness ranges from 1,135 m in well 44 in Fayette County, Pennsylvania, to less than 50 m in several wells in south-central Kentucky (fig. 24). 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. 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 table 4) 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 25 shows the areal extent, altitude of the top, and thickness of the section in which 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 in figures 6, 7, 9, and 10.

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 NGVD of 1929 in the study area (figs. 23 and 24, and table 3). Nineteen wells are located in West Virginia, 12 in Ohio, four in Pennsylvania, and three in Kentucky. Table 5 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 remainder are found in sandstone and chert. About 70 percent of the potential reservoir porosity occurs above the evaporite-bearing rocks shown in figure 25, 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 NGVD of 1929, 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 comprise about 47 percent of the overlying confining rocks (shale, 33 percent; siltstone, 14 percent), 43 percent is comprised of carbonate rocks (limestone, 25 percent; dolomite, 18 percent), and 10 percent is comprised 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 comprised of carbonate rocks (limestone, 33 percent; dolomite, 23 percent), and 13 percent is comprised 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 NGVD of 1929, and their median thickness is 71 m. Two potential reservoir intervals were found in each of three wells, and one interval occurred in each of the other ten 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 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 NGVD of 1929, 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 NGVD of 1929, 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).

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 (table 4). Within the area where Reservoir Unit D occurs between 300 and 2,500 m below NGVD of 1929, 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. 26). 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. The slight thickening of this unit outlined by the 200-m contour in parts of Breathitt, Lee, Menifee, Powell, and Wolfe Counties, Kentucky, 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 in figures 6 through 10.

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 Cussewago and Berea Sandstones and equivalents of Early Mississippian age (table 4). The top of this unit is deeper than 300 m below NGVD of 1929 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. 27). 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, where the altitudes of the top are about 900 m and 500 m below NGVD of 1929, respectively. The shallowest occurrence is found along the axis of the Burning Springs anticline from Pleasants to Wirt Counties, West Virginia, where the top is less than 100 m below NGVD of 1929 (fig. 27).

A study of geophysical and lithologic logs suggested that potential-reservoir sandstone beds have an aggregate thickness of about 8 to 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. 27). Throughout the remainder of the area, where it lies deeper than 300 m below NGVD of 1929, 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 in figures 6, 7, and 10.

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 (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 NGVD of 1929 (fig. 27). 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 NGVD of 1929, 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. The altitude of the top of this interval is 312 m below NGVD of 1929, 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.

Confining Unit E-F

Primarily, Lower Mississippian shales and siltstones comprise Confining Unit E-F, which overlies Reservoir Unit E (table 4). In the two separate areas where the underlying reservoir unit is deeper than 300 m below NGVD of 1929 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. The average thickness of the unit is about 150 m in the southern area and slightly over 100 m in the northern area (fig. 28). 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 in figures 6, 7, 8, and 10.

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 (table 4). 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. 29). 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. The middle area is composed 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. 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. 29 and 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, where the top descends to nearly 600 m below NGVD of 1929. Where the top is deeper than 300 m below NGVD of 1929 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 (fig. 30). 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 in figures 6, 7, 8, and 10.

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 NGVD of 1929 in the study area (figs. 29 and 30, and table 3). Three wells are located in Virginia, two in West Virginia, two in Tennessee, and one in Kentucky. Table 5 presents a summary of some of the characteristics and distribution of the reservoir porosity identified in Reservoir Unit F.

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 NGVD of 1929, 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 NGVD of 1929, 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) comprise the overlying confining rocks, and equal amounts of limestone and shale comprise 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 NGVD of 1929, 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. The interval occurs in sandstone. The altitude of the top of the interval is 370 m below NGVD of 1929, 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.

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 NGVD of 1929, 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. The average area-weighted thickness of this unit is about 50 m (fig. 31).

Hydrogeologic sections displaying the depth to and thickness of the Confining Unit above Unit F and its relation to the other rocks are shown in figures 6, 7, 8, and 10.

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 6, 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 12 through 29, and column 1 in table 6, indicates that Units A, B, C, and D are the most widespread, occuring 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 58-m thickness 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 to 10 m or more.

Column 3 indicates 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

Table 6.--Regional physical characteristics of potential reservoir and confining units

Potential Reservoir Unit (PRU)	1 Area where top of PRU occurs between 300 m and 2,500 m below NGVD of 1929 (km^2)	2 Average area-weighted thickness (m)	3 Volume Column 1 times Column 2, divided by 1,000 (km^3)	4 Estimated percent of unit thickness with reservoir porosity (percent)	5 Median thickness-weighted porosity, in percent, for Column 4, taken from Table 5 (percent)	6 Relative reservoir volume index (a product of Columns 1, 2, 4, and 5 divided by 1,000) (km^3)	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)
A	77,300	144	11,131	4.9	8	44	1,260	156	1 to basement	Below A basement
B	96,400	850	81,940	1.7	7	98	1,224	66	64	A-B 217
C	81,600	36	2,938	3.3	7	6.8	1,473	96	586	B-C 423
D	95,300	410	39,073	1.5	7	41	1,411	157	80	C-D 92
E	13,700 n(4,250)[a] s(9,450)	58 n(31)[a] s(70)	794 n(132)[a] s(662)	1.4	9	1.0	[b]263	134	217	D-E 838
F	4,300	200	860	3.9	5	1.7	388	64	100	E-F 140 above F 50

[a] 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.

[b] Because of a paucity of data, intervals with tops shallower than 300 m below NGVD of 1929 were used to determine interval characteristics for Unit E.

appropriate unit lies between 300 and 2,500 m below NGVD of 1929 with the exception of Unit E. Altitudes for the top of potential reservoir intervals in Unit E are as shallow as 227 m below NGVD of 1929. 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).

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 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 6) and the last ranking given for potential of confinement were used to represent the major physical, economic, and safety characteristics, respectively. Table 7 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.

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 NGVD of 1929. 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.

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 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 and 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 preceeding sections of this report are shown on figure 32.

Table 7.--Ranking of liquid waste-storage reservoir potential for units

Potential reservoir unit	Index of major physical characteristics (Column 6, table 6)	Index of major economic characteristics (Column 7, table 6)	Index of major safety characteristics	Overall reservoir potential; the sum of the preceding 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

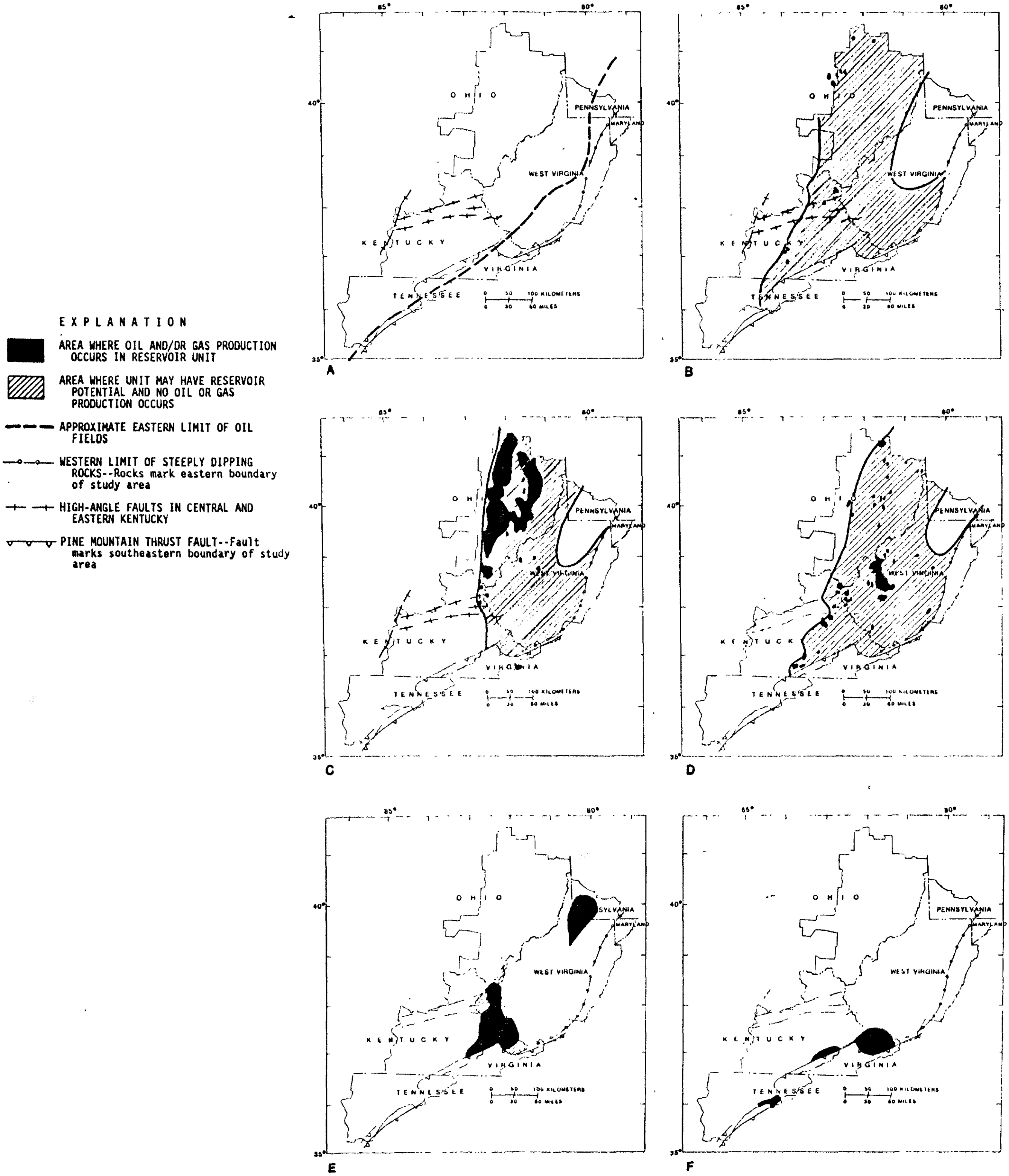

Figure 32.--Distribution of oil and gas production from Reservoir Units B through F.

Producing areas are shaded black. No significant oil and gas fields have been discovered in the sandstones and dolomites that constitute Reservoir Unit A in the study area. Thus, Unit A is not shown in figure 32. 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. 32A). Gas production has occurred from different horizons throughout the study area.

Scattered production from some of the rocks that constitute 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 NGVD of 1929 (fig. 32B). 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 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. 32C).

Production of oil and gas is more widespread in Reservoir Unit D than in any other unit in the study area (fig. 32D). 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 Reservoir Units E and F practically everywhere they occur between about 300 and 2,500 m below NGVD of 1929 (fig. 32). 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. 33). Subsurface thrust faults have been mapped and inferred from deep-well and geophysical data east of the dotted line (A) drawn on figure 33 from northern West Virginia to southern Tennessee (fig. 33, 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 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. 33) 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 are nearly perpendicular to a horizontal plane at land surface) rock is mapped along the eastern border of the study area (C, fig. 33) from just north of the Pine Mountain overthrust block (G, fig. 33) in southwestern Virginia to southwestern Pennsylvania. This folded rock area and the major faulted areas are shown on the figures that illustrate the top or thickness of the reservoir 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 34 shows the approximate location of seismic events that have occurred in the area from 1776 to present, and table 8 lists the location, number, and some intensities of earthquakes that occurred at each site (Stover and others 1978c, 1979a, 1979b, 1980a, 1980b, 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

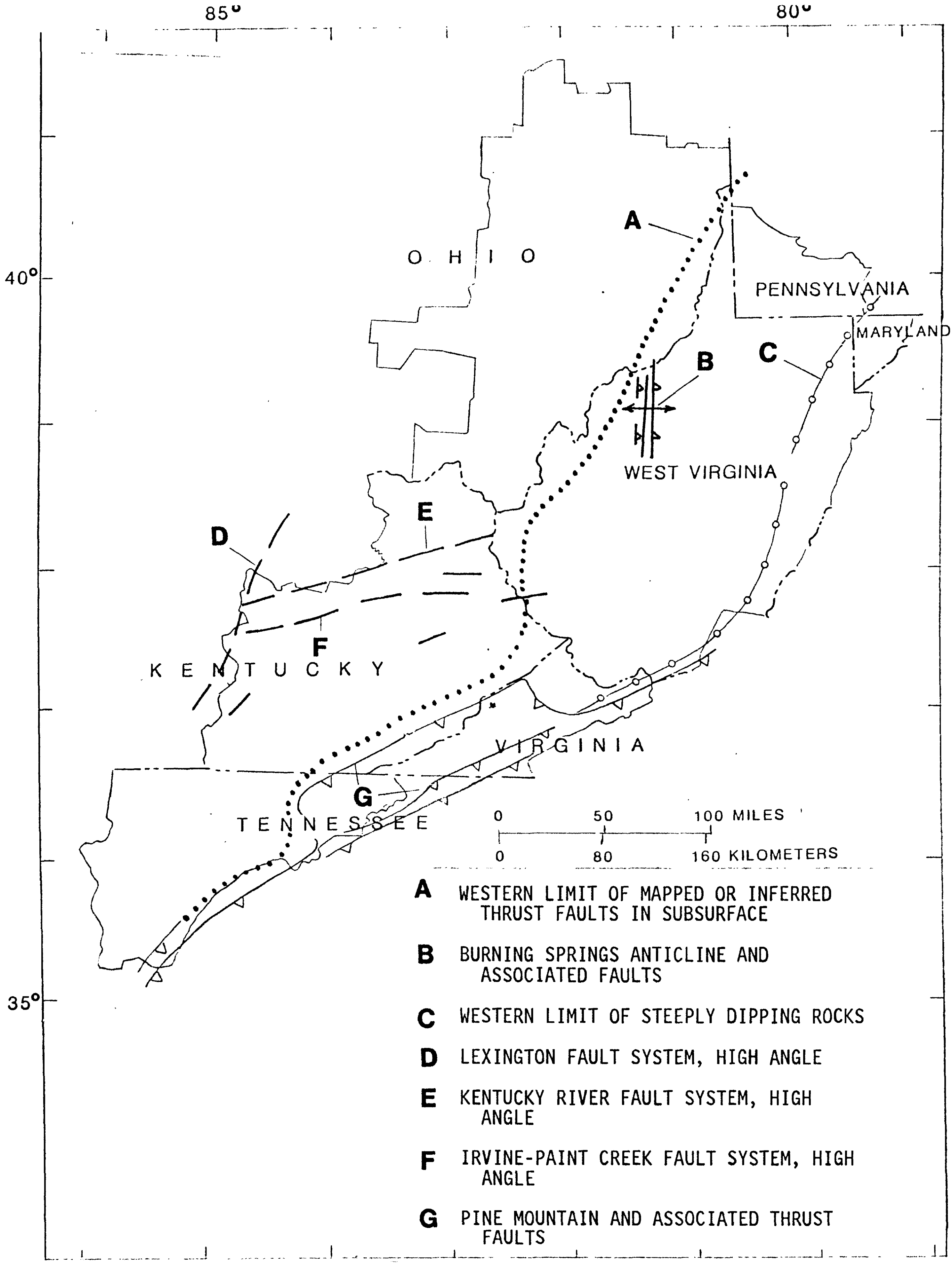

Figure 33 .--Approximate location of major fault and fold structures.

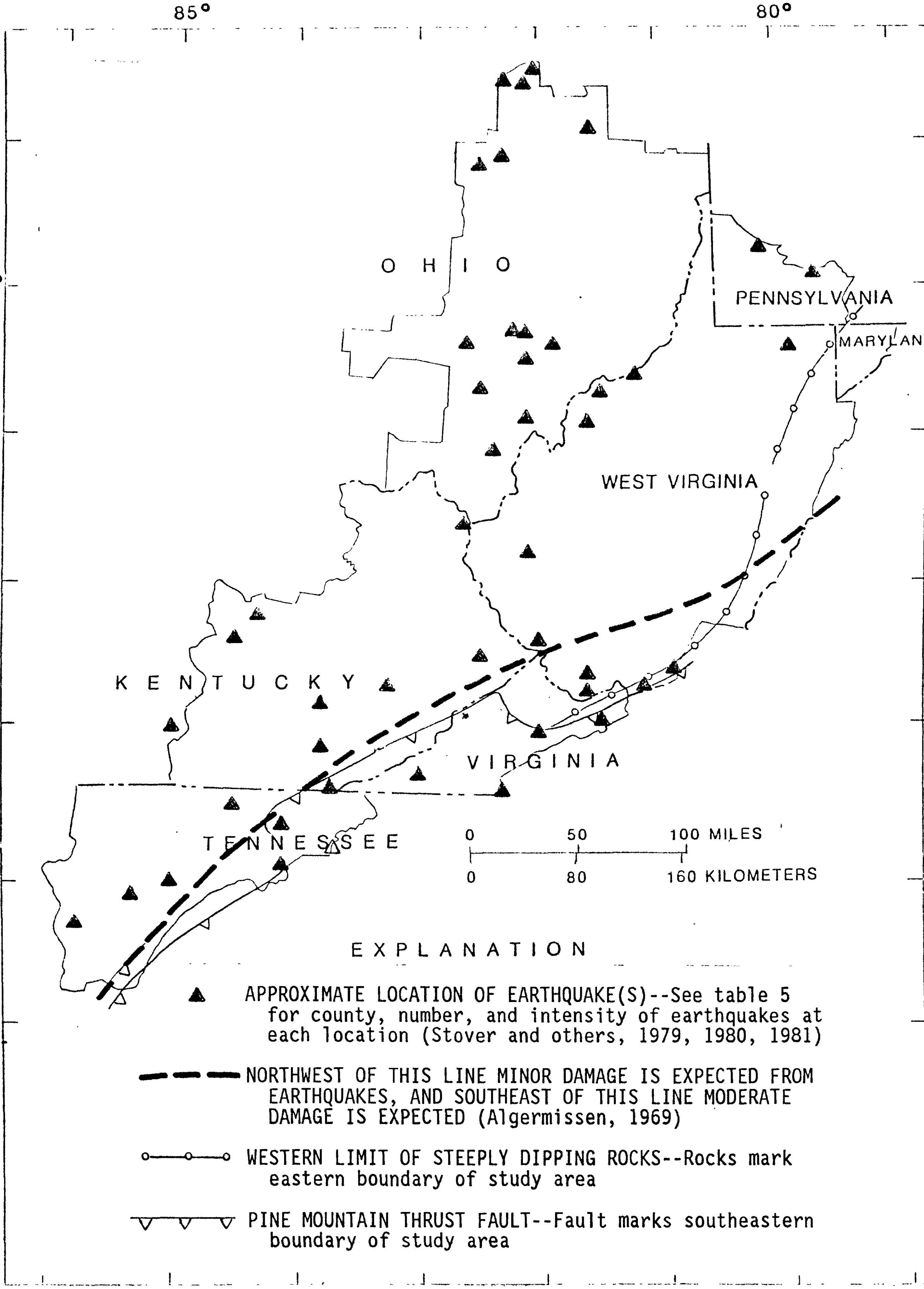

Figure 34.--Distribution of earthquakes from 1776 to 1980, and location of damage-risk zones.

Table 8.--Earthquakes in central and southern parts of the Appalachian Basin a/

a/ Data for this table were taken from Stover and others (1979a, 1979b, 1979c, 1980a, 1980b, 1981).

b/ JAN-January, FEB-February, MAR-March, APR-April, AUG-August, SEPT-September, OCT-October, NOV-November, DEC-December.

c/ MM stands for Modified Mercalli Intensity Scale of 1931. Abridged version taken from Lessing (1974).

* Number assigned by original compiler from available data.

DATE YEAR	MONTH b/	DAY	County	LATITUDE (North)	LONGITUDE (West)	EPICENTER DEPTH (kilometer)	MAGNITUDE Gutenberg-Richter Scale	INTENSITY MM c/
					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	Monongalia	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	Monongalia	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

Algermissen (1969), most of the study area lies in a zone where only minor earthquake damage can be expected to occur (fig. 34). Moderate damage can be expected along the southeastern border of the area south of the dashed line (A) drawn on figure 34, 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) gives 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) suggest that small-scale injection tests in conjuction with seismic studies could be made in the rock and 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 and 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) indicate 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 indicate 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 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 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 NGVD of 1929 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. Reservoir Unit A overlies the basal confining unit, is composed mainly of sandstone and dolomite, occurs between 300 m and 2,500 m below

NGVD of 1929 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 NGVD of 1929, 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 5). Unit A is overlain by Confining Unit A-B which has an average area-weighted thickness of 217 m.

Reservoir Unit B overlies Confining Unit A-B, is composed mainly of dolomite, limestone, and sandstone, occurs between 300 m and 2,500 m below NGVD of 1929 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 NGVD of 1929, 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 5). About 85 percent of the reservoir porosity occurs below the Knox unconformity on the surface of the Knox Group. Unit B is overlain by Confining Unit B-C which has an average area-weighted thickness of 423 m.

Reservoir Unit C overlies Confining Unit B-C, is composed of sandstone, occurs between 300 m and 2,500 m below NGVD of 1929 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 NGVD of 1929, 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 5). Unit C is overlain by Confining Unit C-D which has an average area-weighted thickness of 92 m.

Reservoir Unit D overlies 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 NGVD of 1929 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 NGVD of 1929, 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 5). 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 Confining Unit D-E which has an average area-weighted thickness of 838 m.

Reservoir Unit E overlies 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 NGVD of 1929 over a 13,700 km^2 area, and have an avergage 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 NGVD of 1929, 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 5). Unit E is overlain by Confining Unit E-F which has an average area-weighted thickness of 140 m.

Reservoir Unit F overlies 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 NGVD of 1929 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 NGVD of 1929, 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 5). The confining unit that overlies Unit F has an average area-weighted thickness of about 50 m.

When all the unit factors listed above are catagorized 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 NGVD of 1929. The occurrence of these resources appears to be most common in the younger, shallower units. However, this may result from the fact that 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 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.

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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 fig. 2 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 the National Geodetic Vertical Datum of 1929 (NGVD of 1929).

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

Deepest stratigraphic penetration: The alphabetical letters stand for the rock system and series that was found in the well at total depth. Precambrian (Pre Є); Cambrian (Є), 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).

Reservoir unit tops and thicknesses: Depth to top is in meters below and above (-) NGVD of 1929; WNDE - Well not depp 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.

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 sections(s).

Table 1.--Record of key wells--continued

Well number	Well name	County	State	Coordinate location Lat.	Long.	Elev. of GL (m)	Total depth (m)	Rock System at Total Depth	Data source	Potential Reservoir Unit A Depth to top (m)	Thickness (m)	Potential Reservoir Unit B Depth to top (m)	Thickness	Potential Reservoir Unit C Depth to top (m)	Thickness	Potential Reservoir Unit D Depth to top (m)	Thickness	Potential Reservoir Unit E Depth to top (m)	Thickness	Potential Reservoir Unit F Depth to top (m)	Thickness	Remarks
1	East Ohio Gas Co., A. Born #1	Lorain	Ohio	41°17'50"	82°19'16"	358	1,399	Pre €	G,L	1,024	114	750	195	363	9	-35	357	UTS	—	UTS	—	Unit C, NP; S
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	—	967	238+	544	12	-163	654	do	—	do	—	QWC
3	Wiser Oil Co., Divoky #2	Medina	do	41°14'00"	81°42'00"	381	1,846	U€	do	do	—	1,152	?	692	17	216	442	do	—	do	—	
4	Wiser Oil Co., Frank L. Smith #1A	do	do	41°13'43"	81°42'07"	361	2,146	Pre €	GL	1,469	171	1,152	284	677	18	213	440	do	—	do	—	
5	Sunshine Petroleum Corp., R. L. Jones #1	Ashland	do	40°54'46"	82°14'48"	349	1,474	U€	G,SF	WNDE	—	902	220+	490	21	124	322	do	—	do	—	QWC
6	M & G Oil Co., K. F. & M. G. Cejna #4	do	do	40°52'39"	82°08'36"	303	1,576	do	G,L	do	—	984	287+	565	10	193	324	do	—	do	—	
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	1,169	272	711	10	312	353	do	—	do	—	
8	East Ohio Gas Co., Knight #3	Summit	do	40°55'59"	81°37'07"	342	1,970	LO	do	WNDE	—	1,362	264+	854?	53?	400	462	do	—	do	—	
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+	1,611	342	1,066	22	514	524	do	—	do	—	QWC
10	East Ohio Gas Co., L. & L. Frederick Comm.	do	do	40°54'53"	81°10'13"	340	2,380	U€	G,SF	WNDE	—	1,704	336+	1,151	31	575	528	do	—	do	—	QWC
11	Management Control Corp., Frank Murray #3	Columbiana	do	40°47'10"	80°52'13"	360	3,122	do	G,L	2,474	284+	2,009	448	1,445	18	767	602	-143	20	do	—	
12	Pan American Petroleum Corp., A. C. Windbigler #1	Morrow	do	40°40'50"	82°41'20"	422	1,490	Pre €	do	918	140	574	311	205	21	-103	278	Absent	—	do	—	Unit C, NPAR; S
13	Tri-State Producing Co., Scott #2	Richland	do	40°41'17"	82°28'50"	442	1,677	do	G	1,095	132	747	317	369	11	49	271	UTS	—	do	—	Unit C, NPAR; S
14	Tri-State Producing Co., J. & A. R. Hoops #1	do	do	40°40'48"	82°28'41"	423	1,417	U€	do	WNDE	—	757	232+	367	9	59	267	do	—	do	—	
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	416	308	NPAR	—	-205	245	Absent	—	do	—	
16	David Cantway, Palos Verdes #1 (Cunningham)	Knox	do	40°31'11"	82°23'15"	378	1,762	U€	do	WNDE	—	?	?	?	?	127	247	UTS	—	do	—	Poor log for Units B and C
17	Kin-Ark Oil Co., Levi S. Erb #1	Holmes	do	40°27'43"	81°44'50"	340	2,082	do	G,L,SF	do	—	1,413	326+	932	18	514	341	do	—	do	—	QWC
18	Management Control Corp., John D. McAllister #1	Carroll	do	40°36'23"	80°59'07"	340	2,766	LO	G,L	do	—	2,056	367+	1,486	26	891	543	-2	12	do	—	
19	St. Joe Petroleum Corp., R. J. Ashcroft #1	Beaver	Pa.	40°36'06"	80°26'02"	341	2,313	UO	G,L,SF	do	—	WNDE	—	1,908	52	1,197	633	12	18	do	—	QWC
20	Humble Oil & Refining Co., Sarah K. Minesinger #1	Hancock	W.Va.	40°32'24"	80°33'23"	317	3,166	LO	do	do	—	2,409	436+	1,773	40	1,100	611	98	48	do	—	QWC
21	Belden Oil & Gas Co., J. Carney #1	Jefferson	Ohio	40°24'55"	80°46'20"	324?	1,517	LD	G,SF	do	—	WNDE	—	WNDE	—	1,118	75+	69	13	do	—	
22	Floyd A. Gearhart, Howard S. Miser #1	do	do	40°24'17"	80°51'40"	341	2,100	UO	G,L,SF	do	—	do	—	1,700	20	1,046	589	UTS	—	do	—	
23	Sanford E. McCormick, Roy Birney #1	Harrison	do	40°15'43"	80°57'59"	339	3,103	LO	G,L	do	—	2,281	479+	1,705	21	1,066	579	86	9	do	—	QWC
24	Atlas Mineral Corp., John G. Scalia #1	Tuscarawas	do	40°25'10"	81°18'25"	272	1,646	UO	G,SF	do	—	WNDE	—	1,312	23	788	471	UTS	—	do	—	
25	Stocker & Sitler, Huebner Unit #2	do	do	40°18'14"	81°25'29"	367	2,506	LO	G,L	do	—	1,774	360+	1,255	34	748	454	do	—	do	—	
26	Bob Tatum, Edwin L. Lee #1	Coshocton	do	40°19'25"	82°00'09"	314	2,124	U€	do	1,618	186	1,221	383?	774	15	415	299	do	—	do	—	QWC
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	719	344	341	19	62	225	do	—	do	—	Unit C, NPAR; S
28	Lake Shore Pipeline Co., Gordon Dixon #1	do	do	40°18'18"	82°36'27"	371	1,295	U€	G,SF	WNDE	—	684	237+	303	18	27	238	do	—	do	—	Unit C, NPAR
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	936	373	523	10	229	245	do	—	do	—	S
30	Ashland Oil & Refining Co., C. S. Schmelzer #1	do	do	39°58'44"	82°44'25"	326	1,464	do	G,L	991	143	583	357	209	22	-24	197	do	—	do	—	Unit C, NPAR; S
31	Worthington Oil Co. Inc., Columbia & Southern Electric Co.	Muskingum	do	40°08'21"	81°51'35"	241	2,046	U€	G,SF	WNDE	—	1,426	377+	971	14	575	323	do	—	do	—	
32	Ballard & Cordell, D. Welker #1	do	do	40°06'00"	81°45'10"	261	1,353	LS	L	do	—	WNDE	—	1,045	24	625	347	do	—	do	—	
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	1,568	438	1,101	15	667	340	do	—	do	—	QWC; S
34	Golden Cycle Corp., M. & C. Vessels #1	do	do	39°57'49"	81°41'19"	312	2,240	LO	G,SF	WNDE	—	1,610	315+	1,149	22	714	361	do	—	do	—	
35	Kewanee Oil Company, Dorothy Mikolojcik #1	Muskingum	do	39°51'52"	81°51'32"	289	1,349	UO	G	do	—	WNDE	—	1,017	11	617	347	do	—	do	—	
36	Oxford Oil Company, T. E. Corder #1	do	do	39°54'18"	81°52'59"	261	1,297	UO	L,SF	do	—	do	—	990	22	605	289	do	—	do	—	
37	Natural Gas Co. of West Virginia, E. A. Mobley #1	Belmont	do	39°57'22"	80°57'25"	358	2,404	do	L	do	—	do	—	1,990	48	1,302	558	do	—	do	—	
38	Oxford Oil Company, Gilbert Dangel #1	Monroe	do	39°50'20"	80°53'57"	399	1,921	LD	G,L	do	—	do	—	WNDE	—	1,443	78+	268	62	do	—	

Table 1.--Record of key wells--continued

Well number	Well name	County	State	Coordinate location		Elev. of GL (m)	Total depth (m)	Rock System at Total Depth	Data source	Potential Reservoir Unit A		Potential Reservoir Unit B		Potential Reservoir Unit C		Potential Reservoir Unit D		Potential Reservoir Unit E		Potential Reservoir Unit F		Remarks
				Lat.	Long.					Depth to top (m)	Thickness (m)	Depth to top (m)	Thickness	Depth to top (m)	Thickness	Depth to top (m)	Thickness	Depth to top (m)	Thickness	Depth to top (m)	Thickness	
39	Occidental Petroleum Corp., John Burley #1	Marshall	W.Va.	39°45'47"	80°31'48"	434	5,033	U€	G,L,SF	WNDE	—	3,461	1,134+	2,677	74	1,871	675	527	32	259	102	S
40	John T. Galey Samuel Cooper #1	Washington	Pa.	40°04'32"	80°09'30"	347	2,480	LD,US?	G,L	do	—	WNDE	—	WNDE	—	1,918	212+	374	120	UTS	—	S
41	PNG-SNEE-Eberly Duane Duvall #1	do	do	40°06'19"	79°56'45"	387	2,663	US	G,L,SF	do	—	do	—	do	—	1,986	286+	315	136	do	—	
42	A.J. Fox et al., G.W. Gordon #1	Greene	do	39°51'35"	80°08'52"	425	2,639	LD,US?	do	do	—	do	—	do	—	2,007	204+	395	122	do	—	S
43	Amoco Production Co., Francis R. Griffin #1	Fayette	do	39°50'02"	79°50'39"	368	2,652	do	do	do	—	do	—	do	—	2,045	234+	UTS	—	do	—	
44	Snee & Eberly et al., Leo F. Heyn #1	do	do	39°51'02"	79°39'38"	704	3,527	LS	do	do	—	do	—	2,719	99+	1,302	1,135	do	—	do	—	
45	William E. Snee and Eberly, E. C. Ricks #1	do	do	39°50'37"	79°39'11"	769	3,610	UO	do	do	—	do	—	2,747	149+	1,590	930	do	—	do	—	S
46	Amoco Production Co., Leonard Svetz #1	Somerset	Pa.	39°58'40"	79°20'02"	748	6,541	U€	do	do	—	4,080	1,707+	2,771	102	1,788	797	-23	203	do	—	QWC
47	Snee & Eberly-NY State Nat. Gas, USA Collier #1	Garrett	Md.	39°40'18"	79°16'00"	870?	2,684	LD	L	do	—	WNDE	—	WNDE	—	1,655	116+	UTS	—	Absent	—	
48	Texas Eastern Gas Transmission, Bowman-Seibert #2	do	do	39°37'59"	79°21'12"	729	3,541	UO	do	do	—	do	—	2,653	143	1,430E	1,098E	do	—	do	—	
49	Texas Eastern Transmission Corp., U.S.A. Savage River #1	do	do	39°37'17"	79°17'14"	813	2,481	LD	G	do	—	do	—	WNDE	—	1,572	91+	do	—	do	—	
50	Snee & Eberly Collier Unit #1	do	do	39°37'20"	79°18'40"	731	2,242	do	do	do	—	do	—	do	—	1,393	?	do	—	do	—	
51	New York State Natural Gas Corp., (N-247) John Shaw #2	do	do	39°24'01"	79°22'00"	747	2,183	LS	do	do	—	do	—	1,376	69+	395	821	do	—	do	—	
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	do	—	3,708	177+	2,628	138	1,728	713	-126	37	UTS	—	
53	Phillips Petroleum Corp., Clifford J. May #A-1	Monongalia	do	39°33'51"	79°52'23"	665	3,373	LS	do	do	—	WNDE	—	2,615	88+	1,665	782	-390	126	do	—	
54	Phillips Petroleum Corp., R. R. Finch #A-1	Marion	do	39°25'57"	80°00'42"	409	5,215	LO	do	do	—	3,581	1,219+	2,651	95	1,779	700	-4	67	do	—	QWC
55	Truman Smith-Smith Oil & Gas #1 Charles R. & Goldie Stonekring	Wetzel	do	39°37'31"	80°29'03"	322	2,346	LD	*L,SF	do	—	WNDE	—	WNDE	—	1,917	107+	ND	—	do	—	No Logs for Unit E part of section
56	Consolidated Gas Supply Corp., L. G. Robinson	do	do	39°27'31"	80°34'10"	386	1,696	U-MD	G,SF	do	—	do	—	do	—	WNDE	—	502	53	do	—	QWC
57	Quaker State Oil Refining Corp., C.D. Cottrill #1	Tyler	do	39°22'03"	80°51'06"	292	2,078	LD	do	do	—	do	—	do	—	1,665	110+	482	—	219	99	Unit E, NPAR
58	Dee Drilling Company, P.A. Watkins #1	do	do	39°28'12"	80°49'59"	274	873	U-MD	G	do	—	do	—	do	—	WNDE	—	525	25	249	105	is present as
59	Mobay Chemical Corp., H. Emch and A. Pyles #1	Wetzel	do	39°40'40"	80°49'20"	410	2,142	LD	G,SF	do	—	do	—	do	—	1,622	107+	NPAR	—	UTS	—	silt and shale QWC; S
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	do	—	do	—	do	—	1,530	265+	—	—	do	—	
61	Clifford L. Sayre (FMC), #1 Benjamin (E & R Wells)	Tyler	W.Va.	39°27'28"	81°05'45"	197	1,979	do	L	do	—	do	—	do	—	1,464	318+	NPAR	—	do	—	
62	F.M.C. Corp. (Benj. #5) EARL & Rosalene Wells #5	Pleasants	do	39°27'37"	81°05'50"	217	1,976	do	do	do	—	do	—	do	—	1,467	237+	do	—	do	—	
63	F.M.C. Corp., #10 FMC Corp.	do	do	39°27'42"	81°06'29"	203	2,401	UO	G,SF	do	—	do	—	2,119	49	1,438	568	do	—	do	—	S
64	Consolidated Gas Supply Corp., P.B. Case	Ritchie	do	39°16'58"	81°11'55"	334	2,383	US	G.	do	—	do	—	WNDE	—	1,445	600+	398	—	do	—	QWC
65	Hope Natural Gas Company, Jessie Powell	do	do	39°14'20"	81°15'30"	307	1,771	LD	G,L,SF	do	—	do	—	do	—	1,362	102+	346	4	do	—	
66	Hope Natural Gas Company, Power Oil Company	Wood	do	39°15'22"	81°16'16"	317	4,063	Pre€	do	UTD	—	2,603	871?	2,021	27	907	985	NPAR	—	do	—	QWC
67	Commonwealth Gas Corp., William C. Kerns #1	Pleasants	do	39°19'46"	81°17'16"	327	2,092	US	do	WNDE	—	WNDE	—	WNDE	—	1,021	740	56	—	do	—	
68	Guernsey Petroleum Corp., Carl Matheny Unit #2	Washington	Ohio	39°28'14"	81°17'30"	195	2,819	MO	do	do	—	2,423	198+	1,871	49	1,262	444	312	3	do	—	
69	Amerada Petroleum Corp., B. Ullman #1	Noble	do	39°36'36"	81°20'50"	312	3,488	Pre€	G,L	2,922	243	2,249	657	1,721	45	1,149	466	266	1	do	—	QWC; S
70	Berry Holding Company, Cecil E. Offenberger #1	Washington	do	39°31'45"	81°34'32"	289	1,849	UO	do	WNDE	—	WNDE	—	1,503	39	1,008	401	302	3	do	—	QWC
71	Columbia Gas Transmission Corp., Denver B. Kittle	Morgan	do	39°29'34"	82°01'10"	260	1,988	LO	G	do	—	1,409	316+	990	40	623	299	127	42	do	—	QWC
72	Columbia Gas Transmission Corp., George Campbell, et al.	do	do	39°42'49"	82°00'38"	313	1,906	do	G,L	do	—	1,344	247+	929	31	563	308	81	40	do	—	
73	Buckeye Management Co. & Columbia Gas Trans. Corp., H.V. Thomas #1	Perry	do	39°42'50"	82°02'21"	277	1,887	do	do	do	—	1,308	299+	900	29	540	300	UTS	—	do	—	
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	do	—	WNDE	—	803	12	470	290	do	—	do	—	
75	Pure Oil Company, J.C. Kiener #1	do	do	39°42'27"	82°09'43"	308	1,106	UO	G,L,SF	do	—	do	—	757	12	435	271	do	—	do	—	
76	Clark Oil & Refining Corp., Rosa Thomas Heirs #1	Fairfield	do	39°36'36"	82°46'30"	333	1,149	U€	do	do	—	573	241+	NPAR	—	2	172	do	—	do	—	

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)	Unit A: Thickness (m)	Potential Reservoir Unit B: Depth to top (m)	Unit B: Thickness	Potential Reservoir Unit C: Depth to top (m)	Unit C: Thickness	Potential Reservoir Unit D: Depth to top (m)	Unit D: Thickness	Potential Reservoir Unit E: Depth to top (m)	Unit E: Thickness	Potential Reservoir Unit F: Depth to top (m)	Unit F: Thickness	Remarks
77	Kewanee Oil, E. A. Hopkins # 1	Fayette	Ohio	39°29'25"	83°25'00"	294	1,435	Pre€	G,L	611	176	87	466	NPAR	—	2	172	UTS	—	UTSOA	—	
78	Well Supervision, Inc., Brown # 1	Vinton	do	39°17'32"	82°44'21"	190	1,241	U€	do	WNDE	—	676	374+	330	20	94	175	do	—	UTS	—	Unit C, NPAR; S
79	Ralph Halbert George & Ina Woods #1	Jackson	do	38°57'57"	82°35'35"	262	1,926	Pre€	do	1,484	147	938	476	543	23	312	178	do	—	do	—	QWC
80	E. J. Dunigan, Jr., M.E. & H. Hockman # 1	Hocking	do	39°23'54"	82°23'22"	296	1,980	do	do	1,522	160	1,045	445	664	16	357	236	do	—	do	—	QWC
81	Ohio Fuel Gas Co., Alfred B. and J. B. Windom #1	Meigs	do	39°04'25"	82°00'20"	220	1,467	UO	do	WNDE	—	WNDE	—	1,206	32	814	294	280	10	do	—	
82	Hunting Oil Co., Inc., Earl W. and Phyllis H. Cleek # 1-A	do	do	38°56'19"	81°45'52"	183	1,761	do	G,L,SF	do	—	do	—	1,540	23	1,101	333	436	1	do	—	
83	Sinclair-Prairie Oil, No. 1, W. T. Longworth	do	do	39°09'19"	81°48'21"	250	2,276	MO	L	do	—	1,850	176+	1,390	48	958	339	—	—	do	—	
84	Carl E. Smith, Inc., Herman C. Buckley # 2	Athens	do	39°12'37"	81°54'57"	198	2,283	U€	G,SF	do	—	1,676	406+	1,249	37	845	305	280	3	do	—	
85	Quaker State Oil Refining Corp., Barber & Fowler #1	do	do	39°11'29"	81°46'53"	222	1,698	UO	G,L	do	—	WNDE	—	1,415	32	967	344	UTS	—	do	—	
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	2,382	884	1,850	27	1,309	418	485	—	do	—	
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	—	WNDE	—	2,132	42+	1,146	831	182	—	do	—	QWC
88	Pennzoil United, Inc., W. B. Maxwell	Doddridge	do	39°11'45"	80°46'29"	303	2,871	UO	do	do	—	do	—	2,488	70	1,654	677	399	10	do	—	QWC; S
89	Halbert and Prough, Guy Simmons No. 1-A	Gilmer	do	38°59'19"	80°48'15"	246	2,408	U-MS	G,SF	do	—	do	—	WNDE	—	1,641	517+	NPAR	—	do	—	
90	Allegheny Land and Mineral Co., J. T. Lovett	Lewis	do	39°03'35"	80°32'52"	375	2,210	LD	G	do	—	do	—	do	—	1,694	137+	261	73	do	—	
91	Hope Natural Gas Co., J. L. J. Bailey	do	do	39°04'30"	80°32'16"	351	2,140	do	G,L,SF	do	—	do	—	do	—	1,673	115+	250	76	do	—	
92	Consolidated Gas Supply Corp., J. Boring	Harrison	do	39°13'59"	80°26'42"	359	2,225	do	G,SF	do	—	do	—	do	—	1,734	130+	224	134	do	—	QWC; S
93	Hope Natural Gas Co., C. S. Gribble	do	do	39°09'30"	80°19'47"	339	3,051	UO	L,SF	do	—	do	—	2,631?	81+?	1,811	656	UTS	—	do	—	
94	Consolidated Gas Supply Corp., L. E. Bond	Upshur	do	39°04'15"	80°17'56"	382	2,203	U-MD	G,SF	do	—	do	—	WNDE	—	WNDE	—	235	236	do	—	QWC; S
95	Hope Natural Gas Co. B. L. Martin	do	do	39°02'21"	80°16'18"	474	1,433	do	G,L,SF	do	—	do	—	do	—	do	—	UTS	—	do	—	
96	Monitor Petroleum Corp., Junior Phillips # 1	Barbour	do	39°00'31"	80°01'03"	684	2,472	LD	G,SF	do	—	do	—	do	—	1,674	110+	-74	142	do	—	
97	G. L. Cabot, No. 1 O. Shockey et al.	do	do	39°03'47"	80°01'42"	620	2,441	do	L	do	—	do	—	do	—	1,726	94+	UTS	—	do	—	
98	Hope Natural Gas Co., James E. Sayers	do	do	39°13'12"	80°03'59"	482	1,389	U-MD	G,L,SF	do	—	do	—	do	—	WNDE	—	UTS	—	UTS	—	
99	Industrial Gas Associates, Lewis M. Stout # 1	Taylor	do	39°17'05"	80°09'32"	360	2,421	MD	G,SF	do	—	do	—	do	—	do	—	do	—	do	—	
100	Consolidated Gas Supply Corp., Blanche Swisher	do	do	39°17'12"	79°59'14"	460	1,356	U-MD	G,SF	do	—	do	—	do	—	do	—	33	256	do	—	QWC
101	Consolidated Gas Supply Corp., W. W. Nester	Tucker	do	39°12'51"	79°46'12"	556	2,652	LS	G,L	do	—	do	—	1,981	110+	732	1,070	Absent	—	Absent	—	
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	do	—	do	—	1,469	147	716	629	UTS	—	UTS	—	QWC
103	Cities Service Oil Company, USA T-1	Tucker	do	39°13'28"	79°35'00"	621	2,129	LS	do	do	—	do	—	1,446	59+	686	640	Absent	—	Absent	—	
104	Hope Natural Gas Co., West Virginia Board of Control	Randolph	do	38°42'26"	79°58'09"	620	3,999	MO	do	do	—	2,454	920+	1,067	113	131	750	do	—	do	—	QWC; S
105	Craymon Stanton, Inc., Pardee & Curtin Lumber Co. #1	Webster	do	38°30'10"	80°21'45"	495	2,647	UO	do	do	—	WNDE	—	2,040	96	1,355	567	-89	25	UTS	—	
106	Hope Natural Gas Co., West Virginia & Pittsburgh Railroad Co.	do	do	38°19'47"	80°27'06"	768	2,270	LD	do	do	—	do	—	WNDE	—	1,402	100+	UTS	—	do	—	
107	J. C. Baker & Son, Inc., J. C. Baker and Son, No. 1	Braxton	do	38°47'59"	80°33'14"	268	2,187	do	G,SF	do	—	do	—	do	—	1,757	161+	NPAR	—	do	—	QWC
108	Consolidated Gas Supply Corp., Lafayette Mick	Gilmer	do	38°53'56"	80°37'26"	373	716	LM	do	do	—	do	—	do	—	WNDE	—	NPAR	—	do	—	
109	Consolidated Gas Supply Corp., I. N. Brown #11889	Braxton	do	38°50'07"	80°39'05"	336	1,422	U-MD	do	do	—	do	—	do	—	do	—	400	8	do	—	
110	Consolidated Gas Supply Corp., I. N. Brown # 11329	do	do	38°49'09"	80°38'59"	432	753	LM	do	do	—	do	—	do	—	do	—	WNDE	—	do	—	
111	Consolidated Gas Supply Corp., F. J. Dobbins	do	do	38°42'28"	80°49'39"	446	2,059	LD	do	do	—	do	—	do	—	1,551	60+	NPAR	—	do	—	QWC
112	Hope Natural Gas Co., Ed L. Boggs	do	do	38°41'08"	80°49'44"	322	1,932	do	L,SF	do	—	do	—	do	—	1,536	75+	do	—	do	—	
113	Westrans Petroleum Inc., William J. Mohr Heirs # 1	Gilmer	do	38°47'22"	80°52'05"	288	2,081	do	G,L,SF	do	—	do	—	do	—	1,668	121+	454	2	do	—	
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	—	2,865	1,585	2,246	37	1,529	562	NPAR	—	do	—	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)	Unit A Thickness (m)	Potential Reservoir Unit B Depth to top (m)	Unit B Thickness	Potential Reservoir Unit C Depth to top (m)	Unit C Thickness	Potential Reservoir Unit D Depth to top (m)	Unit D Thickness	Potential Reservoir Unit E Depth to top (m)	Unit E Thickness	Potential Reservoir Unit F Depth to top (m)	Unit F Thickness	Remarks
115	Joarus Oil Corp., Allen Beard, G.F. Dillon #2	Roane	W.Va.	38°46'29"	81°12'54"	258	2,438	UO	G,SF	WNDE	—	WNDE	—	2,095	36	1,447	503	ND	—	UTS	—	No log for Unit E part of section; S
116	United Fuel Gas Co., United Fuel Gas Fee	do	do	38°36'30"	81°19'04"	278	2,242	LS	G,L,SF	do	—	do	—	1,921	39+	1,356	433	390	—	do	—	Unit E, NPAR
117	United Fuel Gas Co., U.F.G. Co. Fee	Clay	do	38°27'12"	81°15'54"	348	2,482	UO	do	do	—	do	—	1,914	24	1357	414	NPAR	—	do	—	QWC
118	Harry Holtom, Bruen #1	Kanawha	do	38°29'06"	81°35'10"	239	1,991	do	G,SF	do	—	do	—	1,718	22	1,224	362	ND	—	do	—	No log for Unit E part of section; S
119	Exxon Corp., Walter N. McCoy et al. #1	Jackson	do	38°43'45"	81°34'18"	278	5,387	PreЄ	do	3,737	366?	2,420	1,224	1,841	23	1,301	401	482	2	239	119	QWC
120	United Fuel Gas Co., T.W. Heinzman	Roane	do	38°47'02"	81°30'23"	251	2,160	MO	L	WNDE	—	WNDE	—	1,895	35	1,337	414	475	6	UTS	—	
121	Pennzoil United Inc., L.G. Helmick #1	Jackson	do	38°52'40"	81°33'57"	324	851	D	G	do	—	do	—	WNDE	—	WNDE	—	502	1	do	—	QWC
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	do	—	do	—	1,637	42+	1,173	334	497	5	do	—	
123	Commonwealth Gas Corp., Frank Hardy #3	Putnam	do	38°36'04"	81°46'38"	256	1,996	UO	G	do	—	do	—	1,687	26	1,220	343	498	3	do	—	
124	G.L. Cabot, No. 1 Hatfield Campbell Creek Coal	do	do	38°31'01"	81°48'37"	181	1,423	LD	L	do	—	do	—	WNDE	—	1,166	60+	481	6	do	—	
125	United Fuel Gas Co., Gladys Bailey et al.	do	do	38°28'29"	81°44'53"	236	1,681	US	G,SF	do	—	do	—	do	—	1,187	253+	450	5	do	—	QWC
126	Cyclops Corp., E. Kingery Unit #1	Cabell	do	38°31'25"	82°15'48"	199	2,607	PreЄ	G,L,SF	2,267	114	1,539	684	1,118	29	813	226	414	3	do	—	QWC
127	United Fuel Gas Company, Grover Arrington No. 1	Mason	do	38°42'53"	82°09'32"	182	2,632	do	G,L	2,297	135	1,593	660	1,162	25	823	289	363	15	do	—	
128	Columbia Gas Transmission Corp., John Bane	Gallia	Ohio	38°45'10"	82°15'50"	167	1,246	UO	G,SF	WNDE	—	WNDE	—	1,028	24	710	243	316	9	do	—	QWC
129	Quaker State Oil Refining Corp., R.L. & E.F. Cobb	do	do	38°50'06"	82°21'49"	180	1,084	do	G,L,SF	do	—	do	—	873	18	579	223	228	4	do	—	QWC
130	J. Stanley Goldberg, A.J. Payne #1	Lawrence	do	38°43'51"	82°29'04"	183	2,134	PreЄ	G	1,776	157	1,180	524	771	16	500	190	UTS	—	do	—	
131	Eaststates Gas Producing Co., Cambria Clay #1-A	do	do	38°36'20"	82°38'35"	221	1,607?	UЄ	G,L	WNDE	—	1,032	543+	685	17	418	176	162	24	do	—	QWC
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	PreЄ	do	1,421	114	827	545	493	18	275	135	UTS	—	do	—	Unit C, NPAR; S
133	Commonwealth Gas Corp., D.P. Newell Jr. & Sr. #1	Greenup	Ky.	38°38'21"	83°03'05"	318	1,583	do	G,L,SF	1,131	126	541	531	NPAR	—	53	101	do	—	do	—	QWC; S
134	Ashland Oil and Refining Co., Dewey Wolfe #1	Lewis	do	38°33'09"	83°07'50"	336	1,549	do	do	1,080	114	427	593	do	—	20	85	do	—	UTSOA	—	QWC
135	Ralph Thomas, Daisey Adams #1	do	do	38°32'43"	83°12'59"	169	1,277	do	G	1,021	75	341	592	do	—	-73	96	do	—	do	—	QWC
136	United Carbon Co., Fred Felty #1	Greenup	do	38°25'00"	82°57'02"	215	1,276	LO	G,L,SF	WNDE	—	723	336+	do	—	215	102	17	35	UTS	—	
137	United Fuel Gas Co., Alice Shepherd #1	Lewis	do	38°22'48"	83°17'27"	277	1,387	PreЄ	do	1,052	50	381	578	do	—	-29	12	UTS	—	UTSOA	—	QWC
138	Carter Development Co., Oscar Coleman #4	Carter	do	38°20'00"	83°12'10"	262	1,093	UЄ	G,L	—	—	478	352+	do	—	49	38	—	—	do	—	QWC
139	United Fuel Gas Co., Lloyd Stamper et al.	do	do	38°19'40"	83°07'20"	258	1,550	PreЄ	G,L,SF	1,187	96	564	566	do	—	115	66	—	—	UTS	—	QWC; S
140	Pennzoil Co., Fannie Mays No. 1	Rowan	do	38°10'17"	83°19'40"	275	1,022	UЄ	do	WNDE	—	374	372+	do	—	-26	32	UTS	—	Absent	—	QWC
141	Pennzoil Co., Carmia Jones No. 1	do	do	38°09'55"	83°18'16"	364	1,521	PreЄ	do	1,110	38	304	721	do	—	-8	36	do	—	UTS	—	QWC; S
142	United Fuel Gas Co., I.G. Litton	Elliott	do	38°05'40"	83°11'50"	292	1,644	do	do	1,256	31	468	706	do	—	103	58	—	—	do	—	QWC; S
143	Monitor Petroleum Corp., Cecil Ison #1	do	do	38°08'07"	82°57'38"	206	2,946	M-LЄ	do	1,898	482	873	884	do	—	308	162	—	—	do	—	QWC
144	Inland Gas Co., Everett McDavid	Carter	do	38°10'25"	82°56'48"	241	3,042	LЄ	G,L	1,832	357	917	803	do	—	377	126	141	64	do	—	QWC
145	Inland Gas Co., Coalton Tract Fee #538	do	do	38°17'24"	82°48'00"	237	2,216	PreЄ	G,L,SF	1,678	137	908	693	do	—	411	134	183	36	do	—	QWC
146	Inland Gas Co., Inc., Coalton Tract Fee #533	Boyd	do	38°17'50"	82°45'45"	258	2,924	do	do	1,801	166	1,047	687	678	44?	471	133	230	34	do	—	QW-DST
147	Inland Gas Co., Inc., W.P. & Roberta Young	Lawrence	do	38°13'37"	82°44'40"	264	3,875	do	do	2,140	302	1,174	850	NPAR	—	552	180	311	29	do	—	QWC
148	Inland Gas Co., Inc., I.O. White heirs	Boyd	do	38°20'07"	82°40'17"	196	2,340	LЄ	do	WNDE	—	1,128	697	757?	40?	526	153	269	25	do	—	
149	Inland Gas Co., Inc., #551 Eva Smallridge	do	do	38°20'17"	82°39'43"	214	2,572	M-LЄ	do	1,922	177	1,122	731	773	17	540	158	280	35	do	—	QWC
150	Exxon Corp., Jay P. Smith #1	Wayne	W.Va.	38°13'19"	82°32'03"	181	4,458	PreЄ	G,SF	2,546	355	1,395	1,000	987	27	679	215	372	18	do	—	QWC
151	United Fuel Gas Co., Mineral Tract #1	do	do	38°04'56"	82°25'03"	328	718	UD	G	WNDE	—	WNDE	—	WNDE	—	WNDE	—	—	—	do	—	QWC
152	United Fuel Gas Co., UFG Co. Mineral Tract #23	Lincoln	do	38°03'40"	82°00'13"	366	1,225	U-MD	do	do	—	do	—	do	—	do	—	392	6	do	—	

Table 1.--Record of key wells--continued

Well number	Well name	County	State	Coordinate location		Elev. of GL (m)	Total depth (m)	Rock System at Total Depth	Data source	Potential Reservoir Unit A		Potential Reservoir Unit B		Potential Reservoir Unit C		Potential Reservoir Unit D		Potential Reservoir Unit E		Potential Reservoir Unit F		Remarks
				Lat.	Long.					Depth to top (m)	Thickness (m)	Depth to top (m)	Thickness	Depth to top (m)	Thickness	Depth to top (m)	Thickness	Depth to top (m)	Thickness	Depth to top (m)	Thickness	
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?	1,868	1,431	1,487	26	1,088	280	444	5	UTS	—	S
154	Owens-Libbey-Owens Gas Dept. Bull Creek Coal Land Co.	Boone	W.Va.	38°13'10"	81°39'22"	297	1,830	UO	L,SF	WNDE	—	WNDE	—	1,495	19	1,068	308	—	—	UTS	—	
155	Columbia Gas Trans. Corp., Black Band Coal & Coke Co.	Kanawha	do	38°16'24"	81°37'04"	304	1,683	US	G,SF	do	—	do	—	WNDE	—	1,120	259+	ND.	—	do	—	No Logs for Unit E & F parts of section; S
156	Columbian Carbon Co., Susan Hogue et. al.	do	do	38°17'43"	81°35'10"	334	1,741	MS	G,L,SF	do	—	do	—	do	—	1,143	264+	NPAR	—	do	—	
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	do	—	do	—	1,719	28	1,310	300	456	8	do	—	
158	Columbia Gas Transmission Corp., Sally Dickenson Todd	do	do	38°17'45"	81°22'25"	378	3,227	LO	G	do	—	2,295	551+	1,798	31	1,324	356	390	27	do	—	QWC
159	Shell Oil Co., Fowlke Meadow River Lands # 1	Fayette	do	38°06'40"	80°55'52"	625	2,592	LS	G,L,SF	do	—	WNDE	—	1,917	47+	1,454	384	UTS	—	do	—	QWC
160	Columbia Gas Trans. Corp., Westvaco # 1	Greenbrier	do	38°03'39"	80°43'57"	1,060	3,087	UO	G,SF	do	—	do	—	1,957	55+	1,480	401	104	3	do	—	QWC
161	Rotary Development Corp., New Gauley Coal Corp.	Nichols	do	38°10'56"	80°38'47"	776	2,388	US	G,L,SF	do	—	do	—	WNDE	—	1,460	149+	-188	4	do	—	
162	Tidewater Oil Co., U.S. Forest Service	Pocahontas	do	38°09'10"	80°00'41"	1,065	3,633	MO	do	do	—	1,644	920+	547	92	UTS	—	Absent	—	Absent	—	
163	United Fuel Gas, J. R. Damron	Greenbrier	do	37°41'39"	80°19'30"	866	2,141	UO	do	do	—	WNDE	—	1,180	90	566	544	NPAR	—	UTS	—	
164	Columbia Gas E. M. Thompson	do	do	37°57'45"	80°37'40"	876	1,034	UD	L	do	—	do	—	WNDE	—	WNDE	—	UTS	—	do	—	
165	Ashland Oil & Refining Co. Berwind-White Coal Mining #1	Fayette	do	37°56'20"	80°58'11"	902	2,845	LS	G,SF	do	—	do	—	do	—	1,463	322	do	—	do	—	
166	Columbia Gas Trans. Corp., F. W. Sawyers et al.	Raleigh	do	37°43'56"	80°58'57"	857	2,682	MS	G	do	—	do	—	do	—	1,553	267	247	10	do	—	Unit E mostly silt and shale
167	Anchor Petroleum Co. Elizabeth Ball # 1	Summers	do	37°41'32"	80°55'30"	571	2,521	UO	G,L,SF	do	—	do	—	1,883	55	1,533	294	322	71?	do	—	QWC
168	Phillips Petroleum Co., Beaver # A-1	Raleigh	do	37°40'28"	81°18'09"	621	2,144	LD	G,L	do	—	do	—	WNDE	—	1,459	59+	NPAR	—	103	114	
169	Owens Libbey-Owens, No. 2 W. Pocahontas	Wyoming	do	37°39'43"	81°25'54"	614	2,100	do	L,SF	do	—	do	—	do	—	WNDE	—	Absent	—	218	204	
170	Columbia Gas Trans. Corp., Dickenson Properties, Inc.	Raleigh	do	37°49'48"	81°18'41"	548	2,395	UO	G,L,SF	do	—	do	—	1,801	28	1,421	283	NPAR	—	71	245	QWC
171	Consolidated Gas Supply Corp., Loup Creek Colliery Div. II	Wyoming	do	37°44'25"	81°34'41"	477	2,067	MS	G,SF	do	—	do	—	WNDE	—	1,365	221+	544	4	242	136	QWC
172	Consolidated Gas Supply Corp., Federal Coal Company	Boone	do	37°59'57"	81°38'59"	392	2,002	do	do	do	—	do	—	do	—	1,337	255	560	2	UTS	—	QWC
173	Southeastern Oil & Gas Co., C. C. Chambers # 3	Logan	do	37°55'19"	81°55'53"	364	2,286	MO	G,L,SF	do	—	1,707	211+	1,374	22	1,010	243	390	3	145	87	
174	United Fuel Gas, Mingo and Wyoming Land & Coal Co.	Mingo	do	37°39'08"	81°54'40"	472	1,777	LD	do	do	—	WNDE	—	WNDE	—	1,272	30+	658	8	UTS	—	
175	Columbia Gas Trans., Mineral Tract # 10	do	do	37°54'19"	82°10'15"	285	5,972	Pre€	do	3,213	208?	1,526	1,465	1,205	24	858	227	360	28	119	42	S
176	United Fuel Gas Co., F. D. Caldwell et al. # 42	Wayne	do	37°53'29"	82°23'42"	210	2,408	U€	do	WNDE	—	1,430	768?	1,066	32	737	206	355	31	UTS	—	
177	United Fuel Gas Co., Jasper James et al.	Martin	Ky.	37°51'25"	82°31'19"	197	4,015	M-L€	do	2,536	171	1,347	1,052	985	12	656	217	326	37	133	53	
178	U.S. Signal, # 1 Elkhorn City Coal Corp.	Johnson	do	37°48'09"	82°43'20"	217	4,440	Pre€	do	2,460	129	1,104	1,012	NPAR	—	492	201	239	23	UTS	—	QWC; S
179	United Fuel Gas Co., S. W. McGuire	Floyd	do	37°41'19"	82°42'53"	264	794	MD	G,SF	WNDE	—	WNDE	—	do	—	529	1+	UTS	—	do	—	QWC
180	Kentucky-West Virginia Gas Co., Lark Howard	Magoffin	do	37°39'30"	82°58'57"	338	835	MS	L	do	—	do	—	do	—	330	166	do	—	do	—	
181	CNG Producing Co., Fred Howard # AA-2	do	do	37°47'36"	83°04'11"	302	822	LS	G,SF	do	—	do	—	do	—	222	141	62	18	UTS	—	QWC
182	Cumberland Petroleum Co., # 44 L. C. Bailey	do	do	37°51'17"	83°03'27"	310	1,545	LO	L	do	—	883	352+	do	—	ND	—	ND	—	ND	—	No log data for upper units
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	802	917	do	—	141	235	UTS	—	UTS	—	
184	Monitor Petroleum Corp., Freddy Ison # 1	Morgan	do	37°59'14"	83°02'24"	247	3,052	do	do	1,851	508	689	996	do	—	221	133	49	23	do	—	QWC; S
185	Ashland Oil & Refining Co., Lee Clay Products Co. # 1	do	do	38°02'40"	83°18'24"	237	1,755	Pre€	do	1,280	165	330	843	do	—	59	49	UTS	—	do	—	
186	Exxon Company, U.S.A., Orville Banks # 1	Wolfe	do	37°42'31"	83°22'04"	313	3,756	Pre€	do	1,997	212	607	1,110	do	—	224	68	NPAR	—	do	—	
187	Howard Atha et al., Dewey Tyra No. 1	do	do	37°45'53"	83°29'29"	315	1,463	U€	do	WNDE	—	388	756+	do	—	71	38	do	—	do	—	
188	United Fuel Gas, Frank Brown	Menifee	do	38°00'34"	83°30'47"	299	1,789	Pre€	do	1,180	143	235	811	do	—	-57	22	UTS	—	Absent	—	QWC; S
189	Monitor Petroleum Corp., Campbell # 1	do	do	37°52'24"	83°33'05"	341	2,069	do	do	1,474	228	234	942	do	—	-5	32	do	—	UTS	—	QWC
190	A. H. Carpenter, Maloney # 1	Powell	do	37°49'56"	83°45'41"	206	984	U€	G,SF	WNDE	—	112	665+	do	—	-117	11	Absent	—	Absent	—	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)	Unit A: Thickness (m)	Potential Reservoir Unit B: Depth to top (m)	Unit B: Thickness	Potential Reservoir Unit C: Depth to top (m)	Unit C: Thickness	Potential Reservoir Unit D: Depth to top (m)	Unit D: Thickness	Potential Reservoir Unit E: Depth to top (m)	Unit E: Thickness	Potential Reservoir Unit F: Depth to top (m)	Unit F: Thickness	Remarks
191	The Wider Oil Co., No. 1WD & WH	Lee	Ky.	37°41'37"	83°42'49"	293	954	LO	G,SF	WNDE	—	213	447+	NPAR	—	-38	24	Absent	—	UTS	—	
192	South Central Petroleum, No. 1, James Hall	Powell	do	37°48'30"	83°57'30"	230	1,914	M-L€	L,SF	do	—	45	1,020	do	—	UTS	—	do	—	Absent	—	QWC
193	Texaco, Inc., Tipton #1	Estill	do	37°40'20"	84°00'21"	194	2,078	do	G,L,SF	do	—	-40	1,175	do	—	Absent	—	NPAR	—	UTS	—	QWC; S
194	Texas West Bay Co., W.J. Hamilton #1	Madison	do	37°35'03"	84°19'27"	301	2,098	do	G	do	—	-85	1,331	do	—	do	—	Absent	—	Absent	—	
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+	-149	981	do	—	do	—	do	—	do	—	
196	Texaco, Inc. No. 1 Park Wolfinbarger	Jessamine	do	37°49'08"	84°30'30"	293	1,851	do	do	1,008	526	-226	1,035	do	—	do	—	do	—	UTS	—	QWC
197	Texaco Inc., Leonard Kirby #1	Garrard	do	37°43'02"	84°37'56"	293	1,751	do	do	1,088	335	-204	1,090	do	—	do	—	do	—	do	—	QWC
198	Clinton Oil Co., George and Cristine Hale #1-Y	do	do	37°42'09"	84°29'02"	208	1,688	L€	G,SF	1,187	288+	-212	1,091	do	—	do	—	do	—	do	—	QWC
199	Patrick Petroleum Co., #1, C.C. Broaddus & E.C. Tussey	do	do	37°37'20"	84°29'09"	286	1,548	do	do	1,209	48+	-223	1,145	do	—	do	—	do	—	do	—	QW-DST
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	—	-181	1,218	do	—	do	—	do	—	do	—	QWC; S
201	Rome Oil and Gas Co., Foster-Morrow Unit #1	Lincoln	do	37°32'10"	84°42'02"	310	1,762	do	do	1,328	119+	-174	1,214	do	—	do	—	do	—	Absent	—	QWC
202	The California Co., A.R. Spears #1	do	do	37°27'20"	84°47'20"	343	1,864	Pre€	do	1,235	174	-211	1,156	do	—	do	—	do	—	do	—	
203	Amerada Hess Corp., Hirstel Daulton #1	Pulaski	do	37°07'21"	84°38'52"	318	2,050	do	do	1,618	104	-55	1,304	do	—	do	—	do	—	do	—	QWC
204	Amerada Hess Petrol. Corp., Ray Edwards, et al. #1	do	do	37°05'14"	84°33'37"	288	2,703	do	do	2,358	41	46	1,415	do	—	do	—	do	—	UTS	—	QW-DST; S
205	Kin Ark Oil Co., Burgess Abney #1	Rockcastle	do	37°20'43"	84°12'15"	344	838	LO	do	WNDE	—	100	393+	do	—	-122	3	do	—	do	—	
206	Ferguson and Bosworth, Martha Bond #1	Jackson	do	37°25'23"	84°03'51"	433	955	do	do	do	—	158	361+	do	—	-124	12	do	—	do	—	QWC
207	Monitor Petroleum Corp., Stanley Neeley #1	do	do	37°27'13"	83°56'51"	410	3,111	L€	do	2,610	88+	230	1,314	do	—	-83	42	do	—	do	—	
208	Monitor Petroleum Corp. #1 Brandenburg Minerals-R. Newman	Lee	do	37°31'36"	83°48'49"	267	952	LO	do	WNDE	—	305	378+	do	—	19	15	do	—	do	—	QWC
209	Petroleum Exploration Corp., No. 3, J.C. Botner	Owsley	do	37°28'08"	83°46'38"	303	1,156	do	L	do	—	401	452+	do	—	67	52	UTSOA	—	do	—	
210	Algonquin Petroleum Co., Hubbard #1	Clay	do	37°10'15"	83°56'31"	360	1,948	M-L€	G,L,SF	do	—	300	1,123	do	—	Absent	—	—	—	-142	53	QWC
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	753	1,104	do	—	380	56	290	8	105	89	S
212	United Fuel Gas Co., S.W. Williams	Breathitt	do	37°32'18"	83°17'04"	229	3,392	do	G,L,SF	2,163	61	780	1,054	do	—	353	75	237	17	UTS	—	QWC
213	Ashland Oil Eastern Kentucky Realty Co.	Knott	do	37°21'11"	83°01'10"	495	1,166	MS	G,SF	WNDE	—	WNDE	—	do	—	529	105	342	39	124	140	QWC
214	Cities Service Oil Co., Kelley "A" #1	do	do	37°14'04"	83°01'23"	343	963	UD	do	do	—	do	—	do	—	WNDE	—	495	15	UTS	—	
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	do	—	do	—	do	—	664	87	522	18	217	158	
216	Kentucky-West Virginia Gas Co., W.J. Caudill	Letcher	do	37°07'10"	82°59'59"	540	1,284	UD	G,SF	do	—	do	—	do	—	WNDE	—	584	22	315	173	
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	do	do	—	do	—	do	—	897	133	611	32	265	212	QWC
218	Kentucky-West Virginia Gas Co., Marion Hunter	Knott	do	37°27'35"	82°51'14"	322	1,204	UO	do	do	—	do	—	do	—	557	157	315	50	UTS	—	
219	Signal Oil and Gas Co., Hall #1	Floyd	do	37°29'35"	82°45'29"	206	3,962	Pre€	do	2,417	143	1,094	1,040	do	—	581	162	341	25	192	40	S
220	Signal Oil and Gas Co., Stratton #1	Pike	do	37°28'55"	82°27'47"	359	3,801	do	G,L,SF	2,615	132	1,390	1,058	1,120	25	874	148	532	32	217	157	S
221	Columbia Gas Trans. Corp. The Pittston Co. # 21 well	Buchanan	Va.	37°18'06"	82°15'01"	496	1,756	LD	G	WNDE	—	WNDE	—	WNDE	—	1,224	32+	759	27	312	203	
222	Columbia Gas Trans. Corp., B. Mullins	Dickenson	do	37°16'44"	82°15'32"	462	2,853	LO	G,L	do	—	1,739	647+	1,462	34	1,227	140	752	25	334	230	S
223	United Fuel Gas Co., The Pittston Co. #7 well	do	do	37°12'58"	82°16'48"	477	1,366	UD	G,SF	do	—	WNDE	—	WNDE	—	WNDE	—	843	27	500	167	
224	Columbia Gas Trans. Corp., John W. Pabst, et al.	Buchanan	do	37°09'56"	82°08'31"	509	2,225	LS	G,L	do	—	do	—	1,654	58+	1,441	137	—	—	577	181	S
225	Penn-Ohio Gas Co., Clinchfield Coal Co. #1	Russell	do	37°01'46"	82°08'46"	631	1,878	UD	L,SF	do	—	do	—	WNDE	—	WNDE	—	971	85?	596	268	
226	Consolidated Gas Supply Corp., Rose L. Dennis	McDowell	W.Va.	37°29'28"	81°56'39"	414	1,789	US	G,SF	do	—	do	—	do	—	1,309	62+	746	104	315	241	QWC
227	United Fuel Gas Co., Warren Simpson Coal & Land Corp. #13	do	do	37°28'46"	81°45'25"	405?	1,179	UD	do	do	—	do	—	do	—	WNDE	—	739	20	340	210	QWC
228	Phillips Petroleum Co., Wilson #1	Mercer	do	37°21'07"	81°11'19"	794	2,163	UO	G,L,SF	do	—	do	—	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)	Potential Reservoir Unit B Depth to top (m)	Potential Reservoir Unit B Thickness	Potential Reservoir Unit C Depth to top (m)	Potential Reservoir Unit C Thickness	Potential Reservoir Unit D Depth to top (m)	Potential Reservoir Unit D Thickness	Potential Reservoir Unit E Depth to top (m)	Potential Reservoir Unit E Thickness	Potential Reservoir Unit F Depth to top (m)	Potential Reservoir Unit F Thickness	Remarks
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	—	WNDE	—	WNDE	—	WNDE	—	789	8	355	242	
230	United Fuel Gas Co., New River & Pocahontas Consol. Coal Co. #34	Tazewell	Va.	37°11'25"	81°44'40"	879	1,739	do	G,SF	do	—	do	—	do	—	do	—	821	12	421	215	
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	153; 2,256 FR	570; 1,214 FR	1,979	34	1,759	116	—	—	—	—	S
232	Tidewater-Wolf's Head, E. D. Smith #1	Scott	do	36°38'56"	82°19'02"	444	2,201	UO	do	WNDE	—	WNDE	—	1,657	85	1,593	15	1,017	3	UTS	—	
233	Columbia Gas Trans. Corp., Pennsylvania-Virginia Corp.	Wise	do	36°53'44"	82°34'00"	1,052	2,547	MO	do	do	—	803	688+	468	93	262	125	UTS	—	do	—	
234	Ray Resources Corp., Georgia Pacific Corp. #154	Harlan	Ky.	36°59'41"	83°09'53"	517	1,475	MS	G	do	—	WNDE	—	NPAR	—	842	51	712	5	370	238	
235	Ray Resources Corp., Georgia Pacific Corp. #153	do	do	36°58'18"	83°11'26"	500	1,621	M-UO	do	do	—	do	—	do	—	840	48	—	—	366	244	
236	Shell Oil Company, L. S. Bales No. 1	Lee	Va.	36°37'03"	83°21'15"	421	2,444	U€	G,L,SF	do	—	-173	2,193+	Absent	—	Absent	—	Absent	—	Absent	—	Younger units faulted out
237	Columbian Carbon Well #1410, Kentenia Corp. #1	Harlan	Ky.	36°46'30"	83°24'58"	564	1,471	MS	do	do	—	WNDE	—	NPAR	—	848	28	768	7	365	219	
238	United Fuel Gas Co., James Knuckles #2	Bell	do	36°44'56"	83°39'44"	451	3,058	L€	do	2,540	64+	881	1,316	do	—	547	18	272	5	99	132	
239	Petroleum Exploration Co., No. 2 Abe Carnes	Knox	do	36°49'27"	83°47'44"	320	1,988	U€	G,SF	WNDE	—	580	1,086+	do	—	298	18	Absent	—	26	141	S
240	Weaver Oil & Gas Corp. et al., Jack Stewart et al. #1	Whitley	do	36°41'11"	83°54'34"	344	923	LS	do	do	—	WNDE	—	do	—	Absent	—	do	—	216	142	QWC
241	Freida Roach-American Petrd. Co., Josephine Vermillion #1	do	do	36°35'31"	84°09'41"	330	734	S	G	do	—	do	—	do	—	PD	—	do	—	UTS	—	
242	Graham-Michaelia Drilling Co., Oscar White #1	do	do	36°47'47"	84°12'20"	330	405	UM	G,SF	do	—	do	—	do	—	do	—	do	—	-76	151+	
243	Howard Sober, Inc., Cumberland Minerals Co. Inc., #30 & G.	Laurel	do	36°58'33"	84°18'03"	354	2,238	M-L€	G,L,SF	do	—	271	1,460	do	—	Absent	—	do	—	UTS	—	
244	Sam Day & Co., Stearns No. 1	McCreary	do	36°40'17"	84°31'17"	387	1,100	LO	G,SF	do	—	242	469+	do	—	do	—	do	—	do	—	
245	Jerome Goldberg; Lewis Turpin #1	Wayne	do	36°46'16"	84°40'34"	282	1,129	U€	do	do	—	196	650+	do	—	ND	—	ND	—	ND	—	No logs for upper units
246	El Pamco, C. C. Sherrill #1	Clay	Tenn.	36°36'00"	85°25'01"	314	612	LO	G	do	—	-17	315+	do	—	Absent	—	Absent	—	Absent	—	S
247	Perry Fulk, No. 1A Della Bronstetter	do	do	36°29'39"	85°30'29"	169	358	do	L	do	—	-69	258+	do	—	do	—	do	—	do	—	
248	Midwestern Petroleum Corp., No. 5 Wesley Flatt	do	do	36°28'50"	85°29'34"	176	399	do	do	do	—	-73	297+	do	—	do	—	do	—	do	—	
249	Bradfield and Bartle, Grady Pigg No. 1	Jackson	do	36°18'25"	85°32'10"	299	581	do	G,L,SF	do	—	-137	435+	do	—	do	—	do	—	UTS	—	Bottom of Unit F exposed at land surface; S
250	C. A. Perry & Sons, Inc., Verble #1	Putnam	do	36°12'15"	85°25'55"	392	305	MO	G	do	—	-131	44+	do	—	do	—	do	—	do	—	
251	Stanolind Oil & Gas Co., No. 1 Hyder	do	do	36°09'30"	85°25'30"	326	649	LO	L	do	—	-65	389+	do	—	do	—	do	—	do	—	
252	Marine Carrier Inc. (Bob Stuard) Dr. T. R. Billings No. 1	Overton	do	36°23'50"	85°15'50"	327	597	do	G	do	—	-10	281+	do	—	do	—	do	—	do	—	S
253	Petroten, Inc., No. 1, O. Allred	do	do	36°19'32"	85°12'05"	272	570	do	L	do	—	7	292+	do	—	do	—	do	—	do	—	
254	Ratliff Farms, Koppers & Abston Units #1	do	do	36°18'30"	85°08'13"	575	869	do	G	do	—	34	259+	do	—	do	—	do	—	do	—	
255	Jervian Corp., No. 1 Brier Hill	do	do	36°16'35"	85°07'05"	558	920	do	L	do	—	41	322+	do	—	do	—	do	—	do	—	
256	C. G. Collins & Western Reserves Oil Co., Plateau Properties "A"	Putnam	do	36°06'30"	85°09'40"	588	1,104	do	G	do	—	-14	528+	do	—	do	—	do	—	do	—	
257	Perry Fulk Oil Co., No. 1 Walker Trustees	Fentress	do	36°09'14"	85°04'59"	568	1,017	do	L	do	—	86	364+	do	—	do	—	do	—	-385	254	
258	Monitor Petroleum Corp., Gernt Estate #3	do	do	36°20'05"	84°59'50"	531	2,380	Pre€	G,L	1,778	55	28	1,366	do	—	do	—	do	—	UTS	—	QWC; S
259	Associated Oil & Gas Exploration Co., Sells #1	Pickett	do	36°34'15"	85°02'31"	270	1,773	do	do	1,199	29	-69	1,235	do	—	do	—	do	—	do	—	S
260	Lee Ratner, Davis #1	Fentress	do	36°32'25"	84°59'45"	274	570	LO	G	WNDE	—	-35	331+	do	—	do	—	do	—	do	—	
261	Petroleum Development Corp., Koppers West #1	do	do	36°31'25"	84°50'15"	507	1,055	do	G,SF	do	—	87	461+	do	—	do	—	do	—	do	—	
262	Red Feather Gas & Oil Co., No. B-1 Carson Hull	do	do	36°20'50"	84°45'40"	432	488	UO	L	do	—	WNDE	—	do	—	do	—	do	—	-208	209	
263	Riley Oil Co., Louise Lanham #1	Morgan	do	36°17'10"	84°45'10"	450	2,445	M-L€	G,L	do	—	187	1,389	do	—	do	—	do	—	UTS	—	QWC; S
264	Ben E. Tate, Trustee, Baker-Pemberton #1	do	do	36°18'05"	84°39'12"	471	1,682	U€	do	do	—	270	941+	do	—	do	—	do	—	do	—	
265	Martin Shurin, Jr., L. J. West #1	Scott	do	36°27'23"	84°25'48"	485	1,857	do	do	do	—	427	946+	do	—	do	—	do	—	2	189	
266	Howard Atha, Ketchen Coal Company, No. 1	do	do	36°33'57"	84°22'26"	356	2,303	M-L€	do	do	—	415	1,310	do	—	do	—	do	—	-12	174	QWC; 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)	Potential Reservoir Unit B Depth to top (m)	Potential Reservoir Unit B Thickness	Potential Reservoir Unit C Depth to top (m)	Potential Reservoir Unit C Thickness	Potential Reservoir Unit D Depth to top (m)	Potential Reservoir Unit D Thickness	Potential Reservoir Unit E Depth to top (m)	Potential Reservoir Unit E Thickness	Potential Reservoir Unit F Depth to top (m)	Potential Reservoir Unit F Thickness	Remarks
267	Dr. Paul F. Fletcher, American Assoc. Mining Co. #1	Claiborne	Tenn.	36°30'10"	83°55'15"	442	1,068	MS	G,L,SF	WNDE	—	WNDE	—	NPAR	—	Absent	—	Absent	—	127	375	
268	Moore and Weaver, Meredith #1	Campbell	do	36°25'38"	84°15'48"	426	1,166	MO	G,SF	do	—	597	140+	do	—	do	—	do	—	—	—	
269	Columbian Carbon, No. 1 East Tenn. Iron & Coal	do	do	36°19'13"	84°18'34"	435	1,162	do	L	do	—	724?	?	do	—	do	—	do	—	177	184	
270	Petroleum Development Corp., Koppers #7	do	do	36°18'25"	84°17'45"	472	2,026	LO	G,SF	do	—	636	914+	do	—	do	—	do	—	216	189	
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; 635; 1,002 FR	848+; 249; 1,438 FR	do	—	do	—	do	—	Absent	—	Younger units faulted out; S
272	National Energy Corp. Browning & Welch, Briceville #1	do	do	36°09'11"	84°12'11"	347	1,060	MO	do	WNDE	—	—	—	do	—	do	—	do	—	373	216	
273	Columbian Carbon, #1 Tenn. Mining & Manufacturing	do	do	36°09'17"	84°22'40"	424	987	UO	L	do	—	WNDE	—	do	—	do	—	do	—	365	150	S
274	Geo, Inc. Windrock #3-#1	do	do	36°05'07"	84°19'50"	308	899	LM	G	do	—	do	—	do	—	do	—	do	—	359	152	
275	National Energy Corp., Coal Creek Mining & Manufac. Co. #1	do	do	36°04'30"	84°20'09"	306	889	UM	G,SF	do	—	do	—	do	—	do	—	do	—	367	122+	
276	Ladd Petroleum Corp., T. J. Kemmer #1	Cumberland	do	35°56'30"	84°49'15"	715	3,091	Pre€	do	2,254	106	-35	1,749	do	—	do	—	do	—	UTS	—	
277	Shell Oil Co., Guy Peterson #1	do	do	35°55'00"	84°51'18"	798	1,647	LO	G,L	WNDE	—	-210	1,058+	do	—	do	—	do	—	do	—	QWC
278	Kingwood, No. 1 Harrison	do	do	35°52'55"	85°06'25"	591?	1,130	do	L	do	—	153	386+	do	—	do	—	do	—	do	—	S
279	Mt. Carmel Drilling Co., E. C. Wall #1	White	do	35°54'39"	85°16'18"	485	493	U-MO	G,SF	do	—	WNDE	—	do	—	do	—	do	—	do	—	
280	Triangle Oil, Lem Spiva No. 1	do	do	35°53'26"	85°23'18"	339	688	LO	G,L,SF	do	—	do	—	do	—	do	—	do	—	do	—	Bottom of Unit F is at land surface
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	-240	1,564	do	—	do	—	do	—	Absent	—	S
282	Continental Tennessee, Inc., Walker-Flynt-Arnold Unit #1	Warren	do	35°40'24"	85°43'30"	286	2,001	do	G,SF	NPAR?	—	-209	1,414	do	—	do	—	do	—	UTS	—	Bottom of Unit F is at land surface
283	Godfrey L. Cabot, Inc., No. 1 Rocky River	Van Buren	do	35°34'15"	85°29'35"	548	1,544	U€	*L	WNDE	—	-8	1,004+	do	—	do	—	do	—	do	—	S
284	Magnolia Petroleum Co., W. H. Patterson #1	Grundy	do	35°22'30"	85°39'30"	577	1,345	do	G,L	do	—	-34	798+	do	—	do	—	do	—	do	—	QWC; S
285	Weaver Oil & Gas Corp., Pope Estate #1	Sequatchie	do	35°26'09"	85°20'20"	233	2,258	M-L€	do	do	—	149	1,425	do	—	do	—	do	—	Absent	—	

Table 3.--Some characteristics of potential reservoir intervals, individual porous zones and rock with confining potential in selected key wells.

a. Defined as potential reservoir interval mainly where top of unit and interval occurs between about 300 and 2500 meters below the National Geodetic Vertical Datum of 1929 (NGVD of 1929). Data on other intervals shown for comparison purposes.

b. Rock type: SS, sandstone; SLT, siltstone; SH, shale; DOL, dolomite; LS, limestone; ANHYD, anhydrite; B, basement; SALT, salt

c. N: number of items in sample

d. M: median value

e. R: range of values

f. Geophysical log types: BD, bulk density; N, neutron; R, resistivity; S, bore hole sonic; x, cross plot; +, no overlap of logs and no cross plot possible.

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

Well number	Top of interval in meters below NGVD of 1929 a/	Thickness of interval in meters	Dominant rock type for interval b/	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: N c/	M d/	R e/	Aggregate thickness of individual zones in meters	Porosity of individual zones in percent: N c/	M d/	R e/	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: Thickness in meters	Above: Rock type b/	Below: Thickness in meters	Below: Rock type b/	Geophysical logs used for porosity calculations. f/
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	do	6	1.8	0.6-3	10	6	6	5-11	7	187	LS,SH	1 to TD	?	do
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	do	1	-	-	17	1	-	-	5	94	SH,SS	64	SLT,SS	do
do	468	79	LS	5	2	0.6-5	11	5	9	5-9	8	64	SLT,SS	223	SH,SLT	do
230	481	60	do	6	1.2	0.6-2.1	8	6	10	6-15	10	51	LS	287	LS,SH	do
WEST VIRGINIA																
226	315	12	do	1	-	-	12	1	-	-	5	53	SH,SLT	159	SH,LS	BD
227	348	9	do	1	-	-	9	1	-	-	5	62	SH,SS	133	LS,SH	do

Table 3.--Some characteristics of potential reservoir intervals, individual porous zones and rock with confining potential in selected key wells--continued.

Well number	Top of Interval in meters below NGVD of 1929 a/	Thickness of interval in meters	Dominant rock type for interval b/	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: N c/	M d/	R e/	Aggregate thickness of individual zones in meters	Porosity of individual zones in percent: N c/	M d/	R e/	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: Thickness in meters	Above: Rock type b/	Below: Thickness in meters	Below: Rock type b/	Geophysical logs used for porosity calculations. f/
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	do
92	227	126	SS,SLT	11	1.5	0.3-5	23	11	7	5-15	9	119	SH,SLT	276	do	BD

Table 3.--Some characteristics of potential reservoir intervals, individual porous zones and rock with confining potential in selected key wells--continued.

Well number	Top of Interval in meters below NGVD of 1929 a/	Thickness of Interval in meters	Dominant rock type for Interval b/	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: N c/	M d/	R e/	Aggregate thickness of individual zones in meters	Porosity of individual zones in percent: N c/	M d/	R e/	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: Thickness in meters	Above: Rock type b/	Below: Thickness in meters	Below: Rock type b/	Geophysical logs used for porosity calculations f/
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 x BD
211	383	49	do	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
do	609	31	DOL	6	3	0.6-13	21	6	7	6-10	9	91	DOL, SH, ANHYD	537	SH	do
10	999	82	do	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 x 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
do	1,536	53	DOL	6	4	0.9-14	30	6	6	5-11	7	489	ANHYD, DOL, SALT	88	SH, DOL	do
23	1,311	81	DOL	6	1.2	0.6-3	10	6	7	5-13	8	45	DOL, ANHYD	81	DOL, SALT	N x BD
do	1,587	25	do	6	0.6	0.6-3	8	6	6	5-7	6	112	DOL	78	SH	do
26	447	31	do	10	0.6	0.6-4	13	10	6	5-13	7	443	SH	63	ANHYD, DOL, SH	do
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	do	3	3	1.8-4	9	3	7	5-7	6	46	LS	151	ANHYD, DOL	N
74	479	77	do	7	2.4	0.6-4	14	7	9	6-11	8	438	SH	46	DOL	BD
do	617	111	DOL	10	0.9	0.6-3	13	10	7	5-23	8	46	DOL	79	DOL, SH	do

Table 3.--Some characteristics of potential reservoir intervals, individual porous zones and rock with confining potential in selected key wells--continued.

Well number	Top of interval in meters below NGVD of 1929 a/	Thickness of interval in meters	Dominant rock type for interval b/	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: N c/	M d/	R e/	Aggregate thickness of individual zones in meters	Porosity of individual zones in percent: N c/	M d/	R e/	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: Thickness in meters	Above: Rock type b/	Below: Thickness in meters	Below: Rock type b/	Geophysical logs used for porosity calculations. f/
							POTENTIAL RESERVOIR UNIT D									
							OHIO CONTINUED									
79	323	76	DOL	5	1.2	0.9-2.4	8	5	8	5-14	8	269	SH	60	LS	NxBD
80	521	57	DOL	8	1.5	0.6-4	13	8	8	6-9	8	77	ANHYD, DOL, SH	509	SH	do
82	1,321	105	do	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	do
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	2014	19	DOL	4	1.8	1.8-2.1	8	4	5	5-5	5	67	LS	80	LS,DOL	BD
do	2,152	29	do	5	0.9	0.6-5	8	5	6	5-8	6	37	DOL	55	DOL	do
							WEST VIRGINIA									
20	1,105	55	LS	4	4	1.5-8	16	4	6	5-7	6	801	SH	42	LS	NxBD
do	1,201	42	do	5	1.5	1.5-5	12	5	5	5-6	6	42	LS	355	DOL,SH, SALT,ANHYD	do
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	do	11	1.8	0.6-4	20	11	10	6-20	11	256E	DOL,LS	80	DOL,SH	N+BD
53	1,668	48	CHRT	5	5	0.6-22	36	5	8	7-10	8	1551	SH,SLT	260	LS,SH	NxBD
57	1,673	80	SS	12	0.6	0.3-1.8	9	12	6	5-9	7	1,358	SH,SLT	30 TD	?	BD
66	941	239	LS,SS	33	1.2	0.3-18	78	33	6	5-15	8	1,148E	SH	41	SH,LS	N
do	1,220	151	LS,SS	18	1.8	0.6-9	55	18	6	5-8	6	41	SH,LS	40	do	do
do	1,411	73	do	12	1.8	0.3-7	22	12	5	5-6	6	40	do	89	LS	do
do	1,572	173	DOL	14	1.2	0.6-2.1	18	14	8	5-12	8	89	LS	69	DOL,SH	do
do	1,815	53	do	3	2.1	2.1-15	19	3	7	7-8	8	69	DOL,SH	1,036	SH,LS	do
86	1,314	158	LS,SS	12	0.9	0.3-5	14	12	8	5-17	11	800	SH	73	DOL,LS	BD

Table 3.--Some characteristics of potential reservoir intervals, individual porous zones and rock with confining potential in selected key wells--continued.

Well number	Top of interval in meters below NGVD of 1929 [a]	Thickness of interval in meters	Dominant rock type for interval [b]	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 N [c]	M [d]	R [e]	Aggregate thickness of individual zones in meters	Porosity of individual zones in percent N [c]	M [d]	R [e]	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, Thickness in meters	Above, Rock type [b]	Below, Thickness in meters	Below, Rock type [b]	Geophysical logs used for porosity calculations. [f]
			POTENTIAL RESERVOIR UNIT D													
			WEST VIRGINIA CONTINUED													
88	1,677	72	SS	7	0.9	0.9-6	12	7	5	5-7	6	490	SH	61	LS	BD
do	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	24	0.6-5	10	4	6	5-7	6	395	SH	47	SS	N x BD
105	1,357	86	do	13	0.9	0.6-3	13	13	5	5-7	6	1,248[E]	do	62	LS	BD
do	1,662	110	DOL	20	0.6	0.6-1.5	13	20	5	5-12	7	157	DOL, LS	88	DOL	do
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 to log top	?	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 x BD
do	1,422	50	LS	6	1.5	0.9-5	12	6	12	7-19	12	72	LS	76	DOL	do
159	1,526	35	LS	7	0.6	0.6-1.8	8	7	5	5-7	5	52	LS	64	LS	N x BD
161	1,468	132+	SS, LS, DOL	17	0.9	0.6-6	21	17	12	5-20	11	1,276[E]	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

Table 3.--Some characteristics of potential reservoir intervals, individual porous zones and rock with confining potential in selected key wells--continued.

Well number	Top of Interval in meters below NGVD of 1929 a/	Thickness of Interval in meters	Dominant rock type for Interval b/	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 N c/	M d/	R e/	Aggregate thickness of individual zones in meters	Porosity of individual zones in percent N c/	M d/	R e/	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: Thickness in meters	Above: Rock type b/	Below: Thickness in meters	Below: Rock type b/	Geophysical logs used for porosity calculations. f/
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 x BD
10	1,151	30	do	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 x BD
74	807	8	do	1	-	-	8	1	-	-	11	79	DOL,SH	24+	?	BD
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	do	2	8	1.5-15	16	2	6	5-7	7	148	SH	9 to TD	?	do
158	1,813	15	do	2	4	1.2-7	8	2	6	5-6	6	141	SH	695	SH,LS	BD+S

Table 3.--Some characteristics of potential reservoir intervals, individual porous zones and rock with confining potential in selected key wells--continued.

Well number	Top of interval in meters below NGVD of 1929 a/	Thickness of interval in meters	Dominant rock type for interval b/	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: N c/	M d/	R e/	Aggregate thickness of individual zones in meters	Porosity of individual zones in percent: N c/	M d/	R e/	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: Thickness in meters	Above: Rock type b/	Below: Thickness in meters	Below: Rock type b/	Geophysical logs used for porosity calculations. f/
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 x BD
do	949	98	do	24	0.9	0.3-2.1	21	24	6	5-18	7	35	DOL	86	SH, LS	do
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	do	14	1.2	0.6-6	20	14	6	5-11	7	329	LS, SH	37	DOL	N + R
do	936	139	do	14	0.6	0.6-1.8	13	14	5	5-8	6	37	DOL	189	DOL, SH	do
140	486	257+	do	35	0.9	0.3-11	45	35	8	5-16	9	71	LS	?	?	BD
141	600	141	do	20	1.8	0.6-5	45	20	7	5-15	7	36	DOL	86	DOL	do
do	828	114	do	9	1.8	0.6-3	17	9	7	5-11	6	86	do	185	DOL, SH	do
142	713	388	do	47	0.9	0.3-5	57	47	6	5-11	7	80	LS	156	DOL, SH	N
143	1,316	29	do	3	1.2	0.6-6	8	3	5	5-8	7	82	DOL	227	DOL	N x BD
144	1,224	129	do	15	1.5	0.6-9	37	15	7	5-	7	33	LS	110	do	do
145	1,167	169	DOL	16	0.9	0.6-3	23	16	6	5-14	7	49	LS	35	DOL	N x BD
do	1,372	70	do	8	1.2	0.6-2.1	11	8	6	5-7	6	35	DOL	41	do	do
146	1,286	63	SS, DOL	11	0.9	0.3-5	17	11	5	5-7	6	34	LS	34	DOL	do
do	1,504	42	DOL	7	0.9	0.6-2.4	8	7	7	5-8	7	31	DOL	57	do	do
147	1,486	37	SS	9	0.9	0.6-11	23	9	6	5-8	6	48	do	36	DOL	do
do	1,622	96	DOL	10	0.6	0.3-2.4	10	10	6	5-16	9	31	DOL	89	do	do
148	1,375	40	SS	8	1.2	0.3-9	21	8	7	5-8	8	38	LS	33	DOL	do
do	1,447	203	DOL, SS	28	0.6	0.3-4	32	28	7	5-15	8	33	DOL	45	do	do
do	1,695	62	DOL	7	0.6	0.6-3	8	7	5	5-7	6	45	do	138	DOL, SH	do
149	1,403	271	DOL, SS	48	0.6	0.3-5	48	48	8	5-24	9	47	LS	61	DOL	do
178	1,717	40	DOL, SS	3	3	2.4-4	9	3	7	6-10	8	110	do	305	do	BD x S
184	1,175	17	SS	5	0.9	0.3-3	8	5	5	5-9	7	171	LS, DOL	34	SS, DOL	do

Table 3.--Some characteristics of potential reservoir intervals, individual porous zones and rock with confining potential in selected key wells--continued.

Well number	Top of Interval in meters below NGVD of 1929 a/	Thickness of Interval in meters	Dominant rock type for Interval b/	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: N c/	Thickness: M d/	Thickness: R e/	Aggregate thickness of individual zones in meters	Porosity of individual zones in percent: N c/	Porosity: M d/	Porosity: R e/	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: Thickness in meters	Above: Rock type b/	Below: Thickness in meters	Below: Rock type b/	Geophysical logs used for porosity calculations. f/
POTENTIAL RESERVOIR UNIT B																
KENTUCKY CONTINUED																
210	490	67	LS	7	3	1.5-7	18	7	7	6-10	7	37	LS	55	LS	N
do	611	152	DOL	18	2.4	0.6-17	78	18	7	5-10	8	55	do	35	DOL	do
do	799	81	do	7	1.5	0.3-14	25	7	6	5-8	6	35	DOL	110	do	do
do	1,190	65	do	7	1.5	0.9-1.5	9	7	7	5-11	7	72	do	70	do	do
212	1,605	37	do	5	1.8	0.6-11	18	5	6	5-7	6	52	DOL	65	do	do
do	1,707	94	do	16	1.2	0.6-5	24	16	6	5-9	6	65	do	325	SLT, SH, LS	do
219	1,166	54	LS	8	0.6	0.6-5	12	8	6	5-24	10	480	SH, LS	84	LS	BD
do	1,679	172	DOL	13	1.2	0.9-7	29	13	7	5-23	10	46	DOL	79	DOL	do
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	do	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 X BD
11	2,353	30	SS	5	1.5	1.2-2.4	8	5	6	5-7	6	41	DOL	132	DOL, SH	do
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
do	1,033	28	do	5	1.5	0.9-2.1	8	5	5	5-8	6	52	DOL	43	DOL, SH	do

Table 3.--Some characteristics of potential reservoir intervals, individual porous zones and rock with confining potential in selected key wells--continued.

Well number	Top of Interval in meters below NGVD of 1929 [a]	Thickness of Interval in meters	Dominant rock type for Interval [b]	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: N [c]	M [d]	R [e]	Aggregate thickness of individual zones in interval in meters	Porosity of individual zones in percent: N [c]	M [d]	R [e]	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: Thickness in meters	Above: Rock type [b]	Below: Thickness in meters	Below: Rock type [b]	Geophysical logs used for porosity calculations. [1]
POTENTIAL RESERVOIR UNIT B																
OHIO CONTINUED																
17	1,650	82	DOL	7	1.5	1.2-3	13	7	7	6-15	8	66	LS	6 to TD	?	N+BD
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 x BD
26	1,450	111	DOL	10	0.9	0.6-5	18	10	5	5-9	6	70	LS	58	DOL	do
27	930	107	do	9	2.1	0.3-13	42	9	8	5-13	9	66	LS, SH	85	DOL, SH	N
28	886	33+	do	1	-	-	33	1	-	-	7	182	LS	2.7 to TD	?	N x BD
29	1,158	34	do	8	1.8	0.6-2.1	10	8	6	5-6	6	108	do	40	SH, DOL	N
do	1,232	67	do	8	1.2	0.9-2.4	11	8	7	5-11	7	40	SH, DOL	54	do	do
30	779	156	do	13	2.1	0.9-25	55	13	6	5-10	7	36	LS, SH	64	DOL, SH	BD
31	1,671	14	do	4	1.8	0.6-3	8	4	8	7-11	8	193	LS	34	DOL	BD
do	1,719	52	do	6	0.6	0.6-13	17	6	5	5-8	7	34	DOL	31 to TD	?	do
33	1,904	81	do	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 x 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 x BD
do	1,260	153	DOL	23	3	0.6-33	106	23	7	5-10	7	34	do	79	SH, DOL	do
80	1,201	263	do	39	1.8	0.6-16	122	39	6	5-13	7	112	LS	77	DOL	N x 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 x BD
132	1,011	201	DOL	30	0.9	0.6-5	36	30	8	5-28	9	625	LS, SH	44	DOL	N x BD
TENNESSEE																
266	800	107	DOL	8	0.6	0.6-2.4	9	8	6	5-11	6	89	LS	91	LS	N x BD
do	998	136	do	9	0.6	0.3-11	13	9	9	5-35	10	91	LS, DOL	80	LS, DOL	do
do	1311	101	do	11	0.9	0.6-1.5	10	11	7	5-13	8	55	do	47	do	do
do	1216	40	SS, DOL	8	1.2	0.6-1.2	8	8	6	5-15	7	81	DOL	76	DOL	do
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
do	2,142	47	do	8	0.9	0.6-4	10	8	7	6-11	8	204	do	234	DOL	do

Table 3.--Some characteristics of potential reservoir intervals, individual porous zones and rock with confining potential in selected key wells--continued.

Well number	Top of Interval in meters below NGVD of 1929 a/	Thickness of Interval in meters	Dominant rock type for Interval b/	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: N c/	M d/	R e/	Aggregate thickness of individual zones in meters	Porosity of individual zones in percent: N c/	M d/	R e/	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: Thickness in meters	Above: Rock type b/	Below: Thickness in meters	Below: Rock type b/	Geophysical logs used for porosity calculations. f/
						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 to Basement		N x BD
134	1,168	23	SS	2	9	4-15	19	2	16	14-18	17	40	DOL	3 to Basement		BD
139	1,264	9	SS	1	-	-	9	1	-	-	10	189	DOL, SH	8 to Basement		N + R
141	1,126	21	SS	2	5	3-6	9	2	8	7-9	8	185	DOL, SH	0 to Basement		BD
142	1,257	27	do	5	0.9	0.6-6	9	5	6	5-8	6	156	do	2.1 to Basement		N
144	2,145	43	do	2	7	2.8-11	13	2	12	10-14	13	160	do, do	202	SS, DOL	N X BD
188	1,180	90	SS, LS	7	4	0.9-7	24	7	11	7-13	11	223	SH, LS	37	SH	N x BD
189	1,475	113	SS	13	1.2	0.6-9	28	13	7	5-12	7	347	do	49	SLT, SS	BD
195	1,185	17	do	3	4	2.7-4	11	3	10	8-10	9	460	SH, LS	52	SH, SLT	BD x S
do	1,254	366	do	45	1.2	0.6-2.7	64	45	6	5-14	7	52	SH, SLT	30 to Basement		do
196	1,026	12	do	1	-	-	12	1	-	-	12	303	SH, DOL	47	SS, DOL	N x BD
do	1,084	402	SS, LS	57	2.1	0.6-8	149	57	8	5-14	9	47	SS, DOL	30	SS, SLT	do
199	1,209	8	SS	1	-	-	8	1	-	-	7	273	SLT, SH	23+	SLT, SH	S
201	1,336	91+	do	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	24	0.6-6	11	4	6	5-8	6	384	SH, LS	15 to Basement		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
do	1,665	25	SS	7	0.9	0.6-2.4	8	7	6	6-7	6	126	DOL	5 to Basement		do
12	1,037	21	do	1	-	-	21	1	-	-	11	37	DOL, SH	0 to Basement		do
13	1,212	14	do	4	2.1	0.9-3	8	4	6	6-7	7	81	DOL	0.9 to Basement		do
26	1,783	17	do	6	1.2	0.9-1.8	8	6	8	5-9	7	158	do	16 to Basement		N X BD
27	1,231	27	do	3	5	2.1-15	22	3	8	7-14	12	56	do	0 to Basement		N
29	1,468	32	do	6	3	1.5-5	18	6	8	6-13	9	105	DOL	0 to Basement		N
30	1,033	97	DOL, SS	12	0.9	0.6-4	17	12	12	5-18	13	33	DOL	4 to Basement		N x BD
33	2,049	18	DOL	1	-	-	17	1	-	-	6	64	do	254 to Basement	DOL, SS	N
79	1,601	19	SS	5	1.5	1.2-2.7	9	5	15	6-16	14	91	do	11 to Basement		N x BD
80	1,541	48	DOL	6	1.5	0.6-5	15	6	5	5-8	6	77	do	67	DOL	N x BD
do	1,657	16	SS	5	1.2	0.9-3	8	5	10	7-10	9	67	do	10 to Basement		do
130	1,897	18	do	4	1.8	0.9-5	9	4	8	6-8	7	219	DOL, SH	18 to Basement		N + BD
132	1,517	16	SS, DOL	2	4	0.9-8	9	2	10	7-14	13	175	DOL, SH	2.1 to Basement		N x BD
						TENNESSEE										
258	1,802	18	SS	1	-	-	18	1	-	-	7	460	SH, SLT	11 to Basement		N x S
259	1,201	27	DOL, SS	3	5	3-15	23	3	7	6-8	7	78	LS, SH	0 to Basement		N

Table 3.--Some characteristics of potential reservoir intervals, individual porous zones and rock with confining potential in selected key wells--continued.

Well number	Top of interval in meters below NGVD of 1929 [a]	Thickness of interval in meters	Dominant rock type for interval [b]	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: N [c]	M [d]	R [e]	Aggregate thickness of individual zones in meters	Porosity of individual zones in percent: N [c]	M [d]	R [e]	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: Thickness in meters	Above: Rock type [b]	Below: Thickness in meters	Below: Rock type [b]	Geophysical logs used for porosity calculations. [f]
	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 to Basement		N x BD
134	1,168	23	do	2	9	4-15	19	2	16	14-18	17	40	DOL	3 to Basement		BD
139	1,264	9	do	1	-	-	9	1	-	-	10	189	DOL,SH	8 to Basement		N + R
141	1,126	21	do	2	5	3-6	9	2	8	7-9	8	185	DOL,SH	0 to Basement		BD
142	1,257	27	do	5	0.9	0.6-6	9	5	6	5-8	6	156	DOL,SH	2.1 to Basement		N
144	2,390	371	do	33	1.2	0.6-4	52	33	11	6-25	12	202	SS,DOL	34 to TD	SS,SH	N x BD
145 [g]	1,880	32	do	7	1.8	0.6-5	15	7	12	6-15	12	197	DOL,SH	30 to Basement		do
146 [g]	2,077	93	SS	9	0.9	0.6-4	11	9	8	5-10	8	62	SH	40	SS,SLT	do
188 [g]	1,307	156	do	20	1.8	1.5-8	57	20	11	7-15	11	37	SH	11+	SH	do
189	1,475	113	do	13	1.2	0.6-9	28	13	7	5-12	7	347	SH,LS	49	SLT,SS	BD
195	1,185	17	do	3	4	2.7-4	11	3	10	8-10	9	460	SH,LS	52	SH,SLT	BD x S
do	1,254	366	do	45	1.2	0.6-2.7	64	45	6	5-14	7	52	SH,SLT	30 to Basement		do
199	1,209	8+	do	1	-	-	8	1	-	-	7	273	SLT,SH	22	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 to Basement		do
12	1,037	21	do	1	-	-	21	1	-	-	11	37	DOL,SH	0 to Basement		do
13	1,212	14	do	4	2.1	0.9-3	8	4	6	6-7	7	81	DOL	1 to Basement		do
26	1,783	17	do	6	1.2	0.9-1.8	8	6	8	5-9	7	158	do	16[E] to Basement		N x BD
27	1,231	27	do	3	5	2.1-15	22	3	8	7-14	12	56	do	0 to Basement		N
29	1,468	32	do	6	3	1.5-5	18	6	8	6-13	9	105	DOL	0 to Basement		do
79	1,601	19	do	5	1.5	1.2-2.7	9	5	15	6-16	14	91	do	11 to Basement		N x BD
80	1,657	16	do	5	1.2	0.9-3	8	5	10	7-10	9	67	do	10 to Basement		do
130	1,897	18	do	4	1.8	0.9-5	9	4	8	6-8	7	219	DOL,SH	18 to Basement		N + BD
132	1,517	16	SS,DOL	2	4	0.9-8	9	2	10	7-14	13	175	DOL,SH	21 to Basement		N x BD
							TENNESSEE									
258	1,802	18	SS	1	-	-	18	1	-	-	7	460	SH,SLT	11 to Basement		N x S
259	1,201	27	DOL,SS	3	5	3-15	23	3	7	6-8	7	78	LS,SH	0 to Basement		N