PRELIMINARY DELINEATION AND DESCRIPTION OF THE REGIONAL AQUIFERS OF TENNESSEE--CUMBERLAND PLATEAU AQUIFER SYSTEM

By J.V. Brahana, Jo Ann Macy, Dolores Mulderink, and Dawn Zemo

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Dallas L. Peck, Director

For additional information write to:

District Chief
U.S. Geological Survey
A-413 Federal Building
U.S. Courthouse
Nashville, Tennessee 37203

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FACTORS FOR CONVERTING INCH-POUND UNITS TO INTERNATIONAL SYSTEM OF UNITS (SI)

For the convenience of readers who may want to use International System of Units (SI), the data may be converted by using the following factors:

Multiply	By	To obtain
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)
gallons per minute (gal/min)	0.06309	liters per second (L/s)

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

The Cumberland Plateau aquifer system consists of Pennsylvanian sandstones, conglomerates, shales, and coals which underlie the Cumberland Plateau in Tennessee. Major water-bearing zones occur within the sandstones and conglomerates in interconnected fractures. The water-bearing formations are separated by shale and siltstone that retard the vertical circulation of ground water. The Pennington Formation serves as the base of this aquifer system and is an effective confining unit.

The Cumberland Plateau aquifer system is an important water source for the Cumberland Plateau. Wells and springs from the aquifer system supply most of the rural domestic and public drinking-water supplies. water from wells drilled into the Cumberland Plateau aquifer system is generally of good to excellent quality. Of the 32 water-quality analyses on file from this aquifer, only 2 had dissolved-solids concentrations greater than 500 milligrams per liter, and about three-fourths had less than 200 milligrams per liter dissolved solids. However, no samples from depths greater than 300 feet below land surface have been recorded. Ground water from locations where the sandstones are buried deeply, such as the Wartburg basin, may contain dissolved-solids concentrations greater than 1,000 milligrams per liter.

INTRODUCTION

The Safe Drinking Water Act (P.L.93-523) includes provisions for the protection of underground sources of drinking water. Specifically, Part C of the Act authorizes the Environmental Protection Agency to establish regulations to insure that injection of contaminants will not endanger existing or potential sources of drinking water. The regulations developed by EPA require that all underground sources of water with less than 10,000 milligrams per liter (mg/L) dissolved solids be designated for protection whether or not they are currently being used as a source of drinking water.

The eight major aquifer systems of Tennessee have been delineated on a regional basis and are characterized by a unique set of hydrologic conditions, as well as a distinguishing water quality. The aquifer systems are commonly separated from one another by confining units or zones in which the vertical hydraulic conductivity is less than in the aquifer system. The hydrologic effectiveness of the confining units is variable and depends on the local geology. In general, the confining units restrict, but do not exclude, flow between aquifers on a regional scale.

The purpose of this report is to describe the formations that comprise the Cumberland Plateau aquifer system (fig. 1) and to delineate zones within this aquifer system that are actual or potential drinking-water sources. This report provides generalized information on (1) the areal and stratigraphic occurrence of the aquifer and the water within, (2) dissolved-solids content of the ground water, (3) area of ground-water use and potential use, (4) the hydraulic character of the aquifer, (5) the areas of known ground-water contamination, and (6) the known locations of current and potential hydrocarbon, mineral, and geothermal resources in the sequence of geologic formations that includes all of the Pennsylvanian rock units in this area. Formation names used in this report are those of the Tennessee Division of Geology (Miller, 1974) and do not necessarily follow the usage of the U.S. Geological Survey.

GEOLOGY

The Cumberland Plateau aquifer system underlies the Cumberland Plateau (fig. 2) and consists of nine geologic rock units of Pennyslvanian age with highly varied permeabilities (table 1). The upper two-thirds of the aquifer system is primarily shale with thin interbedded sandstones, coals, and siltstones. The lower one-third contains fewer shales and thicker sandstone beds that are commonly conglomeratic. The top of the thick, impermeable Pennington Formation is defined as the base for the Cumberland Plateau aquifer system and is an effective regional confining unit (table 2; fig. 2). It is composed of several hundred feet of shale, siltstone, and fine-grained dolomite.

Throughout most of the Plateau, the rocks of the aquifer system are nearly horizontal with a gentle dip of from 20 to 50 feet per mile toward the east. Although essentially undeformed, they are cut by faults in the central and northern parts of the area. Formations of the Cumberland Plateau are separated from the more intensely deformed Valley and Ridge Province to the east by a zone of thrust faulting and steeply dipping rocks marked by the Sequatchie Valley anticline, Walden Ridge, and the Pine Mountain thrust (fig. 2). Lines of section, which are located in figure 3 and shown in figures 4-7, generalize the structural relations of the rocks that comprise this aquifer system.

In addition to unpublished data, the following reports were used to compile the geology: Born and Burwell (1939); Wanless (1946); Stearns (1954); Wilson and others (1956); Hack (1966); Burwell and Milhous (1967a and b); and, Milici and others (1979).

HYDROLOGY

Ground water in the Cumberland Plateau aquifer system occurs almost exclusively within the Pennsylvanian sandstones and conglomerates. Although the sandstones have low intergranular permeability, secondary permeability is provided by fractures. Water in these sandstone units is effectively confined and separated by shale and siltstone beds with very low permeability. Almost all the ground water is under artesian pressure, and the water level in many wells rises to within a few feet of land surface (Newcome and Smith, 1958). The sandstone layers are classed as a single hydrologic unit because they exhibit similar hydraulic characteristics and contain water of similar chemical quality. A conceptual model of ground-water occurrence and flow in the Cumberland Plateau aquifer system is shown in figure 8.

The recharge of the Cumberland Plateau aquifer system is effectively limited to precipitation on the outcrops of the sandstones and conglomerates. Streams intersecting these outcrops may also contribute to recharge. The shale layers retard the downward movement of ground water and there is very little interformational movement from one sandstone to another, except along fractures.

For the most part, ground-water flow in the Cumberland Plateau aquifer system is shallow flow, with water flowing from points of recharge to points of discharge. In addition to providing base flow of streams, ground water also is discharged through springs, which are common in the escarpments bounding this aquifer system and in the walls of many deep, narrow stream valleys, particularly the Sequatchie Valley. Commonly, the springs in the Cumberland Plateau issue from sandstones near their contact with shale beds (fig. 8).

Ground-water movement between the Cumberland Plateau aquifer system and the Valley and Ridge aquifer system is restricted by a zone of faulting and structural deformation between the two systems. In areas where the water-bearing formations are deeply buried, such as the Wartburg Basin, movement of the water is thought to be very restricted.

Newcome and Smith (1958), Wilson (1965), and Zurawski (1978) were used as the primary hydrology references for this report.

WATER QUALITY

Chemical analyses of water from wells drilled into the Cumberland Plateau aquifer system generally indicate good to excellent quality throughout the area of occurrence of the aquifer. Of the 32 water-quality analyses from this aquifer, only two had dissolved-solids concentrations greater than 500 mg/L, and three fourths had dissolved solids less than 200 mg/L. Two of the more common characteristics of ground water in the Cumberland Plateau are high iron content (typically several milligrams per liter) and the presence of hydrogen sulfide. Water generally is calcium bicarbonate type, with pH below 7.0. Two chemical analyses of water from the northern part of this aquifer system have reported dissolved-solids concentrations greater than 500 mg/L. Figure 9 shows the areal distribution of dissolved solids in the aquifer system and table 2 shows the variation of dissolved solids by depth and water-bearing formation.

It should be noted that all analyses reported from the Cumberland Plateau aquifer system are of water from wells less than 300 feet deep. Although it has not been confirmed by data, it is suspected that the dissolved solids of the water increases in areas where the sandstones are buried by more than 500 feet of shales. Deeply buried sandstones in the Wartburg Basin may contain water with dissolved solids in the range of 1,000 to 10,000 mg/L, but this remains to be documented. Nevertheless, because the water is generally of good quality, this aquifer system does not qualify for deep-well injection.

Water-quality data are based on these reports: DeBuchananne and Richardson (1956), Newcome and Smith (1958), Wilson (1965); and Sprinkle (1977).

DRINKING-WATER SUPPLIES

The Cumberland Plateau aquifer system is an important source of water for the Cumberland Plateau. Wells and springs from this aquifer system supply most of the domestic and public supplies of drinking water used (fig. 10; table 3). Data indicate that ground water is available throughout the Plateau, but the quantity is highly variable from place to place and locally may not be large enough to supply large public needs.

CONTAMINATION

The Cumberland Plateau aquifer system has no documented sites of contamination; however, the area is a site of intensive oil and gas exploration in Tennessee, and saline water from deeper depths has entered into the shallow zones of this aquifer system (Rima, Chase and Myers, 1971; Miller and Maher, 1972). No part of this regional aquifer qualifies for receiving injected underground waste.

CURRENT AND POTENTIAL HYDROCARBON, MINERAL, AND GEOTHERMAL RESOURCE USE

Coal has been mined commercially in the Cumberland Plateau since 1830, reaching peak production in the 1950's with the increase of mechanization and strip mining (fig. 11). Since then, production has declined but remains relatively high at more than 10 million tons annually. Although coal mining, both strip and underground, can have a deleterious impact on surface water, there is no documented information available to indicate that coal mining has impacted ground-water quality.

Intensive oil and gas exploration occurs in the Cumberland Plateau (fig. 11), but these wells are drilled and cased to depths below the Pennington Formation. If these wells are improperly cased and sealed, however, contamination by seepage may result.

Luther (1959), May and Maher (1979), and Tennessee Department of Labor (1981) are the sources of information for this section of the report.

SUMMARY

The Cumberland Plateau aquifer system derives its name from its area of occurrence, the Cumberland Plateau in the east-central part of the State. It is an important source of water, providing many towns and most rural areas with drinking water.

The Cumberland Plateau aquifer system consists of interbedded sandstones, conglomerates, siltstones, shales, and coals of Pennsylvanian age. Major water-bearing zones occur within the sandstones and conglomerates in interconnected fractures. The water-bearing sandstone layers are separated from one another by nearly horizontal shale and siltstone layers that retard the vertical circulation of ground water. The Pennington Formation, which is the base of the aquifer system, is an effective regional confining unit.

Coal has been mined in the Cumberland Plateau since 1830. Intensive oil and gas exploration also occurs in this area. If these wells are not cased and sealed to the base of the Pennington Formation, contamination of the Cumberland Plateau aquifer system may result from seepage of saline water from deeper depths into the shallow zones of this aquifer system.

Because water quality in the aquifer system is generally good to excellent and because the aquifer is used throughout its area of occurrence in Tennessee, the Cumberland Plateau aquifer system is classed as an underground drinking-water source under the criteria defined by the law, and as such does not qualify for receiving injected wastes.

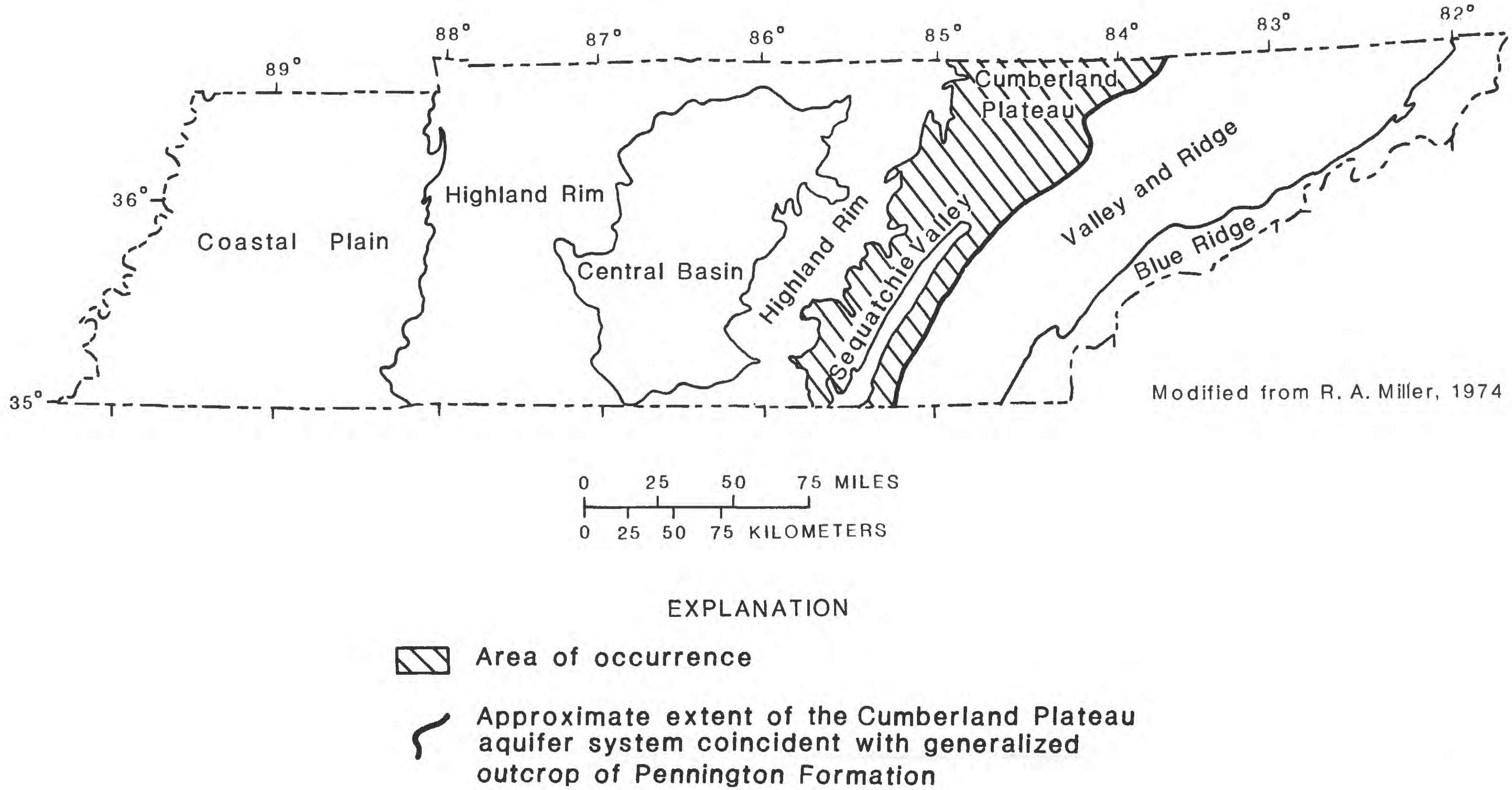


Figure 1.--Areal occurrence of the Cumberland Plateau aquifer system and physiographic provinces in Tennessee.

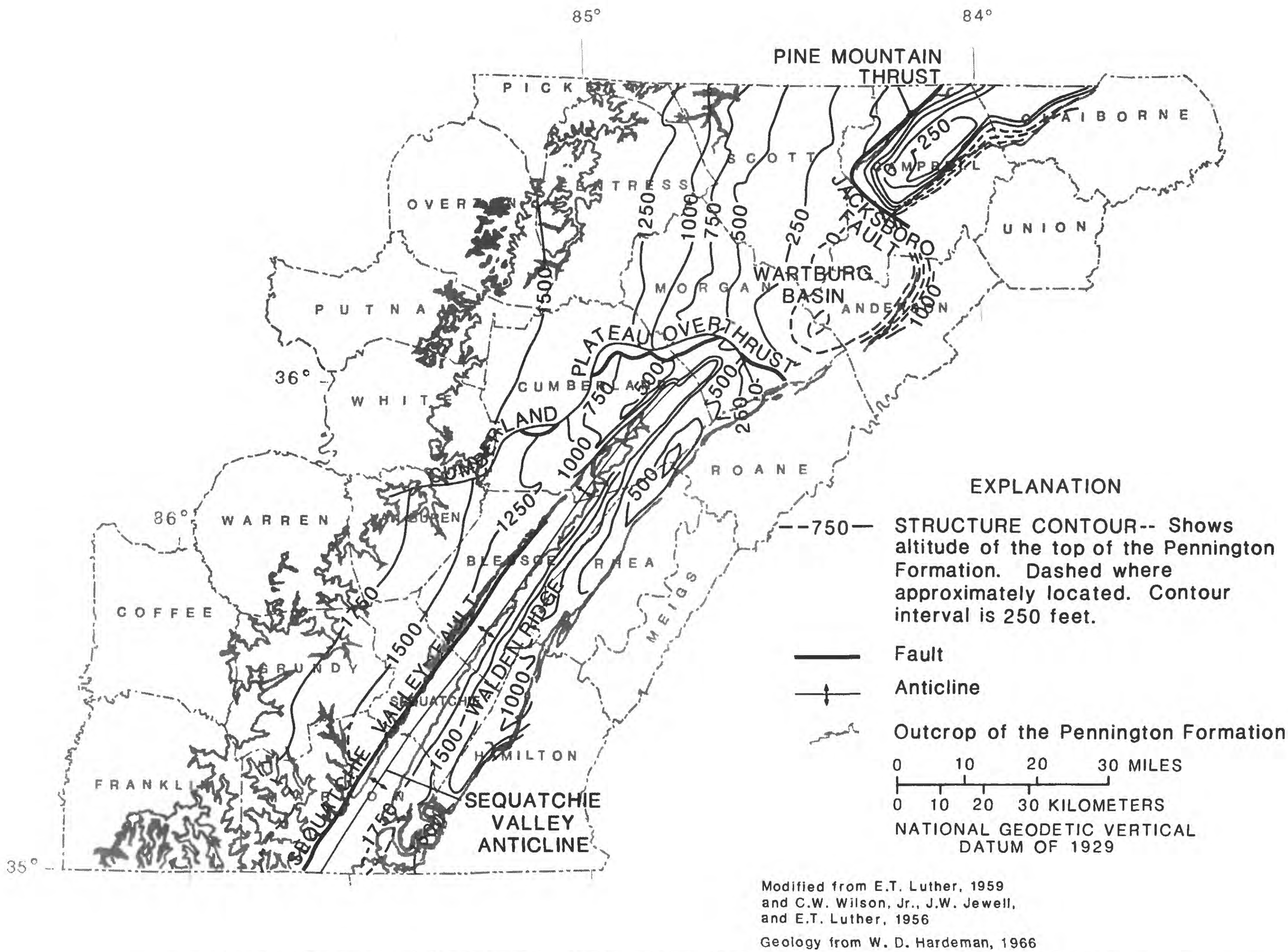


Figure 2.-- Generalized structural features of the Cumberland Plateau aquifer system in Tennessee.

Table 1.--Hydrogeology of the formations comprising the Cumberland Plateau aquifer system

[Sources: Milici and others (1979), Miller (1974), Newcome and Smith (1958), Wilson and others (1956)]

System	Series	Stratigraphic unit	Geologic description	Hydrologic significance		
				Occurrence in Tennessee	Hydrologic classification and character	Yield
PENNSYLVANIAN	Middle	Cross Mountain Formation	Shale, interbedded with sandstone, siltstone, and thin coal beds. Maximum thickness about 550 feet.	Occurs only in Cumberland Mountains of Anderson, Morgan, Scott, and Campbell Counties.	Thin interbedded shales inhibit inhibit vertical movement. Sandstones have low intergranular permeability.	Sandstones may yield enough water for small domestic supply. Shales, siltstones, and coal yield little or no water to wells.
		Vowell Mountain Formation	Shale, sandstone, siltstone, and coal. Thickness from 200 to 400 feet.	Present only in the northeast section of Cumberland Plateau.	Permeability in sandstones is generally low, except where fracturing has occurred. Shales have very low permeability.	Sandstones yield water for domestic and public supplies, commonly 20 gallons per minute or less. Other lithologies yield less than 1 gallon per minute.
		Redoak Mountain Formation	Predominantly shale with interbedded sandstones and coal. Thickness from 250 to 500 feet.	Present only in the northeast section of Cumberland Plateau.	Permeability in sandstones is generally low, except where fracturing has occurred. Shales have very low permeability.	Sandstones yield water for domestic and public supplies, commonly 20 gallons per minute or less. Other lithologies yield less than 1 gallon per minute.
		Graves Gap Formation	Predominantly shale with interbedded sandstone and coal. Thickness from 150 to 350 feet.	Occurs only in the Cumberland Mountains and Cross Mountains.	Permeability in sandstones is generally low, except where fracturing has occurred. Shales have very low permeability.	Sandstones yield water for domestic and public supplies, commonly 20 gallons per minute or less. Other lithologies yield less than 1 gallon per minute.
		Indian Bluff Formation	Alternating shales and sandstones. The shale intervals contain minor sandstones and coal. Ranges from 150 to 500 feet thick.	Occurs only in the Cumberland Mountains and Cross Mountain.	Permeability in sandstones is generally low, except where fracturing has occurred. Shales have very low permeability.	Sandstones yield water for domestic and public supplies, commonly 20 gallons per minute or less. Other lithologies yield less than 1 gallon per minute.

PENNSYLVANIAN	Lower and Middle	Slatestone Formation	Alternating sequence of shales, sandstones, and coals, predominantly fine-grained. Ranges from 300 to 650 feet thick.	Occurs only in the Cumberland Mountains and Cross Mountain.	Permeability in sandstones is generally low, exept where fracturing has occurred. Shales have very low permeability.	Sandstones yield water for domestic and public supplies, commonly 20 gallons per minute or less. Other lithologies yield less than 1 gallon per minute.
PENNSYLVANIAN	Lower and Middle	Crooked Fork Group	Shale, sandstone, conglomerate, siltstone, and coal. Sandstones in this group and above are generally much thinner than those stratigraphically lower and less laterally persistent. Ranges from 150 to 480 feet thick.	Restricted to northern Cumberland Plateau.	Shales restrict vertical movement. Aquifers restricted to fractured sandstones.	Yields to sandstones generally less than 20 gallons per minute. Shales yield little or water.
PENNSYLVANIAN	Lower	Crab Orchard Mountains Group	Three major sandstone units occur in this group: the Sewanee, Newton, and Rockcastle. All are conglomeratic in places and are massive cliff formers. They are separated by shales, siltstone, and coals. Total thickness ranges from 300 to 900 feet.	Occurs throughout most of area, thickens from west to east.	Primary porosity of sandstones is small. Aquifer is best developed where fractures are concentrated in sandstones. Shales siltstones, and coal inhibit vertical movement.	Fractures sandstones yield from 50 to 350 gallons per minute.
PENNSYLVANIAN	Lower	Gizzard Group	The Gizzard may be divided into three parts: a thick lower shale with thin sandstones and several coals; the Warren Point sandstone; and a thin upper shale. Total thickness ranges up to 700 feet.	Present throughout most of area, may be absent locally.	Zones of higher permeability occur where fractures are concentrated in sandstones. Other rock types have extremely low permeability and restrict vertical flow.	Sandstones generally yield less than 20 gallons per minute. Shales yield little or no water to wells.
MISSISSIPPIAN	Upper	Pennington Formation	Shale, siltstone, fine-grained dolomite, limestone, and thin-bedded sandstone. Ranges from 100 to 500 feet thick.	Underlies entire area of the Cumberland Plateau system.	Generally has very low permeability and storage. Some solution openings occur in limestone.	Yields little or no water to wells. Large springs issue from the top of the formation.

Table 2.--Dissolved-solids concentrations from selected wells

[Data source codes: 1, Newcome and Smith, 1958; 2, Sprinkle, 1977; 3, DeBuchananne and Richardson, 1956; 4, USGS unpublished data]

County	Location	Well No.	Well depth, in feet	Aquifer	Dissolved solids concentrations, in milligrams per liter	Data source
Anderson	Stainville	An:H-11	103	Slatestone Fm[1]	79	3
	Rosedale School	An:H-12 (6)	100	Slatestone Fm	219	2
	Beech Grove	An:J-21	200	Crooked Fork Gp[1]	54	4
Bledsoe	Pikeville	Bl:L-11(17)	38	Crab Orchard Mountains Group	76	1
	Pikeville	22	141	Crab Orchard Mountains Group	124	1
Campbell	Jellico	4	194	Crooked Fork Gp	538	1
Claiborne	Clairfield	1-4	50	Crooked Fork Gp	182	1
Cumberland	Crossville	1	85	Crab Orchard Mountains Group	85	1
Fentress	Armathwaite	1	95	Crab Orchard Mountains Group	130	1
	Grimsley	3-1	238	Crab Orchard Mountains Group	287	1
	Pall Mall	78	62	Crab Orchard Mountains Group	140	1
Franklin	Sewanee	6	57	Crab Orchard Mountains Group	26	1
Grundy	Tracy City	2	125	Crab Orchard Mountains Group	109	1
	Palmer	Gy:G-11(6)	40	Crab Orchard Mountains Group	42	1
Hamilton	Chattanooga	2	60	Crab Orchard Mountains Group	102	1
	Soddy	8	75	Crab Orchard Mountains Group	19	1

Table 2.--Dissolved-solids concentrations from selected wells--Continued

County	Location	Well No.	Well depth, in feet	Aquifer	Dissolved solids concentrations, in milligrams per liter	Data source
Marion	Monteagle	2	120	Crab Orchard Mountains Group	56	1
	Whitwell	14	260	Crab Orchard Mountains Group	77	1
	Whitwell	29	185	Crab Orchard Mountains Group	110	1
Morgan	Sunbright	15	100	Crab Orchard Mountains Group	208	1
	Wartburg	16	50	Crab Orchard Mountains Group	154	1
Overton	Cliff Springs	4	90	Crab Orchard Mountains Group	52	1
Putnam	Monterey	Pm:M-22(1-1)	150	Crab Orchard Mountains Group	211	1
	Monterey		145	Crab Orchard Mountains Group	151	2
Rhea	Dayton	Re:F-16(6)	120	Crab Orchard Mountains Group	57	1
Scott	Huntsville	3	90	Crooked Fork Group	1820	1
	Glenmary	5	85	Crooked Fork Gp	242	1
	Huntsville	10	50	Slatestone Fm	42	1
Sequatchie	Dunlap	11	71	Crab Orchard Mountains Group	102	1
	Cagle	8		Crab Orchard Mountains Group	199	2
Van Buren	Spencer	Vb:E-11(3)	112	Crab Orchard Mountains Group	87	1
White	Bon Air	7	71	Crab Orchard Mountains Group	25	1

[1]Calculated from major constitutents

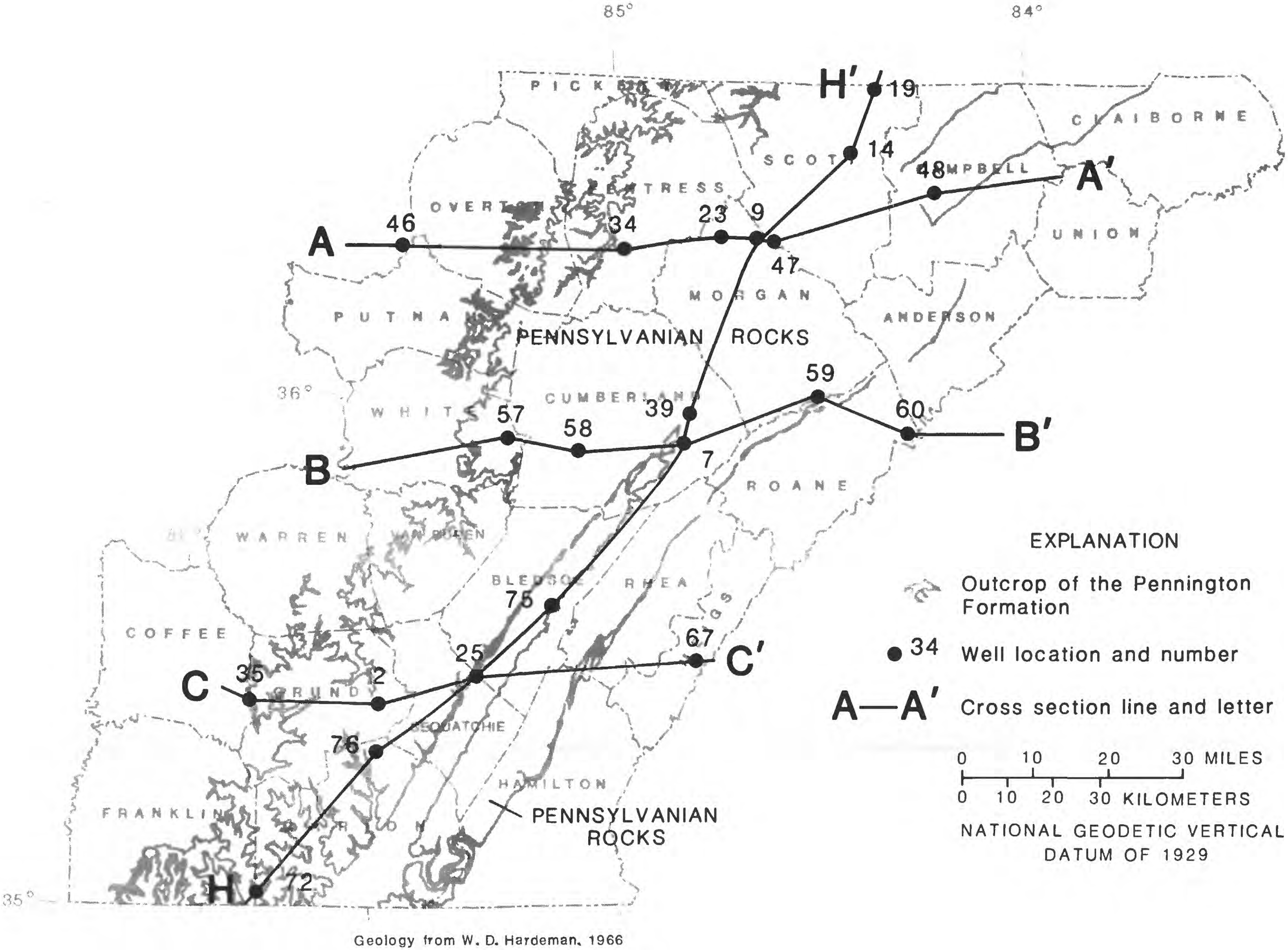


Figure 3.-- Location of cross-section lines.

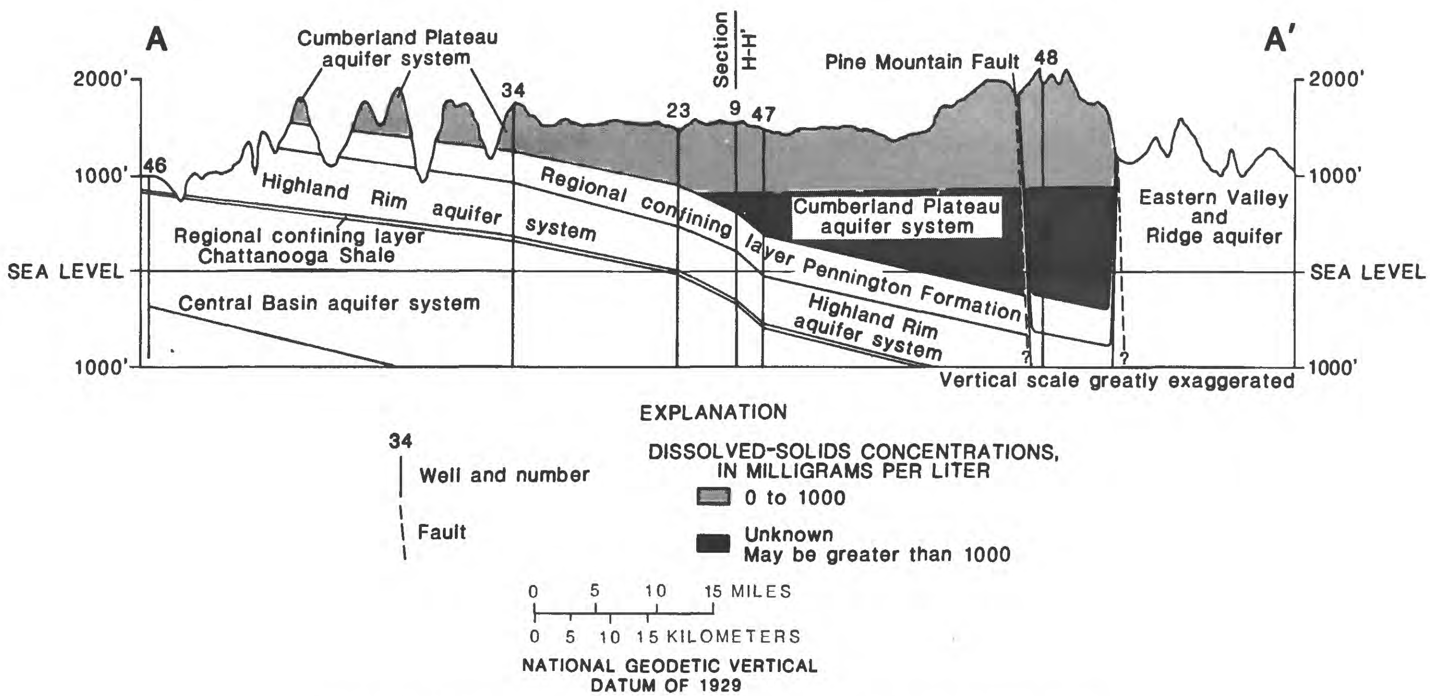


Figure 4.-- Regionalized geohydrologic section showing water quality in the Cumberland Plateau aquifer system along line A-A'.

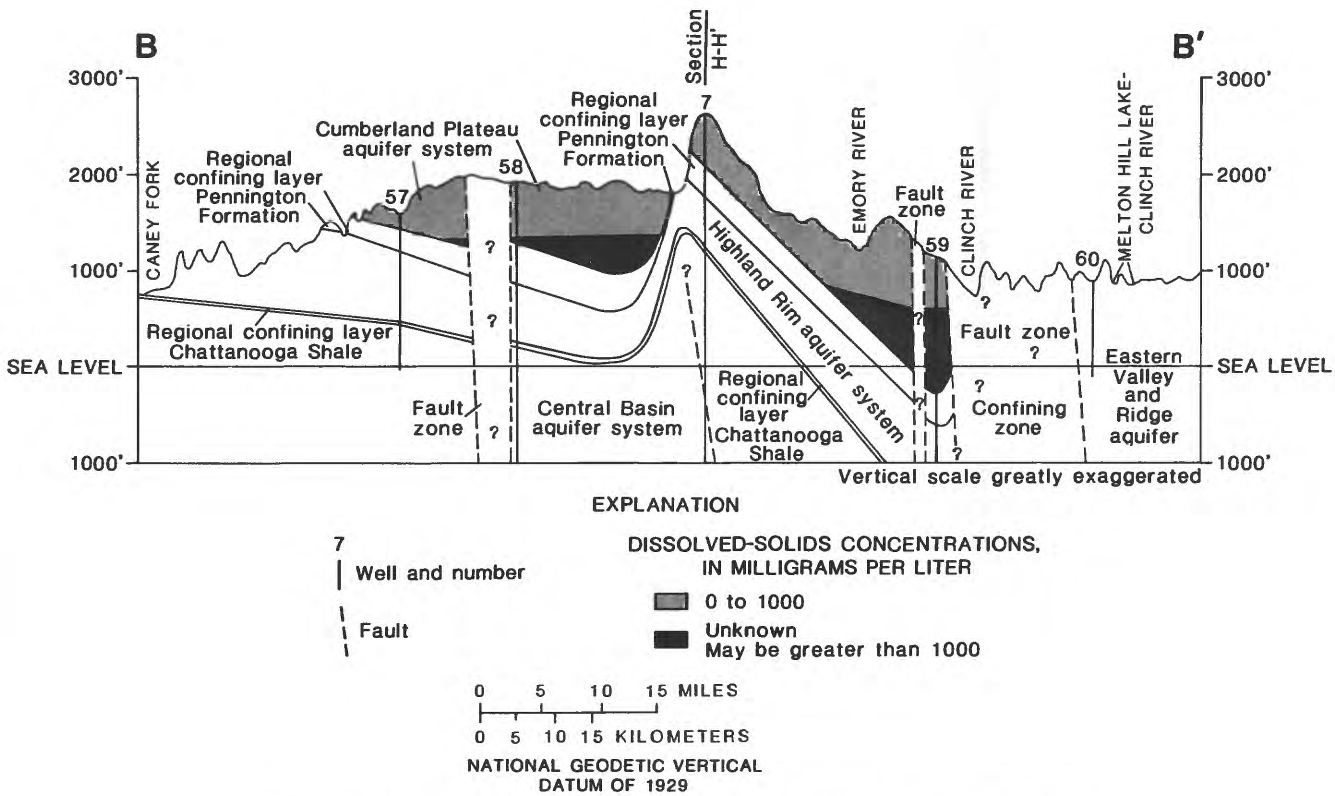


Figure 5.-- Regionalized geohydrologic section showing water quality in the Cumberland Plateau aquifer system along line B-B'.

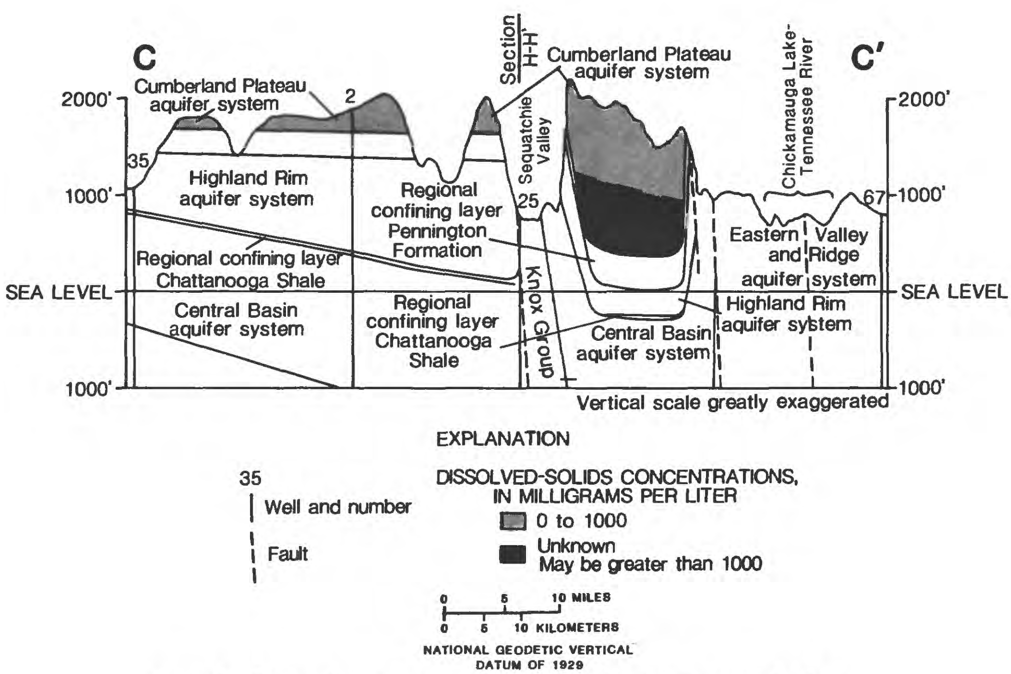


Figure 6.-- Regionalized geohydrologic section showing water quality in the Cumberland Plateau aquifer system along line C-C'.

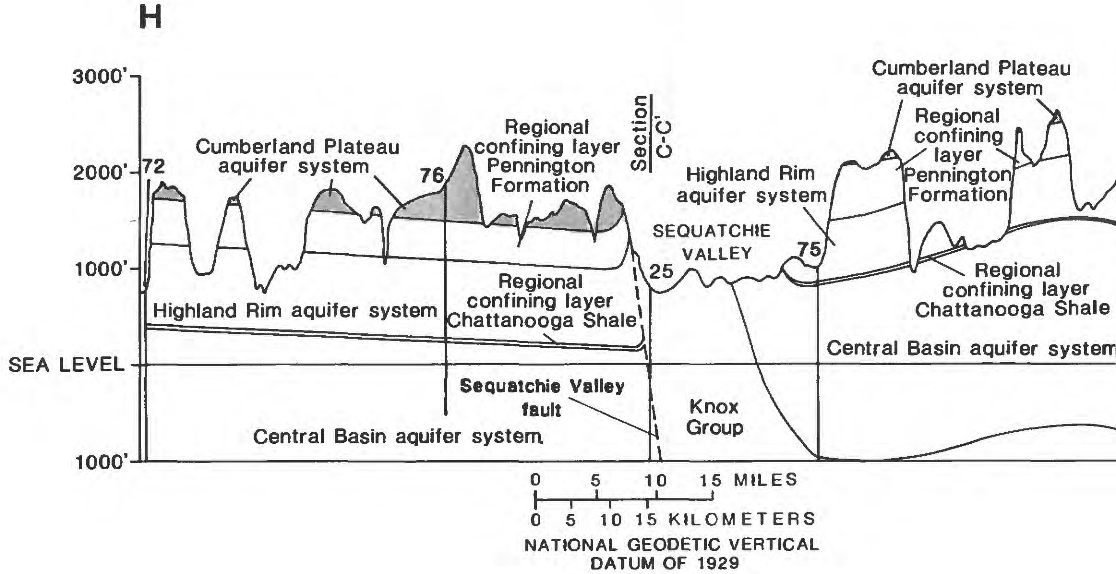
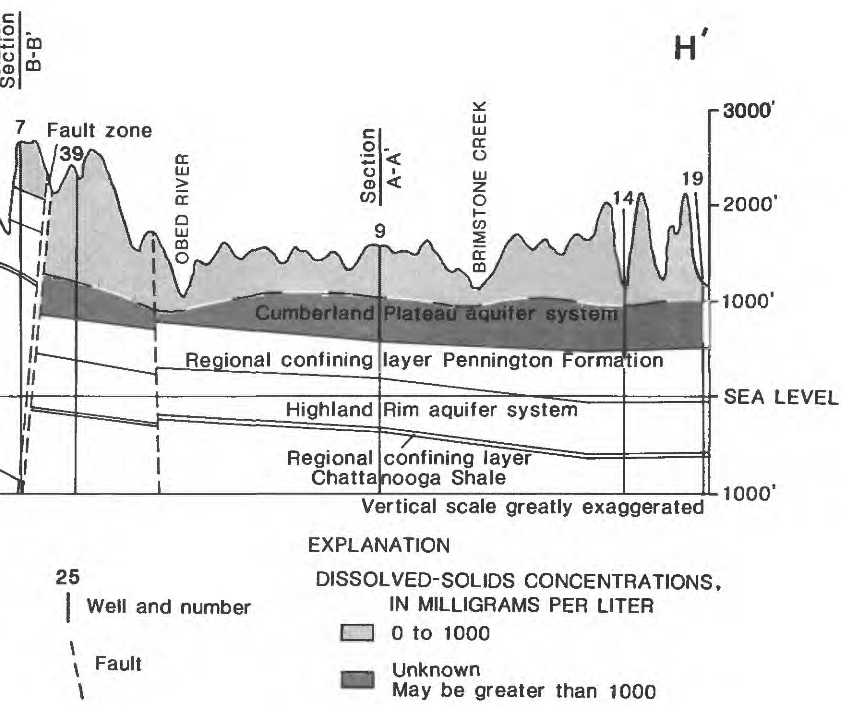


Figure 7.-- Regionalized geohydrologic section showing water quality in the



;umberland Plateau aquifer system along line H-H'.

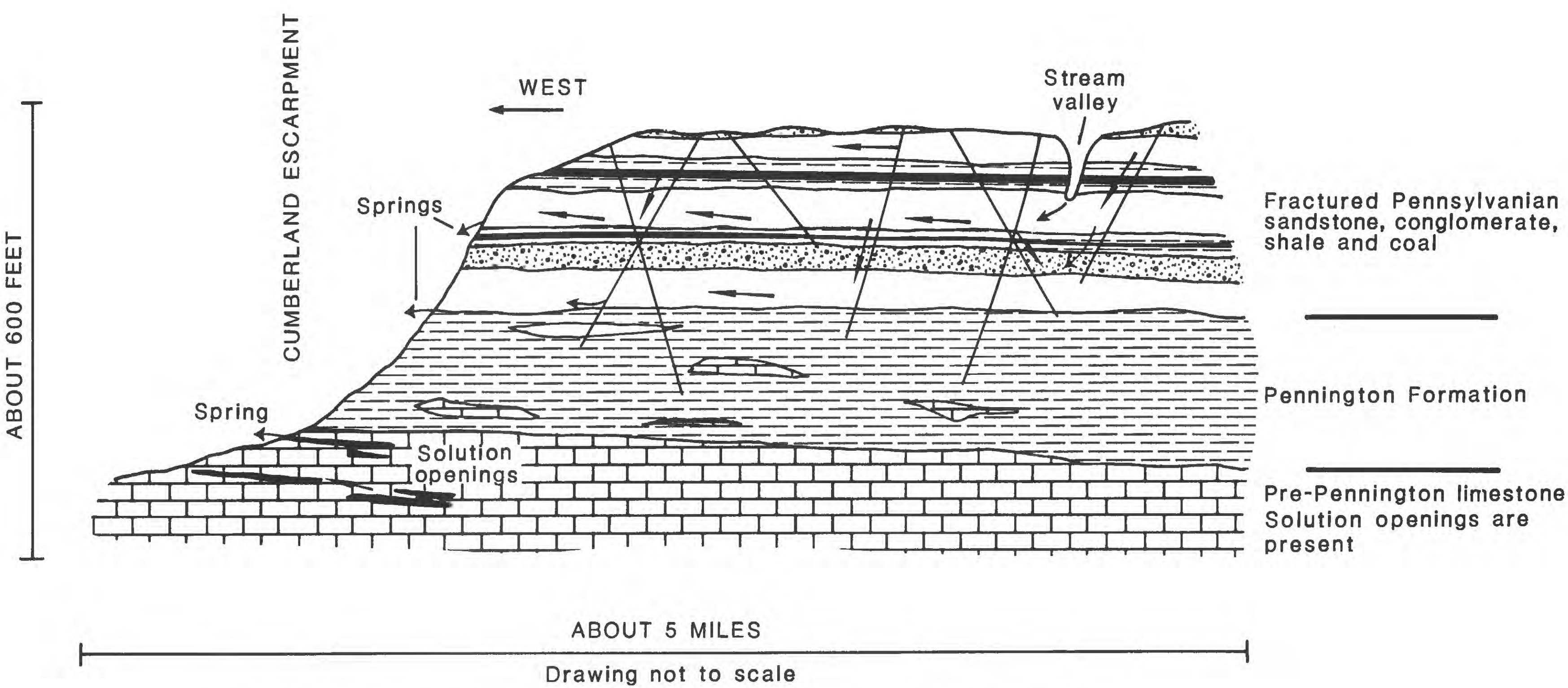


Figure 8.-- Conceptual model of ground-water occurrence and flow in the Cumberland Plateau aquifer system.

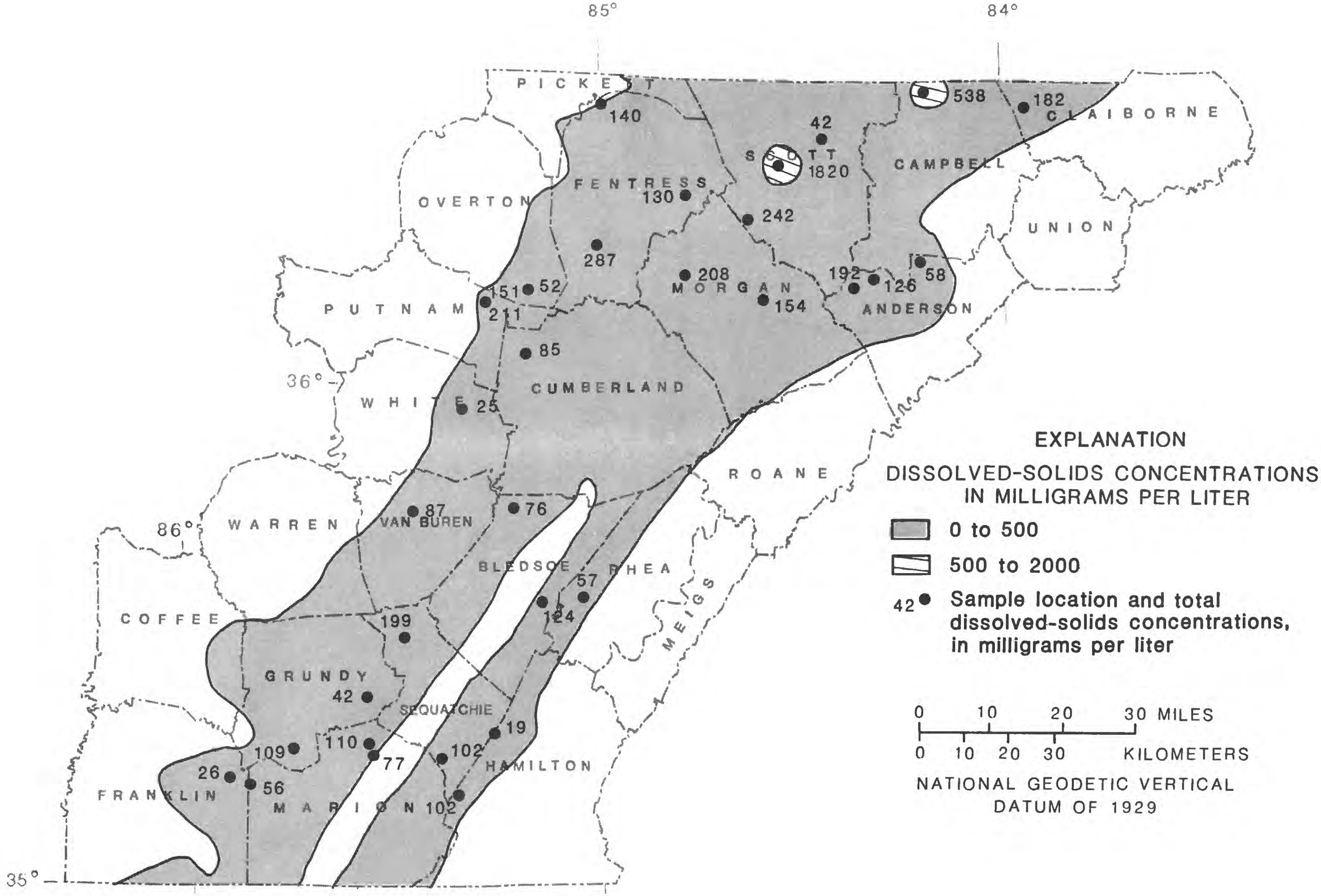


Figure 9.-- Distribution of dissolved-solids concentrations in the Cumberland Plateau aquifer system.

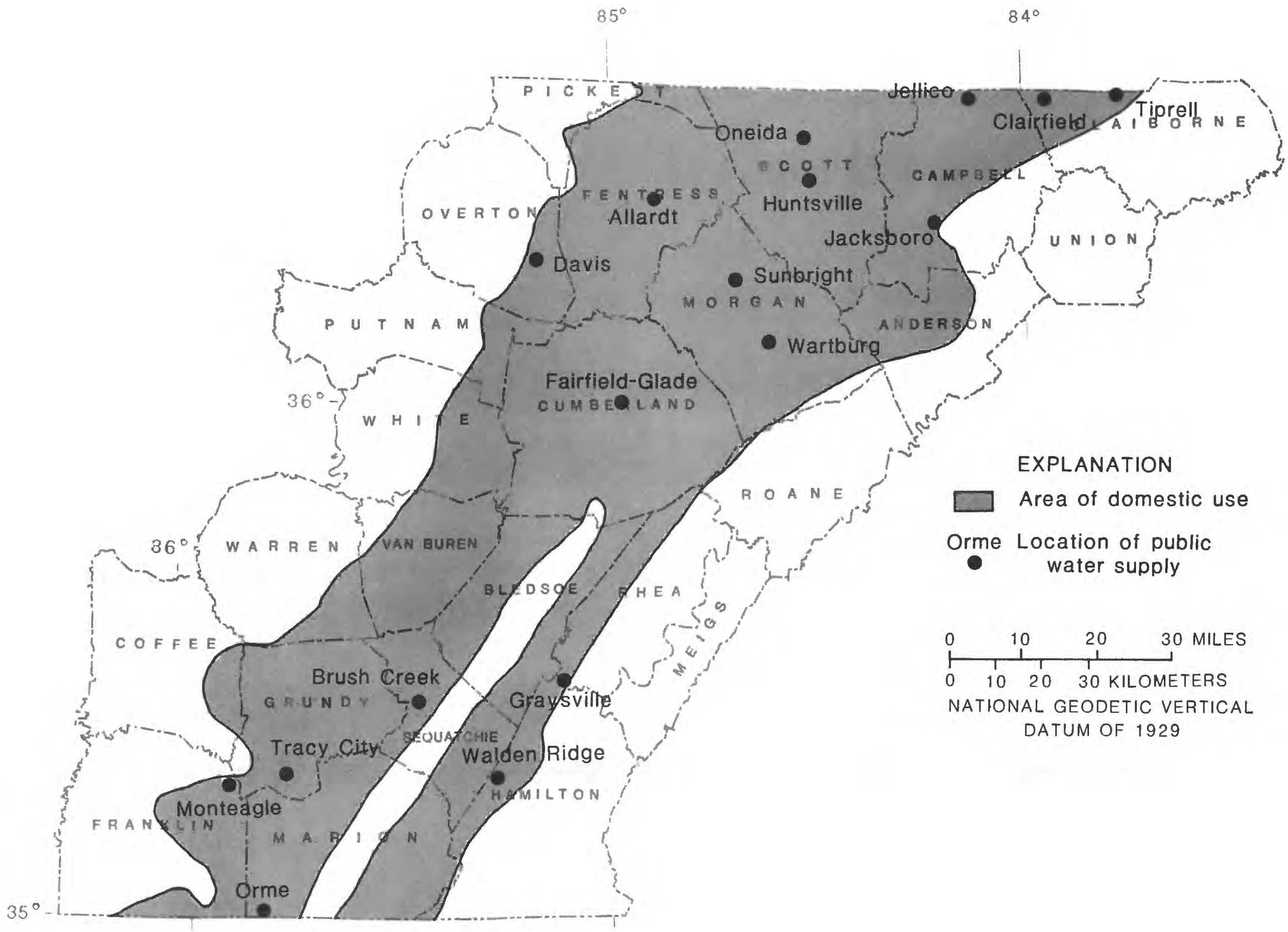


Figure 10.-- Area of use of the Cumberland Plateau aquifer system as a source of drinking-water supplies.

Table 3.--Summary of public drinking-water supplies

[Data Source Codes: 1, Tennessee Comprehensive Joint Water and Related Land Resources Planning, Tennessee Division of Water Resources; 2, Tennessee Division of Water Quality Control; 3, Tennessee Division of Water Resources]

System	County	Data Source
Allardt	Fentress	2,3
Brush Creek	Sequatchie	2
Clairfield	Claiborne	2
Davis	Overton	2
Fairfield-Glade	Cumberland	1
Graysville	Rhea	2
Huntsville U.D.	Scott	2
Jacksboro	Campbell	3
Jellico	Campbell	1,2
Monteagle Rural U.D.	Grundy	2
Oneida	Scott	2
Orme	Marion	2
Plateau U.D. (Wartburg)	Morgan	2,3
Sunbright	Morgan	2
Tipprell	Claiborne	2
Tracy City	Grundy	2
Walden Ridge U.D.	Hamilton	2

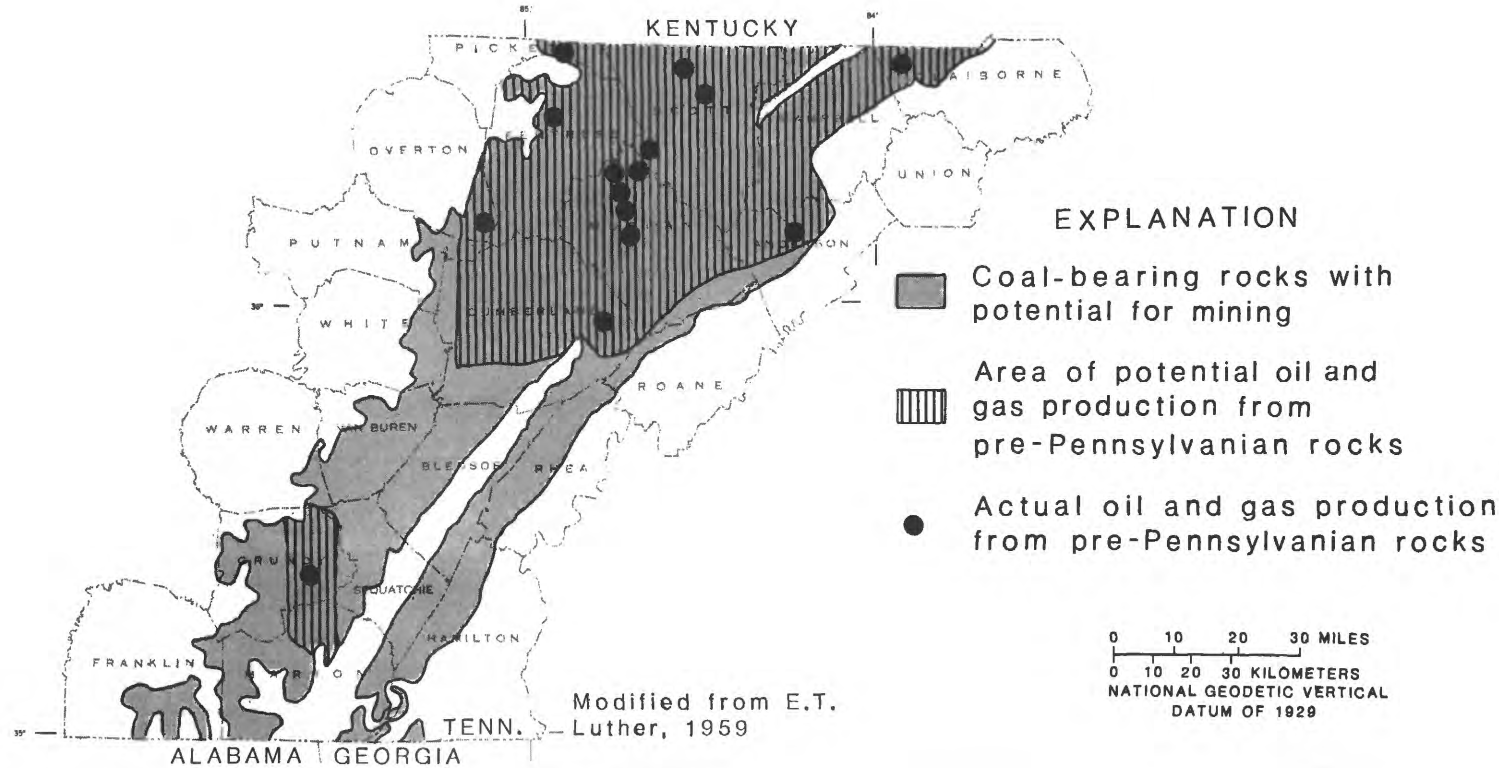


Figure 11.-- Generalized location of potential coal resources in the Cumberland Plateau aquifer system and potential hydrocarbon resources from pre-Pennsylvanian rocks.

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