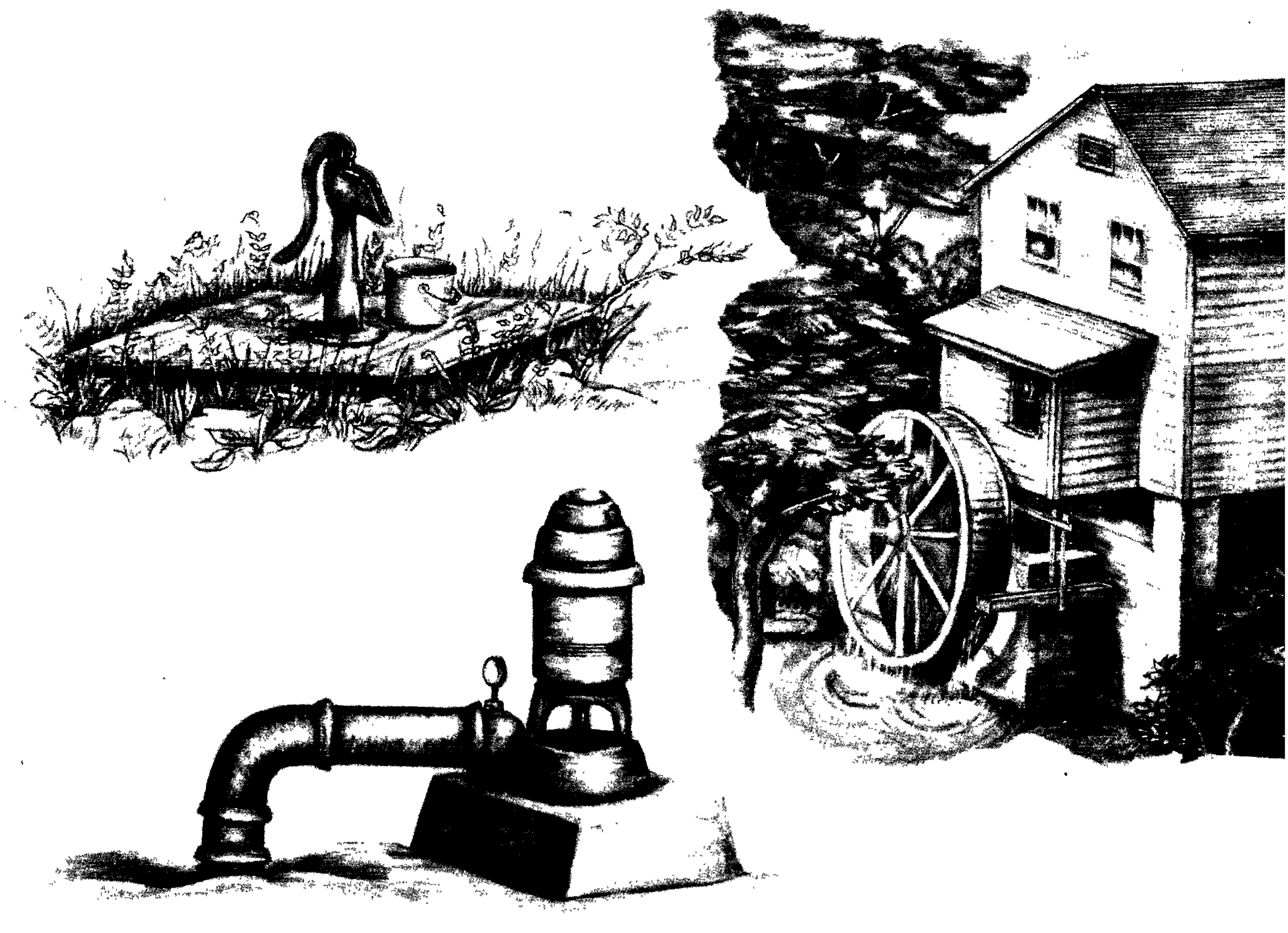
WATER-RESOURCES INVESTIGATIONS REPORT 82-4091

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



Prepared by
U.S. GEOLOGICAL SURVEY
in cooperation with the
U.S. ENVIRONMENTAL PROTECTION AGENCY

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By John V. Brahana, Dolores Mulderink, Jo Ann Macy, and Michael W. Bradley

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UNITED STATES DEPARTMENT OF THE INTERIOR

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CONVERSION FACTORS

In this report, figures for measures are given only in inch-pound units. Factors for converting inch-pound units to International System of units (SI) are shown in the following table:

Multiply	By	To obtain
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.203	meter (m)
cubic foot (ft^3)	0.02832	cubic meter (m^3)
mile (mi)	1.609	kilometer (km)
gallon (gal)	3.785	liter (L)
gallon per minute (gal/min)	0.0631	liter per second (L/s)
foot per day (ft/d)	0.305	meter per day (m/d)
feet squared per day (ft^2/d)	0.0929	meters squared per day (m^2/d)

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. NGVD of 1929 is referred to as sea level in this report.

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ABSTRACT

The East Tennessee aquifer system occurs in the Valley and Ridge and the Blue Ridge provinces of Tennessee. These areas are underlain by rocks of Precambrian to Mississippian age which have been structurally deformed and faulted during the Appalachian orogeny. Ground water in the Valley and Ridge occurs primarily in solution openings in carbonate rocks and in fractures in sandstones and shale. Fractures in the crystalline rocks store and transmit most of the ground water in the Blue Ridge province.

The East Tennessee aquifer system is important as a source of rural and municipal drinking water. Within 300 feet of land surface, ground water generally contains less than 500 milligrams per liter dissolved solids. At greater depths, fractures and solution openings are smaller and fewer in number. There are very few data to define ground-water occurrence at depths greater than about 300 feet. Ground-water flow may be restricted and the dissolved-solids concentrations in the ground water may reach thousands or even tens of thousands of milligrams per liter.

INTRODUCTION

The Safe Drinking Water Act (Public Law 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 underground injection of contaminants will not endanger existing or potential sources of drinking water. As developed by EPA, the regulations require that all underground sources of ground water with less than 10,000 milligrams per liter (mg/L) dissolved solids which do not contain hydrocarbon, mineral, or geothermal resources be designated for protection whether they are or are not currently being used as a source of drinking water.

The geologic formations of Tennessee (Miller, 1974) have been delineated on a regional basis into eight major regional aquifers having broad areal extent. Each regional aquifer is characterized by a unique set of hydrologic conditions and water quality.

The purpose of this report is to describe the formations that comprise the East Tennessee aquifer system (fig. 1) and to delineate zones within this aquifer system that are actual or potential drinking-water sources.

This report on the East Tennessee aquifer system provides generalized information on (1) the areal and stratigraphic occurrence of the aquifer, (2) dissolved-solids content of the ground water, (3) area of 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 Valley and Ridge and Blue Ridge provinces. 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 formations that make up the framework of the East Tennessee aquifer system range in age from Precambrian to Mississipian (table 1). They are composed of folded and faulted sedimentary rocks (limestones, shales, dolomites, sandstones, and conglomerate) in the Valley and Ridge physiographic province, and fractured sedimentary, metasedimentary, and crystalline igneous and metamorphic rocks of the Blue Ridge province. The rocks are overlain by a mantle of residual soil which in places may exceed 150 feet in thickness (De-Buchananne and Richardson, 1958). More commonly, however, the thickness of residual soil is less than 10 feet, and throughout the area it is not uncommon to see exposed rock with no soil. A veneer of alluvium, composed of boulders, gravel, silt, sand, and clay, covers the bottom of major valleys (Zurawski, 1979).

The structural setting of the East Tennessee aquifer system is very important because it is one of the major controlling influences on the occurrence of ground water, especially in the Valley and Ridge. The sedimentary rocks of the Valley and Ridge were folded and broken into a series of sheets that were thrust several miles northwestward. This deformation has resulted in a repetition of the same rock layers and a compartmentalization of aquifers (fig. 2). A map of the major structural features is shown in figure 3, and a section showing the generalized configurations of the rocks is shown in figure 4.

Toward the east in the Blue Ridge province, the rocks become progressivly more deformed and metamorphosed. Commonly, the rocks in this province are massive, and with the exception of the upper several hundred feet, are nonporous and impermeable. Within several hundred feet of land surface, fractures cut across the various rock types and provide homogeneous, secondary permeability.

The East Tennessee aquifer system is separated from other regional aquifers to the west by a zone of faulting. This zone occurs in a broad area which includes the eastern part of the Cumberland Plateau and the western part of the Valley and Ridge province. Faulting has generally occurred in the incompetent shales of the Rome Formation, causing repetition of the sequence of Rome Formation, Conasauga Group, and Knox Group through the Valley and Ridge province (fig. 2). These repeating sequences do not appear to be hydrologically continuous because of the impermeability of the faults and the basal shale which serves as the glide plane and accompanies the faulting.

The geology of East Tennessee has been studied in detail, and in addition to the more accessible references listed below, a store of detailed geologic information exists in quadrangle maps, geologic theses, and site reports that have not received widespread distribution but are nonetheless available. Of a more regional nature, the following publications were used for generalizing the geology presented in this report: Rodgers (1953); Neuman

(1955); Swingle (1959); King (1964); Neuman and Nelson (1965); LeGrand (1967); McMaster and Hubbard (1970); Harris and Milici (1977); Milici and Wedow (1977); and Milici, Hassis, and Statler (1979).

HYDROLOGY

The general hydrology of the Blue Ridge province is distinct from the Valley and Ridge province as shown by figures 5 and 6. Most of the water in the sedimentary, metasedimentary, and crystalline rocks of the Blue Ridge province occurs in the upper 200 feet, in interconnected fractures in the rock and in the pore spaces of overlying soil and regolith (fig. 5). Below several hundred feet, the weight of the overlying rock tends to keep the fractures closed, and regional ground-water flow below this depth is not considered to be significant.

Ground-water occurrence in the Blue Ridge is thus determined by the number, size, and degree of interconnection of the openings in the rocks and by the thickness of the saturated overburden (McMaster and Hubbard, 1970; and Zurawski, 1979). Ground-water circulation patterns tend to be localized rather than regional in extent, with relatively shallow flow paths (LeGrand, 1967). Recharge is areally distributed and discharge areas are local seeps, springs, and streams. Reported well yields and spring discharge are consistent with this interpretation, as is the water-quality distribution. It should be noted that few data exist from depths greater than 300 feet in the Blue Ridge.

In the Valley and Ridge province, it is known from records of water wells and other borings that solution cavities containing water are present at depths 900 to 1,000 feet below the surface (DeBuchanne and Richardson, 1956). Most solution openings, however, are confined to the upper 300 feet. Large spring discharges indicate a more active ground-water system at shallow depths than in the Blue Ridge. However, the highly variable well yields of the Valley and Ridge indicate this aquifer is more anisotropic and nonhomogeneous than the Blue Ridge province. In addition to solution cavities, ground water in the Valley and Ridge province occurs in fractures and, in some instances, along bedding planes of the carbonates and shales (fig. 6). The complexity of the structure and sparse data makes interpretation of the deep regional flow system not possible at this time.

In addition to the importance of structure in the Valley and Ridge province, rock type plays an important role in the hydrology. Carbonates are the most productive water-bearing formations in this area. According to DeBuchananne and Richardson (1956), many sinkholes and other karst features are common in the Valley and Ridge province where extensive solution of the underlying limestone and dolomite has taken place. In such areas, few surface streams are found; most of the drainage is through a well-developed underground drainage system, and the water table is likely to be deeper than in other areas.

There is evidence that solution is more extensive near perennial streams than elsewhere (DeBuchananne and Richardson, 1956). Industries close to rivers are more successful in obtaining large supplies of ground water than those in other locations. It is also likely that solution along zones of weakness in the rocks has determined the stream position in some areas.

Shales may be important water-bearing formations in the East Tennessee aquifer system, unlike in other areas of the State. Normally, shales have little effective primary porosity, and unless secondary openings are formed by fracturing, shales will yield little water to wells. The rocks of East Tennessee have been folded and faulted extensively, however, and shales that are hard and brittle enough to support fractures are among the better aquifers of the area. Shales containing appreciable quantities of calcium carbonate yield more water than noncalcareous shales, as the fractures in such rock are susceptible to enlargement by the solvent action of water. In general, fractures in shale are more closely spaced than those in limestone and dolomite.

Sandstones and noncalcareous shales are composed of particles of minerals and rock more or less firmly cemented together. Rocks of these types found in East Tennessee contain practically no primary openings. Water is transmitted in secondary openings consisting of joints, fractures, and solution openings. Unlike limestone, dolomite, and calcareous shale, the openings in sandstone are not readily susceptible to dissolution by water. Sandstones and noncalcareous shales are not as widely distributed in East Tennessee as limestones, dolomites, and calcareous shales. However, rocks of this type, because of fracturing, will usually yield small supplies of water.

Recharge occurs by the percolation of rainfall through the residuum that overlies the East Tennessee aquifer system. Discharge occurs as springs, base flow to streams and rivers, and pumpage from wells. The residuum yields enough water to supply many domestic wells. During the late summer-early autumn, a period when water levels usually decline, many of these shallow wells may go dry. Water levels in this aquifer system fluctuate several feet in response to varying recharge and discharge conditions.

WATER QUALITY

The quality of water from the East Tennessee aquifer system is generally very good throughout its area of occurrence (fig. 7). The dissolved-solids concentrations in water from most wells were less than 250 mg/L. However, it should be noted that data are available from only one well with a depth greater than 500 feet.

Water from three wells on record had dissolved-solids concentrations of as much as 1,000 mg/L (table 2). Each of these occurrences was isolated and no discernible pattern was observed. None of the three wells was deeper than 135 feet below land surface; two were in a shale, and one was in a limestone. Such high concentrations of dissolved solids are local in extent, and may in part be caused by contamination. They do not reflect the regional water-quality trends, but they do point out that local anomalies are present.

The mode of occurrence of ground water in the Valley and Ridge province (fig. 6) makes contamination to this part of the aquifer a continuing problem. The highly anisotropic nature and occurrence of the water-bearing zones, the high permeability and rapid ground-water movement associated with the solution cavities in the folded carbonates, and the good quality and widespread utilization of the formations for drinking-water sources provide a combination of physical conditions that, on a regional scale, render the aquifer unsuitable for waste disposal. Water quality in the deeper formations of this aquifer system is not known, but dissolved-solids concentrations may be greater than 1,000 mg/L (fig. 6).

The quality of shallow ground water in the crystalline rocks of the Blue Ridge province is very good. Below the upper shallow flow system, however the rocks are effectively impermeable and nonporous.

In addition to much unpublished data, the following reports were used to compile information for this water-quality section: Glenn (1904); and DeBuchananne and Richardson (1956).

DRINKING-WATER SUPPLIES

The East Tennessee aquifer system is used extensively throughout its area of occurrence as an important source of drinking-water supplies (fig. 8). The yields are generally adequate for public and domestic supplies. Public water supplies from this aquifer system are listed in table 3. Little use has been made of water from depths greater than 500 feet. Below several hundred feet, ground water represents a resource whose quantity and quality are essentially unknown.

Most of the data for drinking-water supplies come from unpublished sources, primarily the Tennessee Department of Health and Environment. Historic use of water from this aquifer is documented in DeBuchananne and Richardson (1956); Swingle (1959); and Wilson and Johnson (1970).

CONTAMINATION

The East Tennessee aquifer system has 16 locations of documented contamination. The locations are shown in figure 9 and are described in table 4. Each occurrence of contamination is limited geographically and none is believed to pose an immediate threat to the aquifer except in localized areas.

HYDROCARBON, MINERAL AND GEOTHERMAL RESOURCE USE

The East Tennessee aquifer system includes many mineral deposits that were formed during several periods of Appalachian mountain building. These minerals are localized in two major mining areas, although numerous isolated deposits occur throughout East Tennessee. The occurrence of these deposits is generalized and shown in figure 10.

The Ducktown-Copperhill area of Polk County, in the extreme south-eastern part of the State, is the only copper mining area in the State. Copper sulfides occur in metamorphosed sediments of the Great Smoky Group. These deposits have been mined from the surface to a depth of about 2,500 feet.

The other major mining area is in the vicinity of Mascot and Jefferson City, in Knox and Jefferson Counties, where zinc and associated minerals are concentrated. In this area, zinc and lead sulfides occur in the carbonates of the Knox Formation. Other minerals that have been, or may possibly be mined, are gold, barite, galena, pyrite, and manganese.

Some potential for hydrocarbon resources exists throughout the Valley and Ridge province (fig. 10). The greatest potential probably exists along the western margin of the area, where the more deformed rocks of the Valley and Ridge province have buried a toe of Cumberland Plateau rocks. This buried toe is relatively undeformed and may contain hydrocarbons (Harris and Milici, 1977). Deep exploratory drilling for hydrocarbons is currently taking place in the Tennessee part of the Eastern Overthrust.

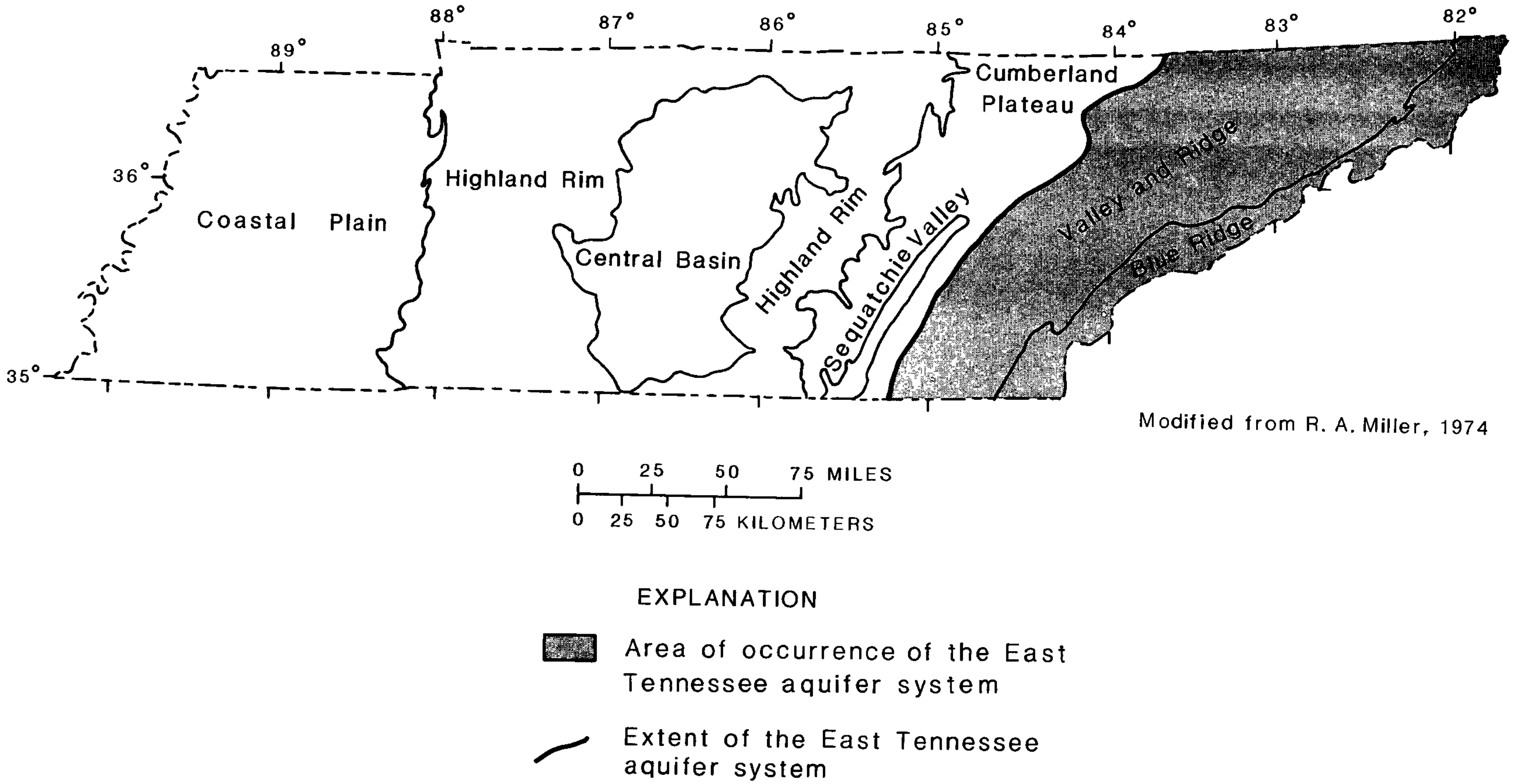
No geothermal resources are known to occur in the East Tennessee aquifer system.

SUMMARY

The East Tennessee aquifer system occurs in the Valley and Ridge and Blue Ridge physigraphic provinces. This aquifer system is composed of formations ranging in age from Precambrian to Mississippian. Limestone, dolomite, and calcareous shale are the principal water-bearing rocks of the area. Unlike the other regional aquifers, the East Tennessee aquifer system is delineated on the basis of its distinct structural and physiographic setting and not on its stratigraphy. Ground-water occurrence in this aquifer, particularly in the Valley and Ridge province, is unique because the water-bearing formations have been deformed by faulting and folding. Regional lateral flow in the permeable formations does not generally occur. For the most part, circulation is restricted to fractures that have been enlarged by solution. Faults that commonly occur within weak shale beds result in discontinuities that tend to isolate ground-water movement into discrete compartments. Ground-water conditions below a depth of about 300 feet are virtually unknown because of the structural complexity of the East Tennessee aquifer system and the paucity of data.

The East Tennessee aquifer system is classified as an underground drinking-water source under the criteria defined by the Safe Drinking Water Act. Water quality in the upper part of the aquifer is generally good to excellent, with dissolved-solids concentrations commonly less than 500 milligrams per liter. This aquifer system is used for drinking water throughout its area of occurrence in Tennessee. There are seven locations where contamination of the aquifer has been documented. However, these are limited geographically and none are thought to threaten the water quality of the aquifer on a regional basis.

Two main areas of mineral resource use occur within the East Tennessee aquifer system. Copper has been mined in the Ducktown-Copperhill area, and zinc and associated minerals are mined in Knox and Jefferson Counties. In addition to these two developed areas of mineral use, exploration for hydrocarbons is currently (1982) taking place along the eastern overthrust belt in the Valley and Ridge province.



Modified from R. A. Miller, 1974

Figure 1.-- Areal extent of the East Tennessee aquifer system and physiographic provinces in Tennessee.

Table 1.--Hydrogeology of the formations comprising the East Tennessee aquifer system

System	Stratigraphic unit	Geologic description	Hydrologic significance: Occurrence in Tennessee	Hydrologic significance: Hydrologic classification and character	Hydrologic significance: Yield
MISSISSIPPIAN	Pennington Formation	Shale, clayey, varicolored, with sandstone partings. Contains massive limestone member. Thickness 150 to 2,250 feet.	Thin outcrops on the western edge of the Valley and Ridge.	Shale and limestone have low porosity and permeability. Little or no development of secondary permeability.	Yields little or no water to wells.
	Newman Limestone	In west, generally pure gray massive limestone containing some chert. Parts contain some shaly beds. Shaly beds appear lower toward the east and the formation becomes more shaly. Thickness 1,200 to 2,500 feet.	Restricted to near the Cumberland Plateau and White Oak Mountain.	Ground water restricted to fractures in the limestone and calcareous shale. Contact between shale and pure limestone is frequently water bearing.	Yield is dependent on number and size of solution cavities. The first 300 feet is most likely to produce water.
	Fort Payne Formation	Limestone, siliceous, gray to bluish-gray, and shale with chert chert stringers. Thickness 100 to 250 feet.	Restricted to White Oak Mountain and western Valley and Ridge.	Contains water in secondary openings.	Yields range from 0 to more than 300 gallons per minute.
	Chattanooga Shale	Shale, black fissile. The Chattanooga Shale is divided into three members. The thickness increases from about 12 to 100 feet.	Restricted mostly to west and northeast margins in Valley and Ridge.	Low porosity and permeability.	Yields little or no water to wells.
DEVONIAN	Hancock Limestone	Thick beds of limestone and dolomite. The majority of these beds are sandy but a few are cherty. Thickness is generally less than 300 feet.	Outcrop restricted to several zones in Valley and Ridge.	Of little importance as an aquifer. Water probably occurs in fractures.	Probable that domestic supplies could be obtained.
SILURIAN	Rockwood Formation	Largely greenish to brownish shale and beds of siltstone and limestone. Hematite beds encountered at varying depths. Thickness 350 to 800 feet.	Outcrop restricted to several zones in Valley and Ridge, from White Oak Mountain toward northeast.	Not important as an aquifer due to limited outcrop. Ground water occurs in fractures.	Springs have small yields. Domestic supplies may be obtained.
	Clinch Sandstone	Thickbedded to massive, well-cemented quartz sandstone. Medium- to coarse-texture.	Outcrop restricted to several zones in Valley and Ridge, from White Oak Mountain toward northeast.	The formation is cemented by silica. Ground water occurs in fractures.	No major water supplies in these rocks. Domestic supplies may be obtained from springs.
ORDOVICIAN	Sequatchie Formation	Mudstone and limestone with some sand, shale, and silty limestone. The limestone is more calcareous in the south than in the north. Thickness 200 to 400 feet.	Narrow linear outcrops in Valley and Ridge.	Ground water occurs in fractures.	Only small quantities of water available for domestic use.
	Chickamauga Limestone	Bluish-gray, well bedded or platy to nodular limestone with interbedded shaly partings. Few thin beds of volcanic ash present. Many fossils in formation. Thickness approximately 2,000 feet.	Widespread occurrence in Valley and Ridge. Northeast to southwest linear outcrops. Repeated occurrence due to faulting.	Ground water occurs in fractures and solution openings.	Domestic supplies available. The aquifer is of no importance for industrial or municipal supplies. Yields range from less than 10 gallons per minute to less than 30.
	Knox Group	Dolomite, gray and brown, fine-grained to granular, and dense white limestone. Chert, thickness approximately 2,500 feet.	Widespread occurrence in Valley and Ridge. Northeast to southwest linear outcrops. Repeated occurrence due to faulting.	Most important aquifer in the area. Water occurs in joints and solution channels. Large springs commonly found in these rocks.	Highly variable, from several gallons per minute to several thousand gallons per minute.
CAMBRIAN	Conasauga Group	Shale, limestone, dolomite. Shale in northwest. Dolomite and limestone to the southeast. Thickness approximately 2,000 feet.	Widespread occurrence in Valley and Ridge. Northeast to southwest liner outcrops. Repeated occurrence due to faulting.	Ground water restricted to small fractures. Shale is so deformed, fractures form an interconnected network. Limestone layers retard downward percolation.	Generally yield several gallons per minute. Some wells yield as much as 200 gallons per minute from limestone solution cavities.

CAMBRIAN	Rome Formation	Sandstone, siltstone, shale, dolomite, and limestone. Shale and siltstone predominate with prominant sandstone beds. In southeast dolomite constitutes half the formation. Thickness varies from 200 to 1,500 feet.	Widespread occurrence in Valley and Ridge. Northeast to southwest linear outcrops. Repeated occurrence due to faulting.	Ground water occurs in fractures in shale and sandstone and in solution channels in the dolomite. The upper zone is more permeable than the lower part of the formation.	Several gallons per minute yields to domestic wells. Springs flow as much as 450 gallons per minute.
	Shady Dolomite	Dolomite, blue-gray to light-gray, silty. Limestone present in lower part and sandy beds occur near the base. Thin layer of argillaceous, shaly dolomite in upper part. Chert present throughout. Thickness approximately 1,000 feet.	Widespread occurrence in Valley and Ridge. Northeast to southwest linear outcrops. Repeated occurrence due to faulting.	Ground water limited to fractures, joints, and bedding planes. Highly variable porosity and permeability. Rock has massive nonporous matrix.	Small to moderately large yields.
	Helenmode Formation	Sandstone and quartzite, fine-grained. Gray to greenish, with shale. Barely exceeds 100 feet in thickness.	Widespread occurrence in Valley and Ridge. Northeast to southwest linear outcrops. Repeated occurrence due to faulting.	Most ground water occurs only in zones of secondary porosity and permeability.	Small to moderately large yields.
	Hesse Sandstone	Sandstone, white, quartzite cemented. Medium- to coarse-grained. Commonly occurs in ledges. Sandstone is interbedded with dark green silty, sandy, or clay shale mixed with very fine siltstones and sandstones. Thickness about 600 feet.	Widespread occurrence in Valley and Ridge. Northeast to southwest linear outcrops. Repeated occurrence due to faulting.	Ground water restricted to fractures in the upper 200 feet of land surface. Most ground water occurs in zones of secondary porosity and permeability.	Small to moderately large yields.
	Murray Shale	Shale, silty, sandy, dull green to brown, micaceous. Thickness approximately 500 feet.	Widespread occurrence in Valley and Ridge. Northeast to southwest linear outcrops. Repeated occurrence due to faulting.	Ground water restricted to fractures in the upper 200 feet of land surface.	Small to moderately large yields.
	Nebo Sandstone	Quartzite, medium-bedded, fine-grain, white, vitreous, in part feldspathic. Approximately 250 feet thick.	Widespread occurrence in Valley and Ridge. North east to southwest linear outcrops. Repeated occurrence due tofaulting.	Ground water occurs in zones of secondary porosity and permeability in the upper 200 feet of land surface.	Small to moderately large yields.
	Nichols Shale	Shale, silty, sandy, containing flakes of detrital mica. Lenses of sandstone present but are relatively thin. Thickness 800 feet.	Widespread occurrence in Valley and Ridge. Northeast to southwest linear outcrops. Repeated occurrence due to faulting.	Ground water restricted to fractures which occur in the upper 200 feet of land surface.	Yields are usually low, generally less than several gallons per minute.
	Cochran Formation	Conglomerate, gray, pebbly arkose, siltstone, and shale. Irregular bedding, micaceous arkose and shale near middle and base. Thickness about 1,200 feet.	Widespread occurrence in Valley and Ridge. Northeast to southwest linear outcrops. Repeated occurrence due to faulting.	Ground water restricted to fractures in the upper 200 feet of land surface.	Small to moderate Yields. Only one of six inventoried springs had an estimated yield greater than 100 gallons per minute.

Table 1.--Hydrogeology of the formations comprising the East Tennessee aquifer system--Continued

System	Stratigraphic unit	Geologic description	Hydrologic significance: Occurrence in Tennessee	Hydrologic significance: Hydrologic classification and character	Hydrologic significance: Yield
PRECAMBRIAN	Walden Creek Group	Shale, siltstone, slate, sandstone, and conglomerate. Consists of four formations: the Sandsuck, Wilhite Formation, Shields Formation, and Licklog Formation. Total thickness about 9,000 feet.	Occurs in extreme eastern part of the State. Limited to Blue Ridge province.	Ground water restricted to fractures caused by joints and cleavage.	Small yields, generally less than several gallons per minute. Capable of supplying domestic water use.
	Cades Sandstone	Metasandstone, with slate and metasiltstone. Gray, well-bedded, fine- to medium-grained, feldspathic. Precise stratagraphic position unknown. Thickness about 1,500 feet.	Occurs in extreme eastern part of the State. Limited to Blue Ridge province.	Ground water restricted to fractures.	Small yields, generally less than several gallons per minute. Capable of supplying domestic water use.
	Great Smoky Group	Sandstone, shale, graywacke, and conglomerate. Charaterized by massive layers oc coarse graywacke and arkose. Thickness 14,000 to 40,000 feet.	Occurs in extreme eastern part of the State. Limited to Blue Ridge province.	Ground water restricted to fractures caused by joints and cleavage. Some small springs.	Small yields, generally less than several gallons per minute.
	Snowbird Group	Siltstone, sandstone, phyllite, quartzite, and graywacke. Total thickness from 13,000 to 20,000 feet.	Occurs in extreme eastern part of the State along North Carolina border.	Ground water restricted to fractures caused by joints and cleavage. Some small springs.	Small yields, generally less than several gallons per minute. Capable to supplying domestic water use.
	Mt. Rogers Group	Metavolcanics, typically purplish and reddish; massive lavas and tuffs, altered rhyolites and quartz latite. Strongly foliated; interbedded arkose, shale, and conglomerate. Thickness 1,000 to 3,000 feet.	Very limited occurrence, only in northeast corner of Tennessee.	Fractures are the only source of porosity and permeability, and are limited to shallow depths. Nonporous and impermeable at depth.	This group yields little water to wells.
	Bakersville Gabbro	Metagabbro, dark, porphyritic, contains diarite, basalt anorthite, and diabase. Occurs as thin to massive dikes. Thickness not known.	Very limited occurrence. Extreme northeastern Tennessee along the border with North Carolina.	Fractures are the only source of porosity and permeability, and are limited to shallow depths. Nonporous and impermeable at depth.	Yield little water to wells, generally less than several gallons per minute.
	Beech Granite	Granite, porphyritic, light-gray to reddish. Spotted appearance. Includes Max Patch Granite. Thickness not known.	Limited occurrence. Extreme eastern Tennessee northern half.	Fractures are the only source of porosity and permeability. Nonporous and impermeable at depth.	Yield little water to wells, generally less than several gallons per minute.
	Cranberry Granite	Migmatite, in a complex of granitic gneisses, monzonite, quartz diorite, greenstone, mica and hornblende schist, and abundant grinitic pegmatite. Thickness not known.	Very limited occurrence. Extreme eastern Tennessee Tennessee on North Carolina border.	Fractures are the only source of porosity and permeability. Nonporous and impermeable at depth.	Yield little water to wells, generally less than several gallons per minute.
	Roan Gneiss	Gneiss, layered hornblende and granite, and granitic migmatite with zones of mica schist and amphibolite; contains numerous granitic and gabboric dikes. Thickness not known.	Very limited occurrence. Extreme eastern Tennessee on North Carolina border.	Fractures are the only source of porosity and permeability. Nonporous and impermeable at depth.	Yield little water to wells, generally less than several gallons per minute.

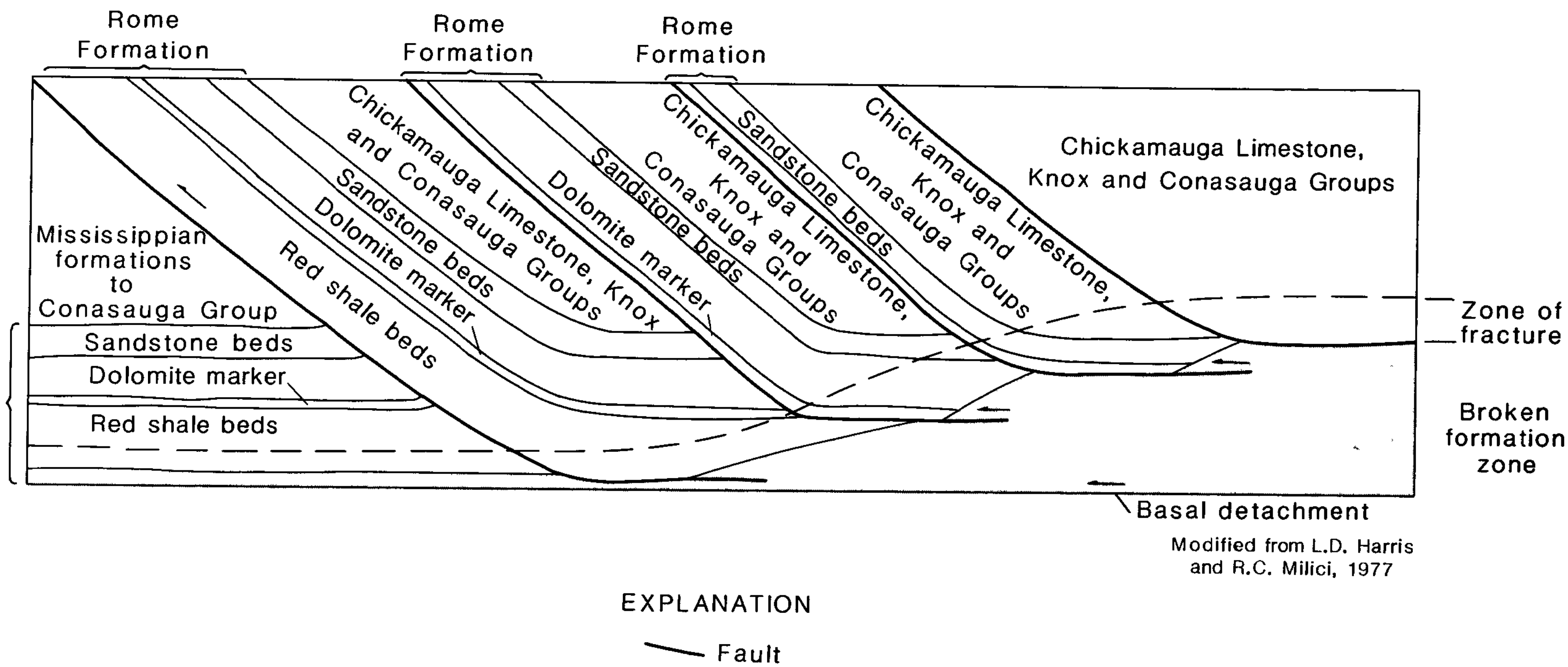


Figure 2.-- Generalized cross section of a fault block in the Valley and Ridge province showing repetition of formations.

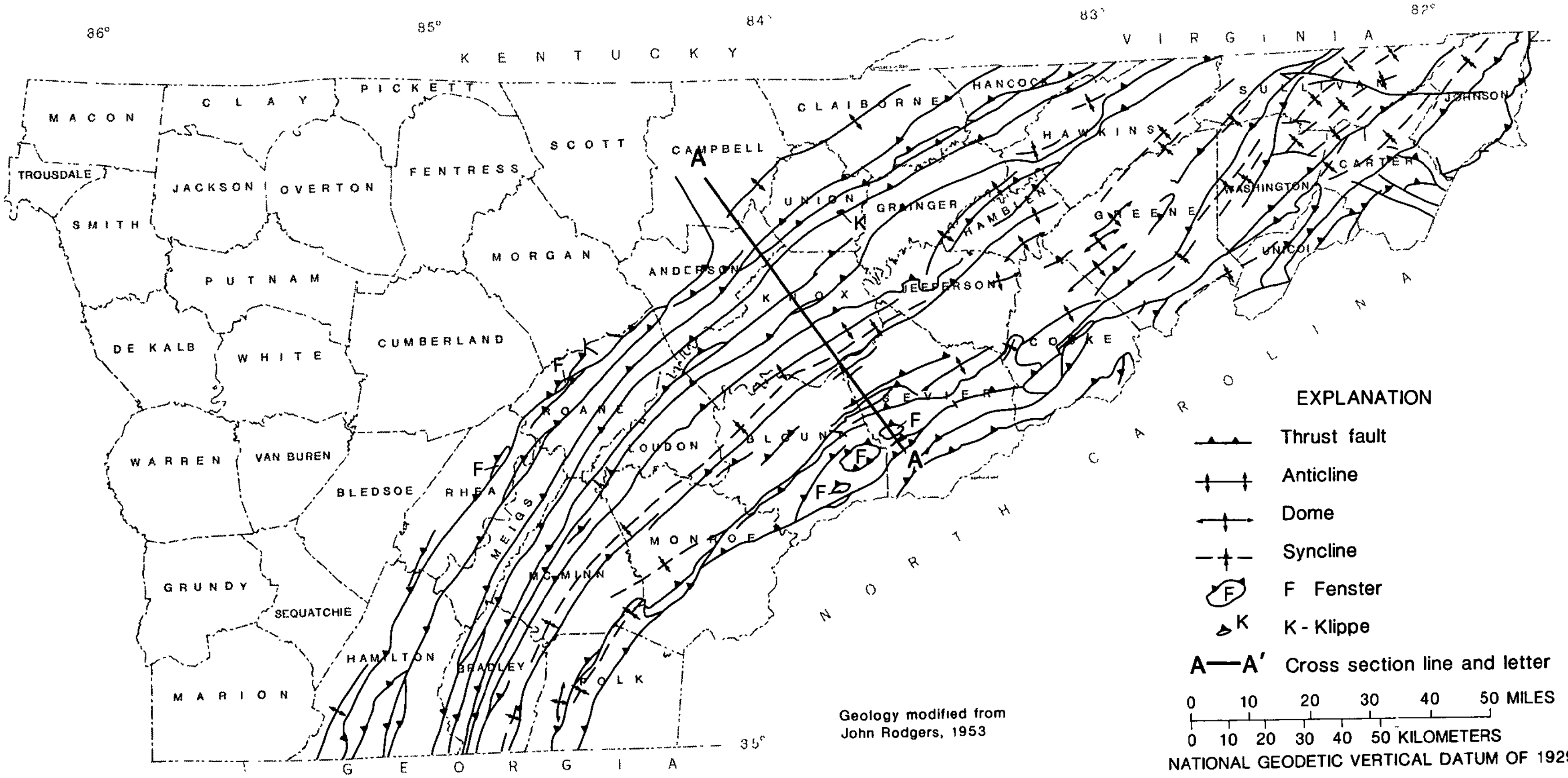


Figure 3.-- Structural features of East Tennessee aquifer system.

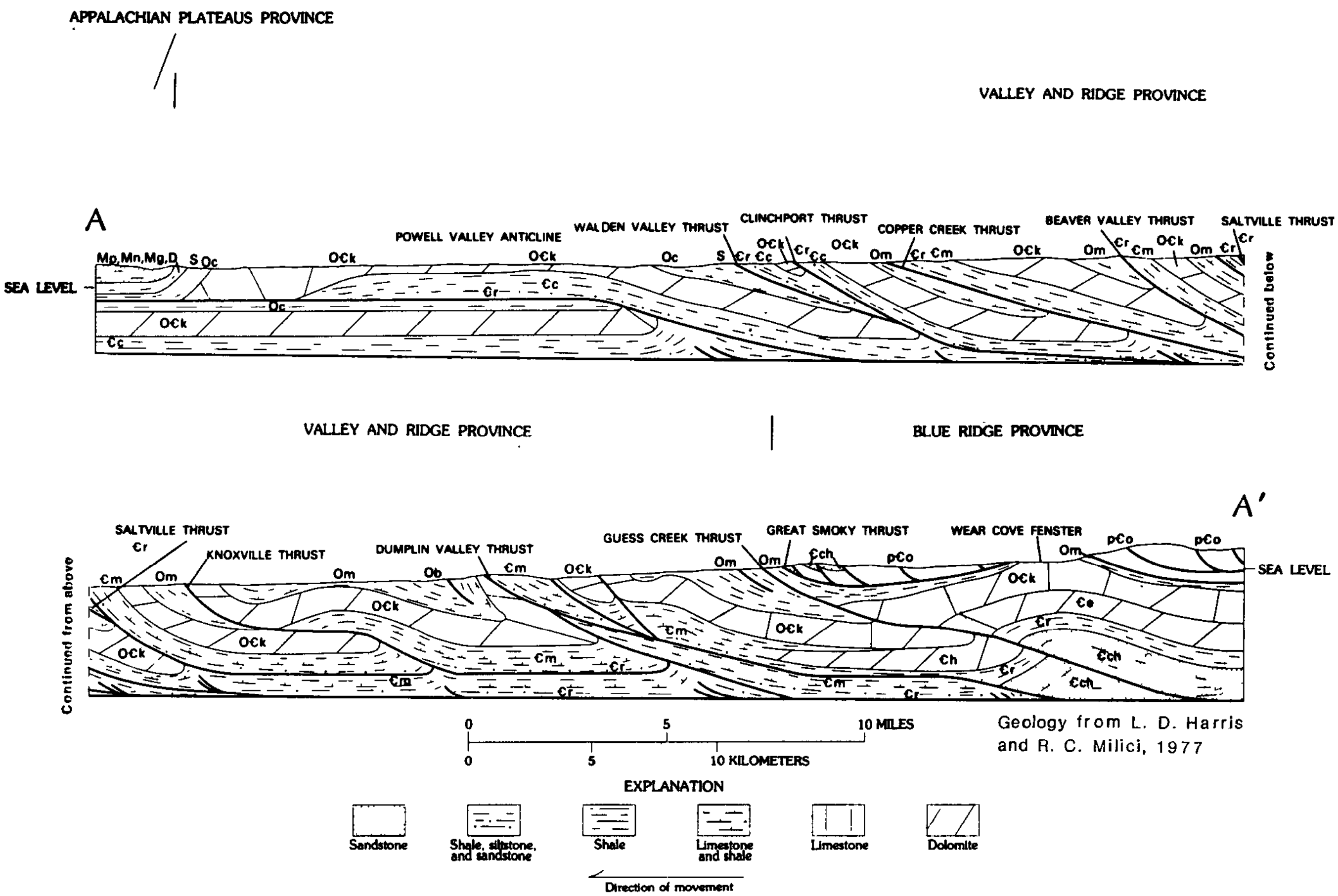


Figure 4.--Generalized geologic cross section of East Tennessee.

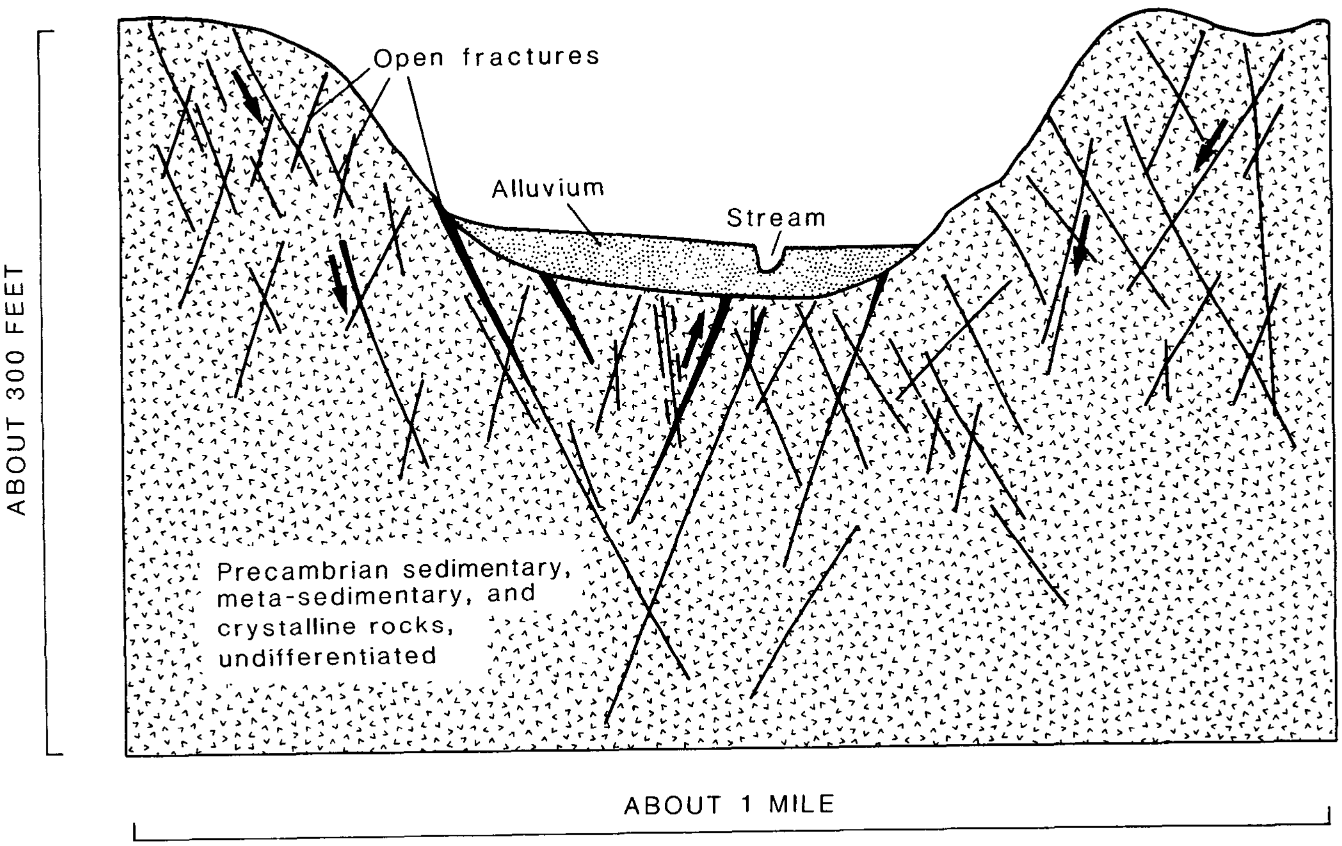


Figure 5.-- Conceptual model of ground-water occurrence in the Blue Ridge province.

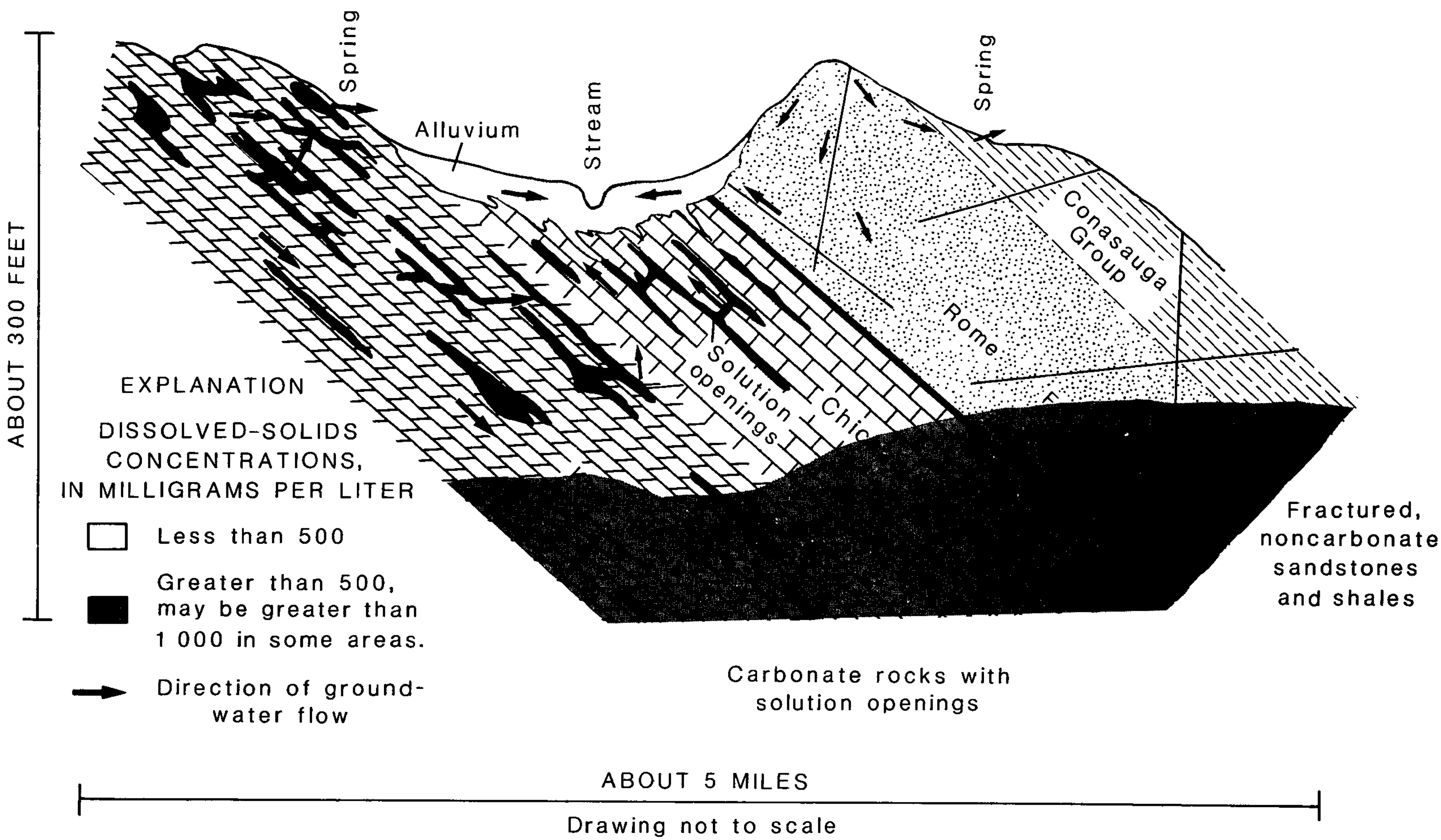
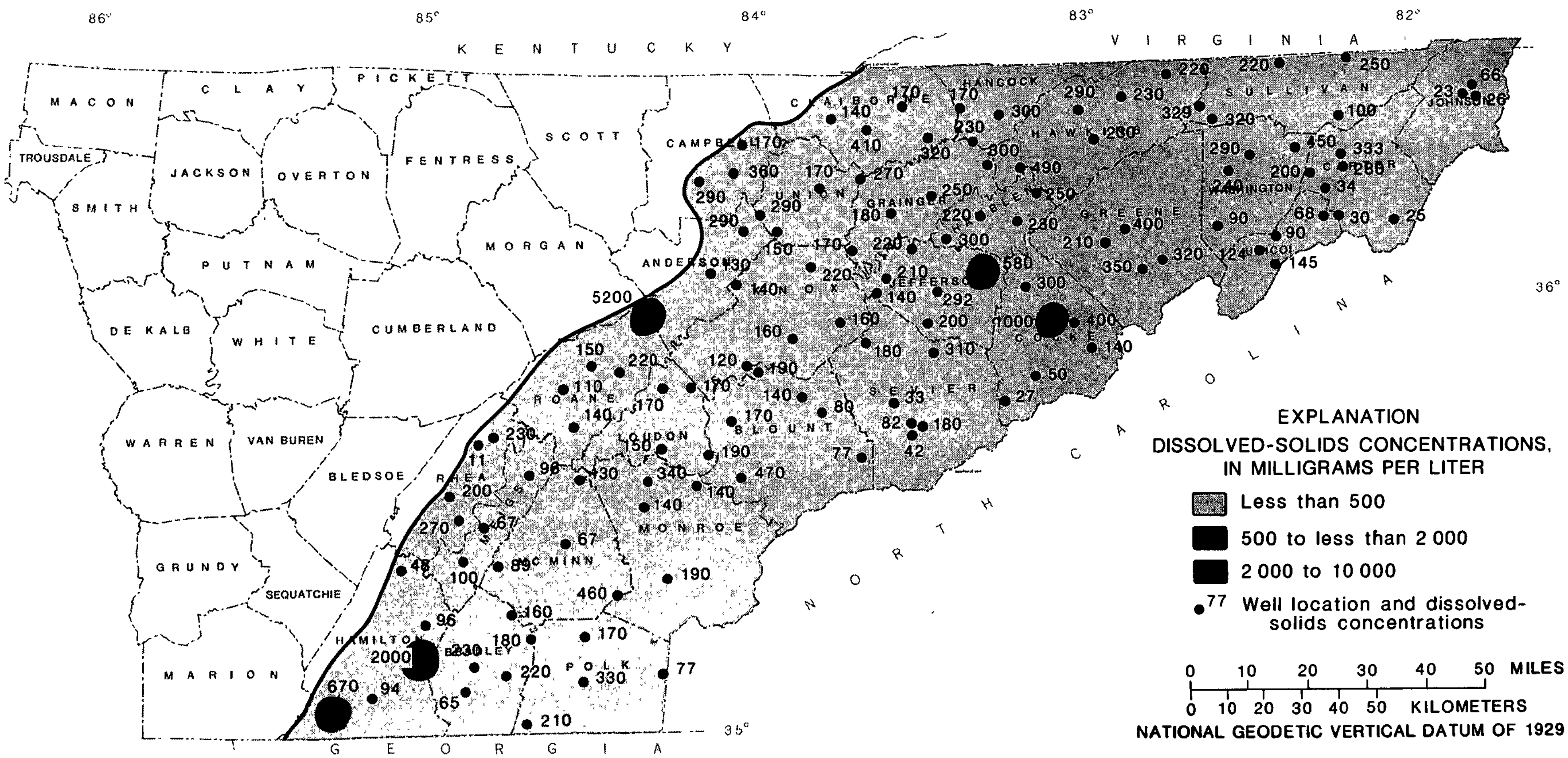


Figure 6.-- Conceptual model of ground-water occurrence and generalized water quality in the Valley and Ridge province.



Base from U.S. Geological Survey
State base map, 1:1,000,000, 1957,
revised 1973

Figure 7.-- Dissolved-solids concentrations in the East Tennessee aquifer system.

Table 2.--Dissolved-solids concentrations in water from the East Tennessee aquifer system

[Data source codes: 1, DeBuchananne and Richardson (1956); 2, McMaster and Hubbard (1970); 3, Maclay (1962); 4, Hollyday and Goddard (1979); 5, Zurawski (1979); 6, Unpublished U.S. Geological Survey records; E Estimated from specific conductance]

County	Location	Well depth, in feet	Water-bearing formation	Dissolved solids, concentrations, in milligrams per liter	Data source
Anderson	Andersonville 0.5 mi NE	114	Chickamauga Limestone	290 E	1
	Clinton 0.5 mi W	Spring	Knox Group	130 E	1
Blount	Friendsville 3 mi SE	Spring	Knox Group	170 E	1
	Mentor 3 mi N	264	Holston Formation	190 E	1
	Rockford 0.5 mi S	460	Lenoir Limestone	140 E	1
	Tallassee 4.5 mi N	64	Athens Shale	470 E	1
	Walland 2.5 mi N	77	do	80 E	1
	Tremont	130		77	2
Bradley	Benton 4.5 mi NW	100	Conasauga Group	180 E	1
	Charleston 2.5 mi SW	Spring	do	160 E	1
	Cleveland 1 mi SW	423	do	230 E	1
	McDonald	30	do	65 E	1
	Ocoee 4 mi W	95	do	220 E	1
Campbell	Duff 3 mi SE	230	Chickamauga Limestone	170 E	1
	Jacksboro 1 mi E	4219	Newala Formation	290 E	1
	Lafollette 4.5 mi SE	300	Copper Ridge Dolomite.	360 E	1
Carter	Elizabethton 3 mi S	135	Honaker Dolomite	280	3
	Elizabethton	95	do	333	3
	Hampton 2 mi SW	109	Shady Dolomite	34 E	1
	Milligan College 0.5 mi S	Spring	Knox Group	210 E	1
	Shell Creek 1 mi SW	Spring	Precambrian crystalline complex.	25 E	1
	Unicoi 6.5 mi E	65	do	30 E	1
Claiborne	Clouds 3.5 mi S	Spring	Longview Dolomite	410 E	1
	Goin 4 mi NW	Spring	Copper Ridge Dolomite.	140 E	1
	Tazewell 3 mi NE	Spring	Mascot Dolomite	170 E	1
	Thorn Hill 4.5 mi NW	128	Conasauga Group	320 E	1

Table 2.--Dissolved-solids concentrations in water from the East Tennessee aquifer system--Continued

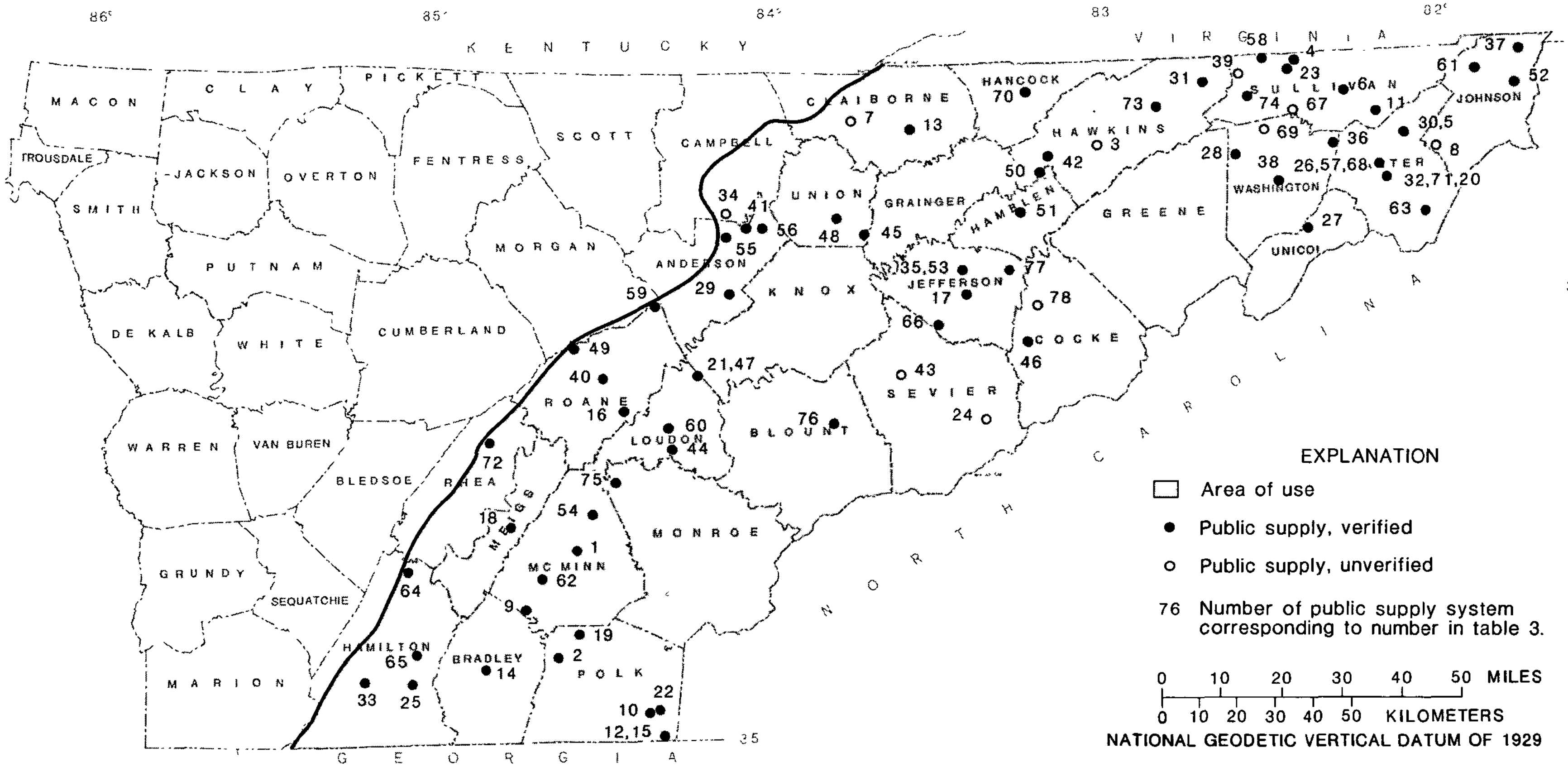
County	Location	Well depth, in feet	Water-bearing formation	Dissolved solids, concentrations, in milligrams per liter	Data source
Cocke	Bybee	47	Sevier Shale	300 E	1
	French Broad 1 mi S	51	Sandsuck Shale	140 E	1
	Hartford 3.5 mi NW	15	Shady Dolomite	50 E	1
	Newport 1.5 mi NE	135	Sevier Shale	1000 E	1
	Parrottsville 4.5 mi SE	105	Honaker Dolomite	400 E	1
	Indian Camp Creek	194		27	2
Grainger	Blaine	75	Conasauga Group	170 E	1
	Joppa 2 mi E	Spring	Copper Ridge Dolomite.	180 E	1
	Mooresburg 3 mi W	Spring	Chickamauga Limestone	300 E	1
	Rutledge 3.5 mi E	210	Copper Ridge Dolomite.	250 E	1
Greene	Cedar Creek 6 mi NE	25	Knox Group	350 E	1
	Greenville 2.5 mi NW	310	Sevier Shale	400 E	1
	Mosheim 3 mi SE	90	do	210 E	1
	Tusculum College 5 mi S	195	Knox Group	320 E	1
Hamblen	Morristown 1.5 mi NW	Spring	Newala Formation	220 E	1
	Russellville 3.5 mi S	Spring	Knox Group	230 E	1
	Talbott 1 mi N	201	Newala Formation	300 E	1
	Whitesburg	Spring	Knox Group	250 E	1
Hamilton	Chattanooga	65	Knox Group	670 E	1
	Georgetown 5 mi SW	Spring	do	96 E	1
	McDonald 5 mi NW	67	Chickamauga Limestone.	2000 E	1
	Sale Creek 0.5 mi E	60	Newman Limestone	48 E	1
	Tyner 2 mi W	200	Newala Formation	94 E	1
Hancock	Luther 6.5 mi W	45	Pumpkin Valley Shale	300 E	1
	Thorn Hill 9.5 mi N	Spring	Newman Limestone	170 E	1
	Thorn Hill 5 mi NE	43	Chickamauga Limestone	230 E	1
Hawkins	Church Hill 2.5 mi N	Spring	Conasauga Group	220 E	1
	Eidson 3 mi SE	17	Newman Limestone	290 E	1
	Mooresburg 2.5 mi E	220	Moccasin Formation	490 E	1
	Rogersville 3 mi E	Spring	Copper Ridge Dolomite.	230 E	1
	Surgoinsville 2 mi N	Spring	Conasauga Group	230 E	1

Table 2.--Dissolved-solids concentrations in water from the East Tennessee aquifer system--Continued

County	Location	Well depth, in feet	Water-bearing formation	Dissolved solids, concentrations, in milligrams per liter	Data source
Jefferson	Dandridge 0.25 mi NW	400	Copper Ridge/Chepultepec Dolomite.	292	4
	Dandridge 5.5 mi SW	117	Sevier Shale	200 E	1
	Jefferson City 3 mi NW	Spring	Copper Ridge Dolomite.	220 E	1
	New Market 6.5 mi SW	130	Mascot Dolomite	140 E	1
	Strawberry Plains 0.5 mi E	Spring	Lenoir Limestone	210 E	1
	White Pine 1.5 mi SW	105	Knox Group	580 E	1
Johnson	Mountain City 1 mi W	107	Rome Formation	23 E	1
	Mountain City 1 mi E	Spring	Shady Dolomite	26 E	1
	Mountain City 1.5 mi NE	Spring	Rome Formation	66 E	1
Knox	Corryton 4 mi SW	Spring	Chickamauga Limestone	220 E	1
	Heiskell 0.5 mi W	60	do	140 E	1
	Knoxville 2.5 mi SE	168	Holston Formation	160 E	1
	Louisville 4 mi N	30	Chepultepec Dolomite	120 E	1
	Mascot 5.5 mi S	168	Mascot Dolomite	160 E	1
Loudon	Greenback	82	Knox Group	190 E	1
	Lenoir City 2.5 mi NW	68	Chickamauga Limestone	170 E	1
	Loudon 5 mi SE		Copper Ridge Dolomite	150 E	1
	Martel	Spring	Lenoir Limestone	170 E	1
McMinn	Athens	Spring	Kingsport Formation	67 E	1
	Big Spring 5.5 mi E	Spring	Knox Group	89 E	1
	Erie 3 mi SE		Longview Dolomite	130 E	1
	Etowah 4 mi E	26	Athens Shale	460 E	1
Meigs	Big Spring	Spring	Chickamauga Limestone	100 E	1
	Decatur 3.5 mi SW	Spring	Knox Group	67 E	1
	Ten Mile 4.5 mi SW	54	do	96 E	1
Monroe	Madisonville 0.5 mi E	80	Conasauga Group	140 E	1
	Philadelphia 5.5 mi SE	85	Newala Formation	340 E	1
	Tellico Plains	90	Shady Dolomite	190 E	1
	Vonore 2.5 mi E	300	Knox Group	140 E	1
Polk	Archville 1.5 mi SW	200	Ocoee series	330 E	1
	Conasauga	125	Athens Shale	210 E	1
	Delano 2.5 mi S	Spring	Conasauga Group	170 E	1
	Turtletown 1.5 mi E	60	Great Smokey conglomerate.	77 E	1

Table 2.--Dissolved-solids concentrations in water from the East Tennessee aquifer system--Continued

County	Location	Well depth, in feet	Water-bearing formation	Dissolved solids, concentrations, in milligrams per liter	Data source
Rhea	Evensville	84	Chickamauga Limestone	200 E	1
	Evensville 4 mi SE	85	do	270 E	1
	Grandview 2.5 mi SE	43	Knox Group	230 E	1
	Spring City 1 mi S	25	do	11 E	1
Roane	Erie 6 mi N	45	Chickamauga Limestone	140 E	1
	Kingston 2.5 mi NW	12	Conasauga Group	150 E	1
	Kingston 6 mi SW	69	Chickamauga Limestone	110 E	1
	Kingston 4 mi E	88	Conasauga Group	220 E	1
	Oak Ridge	90	do	5200 E	6
Sevier	Boyds Creek 1 mi W	Spring	Knox Group	180 E	1
	Gatlinburg	100	Great Smokey conglomerate.	180 E	1
	Gatlinburg	255	Snowbird Group	82	5
	Gatlinburg	230	do	42	5
	Pigeon Forge 2.5 mi SW	36	Sandsuck Shale	33 E	1
	Sevierville 6.5 mi NE	38	Sevier Shale	310 E	1
Sullivan	Blountville 4 mi NW	209	Knox Group	220 E	1
	Bluff City 4.5 mi SE	Spring	Sevier Shale	100 E	1
	Bristol	280	Knox Group	250 E	1
	Fall Branch 3.5 mi N	80	Sevier Shale	330 E	1
Unicoi	Erwin	135	Honaker Dolomite	90	1
	Erwin 3 mi SW	122	Erwin Formation	124	1
	Erwin 4 mi S	Spring	Unicoi Formation	145	1
	Unicoi 5 mi E	30	Shady Dolomite	68 E	1
Union	Andersonville 6 mi E	Spring	Kingsport Formation	150 E	1
	Andersonville 4 mi NE	350	Chickamauga Limestone	290 E	1
	Maynardville 3.5 mi N	Spring	Ottosee Shale	170 E	1
	Powder Springs 4 mi N	20	Conasauga Group	270 E	1
Washington	Johnson City 6 mi NW	342	Knox Group	290 E	1
	Jonesboro 3.5 mi W	Spring	do	240 E	1
	Washington College 4 mi S	57	do	90 E	1
	Watauga 3 mi W	136	Sevier Shale	450 E	1



Base from U S. Geological Survey
State base map 1 1,000,000,1957,
revised 1973

Figure 8.-- Public-supply systems and area of use of water from the East Tennessee aquifer system.

Table 3.--Summary of public-supply systems using water from the East Tennessee aquifer system

[Data source codes: 1, Reported - Tennessee Division of Water Resources; 2, Reported - Tennessee Division of Water Quality Control; 3, Tennessee comprehensive joint water and related land resources planning, Tennessee Division of Water Resources]

Location No.	System	County	Data source
1	Athens	McMinn	1,2,3
2	Benton	Polk	1,2,3
3	Big Creek U.D.	Hawkins	2
4	Bloomingdale U.D.	Sullivan	1,3
5	Blue Springs U.D.	Carter	2
6	Bluff City	Sullivan	1,2,3
7	Cape Norris Subdivision	Claiborne	2
8	Carderview U.D.	Johnson	2
9	Charleston-Calhoun U.D.	McMinn	1,2,3
10	Cherokee Hills	Polk	1,2,3
11	Chinquapin Grove U.D.	Sullivan	1,2,3
12	Cities Service	Polk	1,2,3
13	Claiborne Co. U.D.	Claiborne	1,2,3
14	Cleveland	Bradley	2,3
15	Copperhill	Polk	1,2,3
16	Cumberland U.D.	Roane	1,2,3
17	Dandridge	Jefferson	1,2,3
18	Decatur	Meigs	1,2,3
19	Delano	Polk	1,2,3
20	Dividing Ridge Utilities, Inc.	Carter	2
21	Dixie Lee U.D.	Loudon	1,2,3
22	Ducktown	Polk	2,3
23	East Kingsport U.D.	Sullivan	1,3
24	East Sevier U.D.	Sevier	2
25	Eastside U.D.	Hamilton	1,2,3
26	Elizabethton	Carter	1,2,3
27	Erwin	Unicoi	1,2,3
28	Fall Branch	Washington	1,2,3
29	First U.D. of Anderson Co.	Anderson	1,2,3
30	First U.D. of Carter Co.	Carter	1,2,3
31	First U.D. of Hawkins Co.	Hawkins	1,2,3
32	Hampton U.D.	Carter	1,2,3
33	Hixson U.D.	Hamilton	1,2,3
34	Indian River	Campbell	2
35	Jefferson City	Jefferson	1,2,3
36	Johnson City	Washington	1,2,3
37	Johnson Co. Utilities Nos. 1 and 2	Johnson	2,3
38	Jonesboro	Washington	1,2,3
39	Kingsport	Sullivan	2

Table 3.--Summary of public-supply systems using water from the East Tennessee aquifer system--Continued

Location No.	System	County	Data source
40	Kingston	Roane	1,2,3
41	Lake City	Anderson	1,2,3
42	Lakemont	Hawkins	1,2,3
43	Little Ponderosa	Sevier	2
44	Loudon	Loudon	1,2,3
45	Luttrell-Blaine-Corryton U.D.	Union	1,2,3
46	L.W. Hooper	Cocke	1,2,3
47	Martel U.D.	Loudon	2
48	Maynardville	Union	1,2,3
49	Midtown Water Co.	Roane	1,3
50	Mooresburg U.D.	Hawkins	1,2,3
51	Morristown	Hamblen	1,2,3
52	Mountain City	Johnson	1,2,3
53	New Market U.D.	Jefferson	2
54	Niota	McMinn	1,2,3
55	Norris	Anderson	1,2,3
56	North Anderson Co. U.D.	Anderson	1,2,3
57	North Elizabethton Water Co-op	Carter	2
58	North Kingsport U.D.	Sullivan	1,3
59	Oliver Springs	Roane	1,2,3
60	Piney	Loudon	1,2,3
61	Pleasant Valley U.D.	Johnson	1,2,3
62	Riceville U.D.	McMinn	1,2,3
63	Roan Mountain Water Co.	Carter	1,2,3
64	Sale Creek	Hamilton	1,2,3
65	Savannah Valley U.D.	Hamilton	2
66	Shady Grove U.D.	Jefferson	2
67	Sharps Creek Subdivision	Sullivan	2
68	Siam U.D.	Carter	2
69	Sinking Creek Spring	Washington	2
70	Sneedville U.D.	Hancock	1,2,3
71	South Elizabethton U.D.	Carter	2
72	Spring City	Rhea	1,2,3
73	Surgoinsville U.D.	Hawkins	1,2,3
74	Sullivan Gardens U.D.	Sullivan	1,2,3
75	Sweetwater	Monroe	2
76	Walland	Blound	1,2,3
77	White Pine	Jefferson	1,2,3
78	Wood Acres Subdivision	Cocke	2

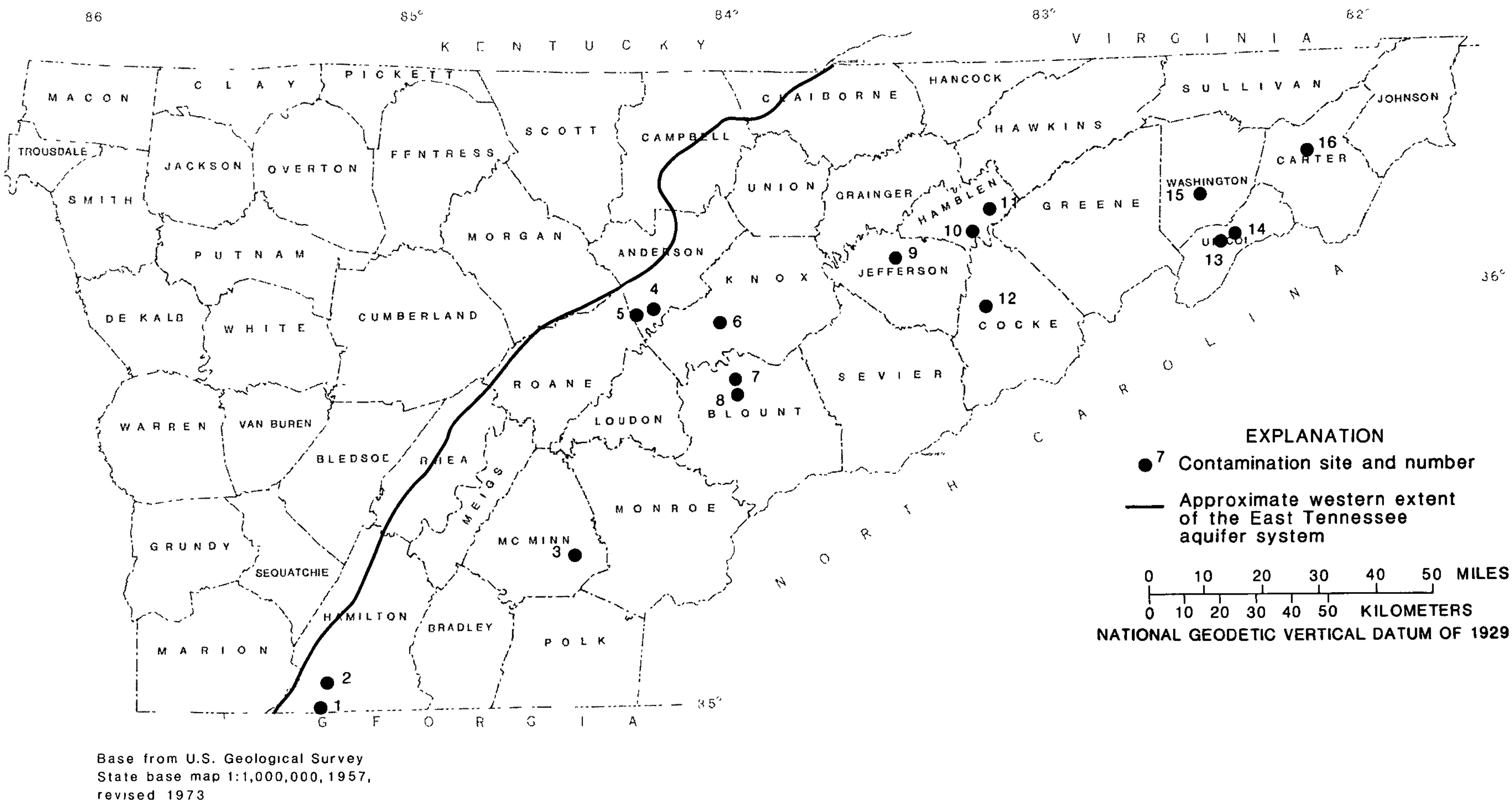


Figure 9.-- Contamination sites in the East Tennessee aquifer system.

Table 4.--Description of contamination sites

[Documentation Codes: a, Tennessee Division of Water Quality Control, unpublished records; b, Webster (1976); c, Residual Waste Study, Tennessee Division of Water Quality Control; d, Hyfantis (1980)]

Site identification No.	Location	Type of contamination	Documentation	Stratigraphic interval	Comments
1	Hamilton County, Residue Hill.	Industrial wastes	a	Knox Group	Initial water-quality data were collected from eight monitoring wells around Residue Hill. Data indicated ground-water contamination by phenolic compounds, chlorinated hydrocarbons, several metals, and several volatile organics such as benzene and toluene.
2	Hamilton County, Chattanooga.	Industrial wastes	a	Knox Group	A test well, drilled by TVA, encountered an oily, organic substance with an odor like coal tar creosote. A coal gasification plant is said to have been located nearby, and the area served as an industrial dump for years.
3	McMinn County	Industrial wastes	a		Ground water and surface water were contaminated with iron, manganese, COD, oil, grease, phenols, and diphenyl ether by dumping finishing oils into trenches. Wastewater from lagoons drained through solution openings in the limestone to a nearby creek.
4	Anderson County	Low level radioactive wastes.	b	Conasauga Group.	Ongoing program to define exact areas and constituents. No present evidence of extensive migration of contaminants.
5	Anderson County	Industrial wastes	a	Conasauga Group.	Nitrate, mercury, and other industrial wastes have contaminated area ground and surface water.

Table 4.--Description of contamination sites--Continued

Site identification No.	Location	Type of contamination	Documentation	Stratigraphic interval	Comments
6	Knox County	Industrial wastes	a	Knox Group	Indiscriminate disposal of industrial wastes resulted in manganese contamination of ground water.
7	Blount County	Industrial wastes	a	Conasauga ? Group.	Earthen pits were used for the disposal of oily wastes. A nearby spring was found to be contaminated with oil and grease.
8	Blount County	Industrial wastes	a	Conasauga ? Group.	This facility has been used for the disposal of fluoride dust from air pollution control facilities. Ground water in the area was contaminated by fluoride.
9	Jefferson County		a	Knox Group	Mining operations have resulted in significant increases of zinc and, at times, suspended solids and turbidity levels in ground water.
10	Hamblen County	Industrial wastes	c	Knox ? Group	Objectionable quantities of organic compounds, dissolved solids, iron, manganese, sodium, sulfate, and phenols. Dissolved solids, sulfates, and phenols exceed drinking-water standards. Extent of ground-water degradation in the vicinity undetermined, but there is a high potential for continued, widespread degradation.
11	Morristown-Hamblen County	Municipal and industrial wastes?	c	Knox ? Group	High iron and manganese concentrations exceed drinking-water standards, definitely associated with the landfill. Hardness and dissolved solids higher than normal for the area, but cannot be specifically linked to the landfill at this time.

Table 4.--Description of contamination sites--Continued

Site identification No.	Location	Type of contamination	Documentation	Stratigraphic interval	Comments
12	Cocke County, Newport.	Laboratory wastewater	a	Knox Group	Laboratory wastewater was discharged into a sinkhole which resulted in the degradation of the ground-water quality. Studies indicated severe degradation of the ground water in the area of a spray irrigation system.
13	Unicoi County, Bumpass Cove.	Hazardous wastes	d	Shady Dolomite.	The illegal dumping of hazardous waste into an approved sanitary landfill resulted in the contamination of area ground water. Methylene chloride and trichloroethylene were found in a resident's well.
14	Unicoi County, Erwin.	Industrial and radiological wastes	a	Honaker ? Dolomite.	The disposal of industrial and radiological wastes has resulted in the contamination of ground water locally.
15	Washington County, Telford.	Industrial wastes	a	Knox Group	The discharge of industrial wastes into an unlined earthen pond resulted in the contamination of surface and ground water by fluoride and nitrate.
16	Carter County, Elizabethton.	Industrial wastes	a	Homaker Dolomite.	Waste disposal and solid residues have caused ground-water contamination by copper and zinc.

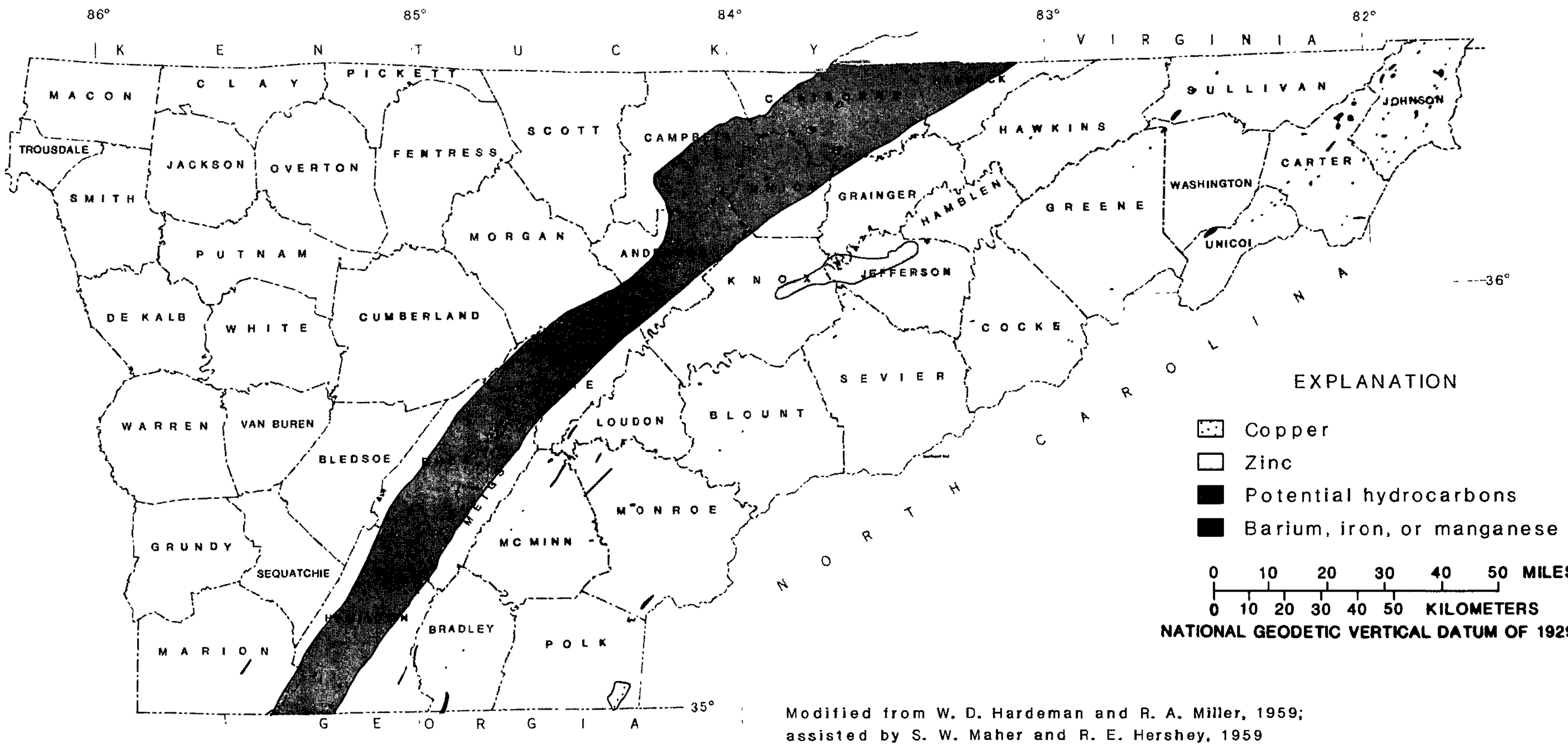


Figure 10.--Current and potential hydrocarbon, mineral, and geothermal resources.

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