The Hydrogeology of Tennessee

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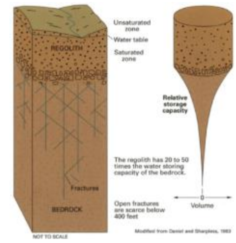
Relative Storage Capacity vs. Depth

- Alluvium generally has highest storage capacity
- Related to sand and gravel content
- Bedrock storage capacity in TN is highly dependent on fractures
- Fewer fractures with depth



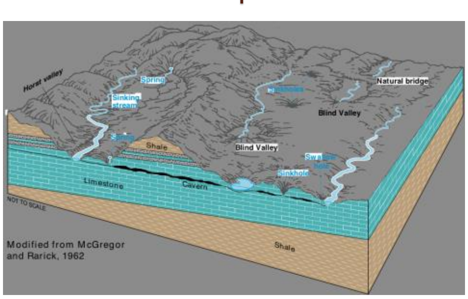
Karst Hydrogeology

- Two thirds of Tennessee is underlain by limestone.
- Karst is an important groundwater source in those areas.
- Primary porosity is low in limestone.
- Secondary porosity i.e. solution cavities and fractures are an important groundwater source.
- Karst aquifers best developed near surface and in relatively pure limestones.

Karst Aquifers

- Openings forming the karst aquifer may be partly or completely water-filled.
- The elevation where all pores are filled with water in an aquifer is the water table.
- Water tables in karst areas can be highly irregular in elevation, because water-carrying conduits can develop at various elevations.

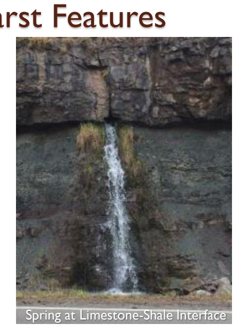
Idealized Diagram of Karst Development



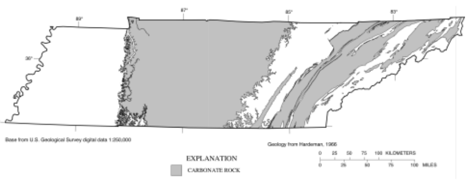
Example Karst Features


Sinking Stream

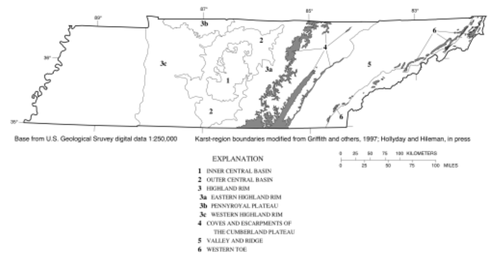

Epikarst Development


Spring at Limestone-Shale Interface

Distribution of Limestone in Tennessee

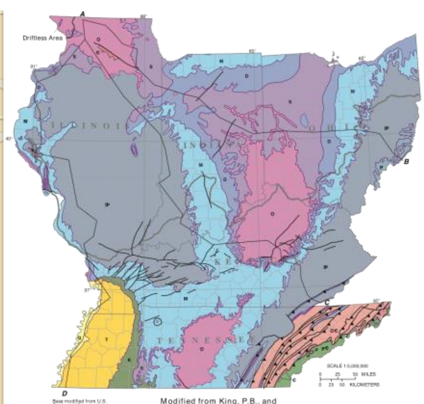


Karst Regions of Tennessee



REGIONAL GEOLOGY

Regional Geology

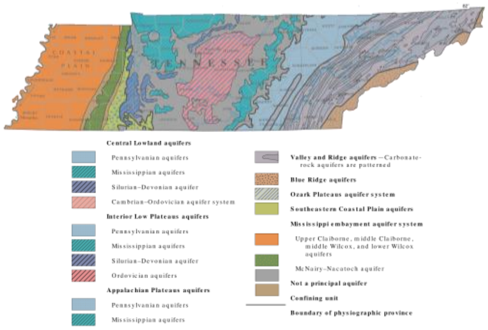


Modified from King, P.B., and Beikman, H.M., 1974, Geologic map of the United States: U.S. Geological Survey, 3 sheets, scale 1:2,500,000.

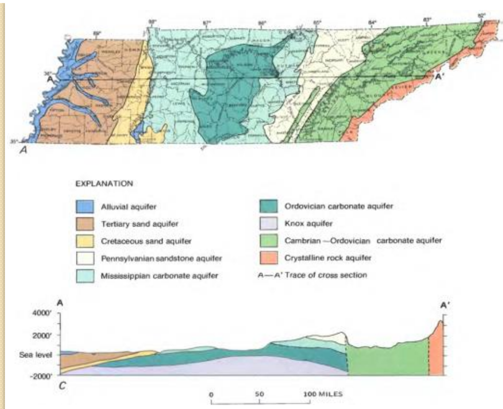
Generalized Geology Key

Regional Structural Setting

Tennessee Aquifer Systems

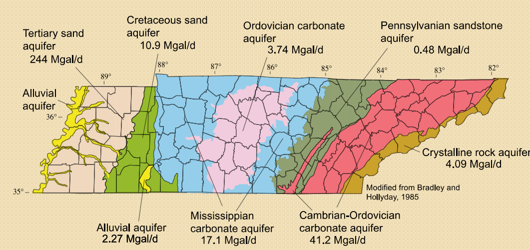


TENNESSEE HYDROGEOLOGY OVERVIEW



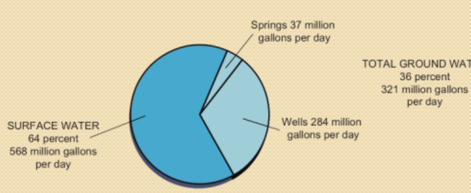
PRINCIPAL AQUIFERS IN TENNESSEE

Rate of water withdrawal by public water systems in millions of gallons per day, 2000
Source: U. S. Geological Survey

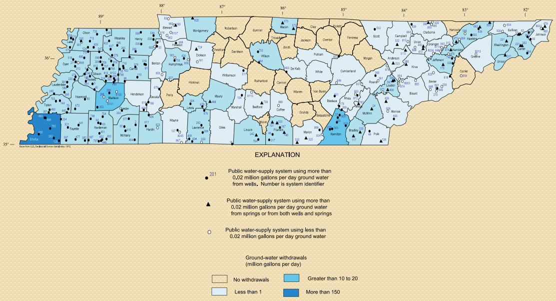


TENNESSEE WATER SUPPLY SOURCES

Source of water supply, in percent, for public water supply withdrawals in Tennessee, 2000
Source: U. S. Geological Survey

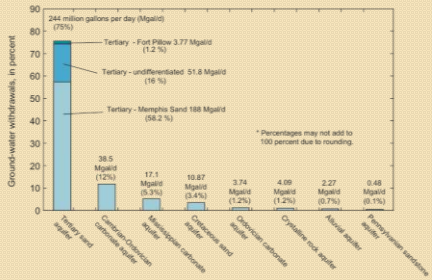


PRINCIPAL TN PUBLIC WATER SUPPLY SYSTEMS THAT WITHDREW GROUNDWATER IN 2000



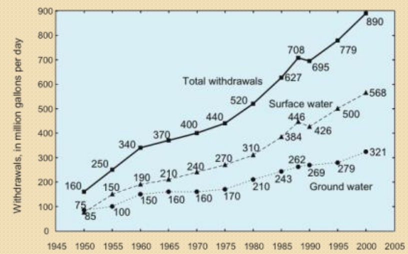
GROUNDWATER WITHDRAWALS FROM PRINCIPAL AQUIFERS, 2000

Source: U. S. Geological Survey



TRENDS IN PUBLIC WATER SUPPLY WITHDRAWALS, 1950-2000

Source: U. S. Geological Survey



TOP 10 COUNTIES FOR PUBLIC WATER SUPPLY WITHDRAWALS, 2010

Source: U. S. Geological Survey

County	Population Served	Withdrawals (Mgd)
Shelby	924,861	173.07
Madison	86,464	13.23
Hamilton	333,606	10.7
Carter	44,302	7.46
Tipton	59,109	6.5
Obion	31,636	5.34
Gibson	39,774	5.25
Dyer	36,890	5.17
Jefferson	38,758	4.58
Montgomery	169,404	3.58

TOP 10 COUNTIES FOR DOMESTIC WATER SUPPLY WITHDRAWALS, 2010

Source: U. S. Geological Survey

County	Population on Well Water	Withdrawals (Mgd)
Rutherford	34,507	2.48
Sevier	31,317	2.25
Fayette	22,675	1.63
Robertson	20.752	1.49
Hawkins	17,885	1.29
Grainger	15,294	1.10
Blount	14,284	1.03
Carter	13,122	0.94
McMinn	13,104	0.94
Jefferson	12,649	0.91

WELL DRILLING TRENDS IN TENNESSEE

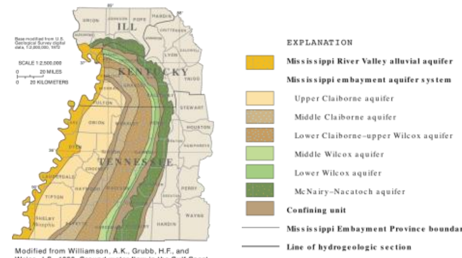
Source: Tennessee Department of Environmental and Conservation, Division of Water Resources

Year	Number of Wells Drilled (approx)
2007	5000
2010	2400
2015	2150

REGIONAL AQUIFER SYSTEMS

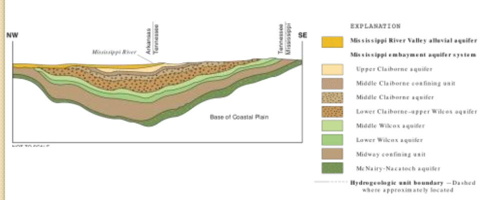
Mississippi Embayment Aquifer System

Mississippi Embayment Aquifer System

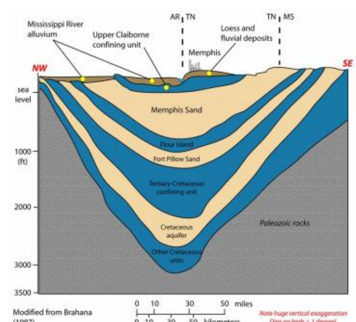


Modified from Williamson, A.K., Grubb, H.F., and Weiss, J.S., 1990, Ground-water flow in the Gulf Coast aquifer systems, south-central United States—A preliminary analysis: U.S. Geological Survey Water-Resources Investigations Report 9–4071, 123 p.

Mississippi Embayment Cross Section



Memphis Aquifers



Mississippi Embayment Stratigraphy

System	Series	Geologic unit: Illinois	Geologic unit: Kentucky	Geologic unit: Tennessee	General lithology	Hydrogeologic unit[1]
Quaternary	Holocene and Pleistocene	Alluvium and terrace deposits	Alluvium and loess deposits	Alluvium and loess deposits	Sand, gravel, and loess	Mississippi River Valley alluvial aquifer
Tertiary	Eocene		Jackson Formation	Jackson Formation	Sand, silt, and clay	Upper Claiborne aquifer (Mississippi embayment aquifer system)
			Claiborne Group: Cockfield Formation	Claiborne Group: Cockfield Formation		
			Claiborne Group: Cook Mountain Formation	Claiborne Group: Cook Mountain Formation	Clay and silt	Middle Claiborne confining unit
			Claiborne Group: Sparta Sand	Claiborne Group: Memphis Sand	Sand and minor clay. Some lignite	Middle Claiborne aquifer
			Claiborne Group: Tallahatta Formation			Lower Claiborne–upper Wilcox aquifer
	Paleocene	Wilcox Formation	Wilcox Formation	Wilcox Group: Flour Island Formation		
				Wilcox Group: Fort Pillow Sand		Middle Wilcox aquifer
				Wilcox Group: Old Breastworks Formation		Lower Wilcox aquifer
		Midway Group: Porters Creek Clay	Midway Group: Porters Creek Clay	Midway Group: Porters Creek Clay	Clay and minor sand	Midway confining unit
		Midway Group: Clayton Formation	Midway Group: Clayton Formation	Midway Group: Clayton Formation		
Cretaceous	Upper	McNairy Sand	McNairy Sand	McNairy Sand	Sand	McNairy–Nacatoch aquifer
		Nacatoch Sand	Nacatoch Sand	Nacatoch Sand		

[1] Hydrogeologic unit names apply to the entire Mississippi embayment aquifer system. Local names may differ.

Detailed Stratigraphy

System	Series	Stratigraphic unit	Geologic description	Hydrologic significance: Occurrence in Tennessee	Hydrologic significance: Hydrologic classification and character	Hydrologic significance: Yield
QUATERNARY	HOLOCENE AND PLEISTOCENE	Alluvial Deposits	Sand, gravel, silt, and clay. 0 to 175 feet thick. Thickest beneath the Mississippi River alluvial plain; probably no more than 50 feet elsewhere.	Underlies the Mississippi River flood plain and flood plains of other major streams. The Mississippi River alluvium occurs along the western part of Lake, Dyer, Lauderdale, Tipton, and Shelby Counties.	Local aquifer in Tennessee. Provides water to domestic wells, recharges deeper aquifers.	Wells yields in Tennessee are generally less than 50 gallons per minute. Wells capable of 2,000 gallons per minute have been constructed in Arkansas and Mississippi.
	PLEISTOCENE	Loess	Wind-deposited silt, silty clay, and minor sand. 0 to 65 feet thick. Thickest on bluffs that border the Mississippi River alluvial plain. Thins towards the east.	Forms a blanket over the terrace deposits and older formations in upland areas.	Local confining unit. Retards downward movement of water to shallow aquifers. Low permeability.	Wells are not known to be constructed in the loess.
	PLEISTOCENE AND PLIOCENE	Terrace Deposits	Sand, gravel, and minor clay. Thickness 0 to 100 feet.	Underlies the upland areas in a broad, irregular belt east of the Mississippi River alluvial plain; may be locally absent. Formations are not continuous.	Local aquifer capable of supplying domestic wells. High permeability.	Well yields are generally less than 50 gallons per minute. The potential for larger yields is good where the formation is thick.
TERTIARY	EOCENE	Jackson Formation	Formation is predominantly clay with lenses of fine sand and layers of lignite, which attain a thickness of several feet. The total thickness of the formation ranges from 0 to 350 feet. This formation is locally called the "capping clay."	Essentially continuous over most of the counties bordering the Mississippi River. Lithologically indistinguishable from the upper clay to the Claiborne Formation. Occurrence has not been mapped in detail.	Generally impermeable and considered to be the upper confining bed for water in the Claiborne Formation.	Fine-grained sand lenses yield several gallons per minute to domestic wells.
		Claiborne Formation	Sand, fine- to coarse-grained, minor amounts of lignite, clay, and silt. Thickness ranges from 200 to 750 feet and averages 450 feet. When divided, the upper clay forms part of the "capping clay," and the sand is also called the Memphis Sand or the "500-foot sand."	Present throughout the western part of West Tennessee.	Highly permeable sand of this formation is the most prolific aquifer in the State. Low permeability clay layers are common but are discontinuous.	A high yielding aquifer, capable of more than 2,000 gallons per minute.
	?	Wilcox Formation	Silt, clay, and sand, with a thickness of 150 to 350 feet. Sand and minor clay, with a thickness of 150 to 300 feet. Known as the "1,400-foot sand." Silt, clay, sand, and lignite, with a thickness of 0 to 300 feet.	Present throughout the western part of West Tennessee.	The upper and lower clay units are confining units. The upper clay unit serves as a confining unit at the base of the "500-foot sand" and at the top of the "1,400-foot sand." The lower clay unit is the basal confining unit of the "1,400-foot sand." The "1,400-foot sand" is a high permeability aquifer.	The "1,400-foot sand of the Wilcox may yield from 400 to 1,200 gallons per minute to large wells.
	PALEOCENE	Porters Creek Clay	Clay, massive, pale brown to brownish-gray, locally contains glauconitic sand. Thickness 45 to 350 feet with slight thickening to the west and thinning to the north. In some areas, it is cut by sandstone dikes which range in width from a fraction of an inch to 22 feet.	Present throughout the western part of Tennessee in the subsurface, outcropping in a narrow band 1 to 5 miles wide.	Regional confining unit due to its fine texture and clay composition. Retards vertical movement of water and serves as the basal confining unit for this aquifer system.	The Porters Creek Clay is not known to be used as an aquifer, and no data exist for yields.

Detailed Stratigraphy

SYSTEM	Stratigraphic unit	Geologic description	Hydrologic significance: Occurrence in Tennessee	Hydrologic significance: Hydrologic classification and character	Hydrologic significance: Yield
TERTIARY	Porters Creek Clay	Clay, medium-gray to brownish-gray, massive, locally contains glauconitic sand. Thickness 45 to 400 feet. In some areas it is cut by sand dikes which range in width from a fraction of an inch to 22 feet.	Present throughout the western three-fourths of West Tennessee in the subsurface, outcropping in a narrow band 1 to 5 miles wide.	Due to its fine texture and clay composition, the Porters Creek retards the vertical movement of water and serves as the upper confining unit for the Cretaceous aquifer system. Its continuity, homogeneity, and thickness distinguish it as an effective confining unit.	No data exist for yields, but at best they would be suitable only for domestic supplies.
	Clayton Formation	Sand, clay, and limestone. Locally contains marine fossils. Thickness 0 to 80 feet.	Outcrop mapped in Hardeman and McNairy Counties. Occurs in subsurface in the western part of West Tennessee.	Generally acts as a confining unit although fine sands locally supply small quantities of water for domestic supplies.	Yields suitable for small domestic supplies.
CRETACEOUS	Owl Creek Formation	Sand, fine-grained, and clay, micaceous; commonly contains glauconite and marine fossils. Thickness 0 to 35 feet.	Outcrop in Tennessee limited to Hardeman and McNairy Counties. Occurs in the subsurface in the western part of West Tennessee.	Confining unit. Fine texture confines downward movement of water.	Yields little or no water to wells.
	McNairy Sand	Sand with interbedded clay and locally some lignite. Fine sand at base contains heavy minerals. Thickness 300 to 400 feet.	Crops out in the western valley of the Tennessee River. Occurs in subsurface throughout western part of West Tennessee.	High permeability sands are capable of transmitting large quantities for public supplies.	Yields range from several gallons a minute to more than several hundred gallons per minute depending on thickness.
	Coon Creek Formation	Sand and clay; glauconitic, fossiliferous, and micaceous. Thickness 50 to 180 feet.	Outcrop varies from 2 to 4 miles wide.	Fine-grained sands may locally supply small capacity domestic wells.	Yields little or no water to wells.
	Demopolis Formation	Marl, chalky marl, and calcareous clay; light-gray, very thickbedded, silty, sandy, glauconitic, and fossiliferous. Thickness 0 to 340 feet.	Formation thickens toward the south.	Significant confining unit. Fine-grained material inhibits vertical movement of ground water. Basal units may supply local domestic supplies.	Yields little or no water to wells.
	Sardis Formation	Sand, quartz and glauconite, with with clay; locally fossiliferous; grades upward into calcareous clays. Thickness 0 to more than 40 feet.	Crops out mainly in Henderson County.	Confining unit. Fine-grained texture inhibits vertical movement of ground water.	Yields little or no water to wells.
	Coffee Sand	Sand with lenses of brown clay. Upper sands are commonly cross-bedded. Basal beds contain fine chert pebbles. Thickness 0 to more than 200 feet.	Outcrops mainly in Henderson and Decatur Counties. Present throughout the western	High intergranular porosity and permeability in sands.	Yields range from several gallons a minute to more than 100 gallons per minute.
	Eutaw Formation	Glauconitic and micaceous sand locally interbedded with lenses of gray clay. Basal beds contain chert gravel. Thickness 0 to 180 feet.	Occurrence limited mainly to outcrops in Hardin and Wayne Counties. Formation is absent at various locations.	High intergranular porosity and permeability in sands. Basal confining unit of the "1,400-foot sand." The "1,400-foot sand" is a high permeability aquifer.	Yields range from several gallons a minute to more than 100 gallons per minute.
	Tuscaloosa Formation	Chert gravel, clay, silt, and sand. Gravel contains lenses of quartz sand and thin-bedded clay. Thickness 0 to 140 feet.	Crops out mostly in Hardin and Wayne Counties, east of the Tennessee River. Thin or absent in subsurface west of the Tennessee River.	High intergranular porosity and permeability in gravels. Coarse gravels provide water supplied locally. Direct hydraulic connection with underlying formations.	Yields range from several gallons per minute to more than 10 gallons per minute.
CAMBRIAN TO MISSISSIPPIAN UNDIFFERENTIATED	Paleozoic Carbonates	Carbonate rocks and chert, with minor amounts of shale. Rocks extend several thousand feet to Precambrian crystalline rocks.	Occurs throughout West Tennessee beneath the Cretaceous deposits.	The porosity decrease at the Cretaceous-Paleozoic boundary effectively retards vertical leakage of water. Hydrologic interchange occurs at some locations.	Used as an aquifer only where Cretaceous deposits are too thin to yield water, in the eastern part of the Cretaceous aquifer system. Yields generally low.

Upper Claiborne

EXPLANATION

Thickness of upper Claiborne aquifer, in feet

100
200
300
400

Aquifer absent

Modified from Hosman, R.L., and Weiss, J.S., 1991, Geohydrologic units of the Mississippi embayment and Texas Coastal Uplands aquifer systems, south-central United States: U.S. Geological Survey Professional Paper 1416–B, 19 p.

Middle Claiborne (Memphis Sand)

EXPLANATION

Thickness of middle Claiborne aquifer, in feet

Less than 200

Greater than 200

Aquifer absent

Modified from Williamson, A.K., Grubb, H.F., and Weiss, J.S., 1990, Ground-water flow in the Gulf Coast aquifer systems, south-central United States—A preliminary analysis: U.S. Geological Survey Water-Resources Investigations Report 9–4071, 123 p.

Lower Claiborne – Upper Wilcox

EXPLANATION

Thickness of lower Claiborne–upper Wilcox aquifer, in feet

200
400

Aquifer absent

Modified from Williamson, A.K., Grubb, H.F., and Weiss, J.S., 1990, Ground-water flow in the Gulf Coast aquifer systems, south-central United States—A preliminary analysis: U.S. Geological Survey Water-Resources Investigations Report 9–4071, 123 p.

Middle Wilcox (Fort Pillow Sand)

EXPLANATION

Thickness of middle Wilcox aquifer, in feet

100
200
300

Aquifer absent

Modified from Hosman, R.L., and Weiss, J.S., 1991, Geohydrologic units of the Mississippi embayment and Texas Coastal Uplands aquifer systems, south-central United States: U.S. Geological Survey Professional Paper 1416–B, 19 p.

Lower Wilcox

EXPLANATION

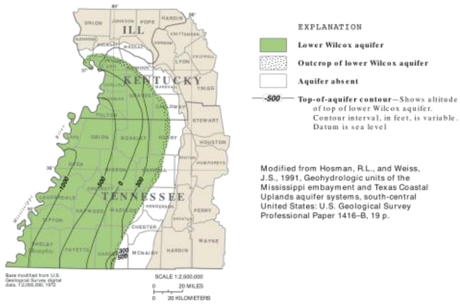
Thickness of lower Wilcox aquifer, in feet

100
200
300

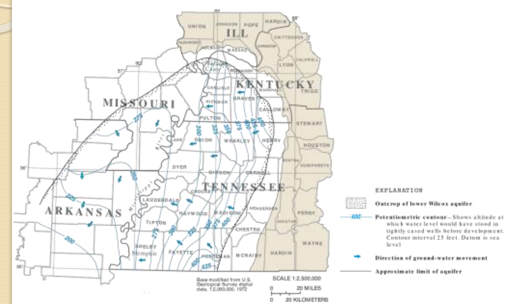
Aquifer absent

Modified from Hosman, R.L., and Weiss, J.S., 1991, Geohydrologic units of the Mississippi embayment and Texas Coastal Uplands aquifer systems, south-central United States: U.S. Geological Survey Professional Paper 1416–B, 19 p.

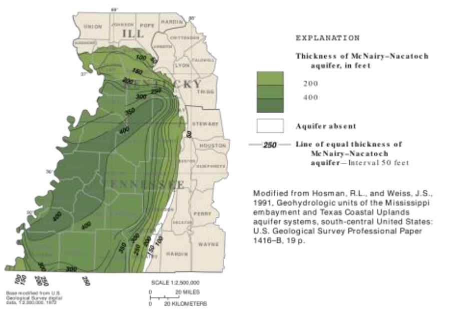
Top of Lower Wilcox Aquifer



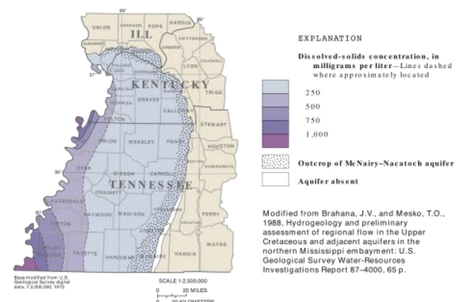
Pre-Pumping Groundwater Flow in the Lower Wilcox Aquifer



McNairy-Nacatoch Aquifer



Water Quality McNairy-Nacatoch Aquifer

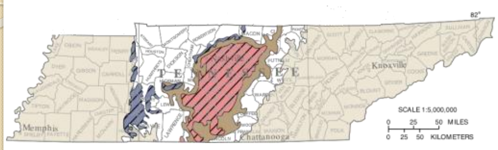


Aquifer Characteristics

- Cretaceous to Quaternary unconsolidated sediments.
- Extremely productive multiple sand aquifers separated by local and regional confining beds.
- Aquifers thicken from east to west where they occur in Tennessee.
- Greatest yields come from the Memphis Sand (Middle and Lower Claiborne) – generally 200 to 1,000 gpm but over 2,000 gpm locally.

Central Basin Aquifer System

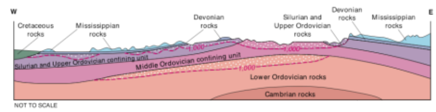
Central Basin Aquifer System



Modified from King, P.B., and Beikman, H.M., 1974, Geologic map of the United States: U.S. Geological Survey, 3 sheets, scale 1:2,500,000.

- Silurian–Devonian aquifers
- Ordovician aquifers
- Upper Ordovician rocks—Generally confining units but might contain local aquifers

Generalized Cross Section

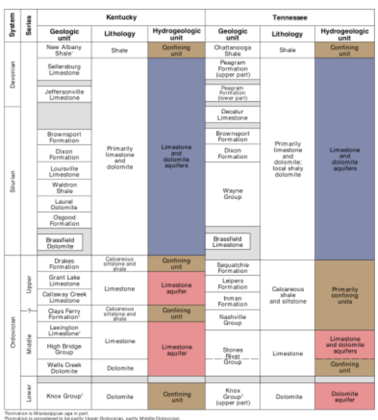


Modified from:
Brahana, J.V., and Bradley, M.W., 1985, Delineation and description of the regional aquifers of Tennessee—The Knox aquifer in central and west Tennessee: U.S. Geological Survey Water-Resources Investigations Report 83–4012, 32 p.
Brahana, J.V., and Bradley, M.W., 1986a, Preliminary delineation and description of the regional aquifers of Tennessee—The Central Basin aquifer system: U.S. Geological Survey Water-Resources Investigations Report 82–4002, 35 p.

EXPLANATION

- Silurian and Upper Ordovician rocks that contain freshwater
- Middle Ordovician rocks that contain freshwater
- Lower Ordovician rocks that contain freshwater
- ---1,000--- Approximate line of equal dissolved-solids concentration, in milligrams per liter

Central Basin Statigraphy



Detailed Stratigraphy

SYSTEM	SERIES	Stratigraphic unit	Geologic description	Hydrologic significance: Occurrence in Tennessee	Hydrologic significance: Hydrologic classification and character	Hydrologic significance: Yield
DEVONIAN	Upper	Chattanooga Shale	Shale, black carbonaceous fissile. It is divided into three members. The thickness ranges from 0 to more than 600 feet, averages about 20 to 30 feet throughout most of the area.	Extends from beneath Highland Rim on east to west of the Tennessee River in the subsurface. Exposed around the margin of Central Basin.	Not an aquifer. It is a regional confining unit.	Yields little or no water to wells.
	Middle	Pegram Formation	Limestone and sandstone, thick-bedded, gray. Thickness from 0 to 30 feet.	Surface exposures extend from Jackson and Macon Counties on the northeast to Wayne County to the southwest. Occurs in the sursurface in the western valley of the Tennessee River.	A local aquifer. Supplies water to domestic wells where fractures have been enlarged by solution. Low intergranular porosity and permeability.	Yields adequate for domestic supplies. Generally from 5 to 20 gallons per minute.
	Lower	Camden Formation	Chert, novaculitic, light gray, tripolitic clay, and minor siliceous limestone. Thickness 0 to 50 feet.	Widely exposed in Benton County and parts of surrounding counties. It has not been recorded farther south than Decatur County.	A local aquifer. Fractures provide porosity and permeability.	Variable yields. From 0 to more than 100 gallons per minute.
		Harriman Formation	Chert, novaculitic, light gray, tripolitic clay, and minor siliceous limestone. Thickness 0 to about 100 feet.	Occurs in northern Decatur County and isolated outcrops in Hardin County. Limited in areal extent.	A local aquifer. Fractures provide porosity and permeability.	Variable yields. From 0 to more than 100 gallons per minute.
		Flat Gap Limestone	Limestone, thick-bedded, coarse-grained, gray with red and brown grains. Thickness 0 to 20 feet.	Occurs in Benton and Humphreys Counties. Few isolated occurrences in western Tennessee.	A local aquifer that supplies water to domestic wells by solution enlarged fractures. Low intergranular porosity and permeability.	Variable yields. From 0 to more than 100 gallons per minute.
		Ross Formation	Siliceous limestone occurs in south, changes to shale in north. It also contains glauconitic limestone. Thickness 0 to 75 feet. Includes Olive Hill and Birdsong Formations of others.	Occurs in Houston, Humphreys, Perry, Decatur, and Benton Counties and south into Hardin County. Limited to the western valley of the Tennessee River.	A local aquifer with general low porosity and permeability.	Yields generally less than 10 gallons per minute.

Detailed Stratigraphy

SILURIAN	Middle	Decatur Limestone	Limestone, thick-bedded, medium- to coarse-grained, gray to reddish-brown. Thickness 0 to 70 feet.	Occurs in limited areas in the western valley of the Tennessee River.	A local aquifer. Supplies water to domestic wells where fractures have been enlarged by solution. Low intergranular porosity and permeability.	Yields are adequate for small supplies. Generally less than 10 gallons per minute.
		Brownsport Formation	Limestone and shale in alternating thin beds. It includes Beech River, Bob, and Lobelville Limestone members. Thickness 0 to 80 feet.	Generally restricted to western Highland Rim.	A local aquifer. Supplies water to domestic wells by solution openings. Low intergranular porosity and permeability.	Yields generally less than 10 gallons per minute.
		Dixon Limestone Member or Formation	Shale, limestone, argillaceous and silty. Red to greenish-gray. Part of Wayne Formation or Group of others. Thickness 0 to 40 feet.	Limited to a line from Montgomery to Hardin Counties.	A local confining unit. General low porosity and permeability.	Small yields. Generally less than several gallons per minute.
		Lego Limestone Member or Limestone	Limestone, gray, even-bedded. Part of Wayne Formation or Group of others. Thickness 0 to 45 feet.	Eastern margin of western Highland Rim.	A local aquifer. Supplies domestic wells by solution openings. Low intergranular porosity and permeability.	Yields generally less than 10 gallons per minute.
		Waldron Clay Member or Shale	Shale and shaly limestone, greenish-gray, fossiliferous. Part of Wayne Formation or Group of others. Thickness 0 to 5 feet.	Eastern margin of western Highland Rim.	A local confining unit. General low porosity and permeability.	Yields little or no water to wells.
		Laurel Limestone Member or Limestone	Limestone, even-bedded. Part of Wayne Formation or Group of others. Thickness 0 to 30 feet.	Eastern margin of western Highland Rim.	A local aquifer. Supplies water to domestic wells by solution openings. Low intergranular porosity and permeability.	Yields generally less than 10 gallons per minute.
		Osgood Limestone Member or Formation	Shale and limestone, argillaceous, greenish- and reddish-gray. Part of Wayne Formation or Group of others. Thickness 0 to 15 feet.	Eastern margin of western Highland Rim.	A local aquifer. Supplies water to domestic wells by solution openings. Low intergranular porosity and permeability.	Yields little water to wells.
	Lower	Brassfield Limestone	Limestone, cherty and locally glauconitic. Thin-bedded, white and brown. Thickness 0 to 130 feet.	Northern, western, and southern margin of Central Basin, and parts of Sequatchie Valley.	A local aquifer that supplies water to domestic wells by solution openings. Low intergranular porosity and permeability.	Yields generally less than 10 gallons per minute.

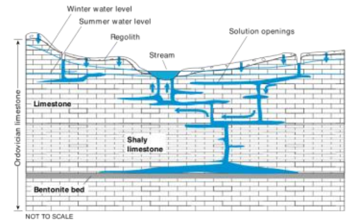
Detailed Stratigraphy

SYSTEM	SERIES	Stratigraphic unit	Geologic description	Hydrologic significance: Occurrence in Tennessee	Hydrologic significance: Hydrologic classification and character	Hydrologic significance: Yield
ORDOVICIAN	Upper	Mannie Shale	Shale and limestone, argillaceous. Thickness 0 to 20 feet.	Northern, western, and southern margin of Central Basin, and parts of Sequatchie Valley.	Local confining unit. General low porosity and permeability.	Yields little or no water to wells.
		Fernvale Limestone	Limestone and shale. Coarse-grained, thick-bedded, gray with varicolored grains. Thickness 0 to 30 feet.	Northern and southern flanks of Nashville Dome.	Local aquifer. Supplies water to domestic wells by solution openings. Low intergranular porosity and permeability.	Yields generally less than 10 gallons per minute.
		Sequatchie Formation	Mudstone and limestone with some sand, shale, and silty limestone. Greenish-gray to green. Thickness 0 to 160 feet.	Limited to northern and eastern flank of Nashville Dome.	Local confining unit. General low porosity and permeability.	Yields little or no water to wells.
		Arnheim Formation	Limestone, silty with interbedded shale. Fossiliferous. Thickness from 10 to 20 feet.	Limited to northwestern flank of Nashville Dome.	Local aquifer. Supplies water to domestic wells by solution openings. Low intergranular porosity and permeability.	Yields generally less than 10 gallons per minute.
		Leipers Formation	Limestone, granular, blue, interbedded shale. Phosphatic in the western part of the Central Basin. Thickness 0 to 75 feet.	Restricted to margin of Central Basin, near boundary with Highland Rim.	Local aquifer. Original porosity and permeability are low. Large solution cavities generally don't develop.	Springs furnish domestic water supply. Yields generally range from 0 to 20 gallons per minute.
		Inman Formation	Limestone, thin to thick-bedded, locally oolitic. Commonly with shale. Thickness ranges from 0 to 100 feet.	Restricted to southeastern margin of Highland Rim and Sequatchie Valley.	Local aquifer. Original porosity and permeability are low. Large solution cavities generally don't develop.	Yields generally range from 0 to more than 20 gallons per minute.

Detailed Stratigraphy

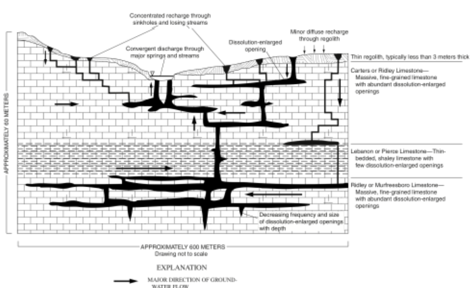
ORDOVICIAN	Middle	Nashville Group	Catheys Formation	Limestone with shale, silty, blue, locally phosphatic. Thins toward the central part of the Central Basin. Thickness 125 to 400 feet.	Occurs in Highland Rim and Central Basin physiographic provinces.	Local aquifer with low porosity and permeability. Some small solution openings occur.	Yields generally less than 5 gallons per minute.
			Bigby and Cannon Limestones	Limestone, sandy, with three facies: Phosphatic facies; pure, massive "dove" facies; and sandy limestone. Total thickness from 60 to 150 feet.	Occurs in Highland Rim and Central Basin physiographic provinces.	Local aquifer. Large solution openings occur within the Cannon; small solution openings are characteristic of the Bigby facies.	Yields generally less than 25 gallons per minute for the Bigby. The Cannon may yield as much as 100 gallons per minute.
			Hermitage Formation	Limestone, dark, shaly, sandy, phosphatic, thinly bedded. Thickness ranges from 50 to 100 feet.	Areally extensive. Present from beneath Cumberland Plateau to west of the Tennessee River.	Confining unit. Water-bearing characteristics are similar to the Leipers and Catheys Formations. Shaly partings forms a seal, restricting vertical flow.	Most yields are less than 5 gallons per minute. Some may be 20 gallons per minute.
		Stones River Group	Carters Limestone	Limestone, light brown, massive, pure. Contains four thin beds of bentonite. Thickness approximately 65 to 250 feet. Equivalent to the Lowville Limestone.	Areally extensive. Present from beneath Cumberland Plateau to west of the Tennessee River.	Local aquifer. Large solution openings develop, especially if the T-3 bentonite is weathered.	Generally yields less than 5 gallons per minute. Yields of more than 100 gallons per minute can be obtained under optimum conditions.
			Lebanon Limestone	Limestone, thin-bedded, with shaly partings. Total thickness about 115 feet.	Areally extensive. Present from beneath Cumberland Plateau to west of the Tennessee River.	Local aquifer. Thin bedding and shale partings restrict the circulation of ground water.	Yields generally from 0 to 25 gallons per minute.
			Ridley Limestone	Limestone, massively bedded, fine- to medium-grained, dolomitic. Prominent shale in the middle unit. Thickness averages 100 feet.	Areally extensive. Present from beneath Cumberland Plateau to west of the Tennessee River.	Local aquifer. Massive bedding of this formation allows solution openings to develop.	Generally yields less than 5 gallons per minute. Yields over 20 gallons per minute can be obtained.
			Pierce Limestone	Limestone, shaly, thin-bedded. Total thickness is about 25 feet.	Areally extensive. Present from beneath Cumberland Plateau to west of the Tennessee River.	Relatively insoluble. Shale impedes the downward movement of water.	Yields little or no water to wells--highly mineralized water.
			Murfreesboro Limestone	Limestone, massive, dense, dark blue to bluish-gray, cherty. Total thickness is about 425 feet.	Areally extensive. Present from beneath Cumberland Plateau to west of the Tennessee River in subsurface. Crops out in valleys in the Central Basin.	Large solution openings occur between shaly zones within the limestone in outcrop area. Only 20 percent of wells obtain water where formation is deeply buried.	Where it occurs at depth, commonly doesn't yield water to wells. Yields may be in excess of 100 gallons per minute in outcrop.
			Pond Spring Formation	Limestone, silty dolomite, and dolomitic limestone. Some shales, and local conglomeratic zones. Thickness from 0 to 150 feet. It is equivalent to the Wells Creek Formation.	Limited to Sequatchie Valley, western Central Basin, and Highland Rim. Pinches out to east.	Confining unit. Variable characteristics. Generally low porosity and permeability, but solution features develop locally.	Does not generally yield water to wells.

Conceptual Groundwater Flow Model

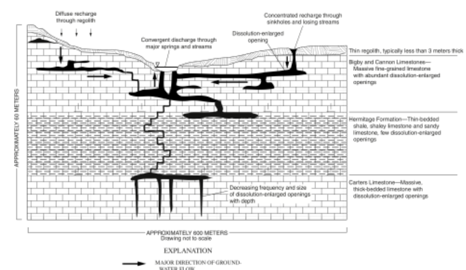


Modified from Zurawski, Ann, 1978, Summary appraisals of the Nation's ground-water resources—Tennessee region: U.S. Geological Survey Professional Paper 813–L, 35 p.

Conceptual Groundwater Model Inner Central Basin



Conceptual Groundwater Model Outer Central Basin



Central Basin Well Yields

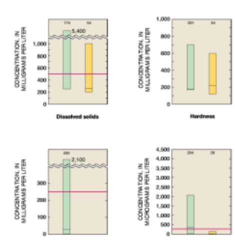
Yields of wells completed in the limestone and dolomite aquifers in Ordovician rocks in Kentucky and Tennessee commonly range between 2 and 20 gallons per minute and might exceed 300 gallons per minute

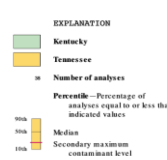
[Data source: U.S. Geological Survey, 1985]

Yield of wells in limestone and dolomite aquifers in Ordovician rocks (gallons per minute)

State	Common range	May exceed
Kentucky	2 to 10	300
Tennessee		
(Aquifers in middle Ordovician rocks)	5 to 20	300
(Knox group)	1 to 10	20

Central Basin Water Quality





Data from:
U.S. Geological Survey files, 1988
U.S. Environmental Protection Agency, 1986, Secondary maximum contaminant levels (Section 143.3, Pt. 143, National secondary drinking-water regulations): U.S. Code of Federal Regulations, Title 40, pts. 100–149, revised July 1, 1986, p. 587–590.

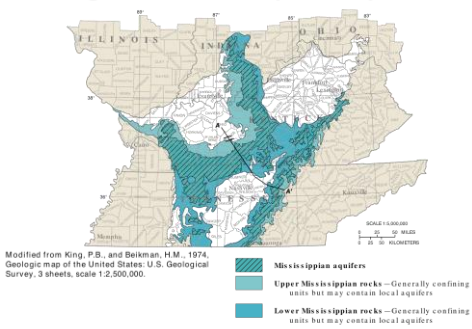
Water from the limestone and dolomite aquifers in Ordovician rocks in Kentucky and Tennessee commonly is hard and can contain large concentrations of dissolved solids, chloride, and iron.

Aquifer Characteristics

- Carbonate rocks (limestone and some dolomite) are primary aquifers.
- Intervening confining units of shale and shaly limestones
- Chattanooga Shale separates Central Basin Aquifer System from overlying Mississippian rocks of the Highland Rim
- Depth of freshwater varies greatly.
- Wells are typically 50 – 200 feet deep.
- Depth to salt water is generally greatest where the limestone and dolomite aquifers crop out i.e. the apex of the Nashville Dome.
- Recharge rates affect depth to salt water.

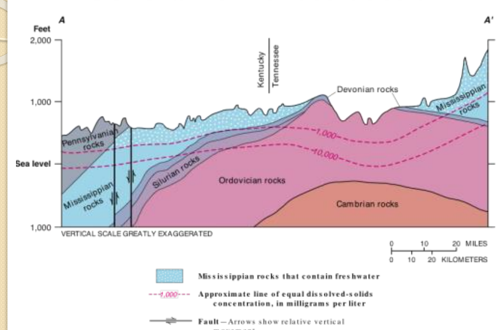
Highland Rim Aquifer System

Highland Rim Aquifer System

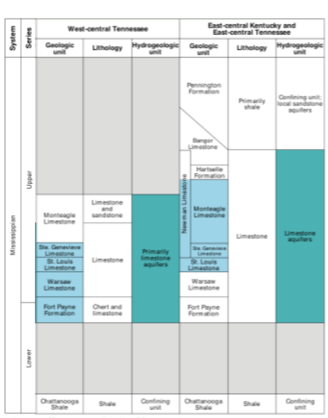


Modified from King, P.B., and Beikman, H.M., 1974, Geologic map of the United States: U.S. Geological Survey, 3 sheets, scale 1:2,500,000.

Generalized Cross Section



Highland Rim Stratigraphy

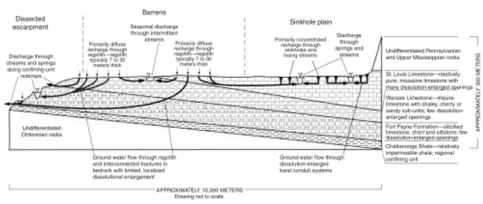


...st productive Mississippian aquifers comprise the Monteagle,

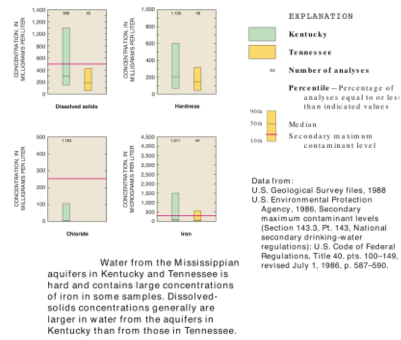
Highland Rim Detailed Stratigraphy

Stratigraphic unit	Geologic description	Hydrologic significance: Occurrence in Tennessee	Hydrologic classification and character	Yield
Pennington Formation	Shale, clayey, vari-colored, with sandstone partings. Contains massive limestone member. Thickness 200-400 feet.	Formation limited to eastern Highland Rim. Isolated occurrences in the southern Highland Rim.	Confining layer. Very low primary porosity and little or no development of secondary permeability.	Yields little or no water to wells.
Bangor Limestone	Limestone, dark-brownish-gray, thick-bedded. Thickness 70 to 400 feet. Includes Glen Dean Limestone.	Occurs in eastern and southeastern Highland Rim and beneath the Cumberland Plateau.	Local aquifer. Supplies water to domestic wells by solution openings. Porosity and permeability are low.	Yields generally range from 2 to 5 gallons per minute although more than 50 gallons per minute may be obtained.
Hartselle Formation	Sandstone, shale, and limestone. Thickness 0 to 80 feet.	Occurs in eastern and southeastern Highland Rim and beneath the Cumberland Plateau.	Local aquifer. Original porosity and permeability are low. Secondary permeability developed locally.	Yields generally range from 2 to 5 gallons per minute although more than 50 gallons per minute may be obtained.
Monteagle Limestone/ Ste. Genevieve Limestone	Limestone, oolitic, light-gray to white, massive-bedded. Thickness 80 to 500 feet. Includes Gasper Formation of others.	Occurs throughout Highland Rim and beneath Cumberland Plateau.	Local aquifer. Some intergranular porosity, but it is low. Secondary permeability developed locally.	Yields generally less than 10 gallons per minute.
St. Louis Limestone	Limestone, dark-gray to gray, coarse-grained, generally massively bedded. Conducive to caves and sinkholes on the western Highland Rim. Thickness 80 to 175 feet.	Occurs throughout Highland Rim and beneath Cumberland Plateau.	Large solution channels have developed in the northwest counties.	Generally yields are less than 10 gallons per minute. Some locations yield more than 50 gallons per minute.
Warsaw Limestone	Limestone, gray, massive, coarse-grained. Gray to red overburden. Thickness 100 feet.	Occurs throughout Highland Rim and beneath Cumberland Plateau.	Water occurs locally in solution openings.	Generally yields are less than 20 gallons per minute. Some locations yield more than 200 gallons per minute.
Fort Payne Formation	Limestone, siliceous, gray to bluish-gray, dolomite, siltstone and chert stringers. Thickness 100 to 350 feet. Evaporites present at some locations. Lower part equivalent to New Providence Shale and Ridgetop Shale. Grades into Grainger Formation to east.	Occurs throughout Highland Rim and beneath Cumberland Plateau.	Local aquifer with low primary porosity and permeability. Weathers to a permeable chert rubble in eastern Highland Rim.	Yields range from 0 to more than 100 gallons per minute.
Maury Shale	Shale, mudstone, and siltstone. Glauconitic, gray to green, sandy with phosphatic nodules. Commonly 1 to 4 foot thick.	Occurs throughout Highland Rim beneath Cumberland Plateau.	Not an aquifer, fine-grained, shaly material retards vertical movement of water.	Yields little or no water to wells.
Chattanooga Shale	Shale, black fissile. Divided into three members. Thickness less than 5 to greater than 100 feet.	Occurs beneath Highland Rim and Cumberland Plateau. Absent in West Tennessee slightly west of the Tennessee River. Removed by erosion from the Central Basin.	Regional confining layer. Retards vertical movement of water	Yields little or no water to wells.

Conceptual Groundwater Model Eastern Highland Rim



Highland Rim Water Quality



Water from the Mississippian aquifers in Kentucky and Tennessee is hard and contains large concentrations of iron in some samples. Dissolved-solids concentrations generally are larger in water from the aquifers in Kentucky than from those in Tennessee.

Aquifer Characteristics

Most Productive Mississippian Aquifers

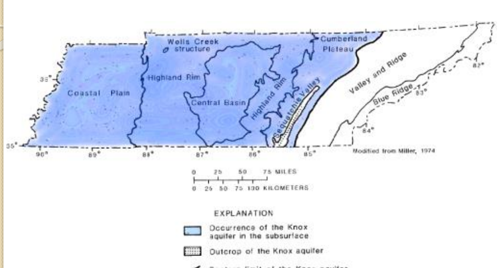
- Ste. Genevieve Limestone
- St. Louis Limestone
- Warsaw Limestone
- Fort Payne Formation

Fine-grained clastic rocks are not generally productive

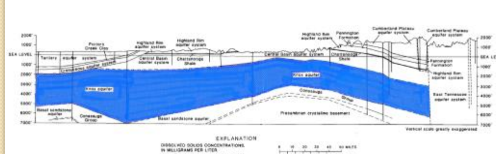
- Mostly karst aquifers
- Groundwater moves through fractures, bedding planes, and solution openings in the limestone
- Hydraulic characteristics (yield and specific capacity) vary greatly over short distances

Knox Aquifer

Knox Aquifer



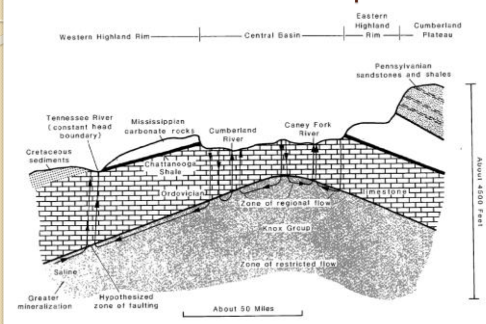
Cross Section of the Knox Aquifer



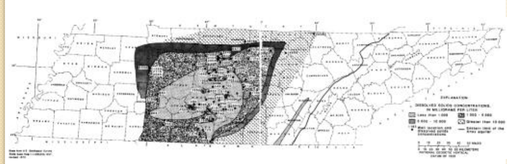
Knox Aquifer Stratigraphy

SYSTEMS	SERIES	STRATIGRAPHIC UNIT	GEOLOGIC DESCRIPTION	HYDROLOGIC SIGNIFICANCE		
				OCCURRENCE IN TENNESSEE	HYDROLOGIC CLASSIFICATION AND CHARACTER	YIELD
ORDOVICIAN	Middle	Pierce Limestone	Limestone, shaly, thin bedded. Total thickness is about 25 feet.	Areally extensive. Present from beneath Cumberland Plateau to west of the Tennessee River.	Relatively insoluble. Shale impedes the downward movement of water.	Yields little or no water to wells. Highly mineralized water.
ORDOVICIAN	Middle	Murfreesboro Limestone	Limestone, massive, dense, dark blue to bluish-gray, cherty. Total thickness about 425 feet.	Areally extensive. Present from beneath Cumberland Plateau to west of the Tennessee River.	Solution openings occur in the outcrop area. Low permeability at depth.	Where it occurs at depth, commonly doesn't yield water to wells. Yields may be in excess of 100 gallons per minute in outcrop area.
ORDOVICIAN	Middle	Pond Spring Formation (Tennessee usage)	Limestone, silty dolomite and dolomitic limestone. Some shales and local conglomeritic zones. Thickness from 0 to 150 feet. This formation is equivalent to the Wells Creek Formation.	Limited to Sequatchie Valley, western Central Basin and Highland Rim pinches out to east.	Confining layer with generally low porosity and permeability. solutional features developed locally.	Does not generally yield water to wells.
ORDOVICIAN / CAMBRIAN	Lower / Upper	Knox Group	Dolomite, gray and brown, fine-grained to granular, siliceous and dense white limestone. Chert abundant near axis of Nashville Dome. Thickness ranges from less than 2,500 to more than 3,000 feet. Includes Mascot Dolomite, Kingsport Formation, Longview Dolomite, Chepultepec Dolomite, and Copper Ridge Dolomite.	Areally extensive, from Valley and Ridge to west of Tennessee River.	Water occurs in thin zones of small tubular voids. Permeable zones separated by thick impermeable sequences of fine-grained carbonates.	Yields consistently 1 to 10 gallons per minute with few wells exceeding 30 gallons per minute. Only rarely does a Knox well fail to provide an adequate domestic supply.
CAMBRIAN	Middle	Conasauga Group	Shale, thick-bedded, bluish-gray, siltstone and limestone. Thickness about 2,000 feet.	Areally extensive, from Valley and Ridge to Mississippi River.	Ground water in the Conasauga is restricted to small fractures. Impermeable.	Yields from this formation are not known from west of the Valley and Ridge, but are thought to be low.

Conceptual Model of Groundwater Flow in the Knox Aquifer



Water Quality of the Upper Knox Aquifer



Aquifer Characteristics

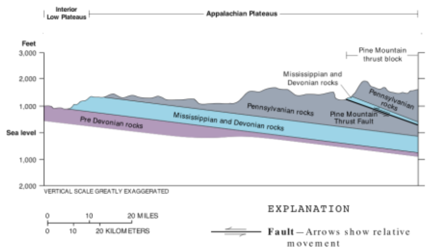
- Regional aquifer.
- Distinct from Knox Formation units in Valley and Ridge.
- Only exposed in Sequatchie Valley.
- Recharge through fractures that transect the overlying confining unit.
- Water yields in upper 50 feet.
- Dolomite typically has the best yield
- Limestones yield little water
- TDS < 1,000 mg/l at center of Nashville Dome and Sequatchie Valley anticline
- Deeper zones have high TDS
- Freshwater-saltwater interface does not coincide with shallower aquifers

Cumberland Plateau Aquifer System

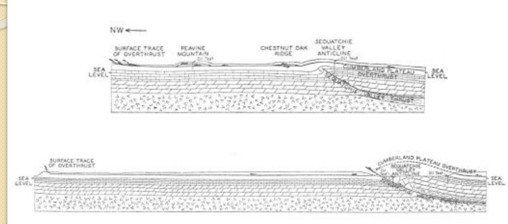
Cumberland Plateau Aquifer System

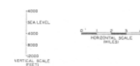
Modified from King, P.B., and Beikman, H.M., 1974, Geologic map of the United States: U.S. Geological Survey, 3 sheets, scale 1:2,500,000.

Generalized Cross Section Northern Cumberland Plateau

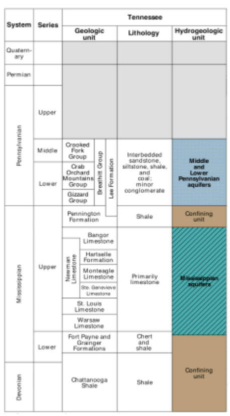


Cross Sections - Mid and Southern Cumberland Plateau in Tennessee





Wilson, C.W., Jr. and Stearns, R.G., 1958, Structure of the Cumberland Plateau, Tennessee, State of Tennessee, Department of Environment and Conservation, Division of Geology, Report of Investigations No. 8



Cumberland Plateau Stratigraphy

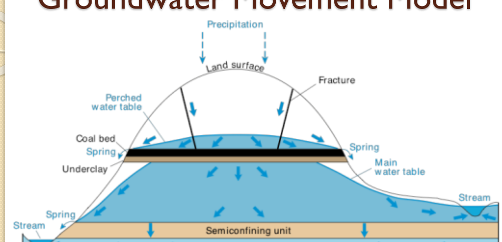
Cumberland Plateau Stratigraphy

System	Series	Stratigraphic unit	Geologic Description	Hydrologic Significance: Occurrence in Tennessee	Hydrologic Significance: Hydrologic classification and character	Hydrologic Significance: 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 1gallon 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 1gallon 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.

Cumberland Plateau Stratigraphy

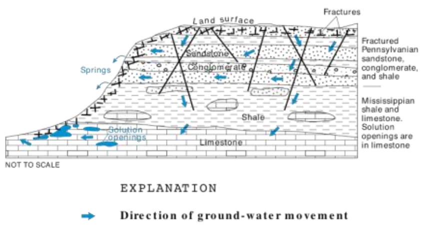
System	Series	Stratigraphic unit	Geologic Description	Hydrologic Significance: Occurrence in Tennessee	Hydrologic Significance: Hydrologic classification and character	Hydrologic Significance: Yield
PENNSYLVANIAN	Lower and Middle	Slatestone Formation	Alternating sequence of shales, sand- stones, and 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 1gallon per minute.
		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 move- ment. Aquifers restricted to fractured sandstones.	Yields to sandstones generally less than 20 gallons per minute. Shales yield little or water.
	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.	Fractured sandstones yield from 50 to 350 gallons per minute.
		Gizzard Group	The Gizzard may be divided into three parts: a thick lower shale with thin sandstones and several coals; tne 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 tnan 20 gallons per minute. Shales yield little or no water to wells.
MISSISSIPIAN	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.

Groundwater Movement Model



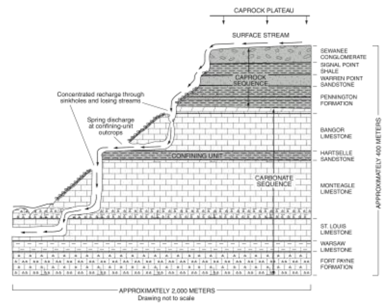
Aquifers in consolidated rocks are directly recharged by precipitation where they are exposed at the land surface. Water enters the aquifers primarily through fractures. Fractures decrease in width and number with depth. In Pennsylvanian rocks, underclay beneath coal beds creates perched water tables, which result in springs that issue from valley walls. Water percolates slowly downward through the underclay to reach the main water table.

Conceptual Groundwater Model Cumberland Plateau



Groundwater moves primarily through fractures in clastic rocks and solution openings in limestone. Fractures in shale confining units allow rapid downward movement. Shallow near-surface fractures yield the most water to wells.

Cross Section and Recharge Cumberland Plateau



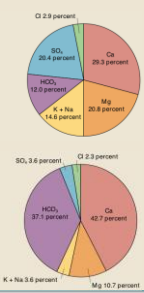
General Water Quality Cumberland Plateau

Middle and lower Pennsylvanian aquifers in Tennessee
Concentrations in milligrams per liter

Constituent	Range	Median	Number of samples
Hardness (CaCO3)	5 to 374	20	30
Calcium (Ca)	6.5 to 43	16	3
Magnesium (Mg)	2.4 to 65	6.9	3
Sodium (Na)	3.4 to 82	8.1	3
Potassium (K)	1.9 to 3.4	1.9	3
Bicarbonate (HCO3)	4 to 272	20	30
Sulfate (SO4)	4 to 166	27	4
Chloride (Cl)	0.4 to 40	3	29
Fluoride (F)	no data	no data	no data
Dissolved solids	56 to 109	no data	2
Iron (Fe)	no data	no data	no data

Mississippian aquifers in Tennessee
Concentrations in milligrams per liter

Constituent	Range	Median	Number of samples
Hardness (CaCO3)	6 to 81,000	120	238
Calcium (Ca)	1.6 to 610	44.5	99
Magnesium (Mg)	0.3 to 210	6.8	99
Sodium (Na)	1 to 1,400	3.1	82
Potassium (K)	0 to 65	1.2	80
Bicarbonate (HCO3)	0 to 1,190	118	239
Sulfate (SO4)	0 to 3,600	9	86
Chloride (Cl)	2.1 to 38,000	4.2	237
Fluoride (F)	no data	no data	no data
Dissolved solids	47 to 6,000	160	55
Iron (Fe)	0 to 18	0.1	97

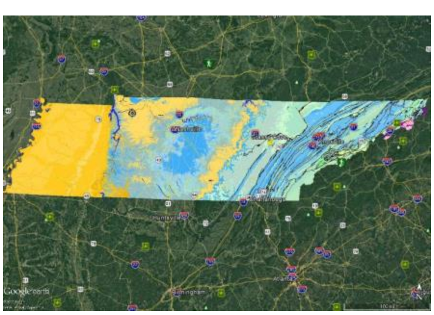


Aquifer Characteristics

- Geology consists of easterly dipping Pennsylvanian and Mississippian rocks.
- Pennsylvanian rocks are primarily sandstone, conglomerate and shale with some coal beds.
- Mississippian rocks are primarily shale and limestones.

- A complete, ideal cycle of Pennsylvania rocks consists of, from bottom to top: underclay, coal, gray shale or black platy shale, freshwater limestone, and sandstone or silty shale.
- Water from limestones tends to be alkaline and from coal/black shale more acidic.

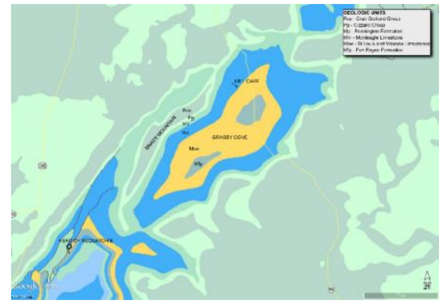
Grassy Cove, Tennessee



Grassy Cove, Tennessee

Grassy Cove, Tennessee

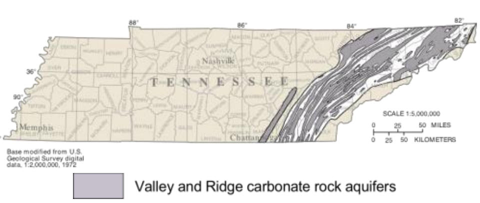
Grassy Cove, Tennessee



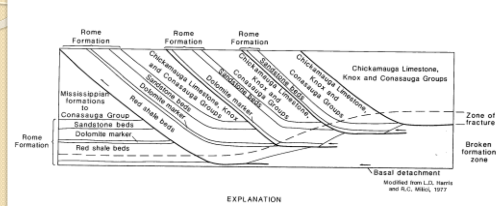
Head of Sequatchie Spring

Valley and Ridge Aquifer System

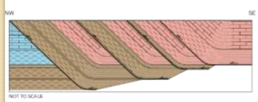
Valley and Ridge Aquifer System



Valley and Ridge Province Generalized Cross Section

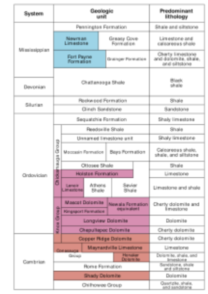


Valley and Ridge Province Conceptual Cross Section



Principal Aquifers in Valley and Ridge

- Principal aquifers are carbonate rocks of Cambrian and Ordovician Age



Valley and Ridge Stratigraphy

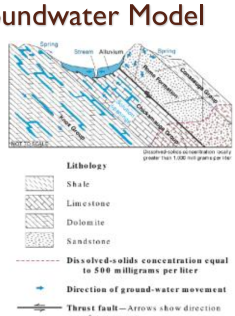
System	Stratigraphic unit	Geologic description	Hydrologic significance: Occurrence in Tennessee	Hydrologic significance: Hydrologic classification and character	Hydrologic significance: Yield
MISSISSIPPIAN	Pennington Formation	Shale, clayey, varicolored, with sandstone partings. Contains massive limestone 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.
MISSISSIPPIAN	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.
MISSISSIPPIAN	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.
MISSISSIPPIAN / DEVONIAN	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 northwest margins in Valley and Ridge.	Low porosity and permeability.	Yields little or no water to wells.
SILURIAN	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.
SILURIAN	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.
ORDOVICIAN	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.
ORDOVICIAN / CAMBRIAN	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.

Valley and Ridge Stratigraphy

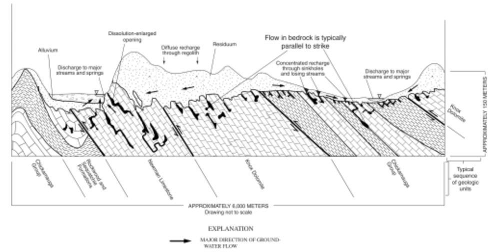
CAMBRIAN	Rome Formation	Sandstone, siltstone, shale, dolomite, and limestone. Shale and siltstone predominate with prominant sandstone beds. In southeast dolomite constitutes half the formation. Thickness varies from 200 to 1,500 feet.	Widespread occurrence in Valley and Ridge. Northeast to southwest 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.
CAMBRIAN	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.
CAMBRIAN	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.
CAMBRIAN	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.
CAMBRIAN	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.
CAMBRIAN	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.
CAMBRIAN	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.
CAMBRIAN	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.

Valley and Ridge Province Conceptual Groundwater Model

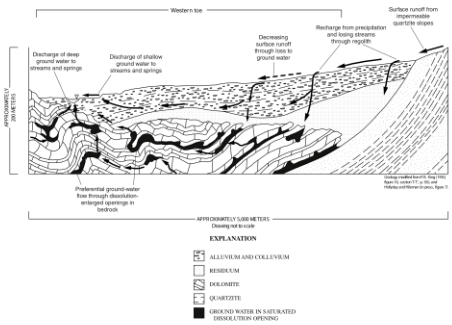
Groundwater moves downward through interstitial pore spaces in residuum and alluvium into the consolidated rocks, where it moves along fractures, bedding planes and solution openings. The general direction of flow is from ridges to toward springs and streams in the valleys.



Conceptual Groundwater Model Valley and Ridge



Conceptual Groundwater Model Western Toe

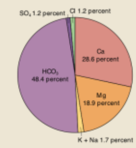


Water Quality – Valley and Ridge

Mississippian, Ordovician, and Cambrian aquifers in Tennessee
Concentrations in milligrams per liter

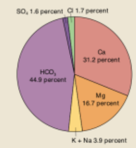
A. Water from wells

Constituent	Range	Median	Number of samples
Hardness (CaCO3)	5 to 475	150	148
Calcium (Ca)	2 to 140	40	140
Magnesium (Mg)	1 to 75	13	137
Sodium (Na) and potassium (K)	1 to 100	6	107
Bicarbonate (HCO3)	6 to 500	175	149
Sulfate (SO4)	1 to 99	5	144
Chloride (Cl)	1 to 680	4	146
Dissolved solids	15 to 1,700	170	150
Nitrate (NO3)	1 to 40	5	60
Iron (Fe)	0.01 to 28	0.07	146



B. Water from springs

Constituent	Range	Median	Number of samples
Hardness (CaCO3)	15 to 275	135	72
Calcium (Ca)	12 to 70	30	82
Magnesium (Mg)	2 to 33	12	86
Sodium (Na) and potassium (K)	1 to 54	2	57
Bicarbonate (HCO3)	20 to 300	155	77
Sulfate (SO4)	1 to 95	3	81
Chloride (Cl)	1 to 14	2	81
Dissolved solids	25 to 300	150	78
Nitrate (NO3)	1 to 14	3	43
Iron (Fe)	0.01 to 9	0.07	77



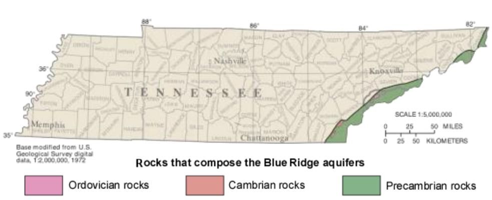
Data from DeBuchananne, G.D., and Richardson, R.M., 1956, Ground-water resources of east Tennessee: Tennessee Division of Geology Bulletin 58, 393 p.

Aquifer Characteristics

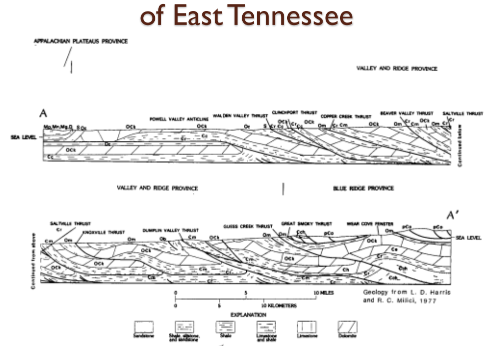
- Geology is defined by series of imbricate faulting related to deep detachment fault system.
- Groundwater is primary stored in fractures, bedding planes and solution openings.
- Nature of the geology dictates no regional flow systems.
- Karst systems generally have the best yields.
- Fractures in clastic rocks can yield water locally.
- Some production from alluvium and residuum.
- Groundwater type is typically calcium-magnesium-bicarbonate.

Blue Ridge Aquifers

Blue Ridge Aquifer System



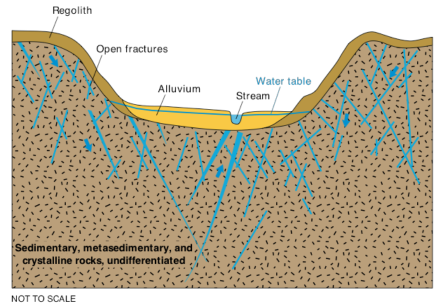
Generalized Geologic Cross Section of East Tennessee



Blue Ridge Stratigraphy

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 stratigraphic 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. Characterized by massive layers of 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 diorite, 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 granitic 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 gabbroic 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.

Blue Ridge Province Conceptual Groundwater Model

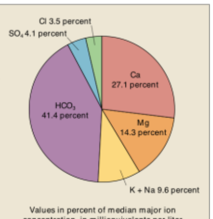


Water Quality – Blue Ridge

Cambrian and Precambrian sandstones in Tennessee

Concentrations in milligrams per liter

Constituent	Range	Median	Number of samples
Hardness (CaCO3)	6.8 to 172	76	11
Calcium (Ca)	1 to 49	17	11
Magnesium (Mg)	0.3 to 15	5.5	11
Sodium (Na) and potassium (K)	2.8 to 58	7.2	11
Bicarbonate (HCO3)	13 to 155	79	11
Sulfate (SO4)	1 to 96	6	11
Chloride (Cl)	1.5 to 26	4	11
Dissolved solids	19 to 297	109	11



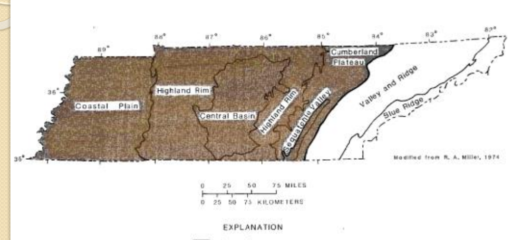
Data from DeBuchananne, G.D., and Richardson, R.M., 1956, Ground-water resources of east Tennessee: Tennessee Division of Geology Bulletin 58, 393 p.

Aquifer Characteristics

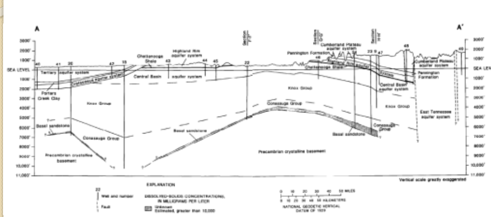
- Most available groundwater is in fractures within a few hundred feet of the ground surface.
- Production capacity defined by number, size and degree of interconnected fractures.
- Fractures close off at depth.
- Regional groundwater flow is not significant
- Groundwater quality is generally good with low TDS.
- Groundwater is calcium-magnesium-bicarbonate type.

Basal Sandstone Aquifer

Basal Sandstone Aquifer System



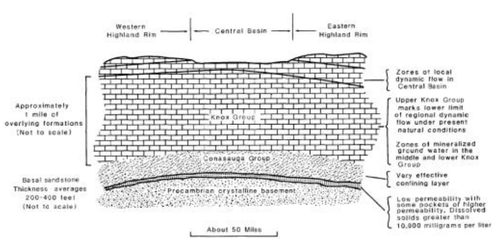
Basal Sandstone Distribution



Basal Sandstone Stratigraphy

SYSTEM	SERIES	STRATIGRAPHIC UNIT	GEOLOGIC DESCRIPTION	HYDROLOGIC SIGNIFICANCE		
				OCCURRENCE IN TENNESSEE	HYDROLOGIC CLASSIFICATION AND CHARACTER	YIELD
CAMBRIAN	Middle and Upper	Conasauga Group and equivalents	Shale, limestone, dolomite. Thickness from several hundred to more than 1,000 feet.	Thought to occur west of Valley and Ridge throughout most of State.	Confining unit. Not defined in subsurface. At depth, assumed to be very impermeable and nonporous.	Indirect geologic evidence suggests that most wells drilled in these rocks would yield very little water.
	Lower and Middle	Rome Formation and equivalents	Sandstone, siltstone, shale, dolomite, and limestone. Highly variable thickness from 0 to more than 300 feet.	Thought to occur in subsurface only. West of Valley and Ridge throughout most of the State.	Very low porosity and permeability. Very few data exists that describe the hydrologic character.	Indirect geologic evidence suggests that most wells drilled in these rocks would yield very little water.
		Unnamed basal sandstone	Sandstone, arkosic, that grades into weathered pockets of granite wash.	Known from drill holes throughout Tennessee west of the Valley and Ridge.	Porosity and permeability are low, but higher than either overlying or underlying rocks. Directly overlies crystalline rocks.	Unknown, but thought to be small. Dissolved-solid concentrations generally not expected to be below 10,000 million gallons per liter.
PRECAMBRIAN		Precambrian crystalline rocks	Granite, and other massive crystalline rocks. Part of crystalline basement. Thickness unknown.	Occurs at great depths beneath land surface. Does not outcrop east of Blue Ridge province.	Confining unit. Highly nonporous and impermeable. Because of great depths, water-bearing characteristics are assumed to be very poor. No direct data exist that define the hydrologic character of these rocks.	Indirect geologic evidence suggests that most wells drilled in these rocks would yield very little water.

Conceptual Model of Basal Sandstone Groundwater Occurrence



Aquifer Characteristics

- No surface exposures
- Occurs at depths of 5,000 to 10,000 feet
- 200 to 400 feet thick
- Similar to other basal units throughout the world
- Limited data
- TDS exceeds 10,000 mg/L
- Not drinking water quality
- Has been used for deep injection wells

Questions?

The Groundwater Guy

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