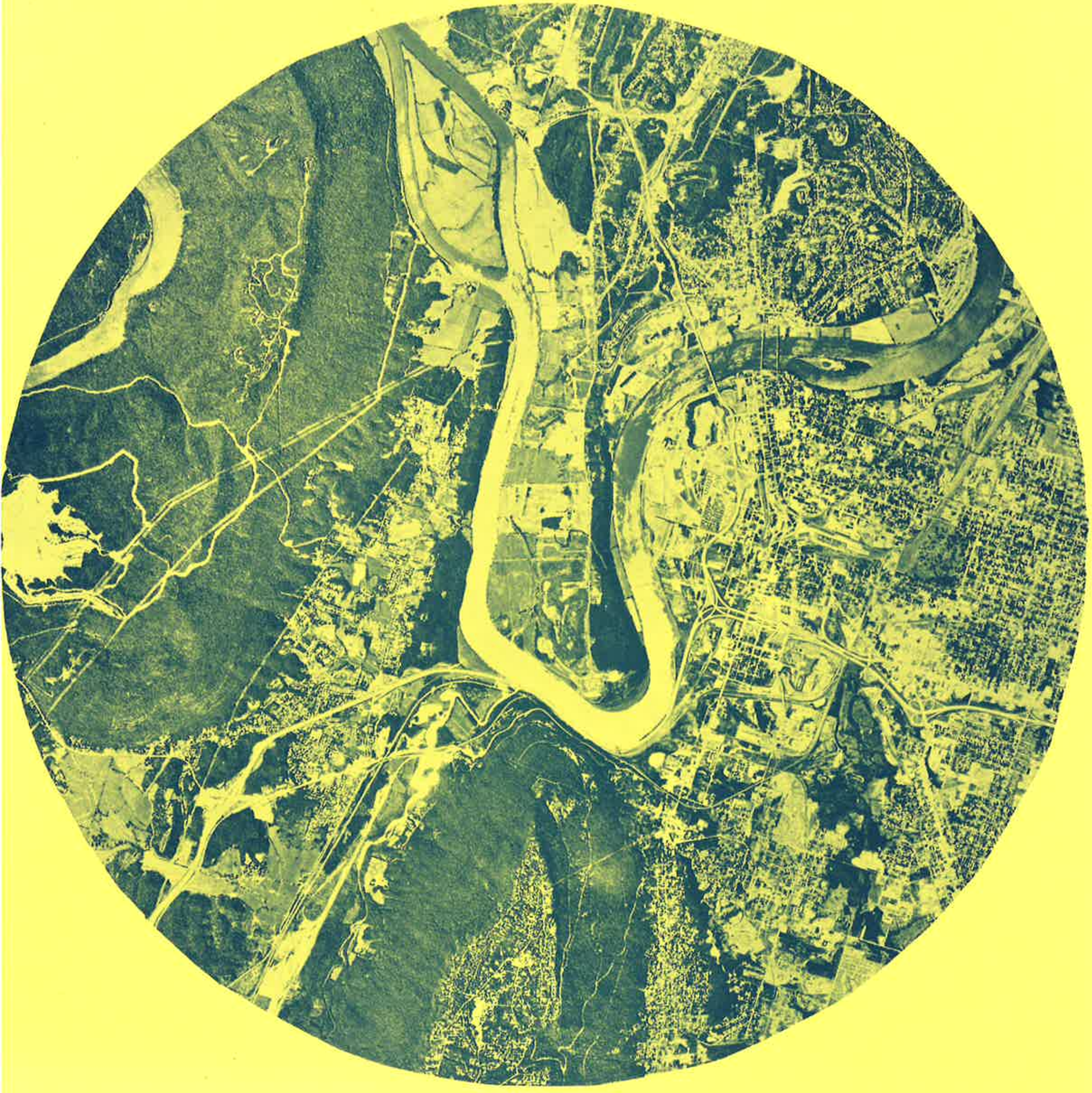

Geology of Hamilton County, Tennessee

Bulletin 79

1979

GEOLOGY

OF

HAMILTON COUNTY, TENNESSEE

TENNESSEE DIVISION OF GEOLOGY

BULLETIN 79

1979

STATE OF TENNESSEE

LAMAR ALEXANDER, Governor

DEPARTMENT OF CONSERVATION

ANN R. TUCK, Commissioner

DIVISION OF GEOLOGY

ROBERT E. HERSHEY, Director
State Geologist

FOREWORD

The Tennessee Division of Geology is publishing this Bulletin as a contribution to the understanding of the effects of geology on the activities of man in urban areas of the State. The complete report consists of Part I, a text including chapters on the stratigraphy, structure, ground water, mineral resources, coal and engineering geology of Hamilton County, contributed by specialists in the various fields; and Part 2, a package containing a generalized geologic map with mineral resource data and magnetic intensity contours at a scale of 1:48,000, and an environmental map at the same scale.

A companion volume to this report is Report of Investigations No. 37 "Field Trips in the Southern Appalachians," which was published early in 1978 at the time of the annual meeting of the Southeastern Section, Geological Society of America, in Chattanooga. The field trip report contains road logs, descriptions, photographs, and diagrams of many features illustrative of the problems and principles discussed in the present report.

Publication of the Bulletin, the accompanying maps, and the Report of Investigations No. 37 has been coordinated by Robert L. Wilson of the Geosciences Department, The University of Tennessee at Chattanooga; Robert J. Floyd of the Geologic Services Branch, Tennessee Valley Authority at Knoxville; and Robert C. Milici of the Tennessee Division of Geology at Knoxville.

Robert E. Hershey
State Geologist

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GENERAL INTRODUCTION TO THE GEOLOGY OF HAMILTON COUNTY, TENNESSEE

BY

EDWARD T. LUTHER[1]

LOCATION

Hamilton County is on the south border of Tennessee, two counties away from its southeast corner. It is bounded on the south by Whitfield, Catoosa, Walker, and Dade counties, Georgia; on the west and northwest by Marion, Sequatchie, and Bledsoe counties, Tennessee; on the north by Rhea and Meigs counties; and on the east by Bradley County. Hamilton County is somewhat elongated, extending about 35 miles (56.3km) in the northeast-southwest dimension compared to a maximum of about 25 miles (40km) in the northwest-southeast dimension. Its area is about 585 square miles (941.8 sq. km) and its seat of government and principal urbanized area is Chattanooga, the fourth largest city in Tennessee.

Hamilton County is readily accessible from almost any direction, being served by a network of highways including Interstates 24 and 75, which funnel traffic from both Nashville and Knoxville through the county enroute to Atlanta and Birmingham. Chattanooga is an important railroad hub as well, served by the Southern, Louisville and Nashville, Central of Georgia, and Tennessee, Alabama, and Georgia railroads.

TOPOGRAPHY

Topographically, Hamilton County is one of the most varied in the state. Along its western margin Lookout Mountain, Raccoon Mountain, and Walden Ridge are dissected remnants of the great Appalachian Plateau, which extends almost unbroken from southern New York to Central Alabama. The eastern border of the county follows Whiteoak Mountain, one of the highest ridges in the southern part of East Tennessee's Great Valley, for much of its length; but swings southeastward to include Grindstone Mountain, the most widely separated remnant of the Appalachian Plateau preserved anywhere in Tennessee southeast of the plateau front. Between Whiteoak Mountain and the plateau front the county consists of relatively low, parallel ridges trending northeast and separated by wide, also northeast-trending valleys. Lookout Valley, which separates Lookout Mountain from Raccoon Mountain, also trends northeast, but is much sharper and narrower than valleys farther east. The county is divided into nearly equal parts by the Tennessee River (Chickamauga Lake) that flows in from the northeast and follows along the grain of the country almost to the Georgia line, but turns abruptly at Chattanooga and leaves the county through the mountains to the northwest by way of the deeply incised gorge sometimes called the Grand Canyon of the Tennessee. It is in this southwestern part of the county that the greatest total relief, about 1500 feet (457m), is found. The low point in the county is less than 640 feet (195m) above sea level, at the point where the Tennessee River flows out near the mouth of Suck Creek, and the high point is 2,146 feet (654m) above sea level on the crest of Lookout Mountain, less than 10 airline miles (16km) away.

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[1] Assistant State Geologist, Tennessee Division of Geology, Nashville.

STRUCTURE

Hamilton County spans the boundary between two of the major physiographic provinces of the eastern United States, the Appalachian Plateau province to the northwest and the Valley and Ridge province to the southeast. About one-fourth of the county is in the Appalachian Plateau province, and the remainder in the Valley and Ridge. In Hamilton County the Appalachian Plateau (Walden Ridge, Raccoon Mountain, and Lookout Mountain) stands, on the average, more than a thousand feet (305 m) higher than the adjacent Valley and Ridge. The Plateau is underlain by flat to gently dipping beds, mostly Mississippian carbonates and shales under the lower slopes but capped by resistant sandstones, shales, and conglomerates of Early Pennsylvanian age that have protected it from erosion and give it a characteristic flat-topped profile. The Valley and Ridge province is underlain by less resistant carbonates and clastics of Cambrian to Pennsylvanian age that have been folded and faulted to such an extent that rock layers commonly dip very steeply, the more resistant beds holding up long, linear ridges and the less resistant underlying the valleys.

CLIMATE

The climate of Hamilton County is temperate but humid, with hot summers and cool winters. Rainfall averages about 50 inches (127cm) per year, fairly well distributed throughout the year but perhaps somewhat drier in the late summer and early fall. Temperatures range during mid-winter from an average daily minimum in the low 30's (16.7°C) to an average daily maximum of a little over 50°F. (27.8°C.), while during mid-summer they range from an average daily minimum in the low 70's (38.9°C) to an average daily maximum near 90°F (50°C). On the average, 210 days elapse each spring between the last sub-32°F (17.8°C) day in spring and the first sub-32°F (17.8°C) day in fall. Such conditions are very conducive to chemical weathering, and areas not undergoing active erosion are commonly covered with a deep mantle of residuum.

THE STRATIGRAPHY OF EXPOSED ROCKS IN HAMILTON COUNTY, TENNESSEE

BY

ROBERT LAKE WILSON[1]

INTRODUCTION

Outcropping rock strata in Hamilton County, Tennessee, range in age from Early Cambrian to Pennsylvanian. Isolated occurrences of terrace gravels as much as 15 feet (4.5m) thick and as much as 130 feet (40m) above the present drainage were recognized, but not mapped. No precise age could be determined for these high level gravels, but similarly situated deposits described by Milici (1967) in the Sequatchie Valley were considered to be of late Tertiary or Pleistocene age.

More than 40 rock units (table 1) are described in this report. However, the accompanying geologic map (plate 1) shows only 19 major map units (mainly because of groupings within the Knox and Chickamauga Groups).

In general, rocks of the older Cambrian strata are confined to the eastern part of the county in the Valley and Ridge area, whereas the younger Mississippian and Pennsylvanian rocks are preserved to the west, capping Lookout, Raccoon, and Signal Mountains. The middle part of Hamilton County is underlain by rocks of the Knox Group and Chickamauga Supergroup. The single most abundant rock unit in the county is the Knox Group, which underlies about 30 percent of the surface area.

C.W. Hayes (1894) made one of the earliest stratigraphic studies of the area in the Chattanooga Folio. The next major effort was not until 1953, when John Rodgers compiled a geologic map of East Tennessee together with an explanatory text. Many of the Hamilton County rock units were described by G.D. Swingle (1959) in his study of the geology, mineral resources, and ground water of the Cleveland area in neighboring Bradley County, where the units are very similar.

Several 7-1½ 1 minute geologic quadrangle maps and mineral resources summaries published by the Tennessee Division of Geology cover more than half the county. These include Soddy Island(Swingle, 1963), Soddy (Luther and Swingle, 1964b), Graysville (Swingle, 1964c), Daisy (Swingle and Luther, 1964a), Fairmount (Swingle and Luther, 1963) and Chattanooga (Finlayson, et. al., 1964). In 1966, the Tennessee Division of Geology also published a state geologic map that included succinct stratigraphic descriptions.

The stratigraphic framework used in this report is based primarily on gross lithologic descriptions and summaries from the literature and recent geologic studies by the writer.

CAMBRIAM SYSTEM

ROME FORMATION

The Rome Formation consists of two members, the Apison Shale Member below and the Sandstone Member above.

Apison Shale Member

The oldest outcropping rocks in Hamilton County consist of some 500 feet (152m) of shales and siltstones that are vividly colored brownish-yellow, pale greenish-gray, grayish-red, purple and brown. The shales are sandy, clayey, and micaceous. Outcrops are limited to a narrow belt of the Apison Shale Member that trends northeastward in a broad valley and closely follows the trace of Clinchport fault. The outcrop belt passes through the town of Apison, its type locality. The base of the Apison Shale Member is cut off by faulting and it grades upward into the overlying Sandstone Member (Swingle, 1959).

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[1] Professor, Geosciences Department, The University of Tennessee at Chattanooga.

TABLE 1. SEQUENCE OF EXPOSED ROCKS, HAMILTON COUNTY, TENNESSEE

SYSTEM	GROUP	FORMATION		TYPE AREA AND ORIGINAL REFERENCE
QUATERNARY		Pleistocene and Recent Alluvium		
TERTIARY		Fluvial Deposits and Other Material Mantling Upland Terraces		
PENNSYLVANIAN	CRAB ORCHARD MOUNTAINS GROUP	Rockcastle Conglomerate		Rockcastle Cove, Fentress Co., TN Wanless, 1946
		Vandever Formation		Vandever, Cumberland Co., TN Nelson, 1925
		Newton Sandstone		Newton, Cumberland Co., TN Nelson, 1925
		Whitwell Formation		Whitwell, Marion Co., TN Butts and Nelson, 1925
		Sewanee Conglomerate		Sewanee, Franklin Co., TN Safford, 1893
	GIZZARD GROUP	Signal Point Shale		Signal Point, Hamilton Co., TN Wilson and others, 1956
		Warren Point Sandstone		Warren Point, Grundy Co., TN Nelson, 1925
		Raccoon Mountain Formation		Raccoon Mountain, Hamilton Co., TN Wilson and others, 1956
MISSISSIPPIAN		Pennington Formation		Pennington Gap, Lee Co., VA Campbell, 1893
		Bangor Limestone	*Upper Newman Limestone*	Bangor, Blount Co., AL Smith, 1890
		Hartselle Formation		Hartselle, Morgan Co., AL Smith, 1894
		Monteagle Limestone	*Lower Newman Limestone*	Monteagle, Marion Co., TN Vail, 1959
		St. Louis Limestone		St. Louis, MO Englemann, 1847
		Warsaw Limestone		Warsaw, Hancock Co., IL Hall, 1857
		Fort Payne Formation		Fort Payne, DeKalb Co., AL Smith, 1890
DEVONIAN		Chattanooga Shale		Chattanooga, Hamilton Co., TN Hayes, 1891

TABLE 1. (Continued)

SILURIAN				Rockwood Formation		Rockwood, Roane Co., TN Hayes, 1891
ORDOVICIAN	UPPER ORDOVICIAN				*Sequatchie Formation*	Sequatchie Valley, TN Ulrich, 1912
				Shellmound Formation		Shellmound, Marion Co., TN Milici, 1977
				Leipers Limestone		Leipers Creek, Maury Co., TN Hayes and Ulrich, 1903
				Inman Formation		Inman, Marion Co., TN Wilson, 1949
	MIDDLE ORDOVICIAN	*Chickamauga Super Group*	**NASHVILLE GROUP**	Catheys Formation		Lewis and Maury Co., TN Hayes and Ulrich, 1903
				Cannon Limestone		Cannon Co., TN Ulrich, 1911
				Hermitage Formation		Hermitage Station, Davidson Co., TN Hayes and Ulrich, 1903
			STONES RIVER GROUP	Carters Limestone		Carters Creek, Maury Co., TN Safford, 1869
				Lebanon Limestone		Lebanon, Wilson Co., TN Safford, 1851
					Jewell Bluff Formation[1]	Jewell Bluff, Meigs Co., TN Wilson (this paper)
				Ridley Limestone		Old Jefferson, Rutherford Co., TN Safford, 1869
				Murfreesboro Limestone		Murfreesboro, Rutherford Co., TN Safford and Killebrew, 1900
				Pond Spring Formation		Pond Spring, Catoosa Co., GA Milici and Smith, 1969
	LOWER ORDOVICIAN		**KNOX GROUP**	Mascot Dolomite		Mascot, Knox Co. TN Oder and Miller, 1945
				Kingsport Formation		Kingsport, Sullivan Co., TN Oder and Miller, 1945
				Chepultepec Dolomite		Chepultepec, Blount Co., AL Ulrich, 1911
				Copper Ridge Dolomite		Copper Ridge, Grainger Co., TN Ulrich, 1911
CAMBRIAN			**CONASAUGA GROUP**	Maynardville Limestone		Maynardville, Union Co., TN Oder, 1934
				Conasauga Undivided		Conasauga Valley, Whitfield & Murray Co. GA Hayes, 1891
				Rome Formation		Rome, Floyd Co., GA Smith, 1890

[1] New formation.

Sandstone Member

The Sandstone Member is about 820 feet (250m) thick and consists of a heterogeneous mixture of sandstone, siltstone, and shale. Thin beds of argillaceous, bluish-gray dolomitic limestone occur near the base. The sandstones are typically reddish-brown, fine- to medium-grained, thin- to medium-bedded, micaceous and glauconitic. The sandstones are interbedded with varicolored, purplish-red, pale greenish-gray, pale-red, and dark reddish-brown siltstone and shale. As with the Apison Shale Member the sandstone beds of the Rome are limited to a narrow belt along the Clinchport fault zone in the southeastern part of the county. Although these sandstone beds are not very thick, they do form a series of prominent northeastward-striking ridges. The top of the Sandstone Member is generally drawn at the first prominent sandstone bed (figure 1).

CONASAUGA GROUP

Rocks of the Conasauga Group within Hamilton County can be divided into two mappable units. The lower of these is an undivided unit about 1500 feet (457m) thick containing shale, siltstone and limestone. The upper unit consists of some 310 feet (95m) of dark-gray limestone, the Maynardville.

In general, belts of Conasauga exhibit faulting and intricate folding, and the absence of distinctive marker beds makes further subdivision very difficult. The shales normally form valleys, whereas the silty limestones form lines of low knobs. The more silty shales and siltstones near the base underlie a series of low hills.

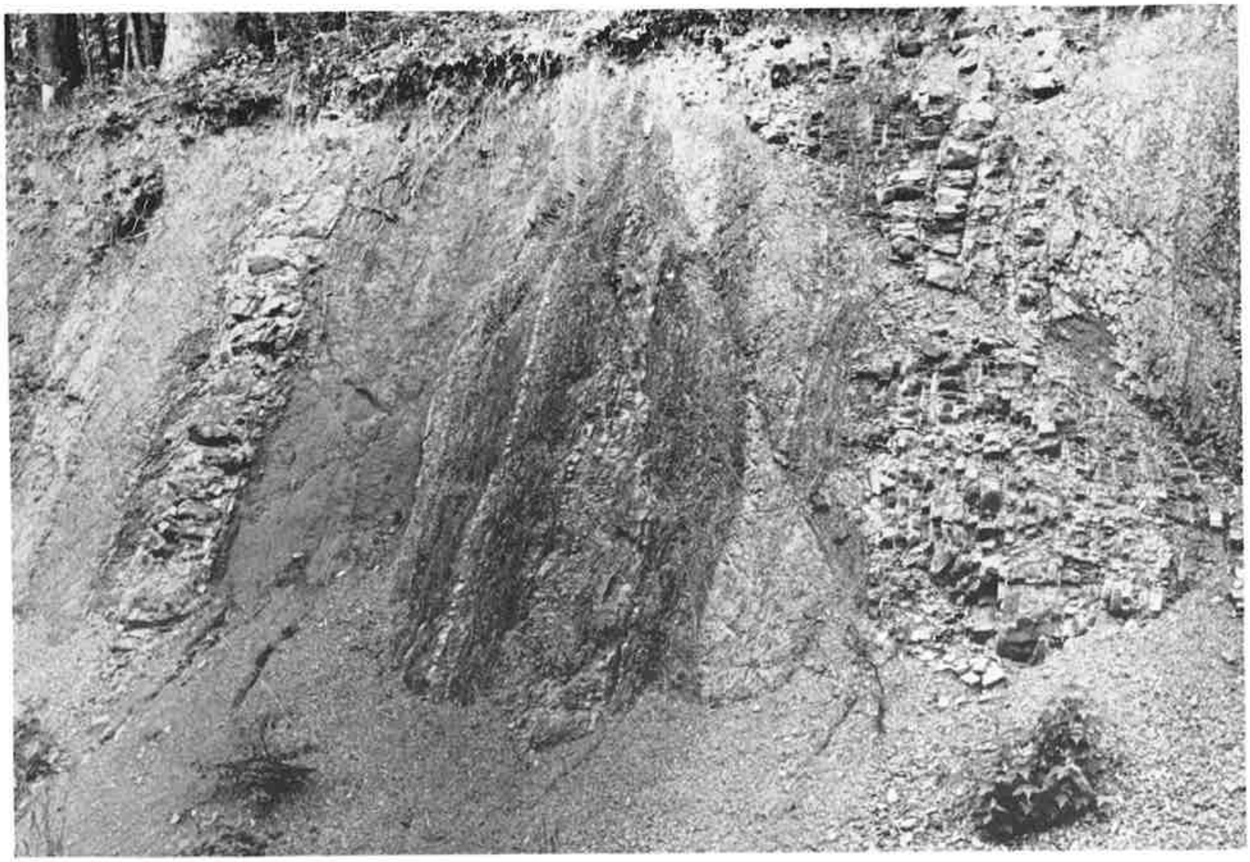

Figure 1. Steeply inclined sandstones and shales in Rome Formation along London Lane in the extreme southwestern corner of Hamilton County. Note minor faulting.

Conasauga Undivided

The undivided Conasauga consists of a series of light-green to light-brown shales as well as zones of medium-gray dolomitic limestone, coarse-grained oolitic limestone, and edgewise conglomeratic limestone. The lower part of the Conasauga contains a sequence of maroon and reddish-brown shales and siltstones. The thickness of this unit is uncertain because of faulting and complex folding, but it has been estimated to be about 1500 feet (457 m).

Outcrops of the shales and limestones of the undivided part of the Conasauga lie along a narrow belt that extends from the Georgia state line northeastward through East Brainerd, Silverdale, and Harrison Bay. The Conasauga here has been brought to the surface along the southeastern side of the Kingston fault. The only other area where the Conasauga crops out is near Apison in the extreme southeastern part of the county.

The Conasauga Shale weathers to a thin, poorly drained, acid soil; but where the limestones are present, the soils are somewhat richer and a dark-red color.

Maynardville Limestone

The Maynardville Limestone is about 310 feet (95m) thick and crops out only in the eastern third of the county. Exposures of the Maynardville are extremely limited; generally it is deeply weathered and covered by residual cherts from the overlying Copper Ridge Dolomite. The upper part is well exposed at Harrison Bay along Tennessee State Highway 58 just south of Wolftever Creek. Here it consists of a medium- to dark-gray, argillaceous limestone with a faint asphaltic odor when freshly broken. Thin bands of silt contained within the formation weather to a most distinctive straticulate appearance. In Hamilton County outcrops of the Maynardville Limestone are restricted to the northwest slopes of northeastward-trending ridges. The contact of the Maynardville with the overlying Copper Ridge Dolomite of the Knox Group is marked by the appearance of dark-gray dolomite containing an abundance of dark-gray nodules and masses of chert. The lower boundary is placed at the base of the lowest massive limestone bed in the upper part of the Conasauga Group (Swingle, 1959).

KNOX GROUP

The Knox Group is about 2300 to 2800 feet (701-853m) thick and consists of four formations. These are, in ascending order, the Copper Ridge Dolomite, the Chepultepec Dolomite, the Kingsport Formation, and the Mascot Dolomite (Harris, 1969).

Copper Ridge Dolomite

The Copper Ridge Dolomite is 980 feet (299m) thick and consists of medium- to dark-gray, fine- to coarsely crystalline dolomite. It is well-bedded with medium to thick beds. It contains a small amount of asphaltic material, and gives off a distinct asphaltic odor when freshly broken. Dark masses of chert in layers or thin nodules are common throughout the formation. Some of these cherts are locally oolitic; some cherts are silicified cryptozoans. During weathering the Copper Ridge releases large quantities of tough, irregularly shaped, dark chert fragments as well as nodules and layers. These chert masses always form hills or ridges. Sandstone beds that commonly mark the basal contact in other areas were not observed in Hamilton County. Outcrops of the Copper Ridge, and residuum derived from it, form a distinctive row of hills or ridges. One such prominent ridge can be seen beside the Tennessee River in downtown Chattanooga (figure 2). Sixty-five-foot (20m) cliffs are visible along the south side of the river beneath the Hunter Art Gallery. From here the Copper Ridge outcrop trends along the river through White Oak, Red Bank and Soddy-Daisy to Bakewell and Sale Creek. Over most of this distance the Copper Ridge follows the trace of the Chattanooga fault. A second major belt of Copper Ridge Dolomite follows along the eastern edge of Chickamauga Lake past Harrison Bay and on to the Meigs County Line. An abandoned quarry on the south side of Wolftever Creek provides the best exposures of the lower part of the Copper Ridge Dolomite.

ORDOVICIAN SYSTEM

KNOX GROUP

Chepultepec Dolomite

The Chepultepec consists of some 980 feet (299m) of light-gray to medium dark-gray dolomite. It is thin- to very thick-bedded and fine- to very coarse-grained. Near the top of the formation are a few beds of light-gray limestone. Upon weathering, the Chepultepec produces large quantities of light-colored, porous chert and porcelaneous chert. Large blocks and masses of chert are characteristic of residuum from this formation, and it forms the highest parts of the Knox ridges in the county. Dividing Ridge, which separates Chickamauga Lake from Tennessee Highway 58 northeastward from Harrison Bay, is underlain by the cherts of the Chepultepec. Good exposures of the Chepultepec Dolomite are rare within this area. Probably the best outcrops are located along the south side of Wolftever Creek.

Near the base of the Chepultepec are several thin sandstone beds. The thickest, as much as 20 inches (51cm), marks the base of the Chepultepec. It is medium- to coarse-grained and commonly cemented by dolomite. Cummings (1960) described these sandstone beds as well-sorted ortho-quartzites that generally are smaller

Figure 2. Bluffs of Copper Ridge Dolomite beneath the Hunter Art Gallery along the Tennessee River.

grained to the south and southwest. However, only one of his data points was within 62 miles (100km) of Chattanooga. He suggested that these sands represented the final stage in a long period of weathering and sorting; the deposition is attributed to a minor regression of the Cambro-Ordovician sea or an uplift of the source area. The upper boundary of the Chepultepec as defined by Bridge (1956) is a difficult contact to pick. For the most part, workers in Hamilton County have relied on changes in topographic expression and the nature of residual cherts rather than on lithologic criteria.

Kingsport Formation

The lower part of the Kingsport Formation contains medium- to coarse-grained dolomite interbedded with light-gray, fine-grained limestone. Scattered nodules and lenses of light-colored porous chert are present. The upper units consist of light-gray, fine-grained limestone with minor amounts of light olive-gray, coarse-grained dolomite. The average thickness of the Kingsport Formation is 250 feet (76m). Good exposures of the Kingsport are limited to the area along the shores of the Wolftever Creek between Harrison and Savannah Bays.

Mascot Dolomite

Overlying the relatively chert-free beds of the Kingsport Formation is well-bedded, light- to medium-gray, finely crystalline dolomite. Highly colored chert nodules are common, as are zones of grayish-red, mottled, argillaceous dolomite. The upper surface of the Mascot commonly shows evidence of a major unconformity.

The upper units of the Mascot are well exposed in the Chickamauga National Cemetery on Bailey Avenue (figure 3). Here many of the well-bedded dolomite beds are characterized by thin veinlets of calcite, which upon weathering give a "butcher block" pattern (figure 4). Several thick, light-gray limestone beds that are very fossiliferous are present. Several opercula of the diagnostic Ordovician gastropod *Ceratopea* have been found weathered from these beds. The thickness of the Mascot ranges from 460 to 590 feet (140 to 180m).

Post-Knox Unconformity

The contact between the Mascot Dolomite of the Knox Group and the overlying Pond Spring Formation of the Stones River Group is marked by regional unconformity. In many places this boundary is indicated only by a change from fine-grained, light-gray dolomite with scattered nodules of light bluish-gray to light pinkish-gray chert to gray, medium-bedded, fine-grained limestones of the Pond Spring Formation. Locally, however, the upper surface of the Mascot Dolomite exhibits a relief of more than 165 feet (50 m). These erosional lows in sinks are commonly filled with varicolored clay shale, sandstone, or breccia blocks of dolomite enclosed in a greenish-gray to maroon clay shale. One such sinkhole and deposit in the upper Mascot can be seen at the intersection of Snow Hill Road and Mahan Gap Road (Snow Hill quadrangle). Farther to the northeast along Snow Hill Road near Savannah church the top of the Knox is marked by a series of prominent beds of quartz sandstone. In several localities throughout the county this contact is marked by a distinctive fine- to medium-grained chert breccia enclosed in fine-grained dolomite or dolomitic limestone. To the south there is another large, collapse-breccia-filled sink some 165 feet (50m) deep in Rabbit Valley, Catoosa County, Georgia, 1-1/4 miles (2km) south of the Hamilton County line (figure 5).

The writer agrees with Milici (1973) that the beds of the upper Knox (Mascot) experienced an interruption of sedimentation and local subaerial erosion throughout the southern Appalachians. The vertical changes observed across the Knox-Stones River boundary may, however, reflect the horizontal distribution of time-equivalent facies rather than a vast regional erosion surface.

STONES RIVER GROUP

Pond Spring Formation

The Pond Formation (Milici and Smith, 1969) is as much as 350 feet (107m) thick in Hamilton County. The lower beds unconformably overlie the Kingsport Formation of the Knox Group. A basal conglomerate consists mostly of greenish-gray and grayish-red silty limestone and mudstone. Light greenish-gray, fine-grained limestone within thin zones of greenish-gray calcareous shale and sandstone are also common in the basal beds above the unconformity.

The lower third of the Pond Spring consists of light-gray, well-bedded, fine-grained limestone, overlain by some 200 feet (61m) of greenish-gray and grayish-red silty limestone and mudstone. The red beds are very distinctive and mark the top of the formation.

The Pond Spring is well exposed in the vicinity of Snow Hill along Mahan Gap Road. G. A. Cooper (1956) measured the section at Mahan Gap Road near Snow Hill and proposed the terms Long Savannah, Mahan, Ooltewah and Bays Formation. Several species of brachiopods were reported from this interval, including *Strophomena, Ancistrorhyncha, Pionodema, Sowerbyella* and *Hesperorthis*. Here a filled sinkhole in the top of the Knox contains a distinctive bluish-gray shale along with a number of *Orthoceras*-type cephalopods. The lower part of the formation is well exposed in an active quarry of Vulcan Materials Company near Lovell Field, the Municipal Airport of Chattanooga (figure 6).

Figure 3. Interbedded limestone and dolomite beds of the Mascot in the Chickamauga National Cemetery on Bailey Avenue.

Figure 4. "Butcher Block" weathering of dolomite beds near the top of the Mascot in the Chickamauga National Cemetery on Bailey Avenue.

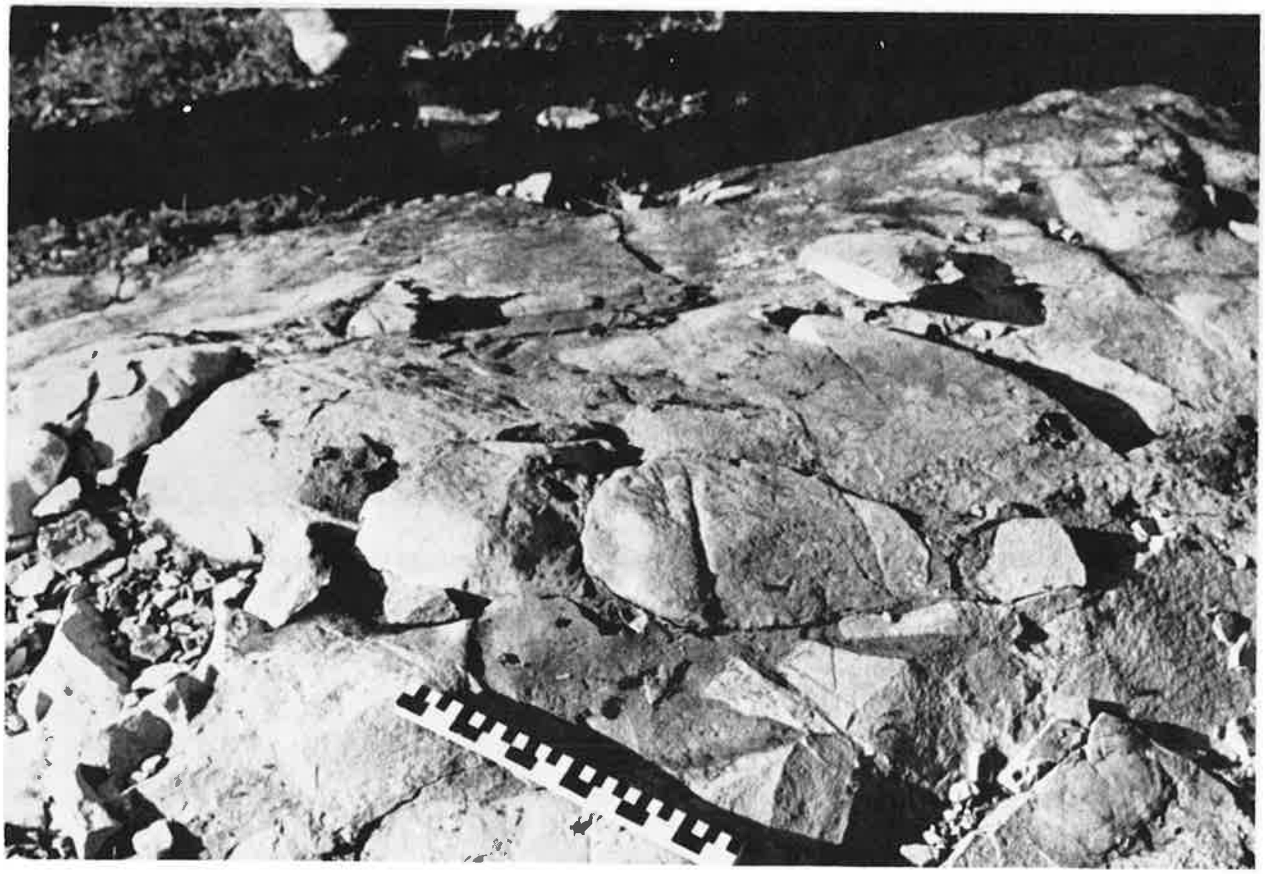

Figure 5. Large post-Knox solution features filled with angular fragments of dolomite in Catoosa County, Georgia, near Hamilton County line.

Murfreesboro Limestone

The Murfreesboro Limestone includes two units, the lower of which consists of 350 feet (107m) of fine-grained, argillaceous, medium- to dark-gray limestone. It is overlain by a sequence of grayish-yellow argillaceous limestone beds as well as several thin beds of greenish-gray calcareous shale. The upper part contains about 100 feet (30.5m) of medium-gray, commonly fucoidal limestone. Near the top is a persistent zone of nodular or ropy dark-gray to black chert. The Pierce Limestone of Middle Tennessee, a thin-bedded unit that separates the Murfreesboro from the overlying Ridley, has not been recognized in this area.

There are few continuous exposures of the Murfreesboro. Most are scattered along a strike belt that extends from the Georgia state line northeastward through Ooltewah and Snow Hill to Georgetown.

Ridley Limestone

There is a sharp contrast between the even-bedded limestones of the Murfreesboro and the silty, poorly bedded, commonly fucoidal, medium- to dark-gray limestones of the Ridley. The maximum thickness is about 460 feet (140m). There is a distinctive zone about 100 feet (30.5m) thick consisting of yellowish-red calcareous shale near the middle of the formation. The soils are very thin over this part of the Ridley, making it extremely easy to trace.

Lebanon Limestone

The Lebanon consists of some 200 feet (60.9 m) of highly fossiliferous, argillaceous, thin-bedded limestone. Most beds are only 8 to 20 inches (20-50 cm) thick. The outcrop belt is recognized by thin, slabby limestones that typically give rise to cedar glades. Bedding surfaces are extremely irregular and typically contain small, branching bryozoans as well as numerous fucoids.

JEWELL BLUFF FORMATION[1]

The basal unit of the Stones River Group in northeastern Hamilton County is the Jewell Bluff Formation, here named from exposures in and near Jewell Bluff, on the north side of the Hiwassee River across from the mouth of Gunstocker Creek. This is in Meigs County, about 4 miles (6.4km) north of the Hamilton County line in the Birchwood (119-SW) 7-1/2 minute quadrangle (figure 7).

The Jewell Bluff consists generally of two members: a lower unit about 260 feet (79m) thick composed mostly of medium-gray, well-bedded limestone below and calcareous, reddish-gray siltstone and shale above; and an upper unit about 121 feet (37m) thick composed of alternating zones of medium- to dark-gray and greenish-gray limestone and siltstone. The limestone is thin- to medium-bedded, but the bedding is locally indistinct.

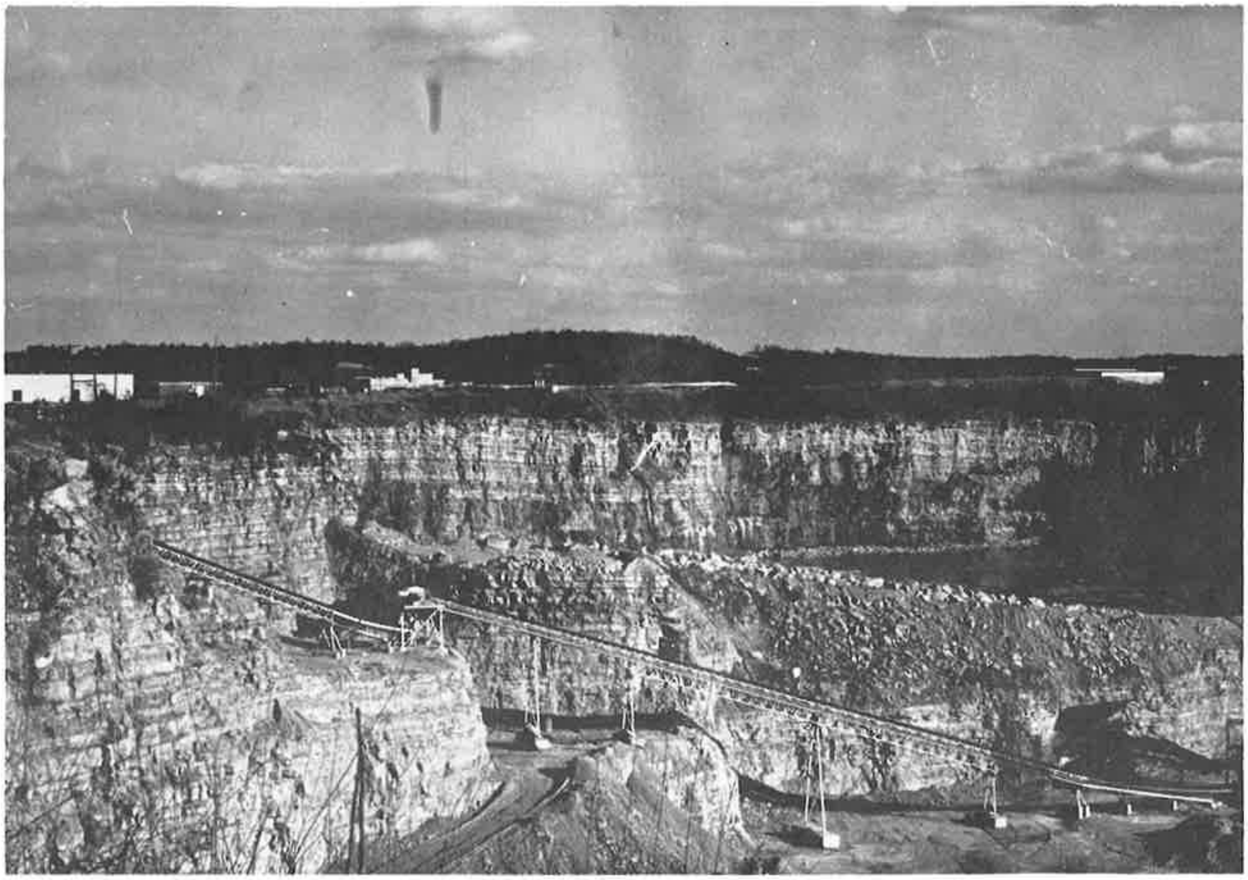

Figure 6. Lower limestones of the Pond Spring Formation as exposed in the Vulcan Materials Quarry.

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[1] New formation.

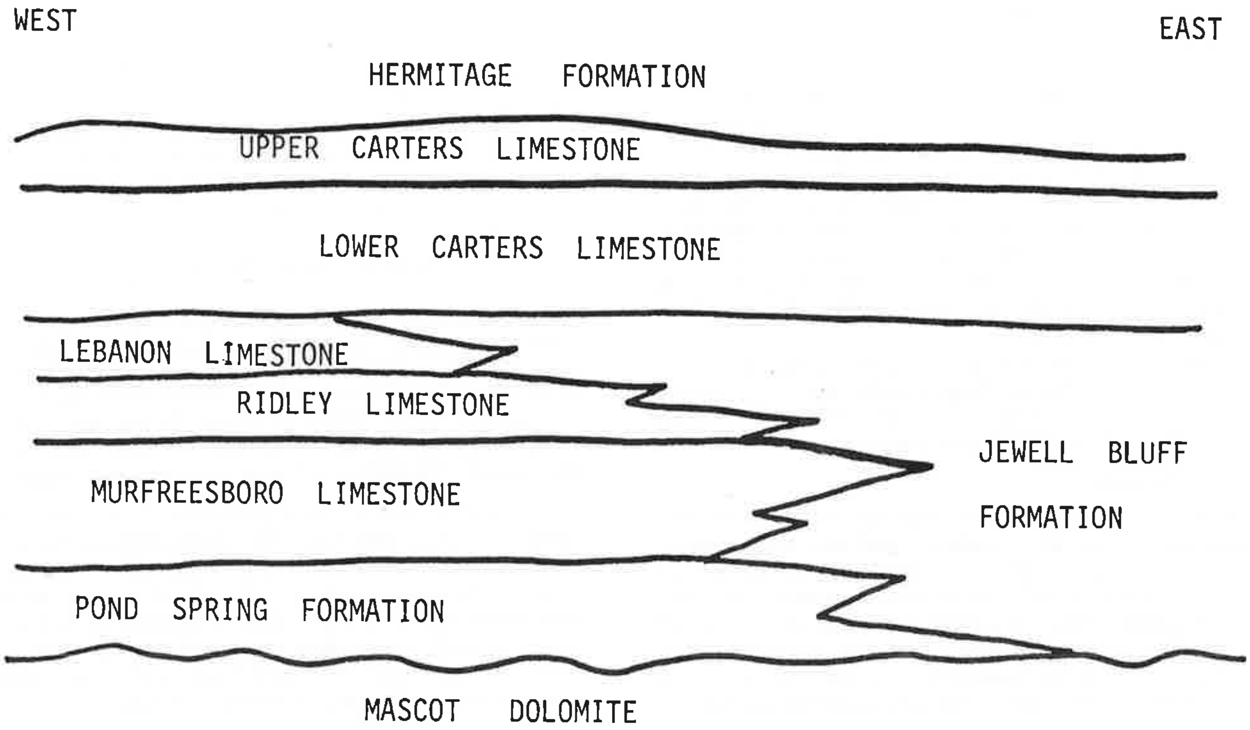

Figure 7. Regional facies relationships of the Stones River Group in Hamilton County.

The Jewell Bluff Formation appears to be a considerably thinner and lithologically different equivalent of all the formations of the Stones River Group below the Carters Limestone. Its thickness of 390 feet (189m) is only about 1/3 of the aggregate thickness of presumably equivalent lower Stones River formations in the western part of the county. At the base, the Jewell Bluff rests unconformably on the Mascot Dolomite of the Knox Group, and at the top it is overlain with apparent conformity by the Carters Limestone, the top formation of the Stones River Group.

Inasmuch as the lithology of the Jewell Bluff is distinctly different from that of the Chickamauga (the older formation or group name under which Middle Ordovician carbonates in East Tennessee have commonly been lumped), and inasmuch as reconnaissance mapping indicates that the Jewell Bluff lithology persists northeastward along the strike across a number of as yet unmapped quadrangles, the new formation name is needed to apply to northeastern Hamilton County and the areas beyond. Type section of the Jewell Bluff Formation is given in Table 2.

TABLE 2. TYPE SECTION OF THE JEWELL BLUFF FORMATION

Jewell Bluff Formation, Birchwood Quadrangle, Tennessee (Section measured along north shore of Hiwassee River at Jewell Bluff, Tennessee Coordinate location 357,500N., 2,323,000E.)

Unit	Thickness (meters)	Thickness (feet)
Carters Limestone		
Calcilutite and calcarenite, medium-gray, medium-bedded, fossiliferous, poorly exposed—	15+	50+
Jewell Bluff Formation (upper member)		
Calcisiltite, fine-grained medium- to dark-gray and brownish-gray, in even beds 6 to 12 inches (15 to 30 cm) thick, forms steep cliff, partly covered near top	16	54
Siltstone, medium-gray to greenish-gray, thin- to medium-bedded, distinct 3- to 4-foot (0.9-1.2m) zone greenish-gray shale about 31 feet (9.4 m) above base; basal part shows abundance of well-preserved mud cracks	23	76
Jewell Bluff Formation (lower member)		
Siltstone, calcareous, thin- to medium-bedded, light-gray with reddish-gray zones —		
Shale, grayish-red, silty, calcareous, partly covered —	3	11
Siltstone, grayish-red to olive-gray, thin-bedded; mud cracks and fucoidal markings common —	7	23
Calcilutite with fucoidal markings —	6	21
Calcisiltite, medium-gray, thin- to medium-bedded: interbedded with thin zones of shale; thick-bedded calcilutite. About 25 feet (7.6 m) below top is a distinctive 2 to 3 foot (0.6-0.9 m) zone of dark-gray chert nodules	23	76
Calcisiltite, medium-gray, thin- to medium-bedded, interbedded with thin zones of shale; weathers into prominent loaf-sized blocks; partially covered near top —	8	25
Calcisiltite, greenish- to purplish-gray, medium-bedded, lower 5 feet (1.5m) partly covered —	8	25
Chert, nodular, dark-gray, in a matrix of medium- to dark-gray calcilutite —	2	8
Calcilutite, medium-gray, well-bedded, medium-bedded, unconformity at base; basal beds include scattered fragments of chert and dolomite from the underlying Mascot —	8	26
Total Thickness of Jewell Bluff	119	380
Mascot Dolomite (Knox Group)		
Dolomite, medium-gray to light brownish-gray, medium-bedded, bedding indistinct; contains minor lenses of reddish-brown, bonded chert nodules; forms prominent bluff; upper surfaces of beds show distinctive "butcher block" weathering; unconformity at top —	11+	36+

Carters Limestone

Carters Limestone may be divided into two distinct members. The T-3 bentonite (Wilson, 1949) serves to separate the two members. The lower member consists of about 250 feet (76m) of medium dark-gray, medium-bedded, fine-grained fossiliferous limestone. Near the middle of this lower member are some 40 to 50 feet (12.2-15.2m) of interbedded shale and greenish-gray argillaceous limestones.

The upper member contains the T-3 and T-4 bentonite beds (Wilson, 1949). These bentonite beds are mostly poorly exposed, but average 2 to 3 feet (0.6-0.9 m) thick. The base of each bentonite bed is marked by a 2 to 3 inch (5-8cm) bed of distinctive dark-gray to dark greenish-gray chert (figure 8). The thickness of the upper member averages about 50 feet (15.2m) and it contains thin-bedded, grayish-yellow to pale reddish-gray, silty limestone. Bedding surfaces are commonly mudcracked, and thin beds of interclasts are common.

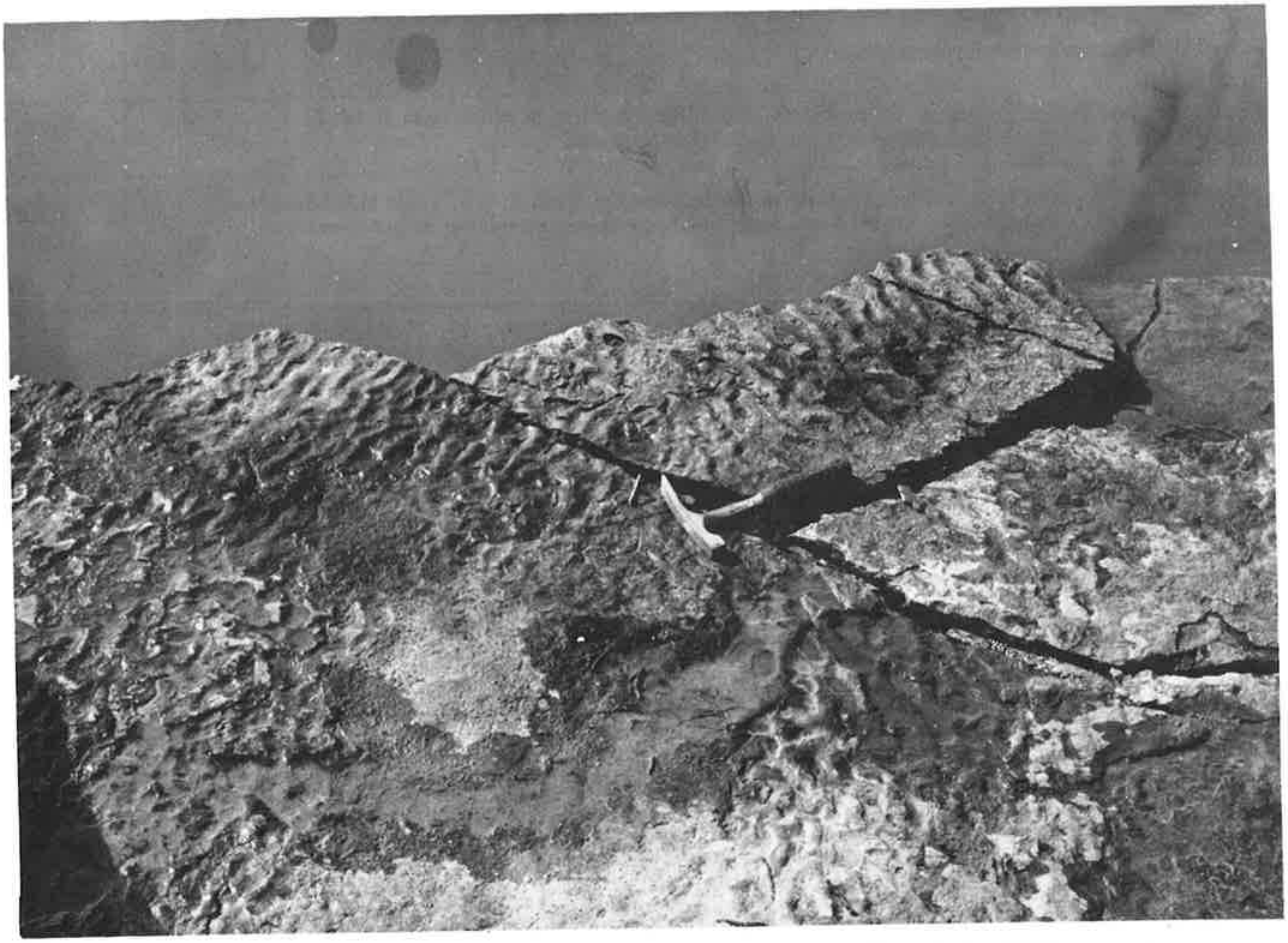

Figure 8. Dark-green chert that underlies the T-3 bentonite in the Upper Carters near Chickamauga Dam.

NASHVILLE GROUP

The Nashville Group has an average thickness of 510 feet (155.4m) and includes (in ascending order) the Hermitage Formation, Cannon Formation and Catheys Formation.

Hermitage Formation

The lowest formation in the Nashville Group, the Hermitage, is easily recognized on outcrop. It consists of from 100 to 200 feet (30.5-61m) of olive-gray, silty, nodular limestones. The bedding is indistinct and the conspicuous coral *Tetradium* is locally abundant. The beds range in thickness from 6 to 20 inches (15-51cm) and the Hermitage commonly weathers to a distinct rubble of irregularly shaped nodules of limestone. The rubbly, weathered appearance of the Hermitage contrasts sharply with the even-bedded Upper Carters Limestone as well as the overlying, darker, well-bedded Cannon Limestone. Locally near the base of the Hermitage is a 2 foot (0.6m) bed of medium-grained calcareous sandstone. Blocky fragments of this sandstone commonly occur in the weathered soil just above the Upper Carters contact.

Exposures of the Hermitage are limited to a strike belt along the northern side of Whiteoak Mountain in the eastern edge of the county and a second belt along the western side of Missionary Ridge.

Cannon Limestone

Overlying the silty, nodular beds of the Hermitage are some 200 feet (61m) of evenly bedded limestones 6 to 12 inches (15-30cm), medium dark-gray to dark-gray and fine- to coarse-grained. Bryozoans are especially abundant along with orthoconic cephalopods, brachiopods and corals. Freshly broken Cannon Limestone gives off a distinctive odor of asphalt.

The most accessible exposure of Cannon is in an abandoned quarry just south of the western portal of the Wilcox Tunnel through Missionary Ridge in East Chattanooga. Here some 100 feet (30.5m) of the formation are exposed.

Catheys Formation

The Catheys consists of some 200 feet (61m) of medium-gray to yellowish-gray, thin-bedded, argillaceous to fine-grained limestone. Thin zones of greenish-gray calcareous shale are common. Limestone beds weather to distinctive, thinly laminated slabs resembling contour maps. Along the western side of Whiteoak Mountain it is commonly covered by colluvium from the overlying Rockwood Formation, and along the northwestern side of Missionary Ridge it is concealed under a mantle of colluvial cherts from the Copper Ridge Dolomite of the Knox Group. In the northeastern part of the county exposures of the Catheys are very limited. It weathers to an olive-gray, silty shale and near the top of the formation is a prominent zone of Hermitage-like, nodular, brownish-gray limestone.

Inman Formation

The Inman Formation is present only in the western part of the county, where it crops out along the flanks of the Lookout Valley anticline. It consists of a thin-bedded to finely laminated, fine-grained, greenish-gray limestone interbedded with green and red calcareous shale. The thickness of the Inman ranges from 0 to 60 feet (0-18.3 m). A distinctive series of red calcareous shales is concentrated at the base along with a prominent glauconite-rich zone just above the contact with the underlying Catheys Formation. Wilson (1949) and Milici and Wedow (1977) reported the thickness of the Inman in Sequatchie Valley to range from 40 to 70 feet (12.2-21.3 m) (figure 9).

Leipers Limestone

The Leipers Limestone is present only in the western half of the county, where it overlies the Inman. It ranges in thickness from 0 to 35 feet (0-10.7 m). The Leipers consists of bluish-gray, argillaceous, nodular limestone, which weathers light gray. Fine- to coarse-grained, it is fossiliferous and contains several distinctive species, one of which is the brachiopod *Platystrophia ponderosa*.

Along I-24 just across the Georgia state line the Leipers is about 33 feet (10m) thick. Here the Leipers consists primarily of thin-bedded, light- to medium-gray, fine-grained, fossiliferous limestone together with thin beds of gray-green shale and light- to dark-gray, medium- to coarse-grained, thin-bedded limestone, which was formed as part of a tidal flat complex (McCullough and Bergenback, 1975).

Shellmound Formation

Milici and Wedow (1977) made an extensive study of the Sequatchie Formation in its type area of Sequatchie Valley. They observed that in northern Sequatchie Valley the Sequatchie is typically calcareous, unfossiliferous, red mudstone that grades southward into silty, gray, fossiliferous limestone. They have proposed the name Shellmound Formation for this gray limestone equivalent of the typical Sequatchie. The type section is along the westbound lane of Interstate 24 near Shellmound, Marion County, Tennessee (figure 10).

The lower part of the Shellmound consists of a few feet of silty, glauconitic limestone. This is overlain by 10 to 20 feet (3.0-6.1 m) of silty, argillaceous limestone that resembles the Leipers Limestone.

Milici and Wedow (1977) also report that the "pseudo Leipers" grades upward vertically into silty calcisiltites and calcarenites that contain thin zones of chamosite and hematite ooids (Chowns, 1979) similar to the iron beds in the Rockwood.

Chowns (1970) considers the ironstone beds in the Shellmound to result from replacement of chamosite by hematite on the floor of a shadow lagoon. These iron beds have been worked locally in Dade County, Georgia and Jackson County, Alabama (figure 10).

Sequatchie Formation

The Sequatchie overlies the Catheys Formation along the western slopes of Whiteoak Mountain and consists of some 250 feet (76m) of brownish-gray to maroon calcareous siltstone and shale. Near the top of this formation is a distinctive grayish-red, massive, coarse-grained, cross-bedded, marble-like limestone about 20 feet (6m) thick

Figure 9. Inman Formation as exposed along US Highways 41 and 11 in Tiftonia. Upper third of cut contains basal Leipers, and the top of the Catheys can be seen at the bottom right.

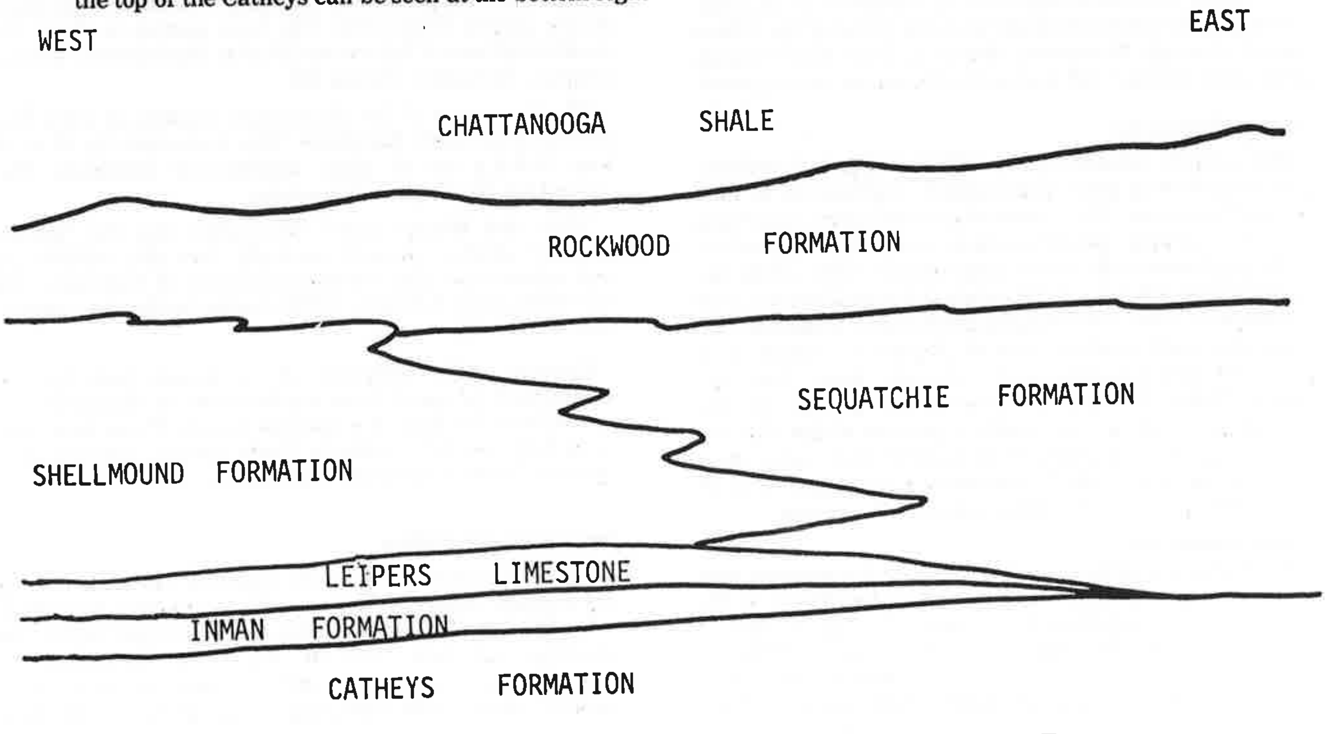

Figure 10. Regional facies relationship of Ordovician strata in Hamilton County, Tennessee.

called the Fernvale Member. Satterfield and Bergenback (1976) made a detailed study of the Fernvale in Dade County, Georgia, about 0.6 miles (1km) south of the Hamilton County line. Their studies suggested that the Fernvale Member represents skeletal sands accumulated as a sandbar or spit. Calcite, precipitated along vertical joints in the more massive beds of the formation, commonly give it a whitewashed or painted appearance (figure 11). A complete section of the Sequatchie is exposed along the south side of I-75 where it crosses Whiteoak Mountain at Green Gap just east of Ooltewah. Chowns (1972) suggests that the Sequatchie is the eastern equivalent of the Inman, Leipers, and Shellmound. However, studies by Milici and Wedow (1977) equate the Sequatchie with the Shellmound only.

The maroon or reddish color of the Sequatchie results from thin hematite coatings on the grains. Chowns (1972) reported that the red facies of the Sequatchie is characterized by a distinct suite of sedimentary structures including desiccation cracks, graded beds, and ripple marks, and concluded that the gray facies represented deposition on intertidal flats, and the red facies was supratidal.

SILURIAN SYSTEM

Rockwood Formation

A thick-bedded, ferruginous, crossbedded, micaceous, and locally conglomeratic sandstone marks the base of the Rockwood Formation in the eastern half of Hamilton County. Here the Rockwood averages about 600 feet (182m) thick and the basal sandstone beds form the crest of Whiteoak Mountain (figure 12). Thin, greenish-gray to grayish-red siltstones and shales together with sandstone and limestone form a dip slope on the eastern side of the mountain. Near the middle of the Rockwood within a 70 foot (21m) zone, there are 10 thin hematite beds. Ranging in thickness from 3/4 to 6 inches (2-15cm), these iron beds consist of fine- to medium-grained hematite replacements of fossil fragments or pellets.

The character of the Rockwood is markedly different on the western side of Hamilton County. On the flanks of the Lookout Valley anticline the Rockwood is only 250 feet (76m) thick and consists of greenish- to brownish-gray calcareous shale, commonly silty and sandy, with thin limestone beds. Scattered layers of hematite locally attain thicknesses of several feet. These hematitic zones are confined to the lower part of the formation. Iron ores from the Rockwood were first mined about 1886 and the mining reached a climax some 30 years later. Old workings, trenches and pits are found on the east side of Lauderback Ridge. Throughout Hamilton County the Rockwood is overlain unconformably by the Chattanooga Shale.

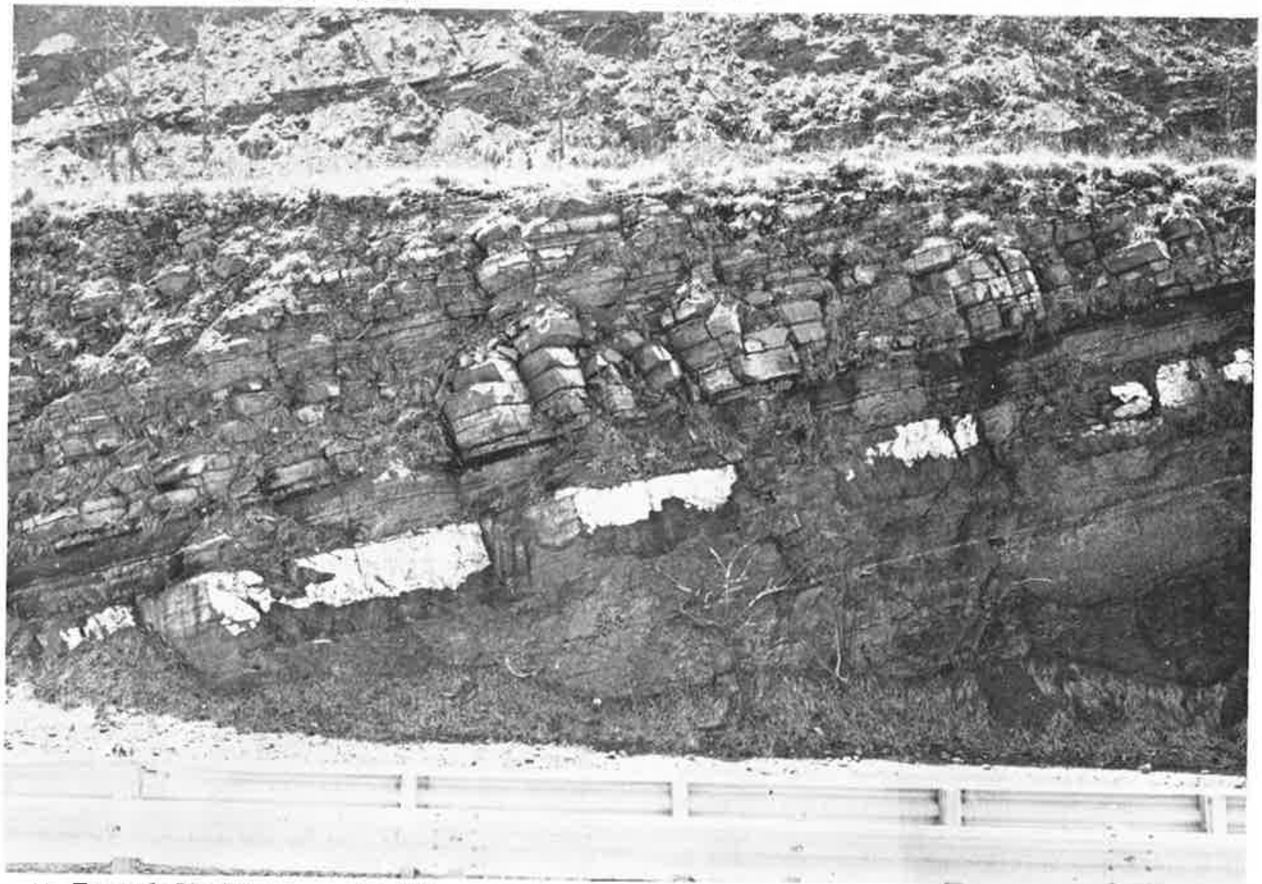

Figure 11. Fernvale Member of the Sequatchie Formation as exposed along Interstate 75 as it crosses Whiteoak Mountain at Green Gap just east of Ooltewah.

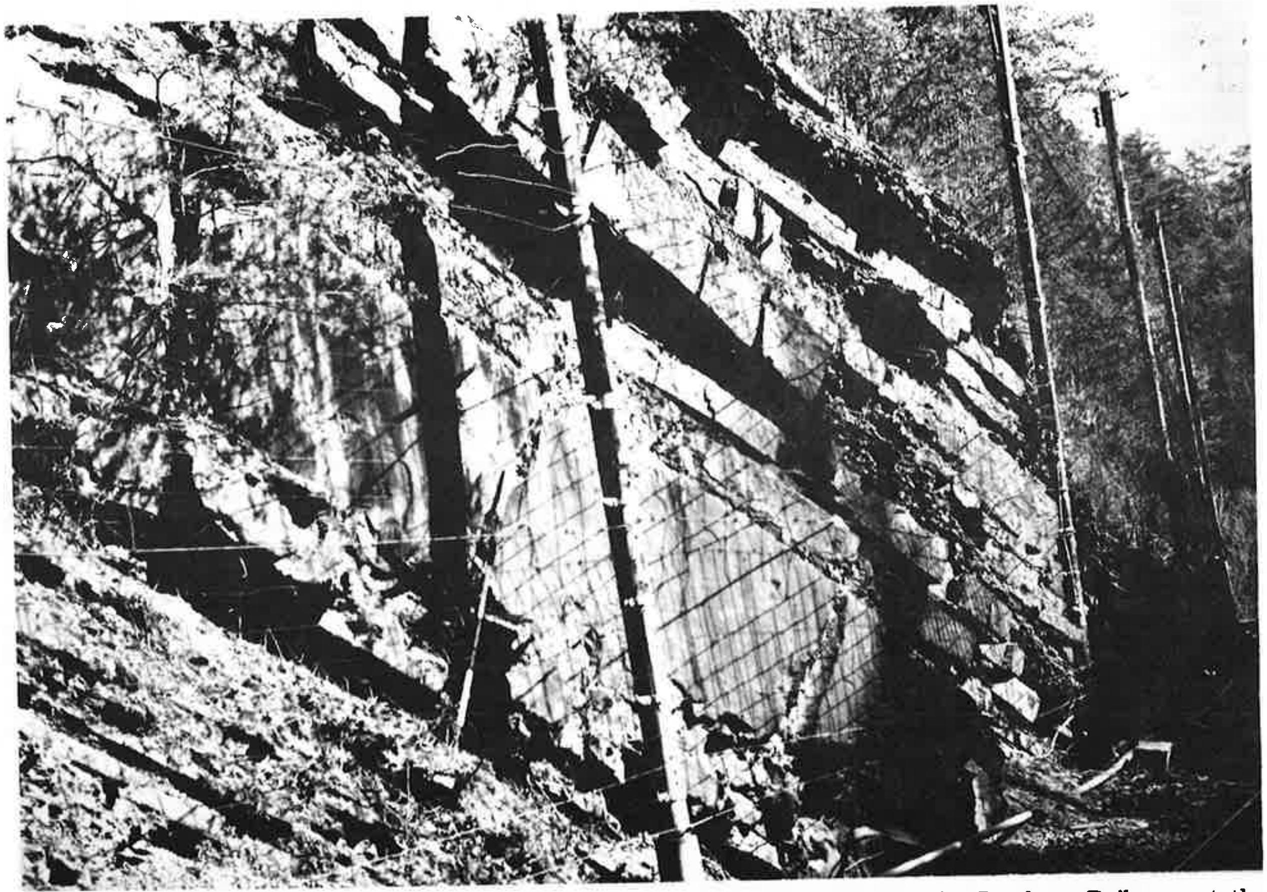

Figure 12. Massive basal sandstone beds of the Rockwood Formation exposed along the Southern Railway cut through Whiteoak Mountain.

DEVONIAN SYSTEM

Chattanooga Shale

Chattanooga Shale consists of 15 to 50 feet (4.5-15.2m) of dark-gray to black fissile, pyritiferous, bituminous shale. At the base of the Chattanooga is a prominent yellowish-brown, medium-grained sandstone 3 to 6 inches (8-15cm) thick, which commonly makes it easy to locate the base of the formation where it is deeply weathered and covered by a thin, acid, silty clay soil. The thickness of the Chattanooga is fairly constant over Hamilton County. It is thinnest at the type locality on the north side of Cameron Hill in downtown Chattanooga (figure 13). Except for this exposure in downtown Chattanooga, outcrops of Chattanooga Shale are restricted to an eastern belt behind Whiteoak Mountain near the Bradley County line, and a western strike belt that follows along the flanks of the Lookout Valley anticline.

MISSISSIPPIAN SYSTEM

Fort Payne Formation

The Fort Payne Formation consists of about 250 feet (76m) of light olive- to medium dark-gray, very siliceous, fine- to coarse-grained limestone and dolomite. The base of the unit is greenish-gray to light-gray calcareous shale 3 to 6 feet (0.9-1.8m) thick called the Maury Shale Member. It commonly contains numerous grape-sized nodules of phosphate.

As the Fort Payne is quite siliceous, upon weathering it produces great amounts of blocky-bedded chert. The cherty soil overlying the Fort Payne is much like that produced by the Knox Group; however, the two can readily be distinguished by the abundant crinoid stem molds in the Fort Payne.

Topographically the Fort Payne forms a series of low, but well-defined, knobby ridges. Lines of Fort Payne hills occur along boths sides of the Lookout Valley anticline and on the east side of Whiteoak Mountain in the Collegedale area. At the base of the Incline Railway on Lookout Mountain the Chattanooga fault has intensely deformed the Fort Payne, Chattanooga, and Rockwood Formations in a local area. This area is currently being used as a source of fill material.

Newman Limestone

Geologic mappers in East Tennessee have traditionally lumped all Mississippian rocks between the Fort Payne Formation and the Pennington Formation in a single unit called the Newman Limestone. Recent mapping has shown, however, that the Newman can be subdivided into the same formations mapped in the Cumberland Plateau and Highland rim areas, at least in the western part of the county. These are, from the top down, the Bangor, Hartselle, Monteagle, St. Louis, and Warsaw Formations. In the easternmost strike belt, however, between the Kingston and Clinchport faults, the Warsaw and St. Louis are not distinguishable, and Monteagle-type rocks rest directly on Fort Payne-type rocks. Since the Fort Payne maintains its normal thickness in this area and there is no evidence of erosional unconformity, it is presumed that the Warsaw and St. Louis either pinch out or grade laterally into the Monteagle in this strike belt. Because the Warsaw and St. Louis cannot be mapped in this area and because of the reduction in mapping scale from 1:24,000 to 1:48,000, it was thought best on the accompanying map (plate 1) to retain the name Newman, but to subdivide it into upper and lower members. The upper member (Mnu) includes equivalents of the Bangor and Hartselle Formations, and the lower (Mnl) includes equivalents of the Monteagle, St. Louis, and Warsaw Formations. Discussions of the lithologic character of the rock units given below are, however, cast in terms of the subdivisions recognized in Middle Tennessee.

Warsaw Limestone

The Warsaw consists of medium- to coarse-grained, grayish-brown, crossbedded limestone. It ranges in thickness from 0 to 70 feet (0-21.3m) and is present only in the western part of the county. The Warsaw weathers to a deep clay soil and exposures are extremely limited. It is best exposed on the north end of Lookout Mountain along the L & N Railway right-of-way.

St. Louis Limestone

Fine- to medium-grained, medium-bedded, dark-gray limestone and dolomite are characteristic of the St. Louis. Silty zones, along with numerous zones of dark-gray, nodular, patchy chert occur throughout the formation. It is generally about 100 feet (30.5m) thick, but is present only in the western part of the county. In contrast to the light-colored cherts of the overlying Monteagle, the St. Louis cherts are generally dark.

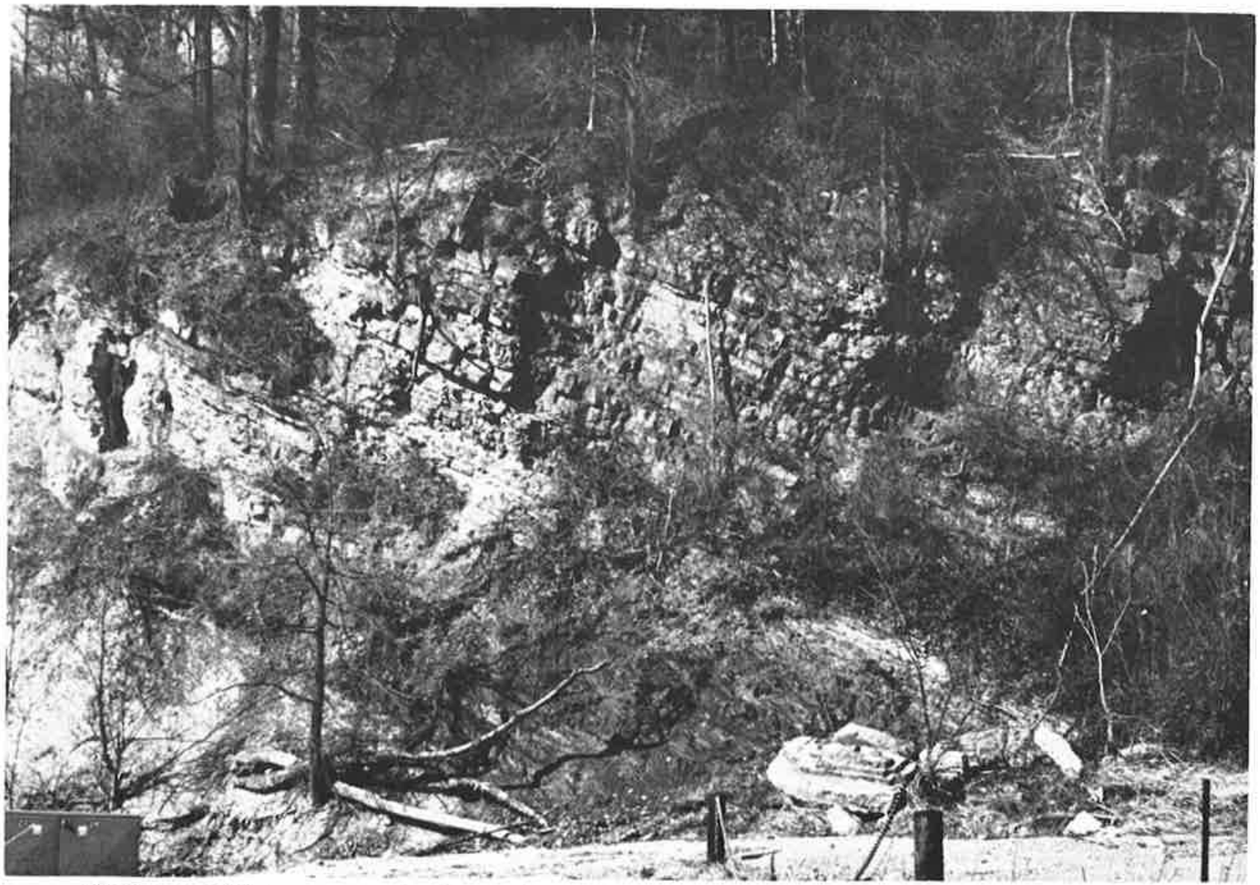

Figure 13. Chattanooga Shale as exposed on the south side of Cameron Hill. It is overlain by blocky Fort Payne Formation, and the upper beds of the Rockwood can be seen in the left corner of the photo.

Monteagle Limestone

The term, Monteagle Limestone, was originated by Vail (1959), published by Peterson (1962) and defined by Stearns (1963).

In the western part of the county the Monteagle is 300 feet (91m) thick and consists of light-gray, fine- to coarse-grained, medium- to very thick-bedded, fossilferous and oolitic limestone. However, in the southeastern part of Hamilton County around Collegedale, the Monteagle is similar in most respects to the western facies except it is slightly thicker, some 400 feet (122m), and is medium- to dark-gray in color. The base of the Monteagle is marked by a distinctive 4 to 24 inch (10-61cm) zone of blocky, *Fenestella*-bearing chert.

Most of the larger caves in Hamilton County, e.g., Lookout Mountain and Crystal Caves, have formed in the highly soluble parts of the Monteagle (figure 14).

Hartselle Formation

The Hartselle Formation forms a "clastic break" that separates the Monteagle Limestone below from the Bangor Limestone above. It consists of a light brownish-gray, fine-grained, thin- to medium-bedded sandstone with zones of pale-red and light-green, bryozoan-rich shale at the top. The thickness ranges from 10 to 50 feet (3.0-15.2m). At Apison this sandstone attains its maximum thickness and was quarried at one time as a refractory sand that was called Baukite. This sandstone is so well developed in the Apison area that previous workers mistook it for the Rockwood (figure 15).

Bangor Limestone

Between the Hartselle Formation and the overlying shales of the Pennington Formation is a thick sequence, some 300 feet (91m), of massive limestone called the Bangor (figure 16). To the west it is a dark-brown to gray, medium- to coarse-grained, crossbedded, petroliferous, medium- to very thick-bedded limestone. To the east, however, the Bangor thickens to nearly 400 feet (122m) in the vicinity of Collegedale and the color changes from the typical dark- to light-gray.

Pennington Formation

The Pennington is a heterogeneous mixture of maroon and olive-gray shale, brownish-gray silty dolomite and minor amounts of fine-grained, brownish-gray sandstone. The thickness ranges from 300 to 500 feet (91-152m). Exposures of the Pennington are found only under the most ideal circumstances. Except for the area around Grindstone Mountain just east of Ooltewah, all the outcrops of the Pennington are confined to the slopes of Lookout, Raccoon, and Signal Mountains. On parts of Lookout and Raccoon Mountains there are prominent, thick sandstones in the uppermost parts of the Pennington that some previous workers have included in the overlying Raccoon Mountain Formation.

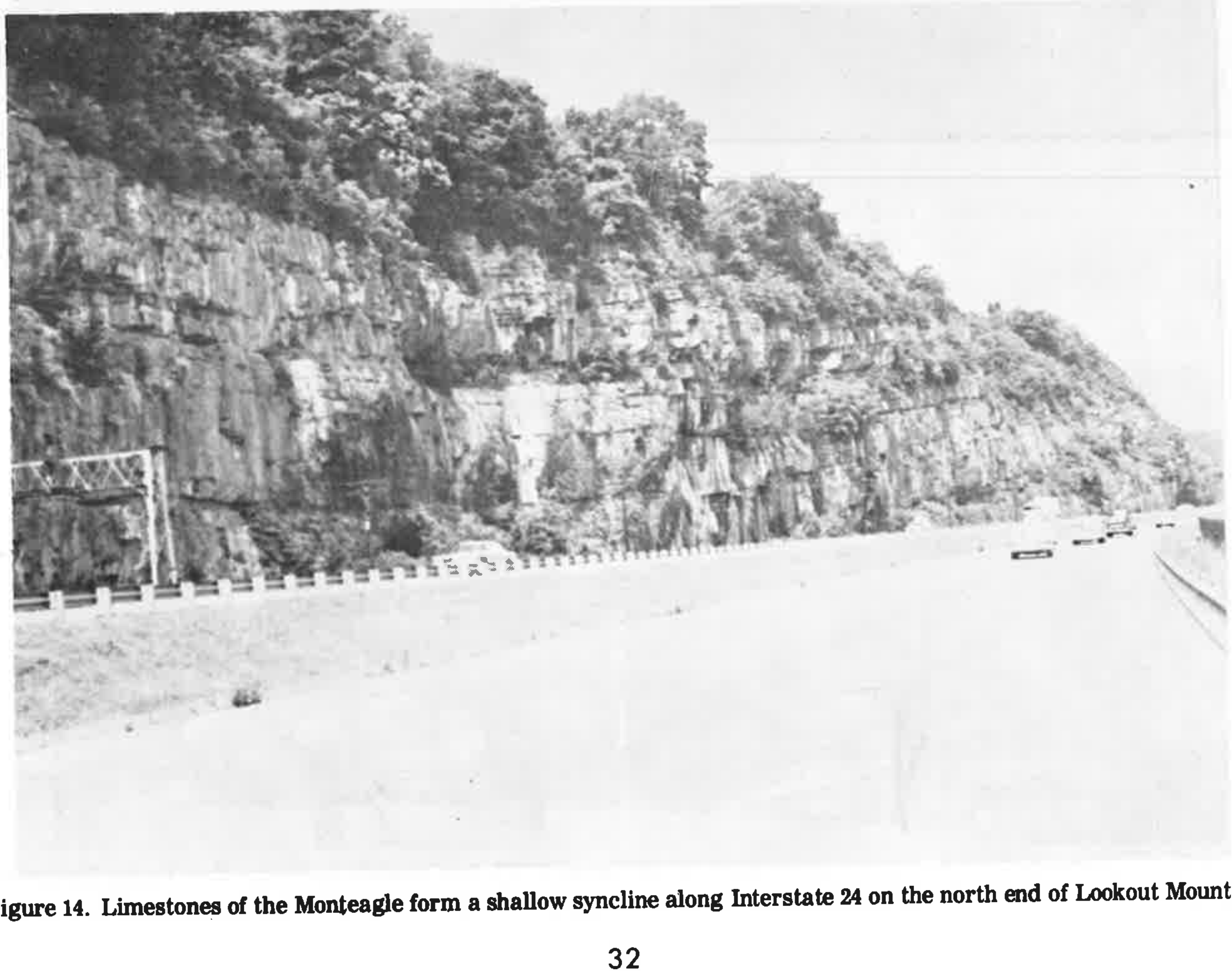

Figure 14. Limestones of the Monteagle form a shallow syncline along Interstate 24 on the north end of Lookout Mountain.

Figure 15. Massive sandstone of the Hartselle Formation exposed in an abandoned quarry on Bauxite Ridge near Apison.

PENNSYLVANIAN SYSTEM

GIZZARD GROUP

The Gizzard Group is 300 to 610 feet (91 to 186m) thick and consists of three formations. These are (in ascending order) the Raccoon Mountain Formation, Warren Point Sandstone and Signal Point Shale.

Raccoon Mountain Formation

The Raccoon Mountain Formation consists of some 150 to 400 feet (46 to 122m) of sandstone, siltstone, shale and coal. Locally the coals are of minable thickness, and the Sale Creek, Goodrich and Nelson seams have been mined in the vicinity of Soddy and Sale Creek. Except for the small area on Grindstone Mountain east of Ooltewah, the Raccoon Mountain Formation is confined to the upper slopes of the Cumberland Escarpment. Its base is generally placed between the lowest occurrence of coal and plant-bearing shale and the uppermost outcrop of maroon and green shales of the Pennington Formation, whereas the upper limit is the base of the massive overlying Warren Point Sandstone. As mapped southward (Wilson, 1975) into northern Jackson County, Alabama, the character of the Raccoon Mountain changes abruptly. The thin local coal seams and minor sandstones give way to more extensive coal beds, such as that currently being mined at Fabius, Alabama, and the upper part of the formation is dominated by a 50-foot (15m), very thick, cliff-forming sandstone, locally termed "Flat Rock".

Warren Point Sandstone

The Warren Point in Hamilton County is a brownish- to light-gray, medium- to coarse-grained, commonly conglomeratic sandstone. It reaches a thickness of nearly 300 feet (91m) on Signal and Lookout Mountains. It forms cliffs of massive, crossbedded sandstone along the edges of Lookout, Signal and Raccoon mountains. The Tennessee part of Lookout Mountain is underlain by massive Warren Point. On Signal Mountain, near Signal Point, a thick Warren Point Sandstone, together with the massive overlying Sewanee Conglomerate, form a most impressive

Figure 16. The lowermost beds of Bangor Limestone as exposed on the northern end of Lookout Mountain.

series of cliffs. The upper 105 feet (28m) of Grindstone Mountain are capped by an outlier of Warren Point Sandstone. Since Grindstone Mountain lies at the east edge of Hamilton County some 22.5 miles (36.2km) east of the Cumberland Plateau, it indicates that these Pennsylvanian sandstones were once much more extensive.

The very thick, crossbedded character of the Warren Point suggests that it was formed as part of a barrier or tidal-delta complex (figure 17). Warren and Bergenback (1977) studied the bed forms in the Warren Point along the W Road near the town of Signal Mountain and confirmed that these beds were formed as part of a major barrier system during early Pennsylvanian time.

Signal Point Shale

The top unit of the Gizzard Group is the Signal Point Shale. Its type locality is at Signal Point along Tennessee State Highway 8 just south of the town of Signal Mountain. It is about 52 feet (15.8 m) thick at the type locality and consists of silty, olive-brown to dark-gray shale with a few thin coal horizons. Southward on Raccoon Mountain the Signal Point reaches a thickness of 155 feet (47m).

CRAB ORCHARDS MOUNTAINS GROUP

The Crab Orchard Mountains Group consists of five formations (in ascending order): Sewanee Conglomerate, Whitwell Shale, Newton Sandstone, Vandever Formation, and Rockcastle Conglomerate. The full thickness of the group is nowhere preserved in Hamilton County, but at its type area in Cumberland County it is about 640 feet (195m) thick; and to the southeast along the eastern edge of Walden Ridge it reaches a thickness in excess of 900 feet (274m).

Sewanee Conglomerate

The Sewanee Conglomerate is a yellowish-gray to light-gray, conglomeratic, medium- to very thick-bedded, medium-grained sandstone. Abundant crossbedding and quartz pebbles as much as an inch (2.5cm) in diameter are characteristic. Its thickness ranges from 65 to 225 feet (19.8 to 69m) and it forms a major part of the upland surface of Signal Mountain.

The Sewanee is one of the most widespread, uniform, and easily traced formations on the entire Cumberland Plateau (Luther, 1959).

Whitwell Formation

The Whitwell Formation is a light-brown to dark-gray, silty, carbonaceous shale with some sandstone beds and as many as four coal horizons. In the Soddy area the Whitwell Shale ranges from 60 to 220 feet (18.3-67.1 m) thick and contains the No. 7, 8, 9, and 10 coals. The No.7 coal is the Richland and the No. 9 is the Sewanee. To the northeast the middle sandstone beds thicken, reaching a maximum of about 80 feet (24.4 m).

Milici (1974) indicates that ironstone and nodular limestones, associated with the dark-gray to black shales like those of the Whitwell, represent a lagoonal environment, whereas the interbedded flasered siltstones are formed on a tidal flat. The thicker sandstones probably formed as tidal splays landward of an advancing tidal delta. The seat earths and coals obviously formed as marsh accumulations.

Newton Sandstone

In Hamilton County the Newton consists of yellowish-gray to pale yellowish-brown, medium-grained, medium- to thick-bedded sandstone. Parts are highly crossbedded and it has been quarried in a few places for "Crab Orchard" type of sandstone. It underlies a major part of the surface of Signal Mountain and continues to be the dominant surface formation northeastward along Walden Ridge. The thickness ranges from 60 to 130 feet (18.3 to 40m).

Vandever Formation

The Vandever ranges in thickness from 260 to 500 feet (79.2-152.4 m) and is composed of three distinct members. A basal shale member consists of light-brown to dark-gray silty shale with minor amounts of clay shale, carbonaceous shale and sandy shale. The Lantana or No. 11 coal occurs near the base.

The middle member of the Vandever is the Needleseye Conglomerate, a light brownish-gray to light-brown, fine- to medium-grained, crossbedded sandstone. Quartz pebbles as much as 1 inch (2.5cm) in diameter occur in the Needleseye in the area from above Soddy to as far south as Signal Mountain. The unit becomes thinner and less conglomeratic northeastward.

The upper shale member consists of light-brown to dark-gray silty and sandy shale with minor amounts of fine-grained sandstone. The No. 12 coal of the Soddy area occurs near the base of this unit, just above the Needleseye Conglomerate. Near the top of the unit the sandstone is coarser and the Morgan Springs coal occurs locally at or near the top, just beneath the overlying Rockcastle Conglomerate.

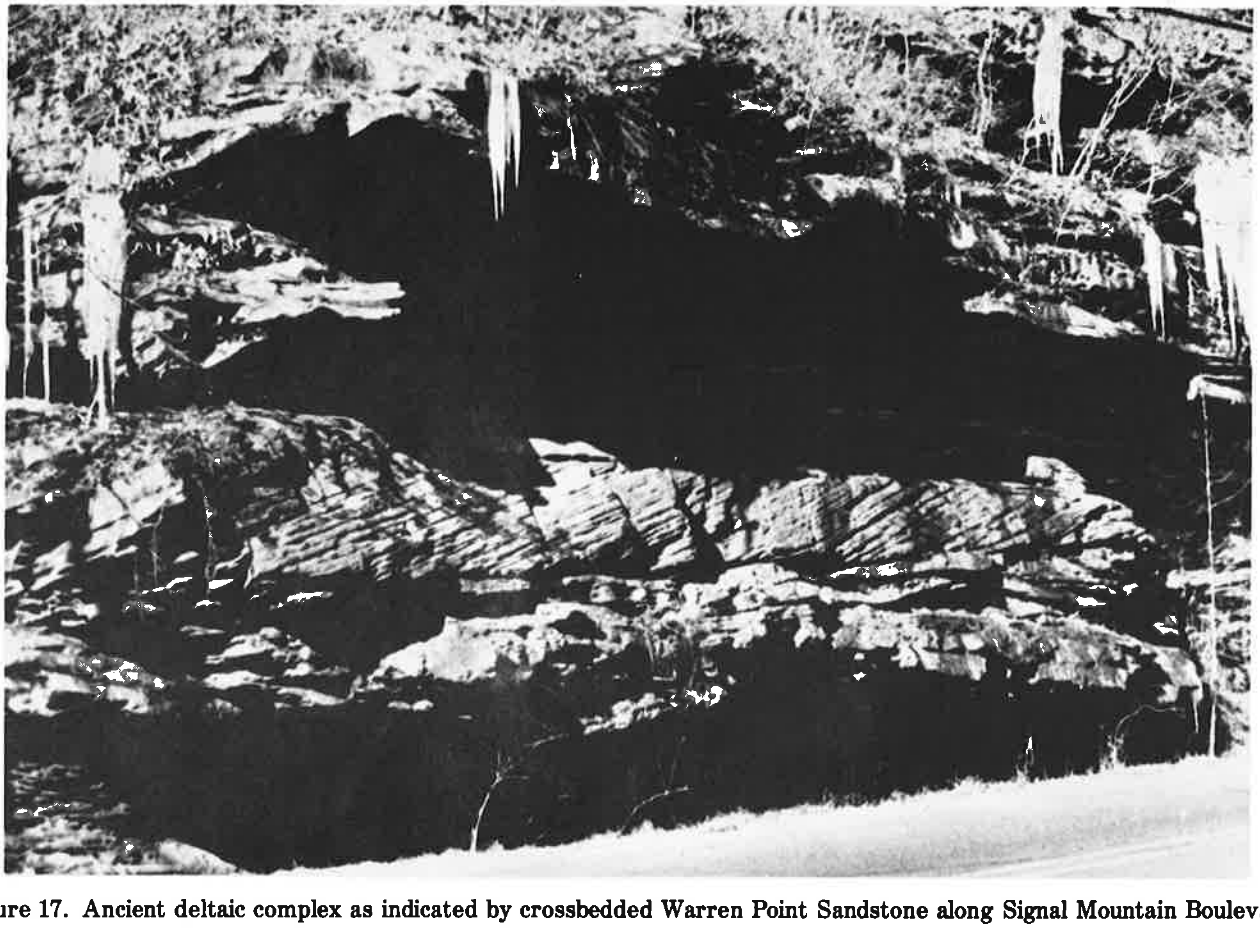

Figure 17. Ancient deltaic complex as indicated by crossbedded Warren Point Sandstone along Signal Mountain Boulevard.

Rockcastle Conglomerate

The Rockcastle Conglomerate is the youngest unit of the Crab Orchard Mountains Group and the youngest formation mapped in Hamilton County. It consists of yellowish-gray to yellowish-brown, fine- to medium-grained, thin- to thick-bedded, crossbedded sandstone, with quartz pebbles like those in the Sewanee Conglomerate except that the pebbles are mostly less than 3/4 inch (2cm) in diameter. The Rockcastle is one of the most prominent and easily mapped units of the southern Cumberland Plateau (Luther, 1959). This unit has been removed by erosion from most of Hamilton County, leaving only the lower 100 feet (30.5m) preserved in the extreme northern part of the county.

TERTIARY SYSTEM

High-level gravel deposits occur along Whiteoak Mountain at an elevation of about 1300 feet (396m). Swingle (1959) reported halloysite in residuum resting on the Fort Payne Chert on the east side of Whiteoak Mountain just across the Bradley County line. These deposits probably originated as alteration products of kaolinite. The kaolinite, in turn, was formed by the weathering of feldspathic rocks in the Blue Ridge area, transported by streams and deposited on an older and higher erosion surface, then altered to halloysite and redeposited on the erosion surface where it now rests.

An intermediate level of gravels and associated bauxite and lignite deposits lie at an elevation ranging between 850 and 950 feet (259 to 290m). These deposits are similar to those reported by Bridge (1950), which he considered to be associated with the unconformity that separates Paleocene from Eocene rocks in much of the southeastern United States.

The bauxite deposits along Missionary Ridge and just east of Silverdale have been preserved from erosion because they accumulated in sink-like depressions. It is not known if the Whiteoak Mountain deposits, at an elevation of 1300 feet (396m), and the Missionary Ridge and Silverdale deposits, at an elevation of about 900 feet (274m), are correlative. They may represent deposition on two distinct erosion surfaces or deposition on a single erosion surface with a relief of about 410 feet (125m).

Fluvial terrace deposits can be seen on the tops of low hills near the Tennessee River. These deposits consist of poorly sorted quartzite pebbles and cobbles as much as 1 foot (0.3m) in diameter in a matrix of fine sand and clay loosely cemented by iron or manganese oxides (figure 18).

Some of the deeper road cuts in Hamilton County expose alluvial deposits that are darker and sandier than the residuum derived from the carbonate rocks in the same area. They also contain an abundance of dark, ellipsoidal manganiferous and ferruginous pellets as well as rounded quartzitic gravels. These low-level gravels are similar to those described by Newman and Wilson (1960) in the Maryville area and are probably of Tertiary age.

QUATERNARY SYSTEM

The lower slopes of Whiteoak, Signal, Lookout, and Raccoon Mountains are largely mantled by unconsolidated colluvium that grades from unsorted, angular, sandstone talus on the upper slopes to crudely layered deposits on the lower slopes that are composed mostly of sandstone fragments and that merge in some places with the valley bottom alluvium. In a few places, as in the Volunteer Ordnance Works, crudely sorted colluvial deposits composed mostly of chert fragments from some of the higher Knox ridges extend downslope for some distance and completely mask the underlying formations.

Alluvium covers the floors of the larger stream valleys. The deposits are generally yellowish- to grayish-brown, silty and sandy clay. The color and texture differ with the source and proximity to colluvial masses on adjacent valley slopes. Many of the stream banks are about 6 feet (1.8 m) high, which shows the thickness of these deposits, as bedrock is commonly exposed in the beds of the streams.

There is no adequate way of dating these deposits; they probably result from erosion of the uplands of Hamilton County from at least as far back as Pleistocene time to the present.

Figure 18. Fluvial terrace deposits at 750 feet (229 m) elevation along South Chickamauga Creek near Highway 58.

STRUCTURE OF HAMILTON COUNTY, TENNESSEE

BY
ROBERT C. MILICI[1]

INTRODUCTION

Hamilton County lies in the western part of the Valley and Ridge physiographic province and in the eastern part of the Cumberland Plateau. Structurally, the county lies across a broad, regionally extensive, faulted anticlinorium, between the Whiteoak Mountain synclinorium on the east and the Walden Ridge syncline on the west (fig. 1). Rocks as young as Pennsylvanian are preserved on both Walden Ridge and Whiteoak Mountain. The intervening area consists mostly of Cambrian and Ordovician strata.

The Allegheny structural front, which extends along the western part of the Valley and Ridge in the Southern and Central Appalachians from Alabama to Pennsylvania, crosses Hamilton County in a northeasterly direction, generally following the trace of the Cranmore Cove fault. Structures in the Plateau west of the front are within the Appalachian Foreland Thrust structural province, whereas those to the east are in the Imbricate Thrust structural province (Milici and Harris, 1976).

The faulted anticlinorium, bounded on the west by the Chattanooga fault system (Chattanooga, Rockwood and Cranmore Cove thrusts) is divided longitudinally by the Kingston fault. This anticlinorium is herein named Kingston, both for the town in Roane County to the north and for the fault located so prominently in its center. On a regional scale the Kingston anticlinorium is a more complicated structural extension of the Powell Valley anticline. (Fig. 2.)

THE FORELAND THRUST STRUCTURAL PROVINCE

The Foreland Thrust structural province of the Southern Appalachians consists of five elongate anticlinal structures in Virginia, Tennessee, Georgia, and Alabama. These are the Powell Valley anticline, Sequatchie anticline, Lookout Valley anticline, Murfree Valley anticline, and Big Wills Valley anticline. With the exception of the Lookout Valley anticline, each of these structures is faulted at the surface and marks a major tectonic ramp. Part of the Lookout Valley anticline extends into Hamilton County from northwestern Georgia.

LOOKOUT VALLEY ANTICLINE

The Lookout Valley anticline is a narrow elongate structure that extends for 40 miles (64km) from Daisy, Tennessee through Dade County, Georgia (Croft, 1964) to DeKalb County, Alabama. The structure is 1 to 2 miles wide (up to 3km) and exposes rocks as old as Middle Ordovician in its core. The anticline is unfaulted on the surface, but probably is faulted at depth in a manner analogous to some of the foreland structures described by Gwinn (1964) in the Central Appalachians. Like the Central Appalachian foreland anticlines, the Lookout Valley anticline is asymmetrical to the southeast.

Two shallow oil tests were drilled into the structure in Tennessee. Both collared in Middle Ordovician strata (Catheys) and penetrated some 2000 feet (610m) into the upper part of the Knox Group.

CRANMORE COVE ANTICLINE

Like the Lookout Valley anticline, the Cranmore Cove anticline lies along and just to the west of the Allegheny structural front. However, the Cranmore Cove anticline is a very shallow-rooted structure. The anticline formed where the Cranmore Cove thrust cut diagonally across Mississippian carbonates (Fort Payne, Newman) between dêcollement levels in Silurian shales below, and Pennsylvanian shales above (Milici and Leamon, 1975), (fig. 3).

The trace of the Cranmore Cove fault lies along the western wall of Cranmore Cove, where the Pennington Formation (Mississippian) is thrust over Pennsylvanian

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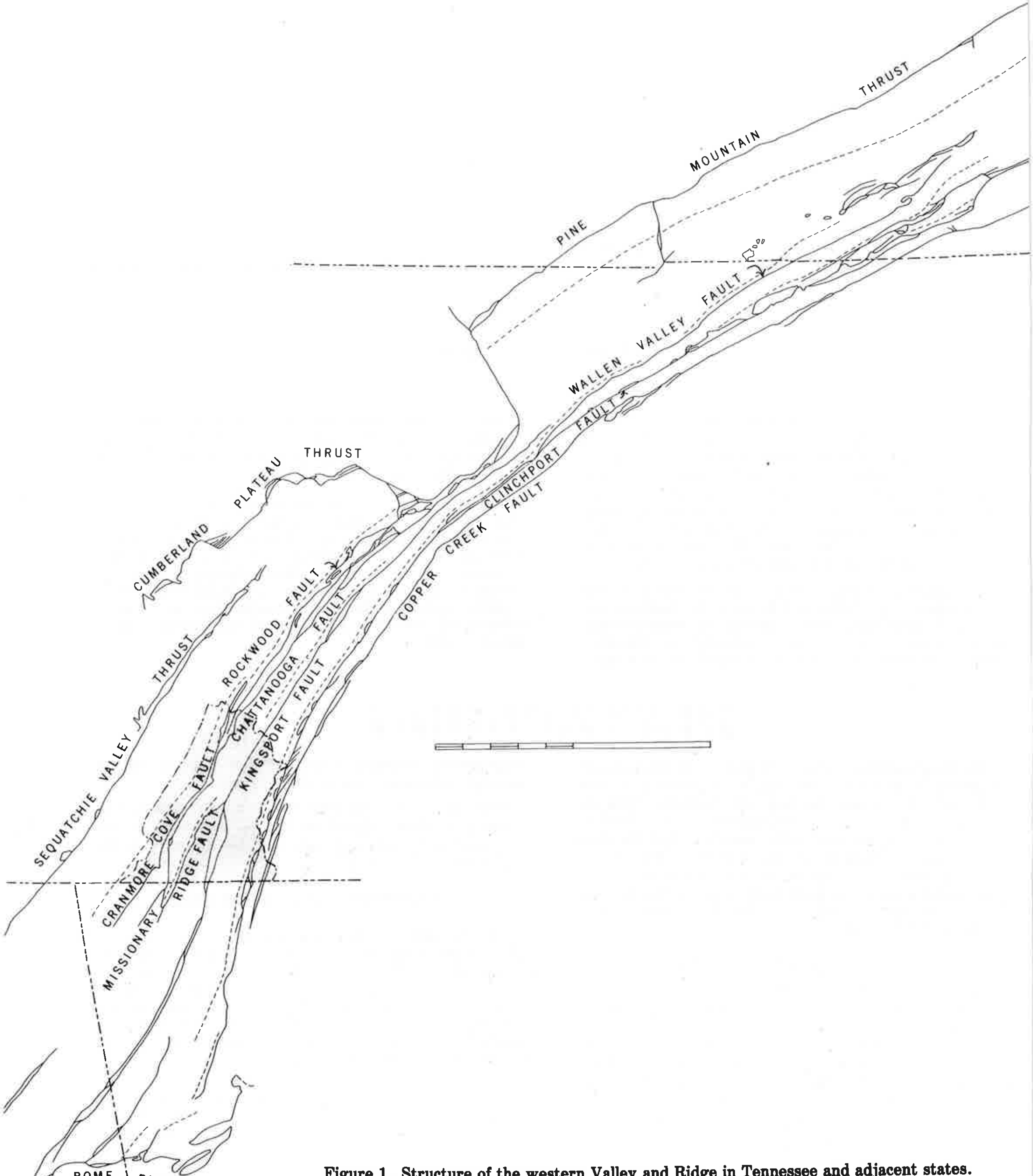

Figure 1. Structure of the western Valley and Ridge in Tennessee and adjacent states.

strata, and the thrust extends a short distance beneath the plateau in the bedding of basal Pennsylvanian shales. The fault was observed in shallow diamond drill cores bored to explore for coal in the area. At the head of Cranmore Cove (in Rhea County) the fault descends to the east to the valley floor, so that the Fort Payne (Mississippian) is thrust over Pennington on the eastern side of the cove.

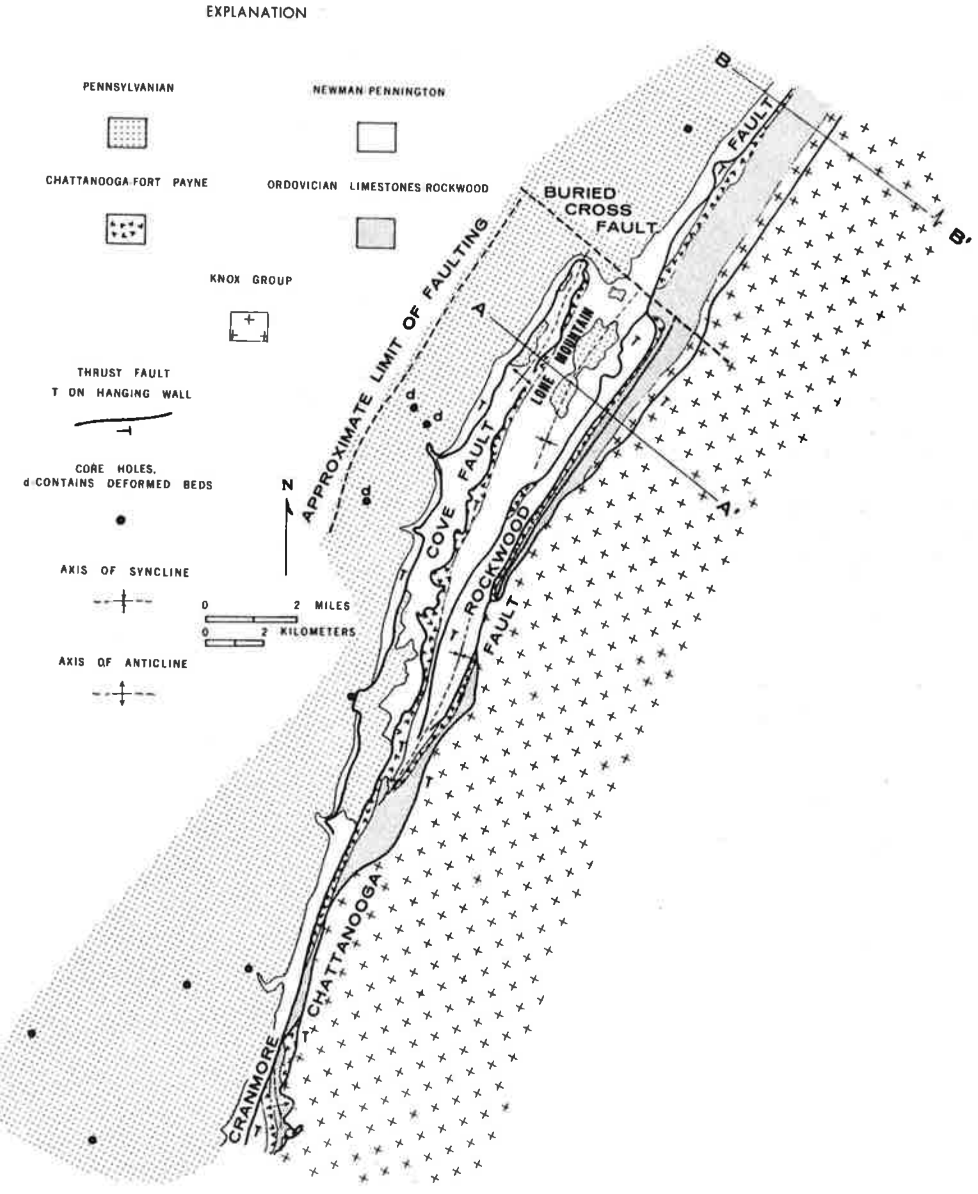

Figure 2. Structure map of part of Hamilton County. Section lines A-A^1 and B-B^1 shown on Figure 3.

THE IMBRICATE THRUST STRUCTURAL PROVINCE

The Cranmore Cove, Rockwood and Chattanooga thrusts constitute the broken remnants of a master thrust that extends from the Pine Mountain block southwestward into northwestern Georgia, generally along the Allegheny structural front. The hanging wall of the master thrust consists of elements that, (1) originally lay above and parallel with a lower dêcollement in Cambrian shales, (2) were crosscut by the major tectonic ramp, or (3) lay above and parallel to upper level dêcollement in Silurian and Pennsylvanian strata (Milici and Leamon, 1975), (fig. 4).

In general, the strata that constitute the hanging walls of the shallow upper-level dêcollements in this area are subhorizontal or gently folded Mississippian and Pennsylvanian beds. Crosscut, ramp-derived beds are steeply dipping and range in age from Cambrian to Lower Mississippian (Knox to Fort Payne). Inclined strata of Cambrian and Ordovician age (Rome, Conasauga, Knox, Chickamauga) on the hanging wall of major thrusts, such as the Chattanooga fault, are beds that were translated from their original position above dêcollement in Cambrian shales diagonally to their present locations up gently to moderately inclined tectonic ramps.

CRANMOVE COVE AND ROCKWOOD THRUST BLOCKS

Only the southernmost end of the Rockwood fault enters Hamilton County. In the northeastern part of the county the fault thrusts Newman limestone over other beds of Newman Limestone on the hanging wall of the Cranmore Cove thrust. Displacement along the Rockwood fault decreases to the south so that the fault dies out in a folded area between Sale Creek and Bakewell.

Generally, in the region to the north of Hamilton County the Rockwood fault block consists of steeply dipping to overturned beds that range from the Knox to Fort Payne. To the south, in both Hamilton County and adjacent parts of Rhea County, the Newman Limestone lies on the hanging wall of the Rockwood block at the fault trace, and beds as young as Pennington are preserved within the Sale Creek syncline. In its southern area of exposure, the Rockwood thrust block is broken by two closely spaced longitudinal thrust faults. The western one places steeply dipping to overturned beds of the Fort Payne on the gently folded beds of Newman and Pennington to the west, whereas the eastern one is of little significance, thrusting steeply dipping to overturned Chickamauga upon steeply dipping to overturned beds that range from the Chickamauga to Rockwood.

In Hamilton County the gently folded beds of Newman and Pennington on the Rockwood thrust block represent beds that were derived from the upper dêcollement position, whereas the steeply dipping beds that range from Chickamauga to Fort Payne are the crosscut beds that were derived from the ramp.

Like the Rockwood thrust block, the Cranmore Cove thrust block consists of beds that were either ramp-derived or were simply translated subhorizontally above the upper dêcollement. Steeply dipping to overturned beds of Chickamauga to Fort Payne between Bakewell and Soddy are apparently ramp-derived. Between Soddy and Chattanooga the Cranmore Cove block consists of gently inclined beds of Fort Payne and Newman that are thrust over the more steeply dipping eastern limb of the Lookout Valley anticline.

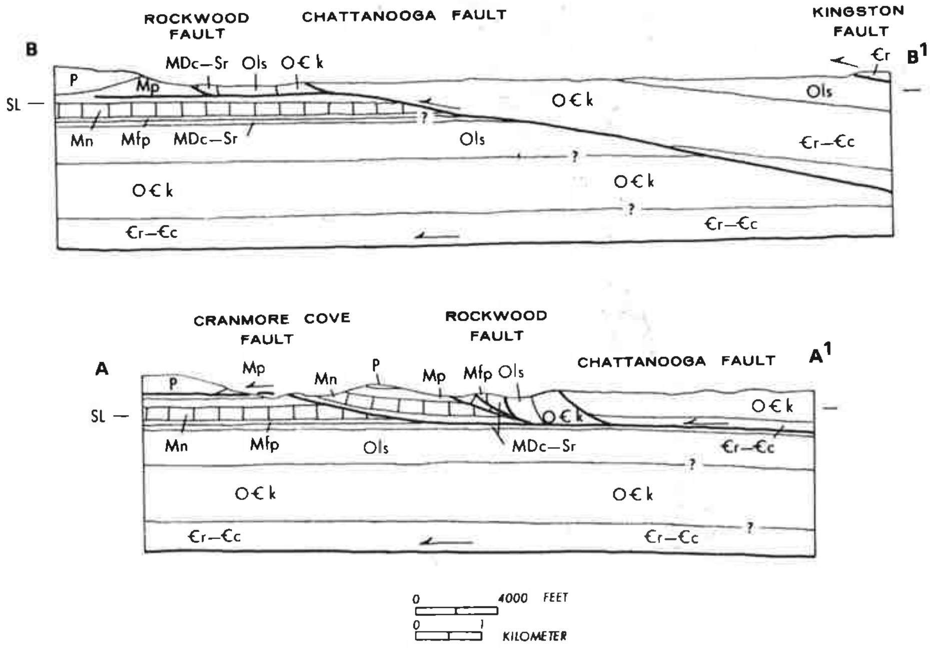

Figure 3. Geologic cross sections of the Chattanooga fault system and Cranmore Cove anticline. Ꞓr-Ꞓc = Rome and Conasauga Formations, OꞒK = Knox Group, Ols = Ordovician Limestone, MDc-Sr = Chattanooga Shale and Rockwood Formation, Mfp = Fort Payne Formation, Mn = Newman Limestone, Mp = Pennington Formation, P = Pennsylvanian (from Milici and Leamon, 1975, figs. 2 and 3).

Between Whiteoak Mountain and Cameron Hill the Cranmore Cove thrust block is folded into an elongate anticline and syncline. In this area the block is also broken by a few small splay thrusts that involve rocks that range from Rockwood to Fort Payne. The position of these folds and faults on the Cranmore cove thrust block and the ages of the beds involved suggest that they are related to irregularities that formed near the top of the tectonic ramp during deformation.

The southern end of the Cranmore Cove thrust block in Tennessee and in adjacent parts of northwestern Georgia contains the Lookout Mountain syncline, in which beds as young as Pennsylvanian are preserved in its trough. East of Lookout Mountain, older westward-dipping beds that range from Chickamauga to Newman occupy the lowlands. Like other parts of the Cranmore Cove and Rockwood thrust blocks this Ordovician to Pennsylvanian sequence represents both the crosscut strata that were derived from the ramp position, and gently folded strata that were translated westward above an upper level dêcollement in Silurian shales.

The subhorizontal nature of the leading edge of the Cranmore Cove thrust block is clearly shown at its southern end in Tennessee by the sinuous nature of the fault trace and the presence of two small klippen near Tiftonia. The map pattern suggests that the Cranmore Cove fault overrode folded beds of the Lookout Valley anticline, so that the fault formed after the fold.

CHATTANOOGA, MISSIONARY RIDGE, AND KINGSTON FAULTS

The Chattanooga, Missionary Ridge and Kingston fault blocks are gently to moderately inclined, and were transported to their present position above subjacent ramps from their original locations above dêcollement in Cambrian shales.

In northern Hamilton County the Chattanooga thrust block is about 5 miles (8km) wide and consists entirely of gently inclined beds of the Knox Group. To the south the dip of the block increases so that Chickamauga beds are preserved in the southwestward-plunging Dallas Bay syncline on the hanging wall of the thrust block. The increase in dip and appearance of the Chickamauga is coincident with the occurrence of the Missionary Ridge thrust block to the east.

On a regional basis, stratigraphic displacement on the Chattanooga fault decreases from north to south as progressively younger beds appear on the hanging wall at the fault trace. The Rome and Conasauga are found at the fault in Rhea County, but these formations are replaced southward by the lower beds of the Knox (Copper Ridge). At Chattanooga the fault cuts farther up section so that higher beds of the Knox are at the fault trace. The Chattanooga fault continues a short distance into Georgia, where it is overridden by the Missionary Ridge fault block in Walker County (Cressler, 1964).

Like the Chattanooga, the Kingston fault has its maximum stratigraphic displacement north of Hamilton County where the Rome is at the fault trace on the hanging wall. In Hamilton County, Rome is replaced by Conasauga along the main fault trace and by Knox along the trace of the Missionary Ridge branch.

The Missionary Ridge fault appears to be a low displacement precursor of the main Kingston fault in this area. Footwall beds of Chickamauga limestone are commonly broken and folded for a few hundred feet below the Missionary Ridge thrust. The thrust surface is gently to moderately dipping, as is suggested both by the sinuous trace of the fault and by several small klippen of Knox a little way to the west of the main fault. The Missionary Ridge fault block is moderately dipping and Chickamauga limestones are the youngest beds preserved on the block in the trough of the Brainerd syncline.

The Kingston fault has a simple linear trace north of Harrison Bay on Chickamauga Lake. To the south, the leading edge of the block crumples so that the fault trace diverges into a number of closely spaced splays that thrust Conasauga and Knox one on another. Near Harrison, one of these fault slices contains a relatively large synclinal preservation of Copper Ridge Dolomite.

It is probable that the cross-strike spatial arrangement of the Dallas Bay syncline on the Chattanooga block, the position of the Missionary Ridge fault block, and the structural imbrication of the main Kingston fault are more than coincidence; it seems likely that some kind of structural complexity within the dêcollement-ramp system has caused this unusual array of structures.

WHITEOAK MOUNTAIN SYNCLINORIUM

The Whiteoak Mountain synclinorium extends along the eastern edge of the Kingston block for a considerable distance from adjacent parts of Georgia, through the Chattanooga area, then northeastward into Virginia. The synclinorium consists of a number of subsidiary downfolds that are arranged linearly in the footwall of the Clinchport fault along much of its length. Near the Pine Mountain block, where the Clinchport fault block rides over the Wallen Valley block, the Whiteoak Mountain synclinorium follows the footwall of the latter.

Only a small part of the Whiteoak synclinorium is preserved in eastern Hamilton County; but that part, Grindstone Mountain, contains the only preservation of Pennsylvanian strata in the Valley and Ridge province of Tennessee. The western limb of the Whiteoak Mountain synclinorium in Hamilton and Bradley counties dips gently to moderately to the east. The eastern limb, which lies in the footwall of the Clinchport thrust, is sharply upturned and completely folded and faulted (see "Field Trips in the Southern Appalachians," Field Trip 1, Stop 2).

Structure along the toe of the Clinchport fault is generally more complex than along other major thrusts in the Tennessee Valley and Ridge province because of the regional development of numerous "horses" or fault slices that commonly consist of Knox carbonate. In Hamilton County, klippen of Fort Payne chert and of Rockwood shale lie a short distance to the west of the main Clinchport thrust block upon the folded beds of the Grindstone Mountain syncline. Near Grindstone Mountain the leading edge of the Clinchport block is broken by a number of splays that involve both the Rome and Conasauga, and two Knox "horse" blocks lie along the thrust.

RELATIVE AGE OF STRUCTURES

The geometric relationships of structures in Hamilton County and adjacent areas support the concept proposed by the writer (Milici, 1975) that Appalachian structure formed from west to east from the Plateau to the Blue Ridge. Specifically, the earlier formed Lookout Valley anticline appears to be overridden by the Cranmore Cove thrust block. The Cranmore Cove, Rockwood, and Chattanooga thrust blocks were shown by Milici and Leamon (1975) to have overridden one another in a west-to-east sequence. The Missionary Ridge thrust block was a part of the leading edge of the Kingston thrust block that was abandoned after only a relatively small amount of movement, as the main Kingston thrust straightened and broke up behind it. Finally, folded elements of the Whiteoak Mountain synclinorium appear to be truncated and overridden by the Clinchport and Wallen Valley faults along their lengths in Tennessee and adjacent states.

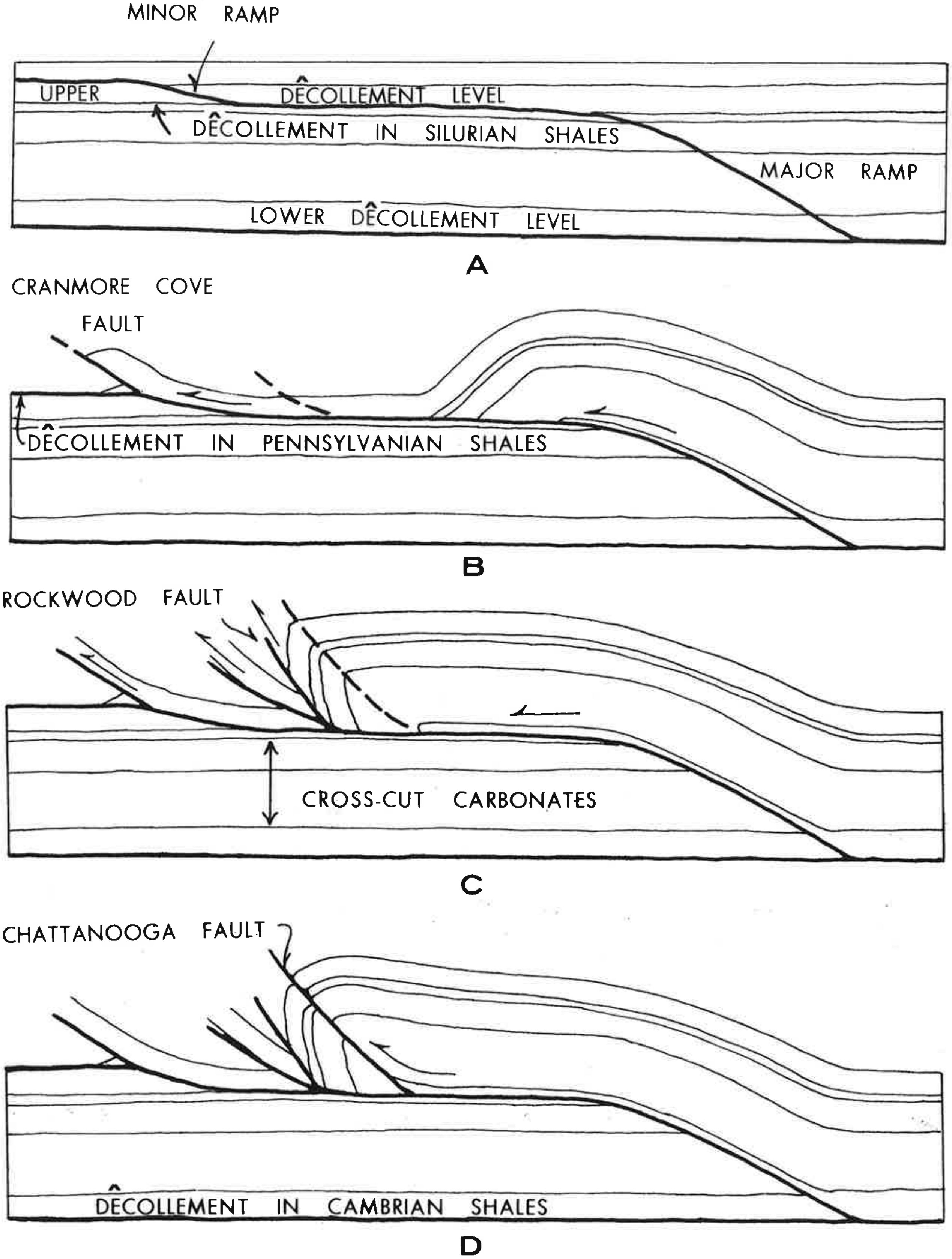

Figure 4. Structural development of the Chattanooga fault system. The Chattanooga fault block was derived from above a lower dêcollement in Cambrian shale, the Rockwood fault block from the major ramp zone, and the Cranmore Cove fault block from above an upper dêcollement level in Silurian and carboniferous shale (from Milici and Leamon, 1975, fig. 6).

ENVIRONMENTAL GEOLOGY OF HAMILTON COUNTY, TENNESSEE

BY
PRESTON D. SITTERLY[1]

INTRODUCTION

If man is to use his land resources effectively, it is imperative that he recognize limitations nature places on that use. The misuse of land through failure to recognize geologic problems and to plan accordingly has led to great financial loss through the years. Although a spectacular natural event, such as a devastating earthquake or flood, is usually necessary to capture the attention of the general public, groups such as local planners, county officials, developers, and engineers are becoming increasingly aware of the less spectacular and often slower acting hazards that create numerous problems. For example, most people are aware of the major hazard of flooding in Hamilton County, but fewer people are aware of several other potential geologic or related hazards in this area such as landslides, karst features, earthquakes, and secondary problems that are related to abandoned rock quarries and coal mines.

NATURAL HAZARDS

FLOODS

Historically, the greatest natural hazard in Hamilton County has been flooding. Since flooding has received much publicity and has been thoroughly documented in the past, the discussion herein will be brief.

Flood problems in Hamilton County are primarily the result of headwater floods on the Tennessee River and the backwater effects of these floods in the lower valleys of tributary streams. Headwater floods on the tributary streams have also resulted in significant damage. The closing of Norris Dam in 1936 marked the beginning of the Tennessee Valley Authority's flood control program upstream from Chattanooga. This program has substantially reduced the magnitude of flooding in the Chattanooga area. A brief discussion of the major floods in Hamilton County effectively illustrates the impact the flood regulatory program has had upon this area.

Flood stage is 30 feet (9.1m). As illustrated in Table 1, the 10 most severe floods on the Tennessee River occurred before 1936. Since 1936, only one flood has exceeded a crest of 36 feet (11.0m). The flood of March, 1973, crested at 36.9 feet (11.4m); and flooded large areas of Chattanooga, causing an estimated 23 million dollars in property damage. It has been estimated that without Tennessee Valley Authority flood controls, the crest would have been 52.4 feet (15.97m) and would have caused additional property damage costing many more millions. In addition, during the flood of February, 1957, the Tennessee River, without upstream flood control pools, would have crested at 54 feet (16.5 m), or 24 feet (7.3 m) above flood stage. This would have been the second highest flood of record.

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TABLE 1. CREST ELEVATIONS OF THE 10 MOST SEVERE FLOODS RECORDED IN CHATTANOOGA (*Tennessee Valley Authority, 1959*)

Order No.	Date of Crest	Gage Height		Elevation		Approximate Elevation at Creek Mouth					
						North Chickamauga Creek		Lookout Creek		Mountain Creek	
		(feet)	(meters)	(feet)	(meters)	(feet)	(meters)	(feet)	(meters)	(feet)	(meters
1	March 11, 1867	57.9	17.5	679.0	207.0	682.4	208.0	676.9	206.3	674.5	205.6
2	March 1, 1875	53.8	16.4	674.9	205.7	678.5	206.8	672.7	205.0	670.5	204.4
3	April 3, 1886	52.2	15.9	673.3	205.2	676.8	206.3	671.1	204.6	668.8	203.8
4	March 7, 1917	47.7	14.5	668.8	203.8	671.8	204.8	666.4	203.1	663.8	202.3
5	April 5, 1920	43.6	13.3	664.7	202.6	667.9	203.6	662.4	201.9	660.0	201.2
6	March 10, 1884	42.9	13.1	664.0	202.4	667.3	203.4	661.8	201.7	659.5	201.0
7	February 1, 1918	42.7	13.0	663.8	202.3	667.1	203.3	661.6	201.6	659.3	200.9
8	March 2, 1890	42.6	13.0	663.7	202.3	667.0	203.3	661.5	201.6	659.2	200.9
9	January 2, 1902	40.8	12.4	661.9	201.7	665.5	202.8	659.8	201.1	657.7	200.5
10	April 5, 1896	40.5	12.3	661.6	201.6	665.3	202.8	659.5	201.0	657.5	200.4

Included with this publication is an environmental map on which the approximate limits of a 100-year flood under present conditions of flood control is illustrated. This information is based upon maps prepared by the Tennessee Valley Authority and Chattanooga-Hamilton County Regional Planning Commission. Flood data on some of the smaller streams were not available at publication date. Should additional information be needed, the most complete documentation of flooding in Hamilton County is in Tennessee Valley Authority publications. The most comprehensive of these publications are Report Numbers 0-5843, 0-5865, 0-5977, and 0-7129, published by the Tennessee Valley Authority Division of Water Control Planning in the years 1958, 1959, 1961, and 1974, respectively.

LANDSLIDES

In many areas of the country, landslide problems have only recently been recognized as a hazard that needs to be considered by local agencies and officials. During the past 15 years, the Tennessee Department of Transportation has been very active, through the efforts of the Division of Soils and Geological Engineering, in the correction of existing landslides as well as the recognition, avoidance, and control of potentially unstable areas along highways. Other studies have been made by the Tennessee Division of Geology. It is encouraging to note that there is now an increasing awareness of landslide problems at the local level in such metropolitan areas as Nashville, Chattanooga, and Memphis. From a monetary viewpoint, this interest is justified by two studies (California and New York) which indicate a 9:1 landslide loss-reduction to investment ratio. In other words, for every dollar invested in landslide avoidance measures based upon improved geotechnical investigations, on the average a saving of nine dollars is realized. Although it is impossible to project exact savings for a specific area such as Hamilton County, it is evident that advantages lie in investments in landslide loss-reduction measures.

Landslides are the downslope movements of rocks and/or soil material in response to gravity. Slump, rockfall, rockslide, soilfall, block glide, debris slide, avalanche, and debris flow are examples of landslides delineated on the basis of the type of materials involved, and rate and type of movement.

Most landslides in Hamilton County occur in colluvium, the Pennington Formation, Fort Payne Formation, Chickamauga Group, and Knox Group. One landslide was found in alluvium (figure 1). They usually occur on steep slopes where variable thicknesses of residual soils and colluvium are present. Colluvium is defined as any loose, heterogeneous, incoherent, highly permeable mass of soil material and/or rock fragments deposited chiefly by mass-wasting, usually at the base of a steep slope or cliff. Colluvial thicknesses in Hamilton County are highly variable over short distances due to the uneven nature of the subtopography. Royster (1973) reports colluvial thicknesses of up to 100 feet (30.5m) along parts of the Cumberland Plateau Escarpment. It is interesting to note that although colluvium is frequently involved in landslide

Figure 1. Large slump on alluvium located (Environmental Map Index No. 17) 1,000 ft. (305 m) west of Cameron Hill.

problems, it has a high shear strength in tests. Stability problems arise when colluvium is present on steep slopes, and is underlain by impervious strata. The introduction of large volumes of water into the permeable colluvium through the surface and subsurface results in large quantities of water becoming trapped within the colluvium above the underlying impermeable or less permeable strata, thus resulting in increased pore pressure. This creates an unstable condition, the degree of instability depending upon several variables such as colluvium composition, thickness, degree of saturation, and slope angle. Another important variable is the role that man plays in the initiation of landslides by unsound engineering practices such as notching, oversteepening, and overloading. The coincidence of these variables in Hamilton County has resulted in numerous landslides of various magnitudes.

The Pennington Formation, which is approximately 260 feet (79m) thick in Hamilton County, occurs on steep slopes along the Cumberland Plateau Escarpment and weathers to a very weak, impervious clay. It is overlain by colluvium of variable thickness up to 100 feet (30.5m). During periods of heavy rainfall, many such slopes are in a metastable state and subject to failure. As a consequence, the Pennington Formation has been involved in numerous landslide problems such as those along Interstate 40 near Rockwood in Roane County. Although Hamilton County has not experienced such severe problems, several landslides involving the Pennington Formation were discovered and studied during the preparation of this report.

The most common class of landslides involving the Pennington Formation is rotational slump in overlying colluvium, which occurs along roads that cross the formation. The slumps are relatively small and are too numerous for all to be shown on the accompanying Environmental Map; all roads on the Cumberland Plateau Escarpment crossing the Pennington Formation experience at least a few such slumps. The most severe slumping has occurred along both the cut and fill sides of the Elder Mountain Road approximately 3.42 miles (5.5km) west of downtown Chattanooga. The development of a typical slump is illustrated in Figure 2, and a typical colluvial slump overlying the Pennington Formation along Elder Mountain Road is illustrated in Figure 3.

Three relatively large, naturally occurring, recent landslides involving the Pennington Formation are located on the Environmental Map at Index Numbers 1 (figures 4,5), 13 (figures 6,7), and 16, and one landslide, partially the result of man's activity, is located at Index Number 12. Refer to Figure 8 for the nomenclature of the parts of a landslide. Table 2 contains data on several landslides in Hamilton County.

Five landslides involving residual soils and colluvium derived from the Fort Payne Formation were noted at Index Numbers 2, 4 (figure 9), 5 (figure 10), 14, and 15 (figure 11) on the Environmental Map during field investigations in Hamilton County. Most of the same variables that were involved in the Pennington landslides (steep slopes, colluvium overlying less permeable strata, and excessive amounts of rainfall) were also involved in the Fort Payne failures. Additionally, it was noted that several of the Fort Payne failures occurred on slopes that had been altered by man by exceeding the critical slope, and by notching at the toe of a colluvial slope. For example, the slide at Index Number 2 is partially the result of an oversteepened slope (in this case due to highway construction) and the slide at Index Number 4 is partially the result of notching (again due to highway construction). Refer to Table 2 for detailed information on the five Fort Payne slides.

Four landslides involving colluvium and residual soils underlain by formations of the Knox Group are located on the Environmental Map at Index Numbers 6 (figure 12), 9, 10 (figures 13, 14) and 18 (figure 15). Steep slopes, colluvium and residual soils, and excessive amounts of rainfall have combined to create unstable slopes resulting in failures. The slide at Index Number 10 is an excellent example of one resulting from the notching and oversteepening of a slope. In this case, slopes were modified for construction of business establishments. Table 2 contains additional information regarding the Knox Group landslides.

Three landslides involving Chickamauga Group residual soils and colluvium from the Knox Group are located on the Environmental Map at Numbers 7 (figure 16), 8 (figures 18, 19) and 11 (figure 17), the most serious of which is Number 8. The west side of Missionary Ridge, on which failures 7 and 8 are located, is potentially unstable. Complexly folded and faulted limestones and shales of the Chickamauga Group, which have weathered to relatively impermeable residual clayey soils, are overlain in places by a layer of Knox Group colluvium. Serious stability problems can result from the introduction of large amounts of water and/or any modification of the natural slope such as notching and oversteepening. The extensive landsliding at Number 8 is the result of such modification. Table 2 includes more information on the Chickamauga Group landslides.

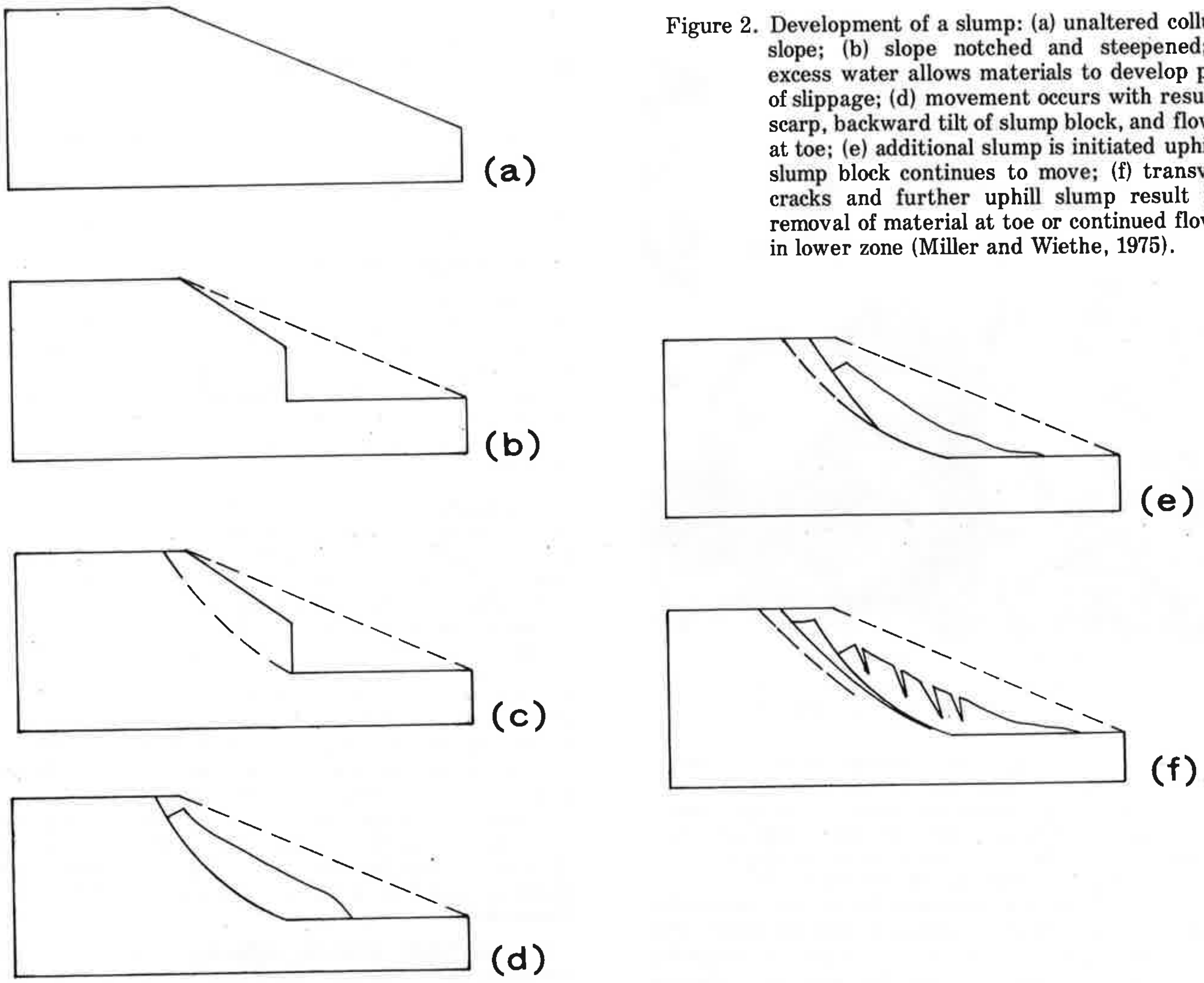


Figure 2. Development of a slump: (a) unaltered colluvial slope; (b) slope notched and steepened; (c) excess water allows materials to develop plane of slippage; (d) movement occurs with resulting scarp, backward tilt of slump block, and flowage at toe; (e) additional slump is initiated uphill as slump block continues to move; (f) transverse cracks and further uphill slump result from removal of material at toe or continued flowage in lower zone (Miller and Wiethe, 1975).

Figure 3. Typical roadside slump in colluvium overlying the Pennington Formation.

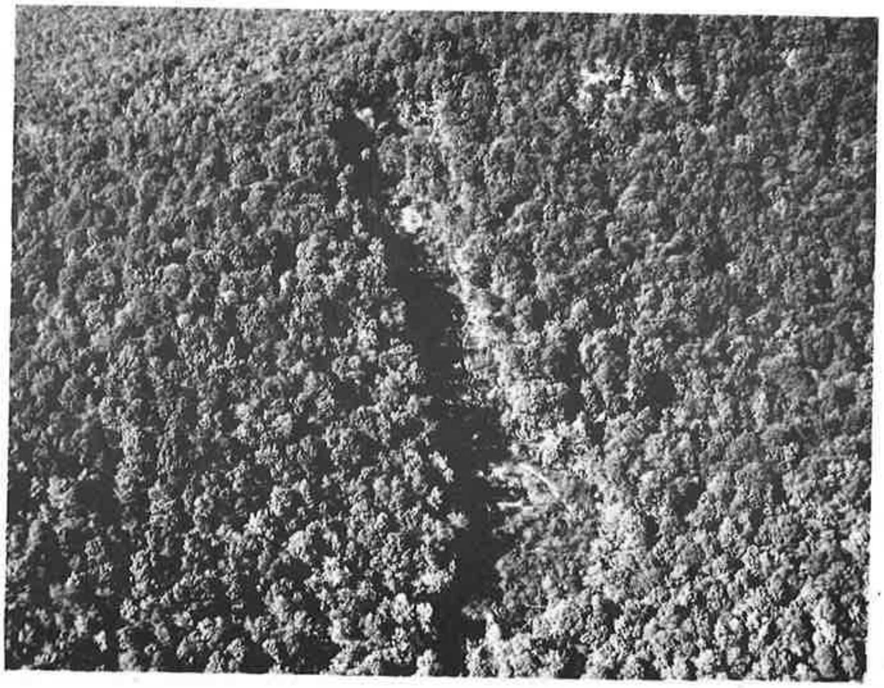
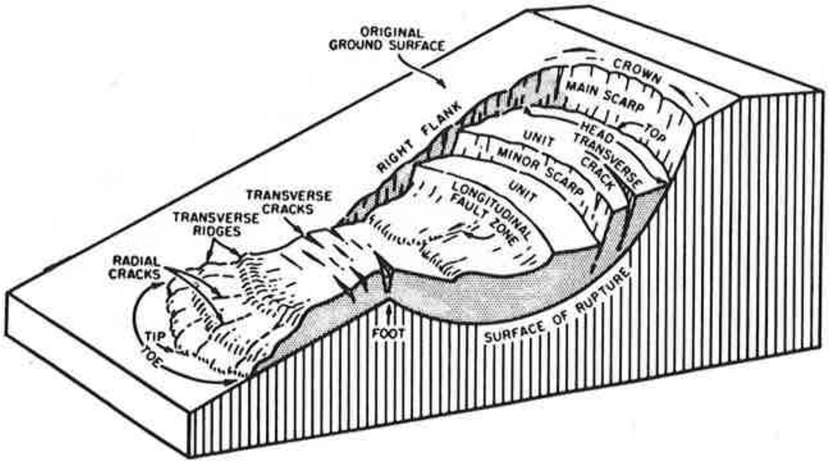


Figure 4. View of Pennington landslide located at EMIN 1 looking from right flank towards toe.

Figure 5. Toe area of Pennington landslide located at EMIN 1.

Figure 6. Aerial view of the largest Pennington Formation landslide in Hamilton County. (EMIN 13).

Figure 7. Right flank area of landslide located at EMIN 13.



MAIN SCARP - A steep surface on the undisturbed ground around the periphery of the slide, caused by movement of slide material away from the undisturbed ground. The projection of the scarp surface under the disturbed material becomes the surface of rupture.

MINOR SCARP - A steep surface on the disturbed material produced by differential movements within the sliding mass.

HEAD - The upper parts of the slide material along the contact between the disturbed material and the main scarp.

TOP - The highest point of contact between the disturbed material and the main scarp.

FOOT - The line of intersection (sometimes buried) between the lower part of the surface of rupture and the original ground surface.

TOE - The margin of disturbed material most distant from the main scarp.

TIP - The point on the toe most distant from the top of the slide.

FLANK - The side of the landslide.

CROWN - The material that is still in place, practically undisturbed, and adjacent to the highest parts of the main scarp.

ORIGINAL GROUND SURFACE - The slope that existed before the movement which is being considered took place. If this is the surface of an older landslide, that fact should be stated.

LEFT AND RIGHT - Compass directions are preferable in describing a slide, but if right and left are used they refer to the slide as viewed from the crown.

Figure 8. Nomenclature of the parts of a landslide (from Highway Research Board Landslide Committee's Classification of Landslides, 1958).

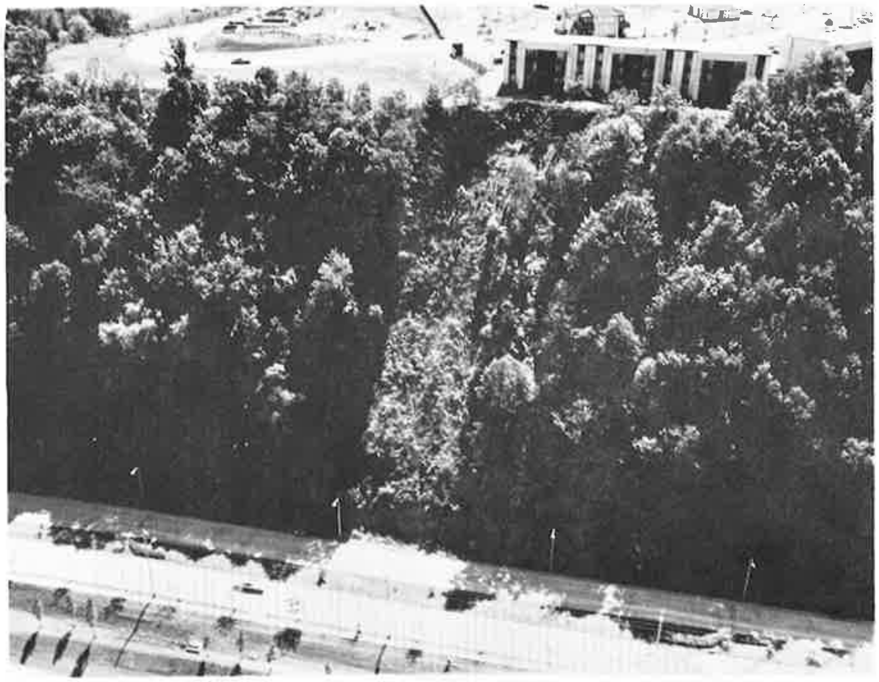


Figure 9. Debris slide underlain by Fort Payne Formation located at EMIN 4 (north end of Cameron Hill).

Figure 10.

Landslide in Fort Payne residuum and colluvium located at EMIN 15 (south end of Stringers Ridge tunnel entrance). Note small, recent secondary mudslide at left of photo.

Figure 11.

Landslide in Fort Payne residuum and colluvium located at EMIN 15 .7 mile (1.1km) north of juncture of Falling Water Road and U.S. 27 on west side of U.S. 27.

TABLE 2. DATA ON SELECTED LANDSLIDES WITHIN HAMILTON COUNTY

Environmental Geology Map Index Number	Underlying Geologic Formation or Group	Landslide Classification and Type of Movement	Dimensions In Feet		Dimensions In Meters		Active[2] (A) or Inactive (Ia)	Illustrating Figure(s)	Type(s) of Material Involved
			Flank to Flank	Crown to Tip	Flank[1] to Flank	Crown to Tip			
4	Pennington	Complex rotational; slumping at head, earthflow at toe	190.5	498.6	59	152	A	6, 10	Colluvium
7	Pennington	Complex rotational; slumping at head, lower 2/3 of slide is earthflow	173.8	934.8	53	285	A	5, 14, 15	Colluvium; bedrock
0	Pennington	Complex rotational; slumping at head, earthflow at toe	170.6	351.0	52	107	A	—	Colluvium
0	Pennington	Debris slide	551.0	144.3	168	44	Ia	—	Colluvium; bedrock
9	Ft. Payne	Complex rotational; slumping at head, earthflow at toe	88.6	239.4	27	73	A	—	Residuum
9	Ft. Payne	Debris slide; rapid movement	49.2	173.8	15	53	Ia	10	Colluvium; residuum
10	Ft. Payne	Complex rotational; slumping at head, earthflow at toe	183.7	180.4	56	55	A	18	Colluvium; residuum
11	Ft. Payne	Translational	154.2	138.6	47	27	A	—	Residuum
11	Ft. Payne	Complex rotational; slumping at head, earthflow at toe	65.6	141.0	20	43	A	7	Colluvium; residuum
6	Knox Group	Complex rotational; slumping at head, earthflow at toe	95.1	390.3	29	119	Ia	0	Colluvium; residuum
—	Knox Group	Translational	68.9	111.5	21	34	A	—	Colluvium; residuum
13 14	Knox Group	Complex rotational; slumping at head, earthflow at toe; 2 distinct areas of sliding separated by a "nose" of land			—	—	A	0, 0	Colluvium residuum
16	Chickamauga Group	Rotational; several areas of slump			Most severe slump 43	18	A	11	Colluvium; residuum
18 19	Chickamauga Group	Complex rotational; slumping at head, earthflow at toe		59.0	—	—	A	8, 8	Colluvium; residuum
17	Chickamauga Group	Rotational			—	—	A	3	Colluvium; residuum
20	Gizzard Group	Rockfall; extremely rapid movement			A block measuring approximately 6.6 by 8.2 feet (2mx2.5m)		Ia		Bedrock

[1] Widest point.

[2] Active slides indicate that, with excessive amounts of rainfall, additional movement is expected.

Figure 12.

Relandscaped landslide scar in Knox Group residuum and colluvium located at EMIN 6 (immediately northwest of Chattanooga High School).

Figure 13. Landslide scarp in Knox Group residuum and colluvium located at EMIN 10 (junction of Tenn. Hwy. 58 and Tunnel Blvd.). Soil benching has been utilized in an attempt to stabilize the slope.

Figure 14.

Part of the landslide located at EMIN 10 that has been abutted by the back of a business establishment.

Figure 15. Small landslide in Knox Group colluvium and residuum located at EMIN 18 (Lakeshore Drive).

Figure 16. Large slump in Chickamauga Group colluvium and residuum located at EMIN 7 (to rear of City View Apartments, east side of Glenwood Drive).

Figure 17. The landslide at EMIN 11 (note tilted tree in upper left part of photograph) resulted in a new roadway alignment. The road shoulder of Lakeshore Drive, which was realigned, originally followed the white, dashed line.

Figure 18.

Landslide in Chickamauga Group colluvium and residuum located at EMIN 8 (Steiner Apartments, east side of North Chamberlain Avenue).

Figure 19. In an unsuccessful effort to stabilize the slopes at EMIN 8, a layer of gunite was applied. This resulted in the large, broken slabs visible in the photograph.

Figure 20. Rockfall in Gizzard Group caused by undercutting of massive sandstone by rapidly weathering shale, located at EMIN 3 (top of Elder Mountain Road).

A rockfall that resulted from a classic case of undercutting is located at Environmental Map Index Number 3. At this location a resistant sandstone was undercut by the more rapid weathering and spalling of an underlying shale in the Gizzard Group, which resulted in a large block of sandstone falling onto the adjacent roadway (see Figure 20). As the shale continues to erode, more blocks of sandstone are likely to fall. Another area where a sandstone is being undercut by weathering and spalling of shale resulting in the possibility of a rock fall is on Hotwater Road approximately 1.2 miles (2km) west of the Soddy community.

In light of the numerous examples of unwise land modification, it is worthwhile to mention an excellent example of sound engineering practice shown in the part of I-24 on the western side of Missionary Ridge. In response to the recognition of the potentially unstable conditions that exist on Missionary Ridge, the Tennessee Department of Transportation (Division of Soils and Geological Engineering) initiated a detailed investigation that resulted in the subsequent bridging of the unstable segment. It is almost certain that failure of the roadway would have occurred if the unstable area had not been recognized and standard sidehill fills been utilized. Such investigative procedures and sound engineering practices serve as models in the recognition and correction of potentially unstable areas.

SINKHOLES

Sinkholes are depressions formed by the chemical action of ground water in soluble rocks such as limestone and dolomite. Most commonly, joints, bedding planes, or existing cavities in bedrock are enlarged by solutional removal of the material. As the solution cavity enlarges toward the surface, a point is reached at which the rock roof or overburden support fails, resulting in surface collapse. This may be a slow, imperceptible process or may occur as a sudden collapse. Often, sinkholes continue to enlarge at variable rates as a function of surface and subsurface water activity. Within Hamilton County, most sinkholes are shallow, less than 35 feet (10.7m) deep, and are restricted to formations of the Knox Group. The three main environmental problems related to sinkholes are flooding, structural foundation problems, and water pollution resulting from the dumping of waste materials.

Following periods of prolonged or intense rainfall, sinkholes frequently are observed to contain a quantity of water. Structures should not, therefore, be located within a sinkhole. Commonly, the natural drainage system of a sinkhole may become plugged by impervious materials such as clay, resulting in the flooding of a sinkhole with no prior flooding history. In such a case, unless drainage can be re-established, the sinkhole will continue to flood with each heavy rainfall.

The structural foundation problems associated with sinkholes are as significant as the flooding problem. Since the presence of sinkholes is a reflection of the solubility of the underlying rock, in areas having a high density of sinkholes the underlying rock commonly has many solution cavities of various sizes not yet evident from surface observation. The problem in these areas inherent in the construction of bridges and massive buildings is the possibility that they may exceed the bearing capacity of the solution-prone underlying rock. When this happens, there may be foundation collapse or settling problems. As a result of such problems in the past, it is now considered sound engineering practice to precede design and construction with a detailed geologic investigation, usually including foundation drilling.

In August, 1977, a serious foundation problem was being experienced by the Roxbury Southern Mill of RDC Inc., located in the 4900 block of Hooker Road. This was the result of the collapse of surface overburden into a solution-widened joint. In addition, during the spring of 1977, a portion of Airport Road approximately 2 miles (3 km) north of the municipal airport collapsed into a cavity, causing considerable damage to the roadway (see Fig. 21).

Sinkholes are frequently viewed as convenient dumping places for waste materials such as garbage. Since many sinkholes provide direct access to the water table, pollutants from such waste materials frequently enter the water table with little, if any, filtration. This practice raises the possibility of illness to people utilizing the contaminated water for household purposes. Waste materials, therefore, should not be introduced into sinkholes. Such disposal is now illegal in Tennessee.

Refer to the Environmental Map for the location of karst areas in Hamilton County. (See Plate 2.)

Figure 21. Sinkhole in Airport Road approximately 2 miles (3.2km) north of northernmost extension of the Chattanooga Municipal Airport.

CAVES

The largest caves in Hamilton County are found in the soluble Mississippian-age limestones underlying the Cumberland Plateau. Crystal Caves, Lookout Mountain Cave, and Ruby Falls Cave have been or are currently developed for commercial use. Several relatively small caves that are not maintained commercially are located in Ordovician-age rocks. The primary hazard associated with caves, especially those not maintained for commercial use, is the danger of personal injury to people who attempt to explore them without proper equipment and experience.

EARTHQUAKES

Hamilton County experiences enough seismic activity to be included within Algermissen's Seismic Risk Zone 2. The Seismic Risk Zones are based on an evaluation of the distribution and intensity of recorded earthquakes, data on strain release in the United States since the year 1900, and the association between strain release patterns and geologic features believed to be related to recent seismic activity. Figure 22 illustrates the Seismic Risk zonation for the 48 conterminous United States. According to Algermissen, areas within Zone 2 may experience earthquakes having a maximum intensity of VII on the Modified Mercalli Intensity Scale, (refer to table 3). To date, 10 earthquakes having Modified Mercalli Scale intensities III to VII have been recorded within a radius of 50 miles (80.5km) of Chattanooga, and 41 earthquakes have been recorded within a radius of 100 miles (161km) of Chattanooga (see Figure 23). The intensity distribution of these earthquakes is illustrated in Figure 24. Although there are many geologic faults with surface traces present in Hamilton County, all are considered geologically inactive, thereby posing no seismic risk. The seismic activity present in Hamilton County is the result of periodic release of stress in rocks at great depth.

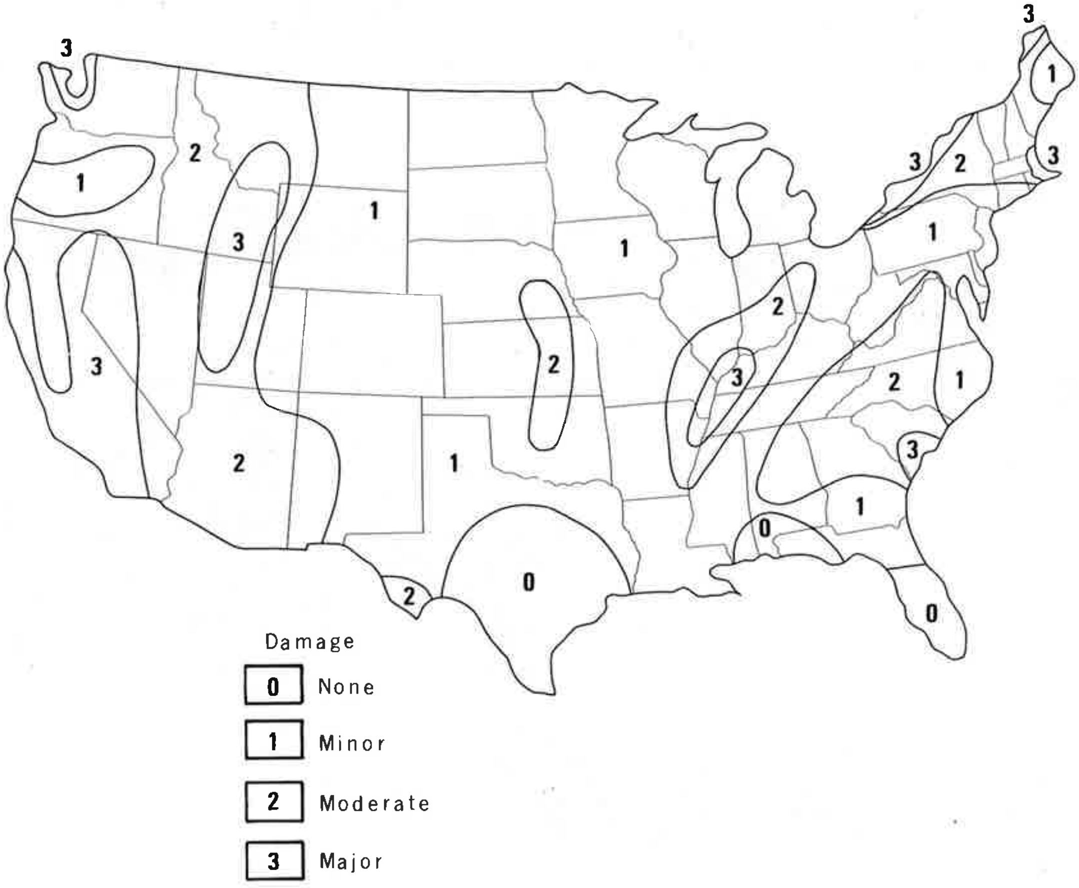


Figure 22. Seismic risk zonation for the 48 conterminous United States.

TABLE 3. MODIFIED MERCALLI INTENSITY SCALE OF 1931[1]

I. Not felt except by a very few under specially favorable circumstances. (I Rossi-Forel Scale).

II. Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing, (I to II Rossi-Forel Scale).

III. Felt quite noticeably indoors, especially on upper floors of buildings, but many people do not recognize it as an earthquake. Standing motorcars may rock slightly. Vibration like passing of truck. Duration estimated. (III Rossi-Forel Scale).

IV. During the day felt indoors by many, outdoors by few. At night some awakened. Dishes, windows, doors disturbed; walls make creaking sound. Sensation like heavy truck striking building. Standing motorcars rocked noticeably. (IV to V Rossi-Forel Scale.)

V. Felt by nearly everyone, many awakened. Some dishes, windows, etc., broken; a few instances of cracked plaster; unstable objects overturned. Disturbances of trees, poles, and other tall objects sometimes noticed. Pendulum clocks may stop. (V to VI Rossi-Forel Scale.)

VI. Felt by all, many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster or damaged chimneys. Damage slight. (VI to VII Rossi-Forel Scale.)

VII. Everybody runs outdoors. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable in poorly built or badly designed structures; some chimneys broken. Noticed by persons driving motorcars. (VII Rossi-Forel Scale.)

VIII. Damage slight in specially designed structures; considerable in ordinary substantial buildings, with partial collapse; great in poorly built structures. Panels were thrown out of frame structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Persons driving motorcars disturbed. (VIII + to IX- Rossi-Forel Scale.)

IX. Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb; great in substantial buildings, with partial collapse. Ground cracked conspicuously. (IX + Rossi-Forel Scale.)

X. Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations; ground badly cracked. Rails bent. Landslides considerable from riverbanks and steep slopes. Shifted sand and mud. Water splashed (slopped) over banks. (X Rossi-Forel Scale.)

XI. Few, if any, masonry structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipelines completely out of service. Earth slumps and land slips in soft ground. Rails bent greatly. (XI Rossi-Forel Scale.)

XII. Damage total. Waves seen on ground surfaces. Lines of sight and level distorted. Objects thrown upward into air. (XII. Rossi-Forel Scale.)

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[1] Wood and Newman, 1931.

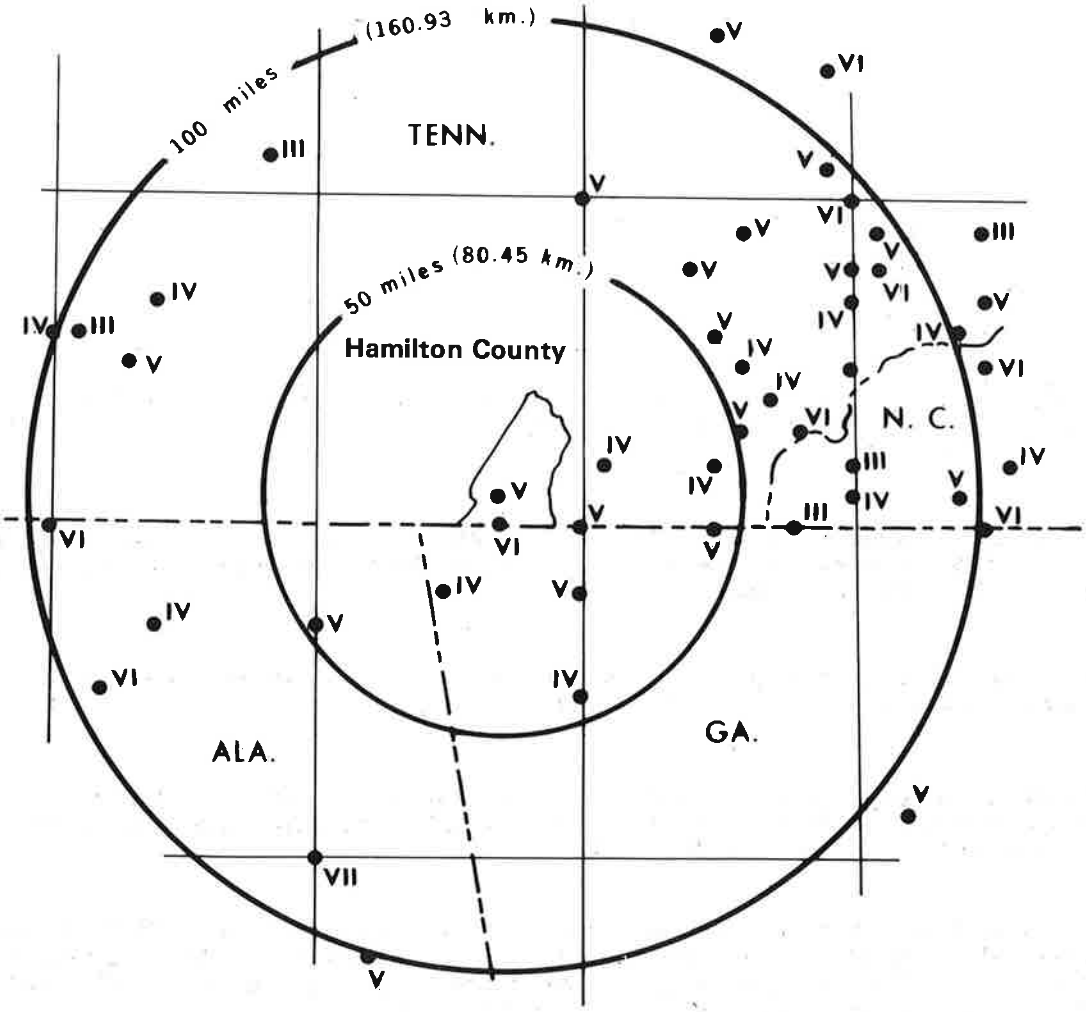

Figure 23. Location of earthquake epicenters.

Modified Mercalli Scale	Number of Occurances
III	4
IV	12
V	16
VI	8
VII	1

Figure 24. Numerical distribution of earthquake intensities within 100 miles (160.9km) of Chattanooga.

MINING-RELATED HAZARDS

ROCK QUARRIES

Limestone quarrying has been an important industry in Hamilton County for many years. Consequently, there are several active and abandoned quarries.

The abandoned quarries are frequently favorite play areas for children. They often partially fill with water. Two such quarries, one located .4 mile (.64km) northeast of Hixson High School, and another 1.1 miles (1.7km) northeast of Chickamauga Dam are frequently used for swimming. Since quarrying activities usually result in perpendicular walls and ledges with sudden dropoffs into deep water, swimming is extremely hazardous. Diving from the edges of these quarries is also hazardous because of hidden ledges and submerged objects, such as large blocks of rock and junked vehicles, immediately beneath the water's surface. Additionally, any quarries, abandoned or active, are dangerous places in which to climb due to the steep walls and spalling of blast-loosened rock from the walls. All such quarries should be made as inaccessible as possible to the public.

Since most active quarries contain little if any standing water and are difficult to enter undetected, they do not present as many hazards as abandoned, water-filled quarries. The principal environmental problems related to active quarrying are noise, vibration, dust from blasting and equipment, and heavy truck traffic.

COAL MINES

There are numerous abandoned strip and underground coal mines in Hamilton County. Many of the older, abandoned strip mines have now reached a degree of erosional stability through natural revegetation and consequently cause little siltation in area streams. There are only five active strip mines in Hamilton County at the time of publication. State surface mining regulations now help to control siltation during such mining operations. Acidization of ground water as a result of coal mining activities is not a major problem in Hamilton County.

Approximately 400 abandoned underground mines exist in Hamilton (at time of publication, there are 13 active underground mines). Roof collapse is the primary hazard to people who enter these mines, since the timbers in many of them are in various stages of decay. This results in a decrease of roof support. Another potential hazard in underground mines is the buildup of highly explosive methane gas.

ACKNOWLEDGEMENTS

The author would like to thank, for their valuable aid during the compilation of this chapter, Stephen Klasek of the Chattanooga-Hamilton County Regional Planning Commission, Dr. Robert L. Wilson of the University of Tennessee at Chattanooga, Gary Pinkerton of the Tennessee Division of Geology and Andy Avel of the Tennessee Valley Authority.

ENGINEERING GEOLOGY OF HAMILTON COUNTY, TENNESSEE

BY

ANDREW P. AVEL[1] AND GARY S. HARTMAN[2]

INTRODUCTION

Engineering geology deals with the design and construction of structural foundations and the treatment of the earth material upon which these rest. The variety of structures, whether a small house or a major power plant, involve loading of the underlying soil or rock and require a carefully planned foundation for each individual project. In the case of dams and mining projects, ground water becomes a major concern in that leakage control can be a matter of life and death, as evident in the failure of the Teton Dam in Idaho, where several lives were lost and many millions of dollars in property damage occurred. The importance of engineering geology has been proven in large-scale construction; however, on smaller projects such as homes, housing projects, subdivisions, roads and buildings, it is sometimes neglected as an important tool in their construction.

Some of the major applications of engineering geology are:

1. Foundation investigations and recommendations for structures such as dams, pumped-storage plants, bridges, nuclear plants, large buildings, and towers.
2. Investigations along tunnel, pipeline, canal and highway routes.
3. Location of sources of rocks, soils, and sediments for construction material.
4. Investigation for future water resource potential.
5. Inspection and evaluation of geologic hazards such as landslides, floods, and earthquakes.

The general public has a relatively limited awareness of the important role that geology plays in its everyday life. For example, most people are generally unaware of the importance of geology when they purchase new lots in subdivisions. The public needs to be advised of the necessity for better land-use planning in its communities. As a result, it will benefit from the knowledge gained from engineering geologic studies. In the future, most of the engineering geology done in Hamilton County will probably be related to the continued expansion of the metropolitan area. This will include foundation investigations for large buildings; location of potential landfill sites; groundwater studies (especially when related to the prevention of pollution); location of adequate sources of construction materials (such as limestone suitable for road metal); evaluations of proposed sites for industiral, commerical, governmental, or residential construction; and making geologic information available to the regional planners so that optimum utilization may be made of the land surface and the materials beneath it.

In order to strive for the best future living conditions in Hamilton County, we need to fulfill the needs imposed by an expanding urban population; but at the same time we must endeavor to protect the natural environment. This has been a difficult issue shrouded by much controversy; but with some compromise from all parties involved, a balance between development and preservation of natural elements may yet be accomplished. Some directions in which we may be guided and that directly relate to engineering geology include the following:

1. Protect our natural environment and, where possible, return improperly developed land to its natural state.
2. Recognize and evaluate geologic hazards, in order to minimize threats to life and property.
3. Minimize waste, particularly of our nonrenewable resources, by insuring that the land and its natural resources are used in the most beneficial and efficient manner.

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[1] Geologist, Geologic Services Branch, Tennessee Valley Authority.

[2] Geologist, Geologic Services Branch, Tennessee Valley Authority.

4. Eliminate pollution of our natural environment (water, air, and land).
5. Make the public aware of the need for and benefits of geologic studies before land development.
6. Preserve land with scenic beauty and historical significance.
7. Reduce problems associated with urban development.

The practice of engineering geology is vitally important to the general public, and until it is realized as a necessary tool for foundation evaluations, potential geologic hazards, remedial treatment and the like, more problems and failures are destined to occur. This is not to say that all foundation problems would be eliminated by consulting an engineering geologist, but that they would be greatly reduced. Hopefully, in the future the public will gradually become aware of the critical role that geologic studies play in regional community planning.

Summarized in the following sections are various types of exploration techniques, general soil and rock conditions of the Chattanooga area from an engineering standpoint, and a few case histories of some of the major TVA engineering projects in Hamilton County and vicinity, including discussions of geologic problems encountered during construction.

It is hoped that the following will serve as a guide for future engineering projects in the county and that it will be useful in evaluating specific problems.

GEOLOGIC EXPLORATION

The extent of geologic exploration and foundation investigations required for any engineering project depends upon the size of the project and the geologic conditions at the site. Considerable time and money can be saved by having a qualified engineering geologist determine the programs required for exploration and construction. Before the final design of a structure can be formulated by engineers, engineering geologists must investigate foundation conditions in the immediate vicinity of the proposed structure. The techniques used include indirect subsurface exploration by percussion drilling and geophysical logging and direct methods such as core drilling, exploratory drift tunnels, and open-pit excavations.

Before detailed geologic exploration is begun on a site, in many instances a wealth of information may be obtained by studying the topography of the site, drainage conditions, general geology, and soil types present in the area. This information may be obtained from various publications. Aerial photographs and topographic maps sometimes serve as valuable sources of reference material for preliminary geologic investigation; and in many cases they reveal features that are not obvious in the field.

Before actual core drilling is undertaken, a field party usually investigates the site in order to identify potential problem areas where concentrated drilling may be required. Such preliminary observations usually include an evaluation of rock types and related features such as jointing in sandstone and limestone, slides and slaking in shales, karstic features in limestone, and local structural anomalies.

Geophysical exploration techniques are usually employed when it is desirable to know the depth to bedrock in the vicinity of the site. Some of the major geophysical methods used in engineering geology are:

Seismic—Generation, reflection, refraction, detection, and analysis of elastic waves in the earth to determine top-of-rock.

Resistivity—Current is introduced in the ground by two contact electrodes, and potential differences are measured between two or more other electrodes.

Density—Measures the density of rock by injecting radiation and tracing absorption rates and patterns.

Natural Gamma—Measures background radiation of the rock, which is useful in differentiating rock types.

Sonics—Measures the travel time of a mechanically produced shock wave through rock.

These geophysical methods have proven to be extremely useful for rapid, though approximate, interpretations of certain geotechnical problems.

Percussion drilling is commonly used on construction sites as a relatively inexpensive method for obtaining subsurface information. This type of drilling may be used to identify top-of-rock conditions and to locate significant cavities or prominent clay seams in the bedrock. Percussion drilling is much faster and more economical than core drilling, but the accuracy is considerably less; however, in situations that allow use of limited data, percussion drilling can be a valuable method of exploration.

Core drilling is a method to review subsurface conditions in a direct manner by obtaining samples of subsurface material which ideally represent typical conditions underlying the site. Drilling is done by a rotary rig, also called a core drill, operating at 40 to 1,000 rpm or greater, and the core is pulled from the ground in a cylindrical shape. Core drilling is commonly used for the foundation exploration of heavy structures such as large dams, bridges, powerhouses, and large buildings. The depth and extent of drilling depends upon the geologic features encountered at the site and also the load of the structure to be built. As a general rule, core holes should be spaced in a manner that will provide adequate coverage, and not in a random or arbitrary manner.

TABLE 1. UNIFIED SOIL CLASSIFICATION SYSTEM AS RELATED TO HAMILTON COUNTY SOILS[1]

Major Divisions		Symbol	Description	Unit Dry Weight lb./cu. ft.	Permeability ft./min.	Drainage Characteristics	Value For Foundations (tons/sq. ft.)	Compaction Characteristics For Fill	Areas of Occurrence in Hamilton County
COARSE-GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	GW	Well-graded gravels or gravel-sand mixtures, little or no fines.	125-140	$> 10^{-2}$	Excellent	Good bearing (5 to 6)	Good, with rubber-tired or steel-wheeled roller.	Principally at or near the base of flood-plain deposits along major streams, and in high level terrace deposits adjacent to major streams; some very cherty residual clays overlying the Knox could be classified "GC".
		GP	Poorly graded gravels or gravel-sand mixtures, little or no fines.	110-130	--do--	--do--	--do--	--do--	
		GM	Silty gravels, gravel-sand-silt mixtures.	120-145	10^{-3} to 10^{-6}	Fair to practically impervious	--do--	Good, with close control, with rubber-tired or sheeps foot roller.	
		GC	Clayey gravels, gravel-sand-clay mixtures.	120-140	10^{-6} to 10^{-8}	Poor to practically impervious	--do--	Fair, with rubber-tired or sheeps foot roller.	
	SAND AND SANDY SOILS	SW	Well-graded sands or gravelly sands; little or no fines.	110-130	$> 10^{-3}$	Excellent	--do--	Good, with tractor	Mainly in the upper portions of flood-plain deposits of rivers and major creeks. Some of the residual soils overlying the Raccoon Mtn., Rome, and Warren Point Formations could be classified as "SM" and "SC".
		SP	Poorly graded sands or gravelly sands; little or no fines.	100-120	--do--	--do--	Good to poor bearing depending on density (2 to 6)	--do--	
		SM	Silty sands, sand-silt mixtures.	105-135	10^{-3} to 10^{-6}	Fair to practically impervious	--do--	Good, with close control, with rubber-tired or sheeps foot roller.	
		SC	Clayey sands, sand-clay mixtures.	105-130	10^{-6} to 10^{-8}	Poor to practically impervious	Fair to poor bearing (1 to 3)	Fair, with rubber-tired or sheeps foot roller.	
FINE-GRAINED SOILS	SILTS AND CLAYS LL < 50	ML	Inorganic silts and very fine sands, silty to clayey, fine sands or clayey silts with slight plasticity.	100-125	10^{-3} to 10^{-6}	Fair to poor	Very poor, subject to liquefaction. (+1)	Good to poor, close control essential, with rubber-tired or sheeps foot roller.	Residual soils over limestones and dolomites are predominantly MH-CH, and ML-CL. The distinction between these depends on whether the liquid limit (LL) is above or below 50 percent.
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.	--do--	10^{-6} to 10^{-8}	Practically impervious	Good to poor bearing depending on density (1 to 4)	Fair to good, with rubber-tired or sheeps foot roller.	
		OL	Organic silts and organic silt-clays of low plasticity.	90-105	10^{-4} to 10^{-6}	Poor	Fair to poor bearing settlement likely (1 to 3)	Fair to poor, with sheeps foot roller.	Organic silts and clays (OL-OH) are found in slough deposits on flood plains.
	SILTS AND CLAYS LL > 50	MH	Inorganic silts, fine, sandy or silty soils, elastic silts.	80-100	--do--	Fair to poor	Poor bearing, (+1)	Poor to very poor, with sheeps foot roller.	The upper portions of most flood-plain and terrace deposits are mixtures of ML-CL and MH-CH.
		CH	Inorganic clays of high plasticity, fat clays.	90-110	10^{-6} to 10^{-8}	Practically impervious	Fair to poor bearing depending on density (1 to 3)	Fair to poor, with sheeps foot roller.	
		OH	Organic clays of medium to high plasticity, organic silts.	80-105	--do--	--do--	Very poor bearing (+1)	Poor to very poor, with sheeps foot roller.	Occur occasionally as pockets of slough clay in flood-plain deposits.
HIGHLY ORGANIC SOILS		PT	Peat and other highly organic soils.	--	--	Fair to poor	Unsuitable	Compaction not practicable.	Do not occur in Hamilton County.

SOIL EVALUATION

Because most small- and medium-sized engineering structures built in Hamilton County are founded on soil rather than on rock, in-depth evaluations of the engineering qualities of the various soil types are needed. Geologically, soils are classified on the basis of their origin—residual or transported. Residual soils have remained at the place of their formation and generally reflect the characteristics of the parent material or bedrock, whereas transported soils have been moved by water (alluvial soils), gravity (colluvial soils), ice (glacial soils), or wind (eolian soils) from the place of their original formation. All soils in Hamilton County are either residual, alluvial, or colluvial types. Because soils commonly reflect the characteristics of or show a direct relationship to the underlying bedrock, predictions may sometimes be made as to the types of soils that will be found in an area with a reasonable degree of accuracy.

The geological classification is too general to be used as the basis for a very reliable interpretation of the engineering properties of soils. To solve this problem, a Unified Soil Classification System has been devised whereby soils are divided into three main groups, which include coarse-grained, fine-grained, and highly organic soils. Highly organic soils (such as peat) are insignificant in their occurrence in Hamilton County and will not be discussed here. Coarse-grained soils are those which contain by weight 50 percent or less fines (particles less than 0.074 mm in size), and fine-grained soils which contain more than 50 percent fines. This system was developed by Dr. Arthur Casagrande and has become widely accepted for evaluating engineering qualities of soils. It is particularly useful because it groups soils with identical characteristics and engineering properties, regardless of their origin or occurrence.

In order to understand the Unified Soil Classification System, it is necessary to understand the manner in which it is constructed. Following is a simple description of symbols used in the system and the meanings that they imply:

Coarse-grained soils
G - gravelly
S - sandy (less coarse-grained than G)
  W : well graded; fairly clean
  P : poorly graded; fairly clean
  C : dirty; plastic (clayey) fines
  M : dirty; nonplastic (silty) fines

Fine-grained soils
M - inorganic silts
C - inorganic clays
O - organic silts and clays
  L : liquid limit lower than 50 percent
  H : liquid limit higher than 50 percent

Soil types are represented by a combination of two letters, such as GP (indicating a gravelly, poorly graded, fairly clean soil) or ML. Borderline materials are usually represented by a double symbol, such as MH - CH. It is possible for several types of soils to be present in the same location at different depths. For example, alluvial deposits may include various soil types ranging from well-graded gravel to inorganic silts and clays.

Table 1 relates the Unified Soil Classification System to soils in Hamilton County, and for each type gives the parameters most crucial to engineering evaluation of soil conditions.

ROCK EVALUATION

Outcrop patterns of rock formations in Hamilton County are shown on the Geologic Map of Hamilton County (Plate I) included with this report. Detailed descriptions of each unit are given in the chapter on stratigraphy. All units are distinguished on the basis of their diagnostic features, which also means that each unit possesses specific engineering characteristics. Data concerning the properties of each formation are found in Table 2. Following is an explanation of some of the major characteristics of the geologic units in Hamilton County.

OVERBURDEN

Overburden is the unconsolidated material that overlies the bedrock in any given area. It may be either residual or transported, according to the mode of origin. Thickness of overburden, or depth to top of bedrock is controlled by several factors, which include rate of weathering, decomposition of the rock material (e.g. amount of insoluble material), abundance and arrangement of fractures, attitude of bedding, and topography. Because numerous factors affect the thickness of overburden, only general predictions may be made as to its thickness in any given area. Knowledge of the weathering characteristics of the underlying bedrock is a valuable aid in making these predictions. For example, the resistant Warren Point Sandstone on the Cumberland Escarpment would be expected to have a thinner overburden than the soluble Knox Formation in the valley below.

WEATHERING

Weathering is the process by which rock is broken down into smaller and smaller particles either by physical or by chemical processes. Weathering is controlled by expansion and contraction resulting from loss and gain of heat, freezing-thawing, composition of the rock, size of individual rock particles, orientation and abundance of fractures in the rock, the presence of organic materials, slope direction, and time. Each rock type in Hamilton County displays mostly consistent weathering characteristics throughout the county.

Sandstone, the most resistant rock type in Hamilton County, forms a cap over most of the Cumberland Plateau and Escarpment in the area. It normally exhibits blanket weathering, but jointing is another important factor in determining the manner in which it weathers. Shales (as in the Pennington and Rockwood Formations) are much less resistant to erosion than sandstone and tend to deteriorate more rapidly when exposed. Limestones are very susceptible to chemical weathering, which in most cases forms an irregular top-of-rock surface. Fractures and bedding planes in limestone promote solution weathering by providing access for ground water. This forms such karstic features as pinnacles, sinkholes, and caverns. Several large caves in Hamilton County attest to the fact that this type of weathering may often be quite extensive. Features such as these are hazardous from the standpoint of engineering geology, and must be treated properly when encountered or suspected under foundations for engineering structures. Additional information on sinkholes and related hazards is presented in the chapter entitled "Environmental Geology."

EXCAVATION

Excavation characteristics of bedrock on construction sites are controlled largely by the composition of the rock, thickness of individual beds, the local dip of the strata, and the presence and development of jointing or faulting. The extent of weathering also may have an effect on the ease with which the rock can be excavated. In a general sense, thin-bedded rocks are more easily excavated than very thick-bedded strata, although very thick-bedded rocks tend to be more stable in excavations such as roadcuts. However, failure in a cut excavated in very thick-bedded rocks is often more serious and extensive than one in thin-bedded rocks, because of the larger volume of material usually involved.

Most cases of rock failure in excavations occur where the slope of the cut is greater than the inclination of the bedding and the strata dip toward the excavation (dip slope). If these conditions are present, an unsupported wedge of rock is left hanging, and could easily slide down the bedding plane into the excavation. Fortunately, this problem is not a major one in Hamilton County, because most of the rock strata are horizontal.

Excavations in areas of extensive karst development may also present problems. Slides and slope failures may occur if these features are deeply weathered and intricately connected. Most problems with karst features are encountered in the top 20 feet (6m) of rock. Relatively minor solution features such as open joints and cavities, encountered in large engineering projects, are sometimes treated with a chemical grout to strengthen the foundation rather than excavated.

AGGREGATE

Aggregate is any material such as sand, gravel, shells, or crushed stone that is used in road building or in mix. Hamilton County contains moderately large quantities of readily available aggregate in the form of sand and gravel, sandstone, and crushed limestone from local quarries. In most cases geologic investigations are made to determine areas most suitable for aggregate. Limestone suitable for aggregate should have a low content of shale, chert, and organic matter; usually the thicker-bedded limestones are more favorable. For additional information regarding geologic units in Hamilton County suitable for aggregate, see Table 2.

TABLE 2. ENGINEERING EVALUATION OF HAMILTON COUNTY ROCK UNITS[1]

Formation	Rock Type	Range of Depth of Residual Overburden	Weathering Characteristics	Excavation Characteristics (Bed Thickness)	Suitability For Aggregate	Landslide Potential For Residual Material
Vandever	Sandstone and Conglomerate	0-10	Blocky weathering along joints and bedding planes	Thin- to thick-bedded	Good	Low
Newton	Sandstone	0-10	---- do ----	Medium- to thick-bedded	-- do --	---- do ----
Whitwell	Shale	0-15	Transitional weathering from rock to soil	Thin-bedded, fissile	Not usable	Moderate
Sewanee	Conglomerate and Sandstone	0-10	Blocky weathering along joints and bedding planes	Medium- to very thick-bedded	Good	Low
Signal Point	Shale	0-20	Some weathering along bedding planes; transitional from rock to soil	Thin- to thick-bedded	Not usable, tilted	Moderate to high
Warren Point	Sandstone	0-10	Blocky weathering along joints and bedding planes	---- do ----	Good	Low
Raccoon Mountain	Sandstone and Shale	0-10	Some weathering along bedding planes and joints; transitional weathering from rock to soil	---- do ----	Fair, depends on shale content	Moderate
Pennington	Shale	0-15	Transitional weathering from rock to soil	Thin- to irregularly bedded	Not usable, tilted	High
Bangor	Limestone	0-30	Irregular top-of-rock with near vertical solution cavities and sinkholes	Thin- to thick-bedded	Excellent	Low to moderate
Hartselle	Sandstone	0-5	Weathering along bedding planes and joints	Medium-bedded	Fair	Low
Monteagle	Limestone	0-30	Irregular top-of-rock with near vertical solution cavities and sinkholes	---- do ----	Excellent, depends on chert content	---- do ----
St. Louis	---- do ----	0-25	Irregular top-of-rock; weathering along joints and bedding planes	---- do ----	Good, depends on chert content	---- do ----
Warsaw	---- do ----	0-25	Irregular top-of-rock; weathering along joints and bedding planes	Medium- to thick-bedded	Good	---- do ----

TABLE 2 (continued)

Formation	Rock Type	Range of Depth of Residual Overburden	Weathering Characteristics	Excavation Characteristics (Bed Thickness)	Suitability For Aggregate	Landslide Potential For Residual Material
Ft. Payne	Limestone and dolomite	0-150+	Blocky; weathers to thick chert ledges	Medium-bedded	Poor	Moderate to high
Chattanooga Shale	Shale	0-5	Transitional from rock to soil	Thin-bedded, fissile	Not usable	Moderate
Rockwood	Shale and siltstone	0-15	Weathers to an iron-rich residuum	Thin- to medium-bedded	Poor	Low to moderate
Upper Chickamauga	Limestone	0-20	Weathering along joints and bedding planes	---- do ----	---- do ----	Low
Lower Chickamauga	---- do ----	0-20	---- do ----	Thin- to thick-bedded	Good, depends on chert and shale content	---- do ----
Knox	Dolomite and limestone	10-40	Irregular, pinnacled top-of-rock; cavities and sink-holes common.	Medium-bedded to very thick-bedded, blocky	Good to excellent, depends on chert content	Moderate
Conasauga	Shale and limestone	0-20	Weathering along joints, faults, and bedding planes	Thin-bedded, commonly contorted	Poor	---- do ----
Rome	Sandstone and shale		Slight weathering of near-surface rock	Thin- to medium-bedded, shaly to blocky	---- do ----	Low

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[1] Data from Terzaghi and Peck (1948), U.S. Army (1958), U.S. Bureau of Reclamation (1960), and U.S. Navy (1961).

CASE HISTORIES OF TVA PROJECTS IN THE HAMILTON COUNTY AREA

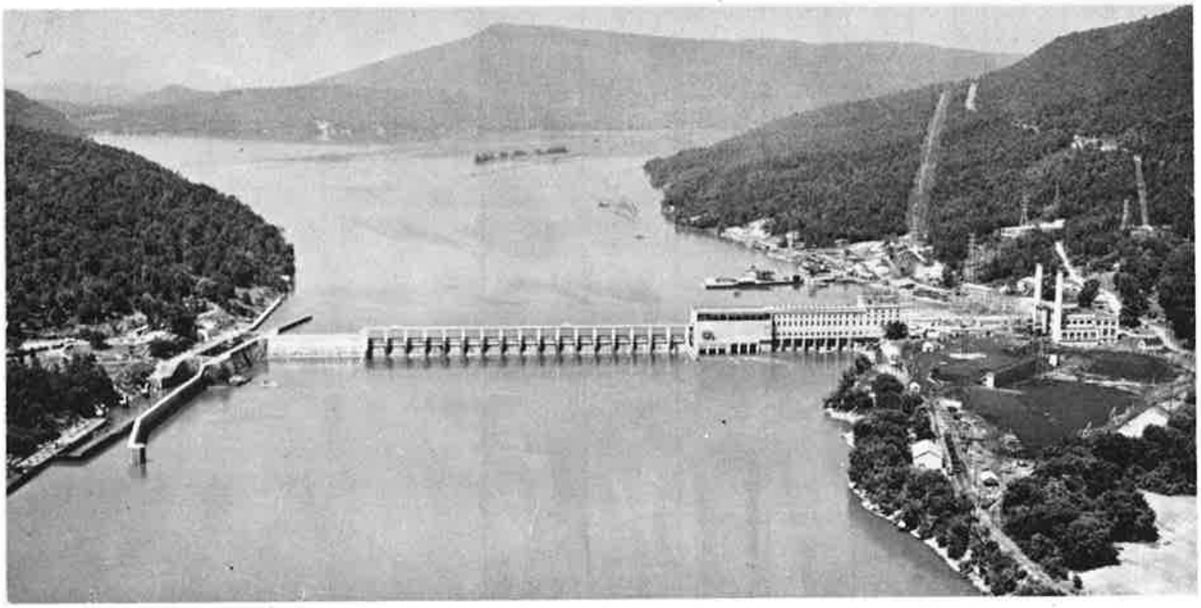

Figure 1. Hales Bar Dam, built beginning 1905, and demolished to make way for the Nickajack Project.

HALES BAR DAM

Hales Bar Dam was located at Tennessee River Mile 431.1 in Marion County, Tennessee, 33 miles (53 km) downstream from, and 13 airline miles (21 km) west of Chattanooga, Tennessee. (See Fig. 1).

The dam was constructed by the Chattanooga and Tennessee River Power Company between 1905 and 1914. Reconstruction of the spillway took place from 1946 through 1948, after work was done to reduce leakage through the limestone foundation. At the time when it was removed by TVA and replaced by the Nickajack Dam downstream, the dam consisted of a 40-foot (12.2m) bulkhead section, a navigation lock 110 feet (33.5m) wide on the dam axis, a non-overflow bulkhead section 232 feet (70.7m) long, a spillway section 776 feet (236.5m) long with 17 radial gates on the east bulkhead, a trashway section 194 feet (59.1 m) long, a concrete powerhouse section 221 feet (67.4 m) long, and an earth embankment with a concrete core wall 742 feet (226.2 m) long. The total length of the dam was 2,315 feet (705.6 m) and normal pool elevation was 634 feet (193.2 m).

General Geology

Hales Bar dam is within the Cumberland Plateau physiographic province on the southeast side of the Sequatchie anticline. The underlying rocks are nearly flat-lying Paleozoic strata ranging in age from Cambrian to Pennsylvanian.

The dam was constructed on the Bangor Limestone of Mississipian age, which contained several small faults located beneath and around the dam site. These small faults had fractured the rock, allowing water leakage and erosion. Joints associated with the faulting as well as weak bedding planes also provided for water percolation and weathering. These factors caused extensive solution in the rocks throughout the dam site area. An aerial view of the geology is shown in figure 1.

History and Dam Siting

Surveys involving improvement of navigation in the section of the Tennessee River beginning at the toe of Williams Island for the following 8 miles (13 km) of treacherous rapids and shoals were begun as early as 1830 by the U.S. Corps of Engineers. During 1900 a program for water navigation was being seriously considered, and at this time a dam with a navigation lock was being discussed.

Congress passed a bill providing for the construction of a dam at Scott Point by the City of Chattanooga or private interests. The city forfeited its right to build and the newly formed Chattanooga and Tennessee River Power Company contracted with the Government to build the dam. Along with the idea of a power-producing dam came the need for a greater reservoir capacity, and the site of the dam was moved to the Hales Bar Dam site. It later became obvious that the geology of the area played a minor role, if any, in the decision on location of the dam. Apparently, topography was the main factor in site selection.

Exploration

Top-of-rock, which ranged in elevation from 558 feet (170.0 m) to 575 feet (175.3 m), was overlain by an active layer of sand, clay and silt. Very little rock exploration was

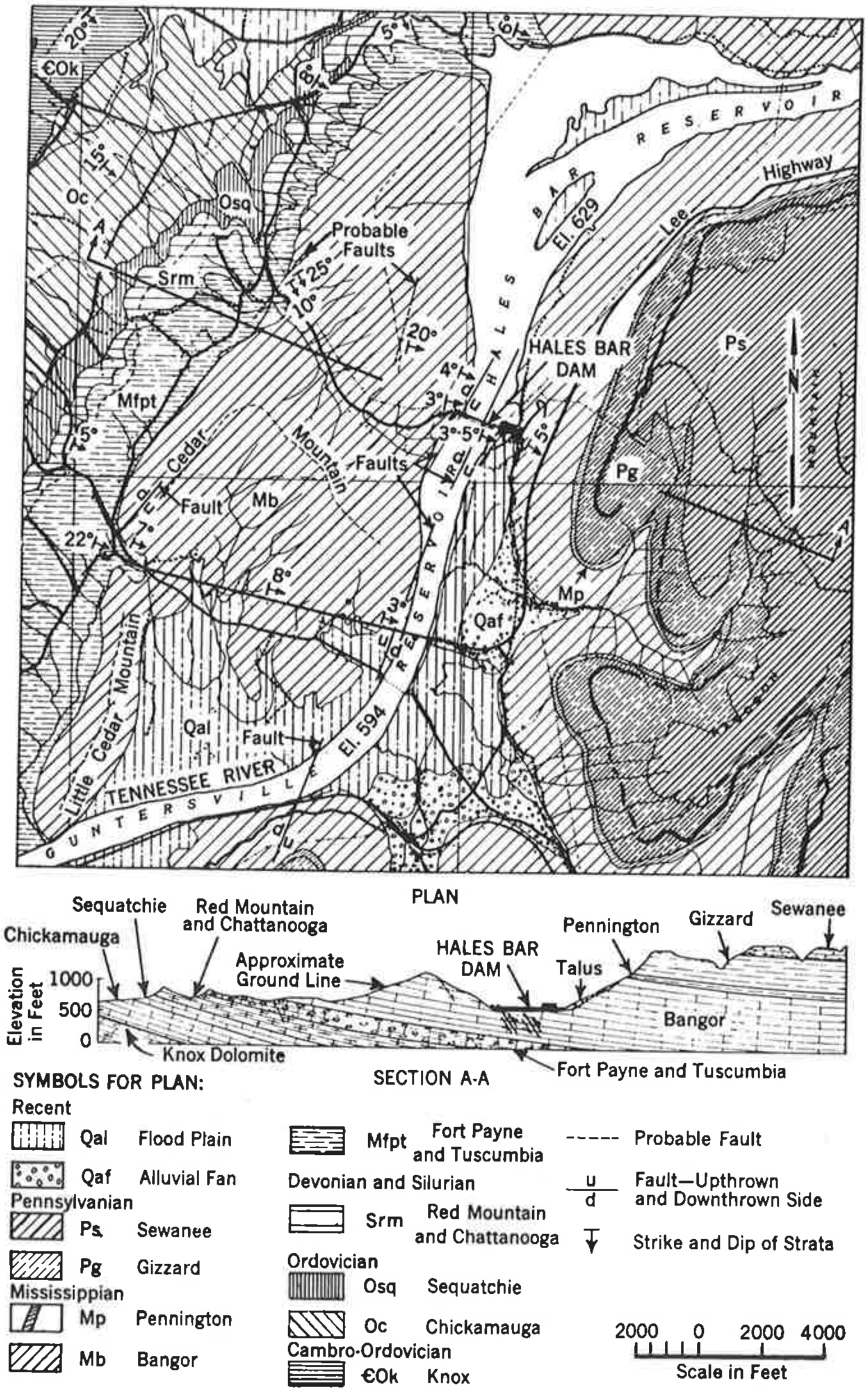

Figure 2. Areal geology of the Hales Bar Dam (TVA, 1949). The Red Mountain Formation is the Alabama equivalent of the Rockwood of Tennessee usage; and the Tuscumbia, also an Alabama name, includes equivalents of the Warsaw, St. Louis, Hartsell, and Monteagle Formations of Tennessee usage.

done prior to construction; however, during the course of construction, and foundation treatment done after completion, a wealth of geologic information was obtained.

Several extensive bedding plane cavities had developed beneath the spillway section of the dam, along with more mildly weathered bedding planes throughout the western part of the dam. Nearly vertical joints intersecting these bedding planes had been severely weathered. Beneath the eastern part of the spillway, vertical joints had been extensively weathered, leaving large boulders (some of which were more than 25 feet [8m] across), bordered by clay-filled crevices. Where bedding planes had weathered beneath the boulders, these huge blocks of limestone settled and tilted due to lack of support. Northeastward-striking faults with adjacent fractured zones had been deeply weathered, and later formed direct openings from the reservoir to the downstream areas.

Foundation Treatment During Construction

Construction was started in October, 1905. By June 1910, construction of the lock and the east embankment had neared completion. Because of extensive weathering and water flow, little of the powerhouse foundation excavation had begun. At this time another contractor began excavations by first pressure grouting the foundation and then excavating. This was probably the first example of pressure grouting of foundations to be used in the United States. Grout was injected into 6-inch (15cm) holes drilled 20 feet (6m) deep and grouted to a final pressure of 85 pounds per square inch. A 2-foot (0.6m) slab of concrete was then placed on the excavation, and final grouting was done through the slab.

Beneath the spillway where joints were filled with mud and clay, grouting was useless; and pressurized caissons were incorporated in the excavation of weathered material below water level. The caissons, which were 1 to 2 feet (0.3-0.6m) apart, were constructed of reinforced concrete and ranged in size from 30x32 feet to 72x54 feet (9.1mx9.8m to 22x16.5m). They were sunk into place and pressurized, providing a space for workers to proceed with the excavation, using small air drills and light powder charges. Joints and cavities in this area could then be cleaned of mud and clay, and filled with cement.

Approximately 35 feet (11m) of rock were removed beneath the powerhouse and eastern part of the spillway. At this elevation, 545 ± feet (166±m), leakage through the bedrock exceeded 15,000 gallons per minute. Six-inch (15cm) holes were drilled 20 feet (6m) into rock, standpipes were installed, and then grout was pumped into the holes starting with low pressure and building up to 80 ± pounds psi. Approximately 125,000 bags of cement grout were used.

Foundation Treatment After Construction

Several attempts were made to grout the foundation using materials varying from carpet, rags, and concrete pads to asphalt, but with little success.

TVA acquired Hales Bar Dam on August 15, 1939, and their foundation investigations led to development of the following grouting program.

In areas where conventional grouting methods proved adequate, holes were drilled on 20-foot (6m) centers, 125 feet (38m) deep and stage grouted under pressures of 30 to 70 psi. In other areas, two overlapping lines of 18-inch (45cm) calyx holes were drilled 20 to 100 feet (6-30m) into rock. A liner of asbestos cement was placed into the hole and concrete was then poured into the pipe, forming a continuous concrete wall across known leakage zones. Grout holes were drilled upstream of the concrete cutoff wall 10 feet (3m) on centers and pressure grouted with either cement or asphalt. Holes were then split-spaced where deemed necessary. Downstream of the wall, 13-inch (33cm) consolidation holes were drilled through the dam into cavities and filled with concrete. Smaller holes were then drilled between the larger holes and pressure grouted, strengthening the concrete wall formed by the 18-inch (45cm) clayx holes.

After construction of the Nickajack Project it became necessary to remove to an elevation of 600 feet (183m) the entire spillway and bulkhead sections, along with the lock gates. The removal of these parts of the dam provided access for the river to pass 270,000 cubic feet of water per second at an estimated maximum velocity of 7.9 feet per second. Lock and spillway gates were salvaged along with their operating equipment and other salvageable items. All old turbines were left in place, and units 15 and 16 were removed and placed in Nickajack as units 1 and 2.

Hales Bar Dam was the site of several engineering firsts in this country. It was the first dam known to use pressure grouting for foundation treatment. Knowledge about weathering characteristics of limestone increased greatly as problems with leakage arose. Also, more emphasis was placed on geologic investigations of future dam sites because of the foundation problems encountered at Hales Bar.

CHICKAMAUGA DAM

Chickamauga Dam is located at mile 471.0 on the Tennessee River in Hamilton County, Tennessee, 46.3 river miles (74.5 km) upstream from Nickajack Dam and 58.9 miles (94.8 km) downstream from Watts Bar Dam.

The dam is about 5,800 feet (1768 m) long and has a maximum height of 129 feet (39.3 m). The concrete powerhouse and service bay reaches a length of 400 feet (122 m). The spillway is 864 feet (263.3 m) long with 18 gates and one trash gate, and the north and south embankment dams total 4,390 feet (1338 m). A navigation lock with a 60-foot by 360-foot (18.3 m x 109.7 m) chamber is located between the spillway and north embankment.

Preliminary investigations were begun by TVA in May 1935, and construction began on December 31, 1936. By January 31, 1941, construction was completed.

General Geology

Chickamauga Dam is located within the Valley and Ridge physiographic province, which is underlain by a thick sequence of limestones, dolomites, shales, and sandstones ranging in age from Early Cambrian to Pennsylvanian. The strata have been compressed and folded into a series of northeastward-trending faulted anticlines and synclines.

Dam Site Geology

A total of six sites were investigated for the dam construction but, because of cavernous foundation conditions at the other sites, the present location was chosen. The foundation of the dam consists of limestones, dolomites, and shales, the oldest of which is the Knox Dolomite of Cambrian and Ordovician age. The Copper Ridge Dolomite (one of the four subdivisions of the Knox) is the only part of the Knox present near the dam; however, the Copper Ridge does not directly underlie the dam but is separated from it by a large thrust fault. The Copper Ridge is a massive, coarsely to finely crystalline, light-gray or black cherty dolomite, in which large cavities or caves are common.

The Chickamauga Supergroup of Ordovician age is the bedrock at the dam site; and contains several formations including the Murfreesboro, Pierce, Ridley, Lebanon, Carters, Hermitage, Cannon, and Catheys limestones (for a description of each formation, see the chapter entitled "Stratigraphy"). Beds of bentonite in these units act as barriers for weathering and as key beds for correlation purposes.

Structure

In the dam foundation the strikes and dips are variable, and some beds are even overturned; however, the general strike is northeast and the dip is 10° to 40° southeast. Figure 3 shows a cross section below the base line of the dam.

The Missionary Ridge thrust fault, extending along the northwestern base of Missionary Ridge, crosses the Tennessee River about 1 mile (1.6 km) upstream of the dam. The lower Copper Ridge Dolomite has been thrust over formations of the Upper Ordovician, resulting in a stratigraphic displacement of at least 5,000 feet (1524 m). Movement along the fault is thought to have occurred during the Allegheny Orogeny in the latter part of the Paleozoic Era, and there is no evidence of more recent tectonic activity. Several small faults with displacements of several feet, striking N. 20° - 50° E. and dipping 20° - 45° southeast, were found beneath the dam.

Foundation Treatment

Earth Dams: Foundation treatment for both the north and south embankment dams consisted of a U-shaped trench with a minimum width of 25 feet (7.6 m) at the top of the sound rock. The purpose of this trench is to cut off seepage through the very permeable gravel and boulder layer at the top-of-rock contact and through the weathered

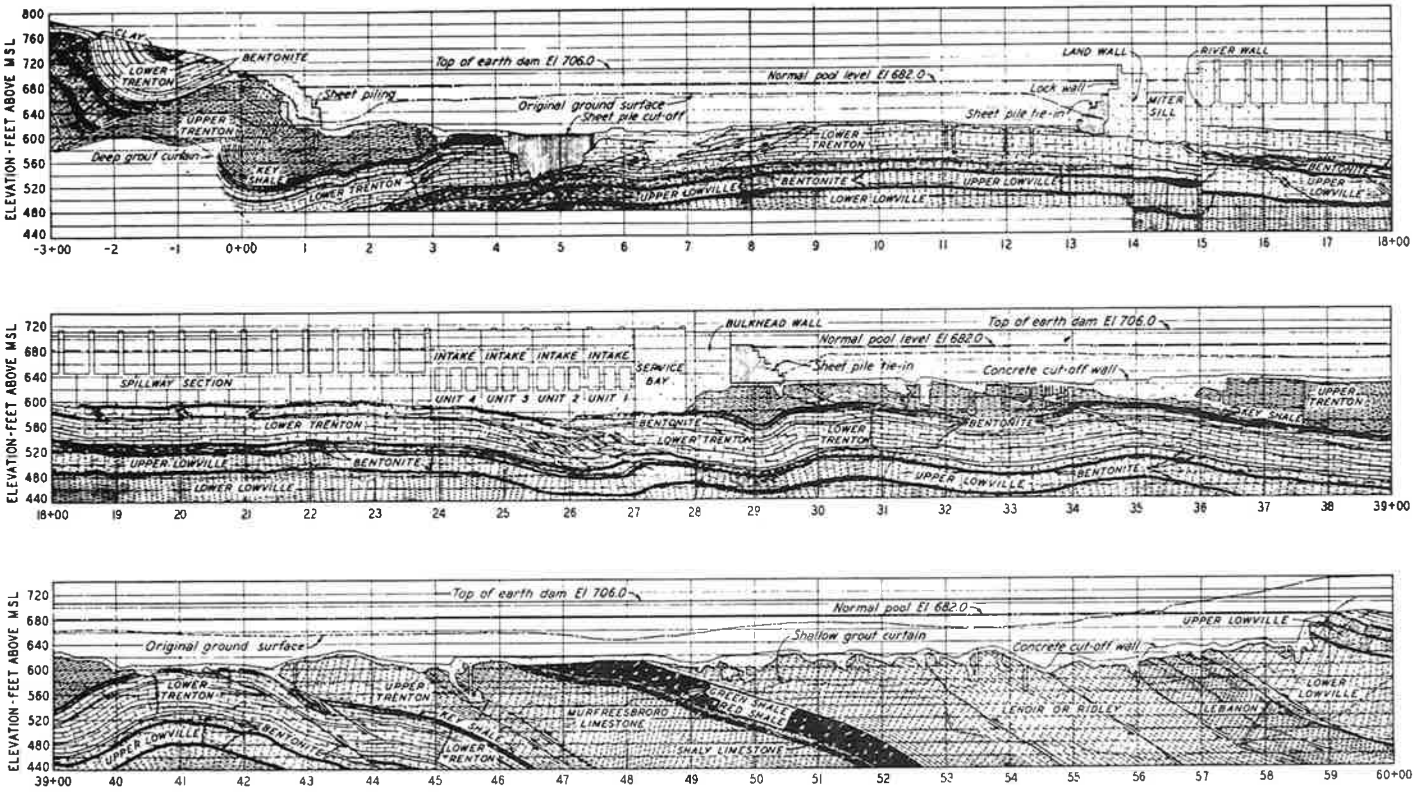

Figure 3. Cross section below baseline of Chickamauga Dam. Taken from TVA Geology and Foundation Treatment - TVA Projects, Technical Report No. 22, page 246. In present terminology, the Lowville Limestone is called Carters, and the Trenton corresponds to the Nashville Group.

parts of the bedrock. After the trench was excavated, drilling and grouting of holes to a final spacing of 12 inches (30.5 cm) and a depth of 40 feet (12.2 m) was done. Cavities close to the surface were excavated and filled with concrete along the cutoff line. Deep cavities were intersected with 36-inch (91.4 cm) calyx holes, which were then cleaned and filled with concrete. After treatment of cavities and grouting were completed, a concrete core wall 5 feet (1.5m) high was built over the grout curtain; and the trench was filled with rolled earth fill. This procedure was followed as a general plan; however, because of conditions encountered, it was modified in order to insure an effective watertight cutoff.

Lock: In order to prevent settlement and to reduce percolation, a regular pattern of wagon drill holes 30 feet (9.1m) deep was drilled and grouted on 10-foot (3.0m) centers. The main grout curtain completely surrounded the lock chamber and connected with the spillway and north earth dam. The main grout curtain consisted of wagon drill holes drilled to a depth of 40 feet (12.2m) on 4-foot (1.2m) centers angled 20° from vertical and grouted to a final pressure of 75 psi. The holes were then split-spaced and the procedure was repeated. Following this main curtain cutoff grouting, a line of core holes was drilled 60 feet deep (18.3m) on 10-foot (3.05m) centers, then grouted to a final pressure of 125 psi; these holes intersected the bentonite at the top of the Hermitage Formation.

Spillway and Powerhouse: At the spillway and powerhouse areas a bed of shale and bentonite was present over most of the area. Above the shale bed, rock was extensively weathered, whereas below the bed weathering was minimal. Weathering continued downward only where faults and joints intersected the shale and bentonite layers. Consolidation holes were drilled 30 feet deep (9.1 m), on 8-foot (2.44 m) centers along parallel lines 10 feet (3.05 m) apart and grouted to low pressures. For the cutoff curtain grouting, holes were drilled 40 feet deep (12.2 m) on 8- to 10-foot (2.44 - 3.05 m) centers angled 20° from the vertical, then grouted to a final pressure of 40 psi. Split-spaced holes were then drilled, angling in the opposite direction and grouted to the same pressure.

After the concrete was placed to an elevation of 632 feet (192.6m) in the spillway and to the powerhouse floor, core holes were drilled 110 feet (33.5m) deep to penetrate the lowest bentonite bed and were grouted to a final pressure of 125 psi. Split-spaced holes were then drilled to a depth of 80 feet (24.4m) and were grouted to a final pressure of 75 psi.

Rim Treatment

On the north abutment, a fault dipping 25° to the southeast had allowed weathering of the bedrock to extend for a considerable distance. Tests indicated that bentonite beds in the overthrust would prevent percolation through the abutment if the fault zone was properly sealed by the grout curtain. For a distance of 350 feet (106.7m) from the north end of the dam, core holes were drilled from 100 to 200 feet (30.5-61.0m) deep on 3- to 12-foot (.91 to 3.7m) centers and grouted in stages.

On the south abutment, studies revealed that extensive grouting was not necessary; however, the cutoff line was extended, providing grouting in a cavernous area located in that region.

Summary of Foundation Treatment

The grouting program essentially consisted of three major steps: consolidation grouting, shallow curtain or low-pressure grouting, and deep curtain or high-pressure grouting. First, consolidation grouting was done to a depth of 20 to 30 feet (6.1 to 9.1 m), drilled on definite patterns and grouted to an approximate pressure of 30 pounds. Next, the shallow curtain grouting was done through 40-foot-deep (12.2 m) holes angled 20° from the vertical, spaced 4 feet (1.22 m) on centers along the main grout line. Alternating holes were angled in opposite directions, forming a crisscrossing pattern. Holes were then grouted to a final pressure of 60 to 75 psi. Finally, deep-curtain grouting was done, which consisted of core holes on approximately 10-foot (3m) centers drilled to depths ranging from 60 to 130 feet (18.3 to 39.6m). The holes were stage grouted to a final pressure of 100 to 125 psi after concrete had been placed to a minimum elevation of 30 feet (9.1m) above the rock surface.

All grouting began with a thin mix. This was then thickened according to the amount of grout being accepted by the hole. The water-cement ratios ranged from 5:1 to 0.5:1, depending on the type of hole and the area being grouted. All holes were washed with air and water prior to being grouted, and uplift gauges were installed where vertical displacement was anticipated.

The foundation and rim treatment programs resulted in injecting a total of 1,453,700 cubic feet of grout into 477,427 linear feet of grout holes. This illustrates the magnitude of work involved in achieving an acceptable cutoff curtain in the foundation of the dam.

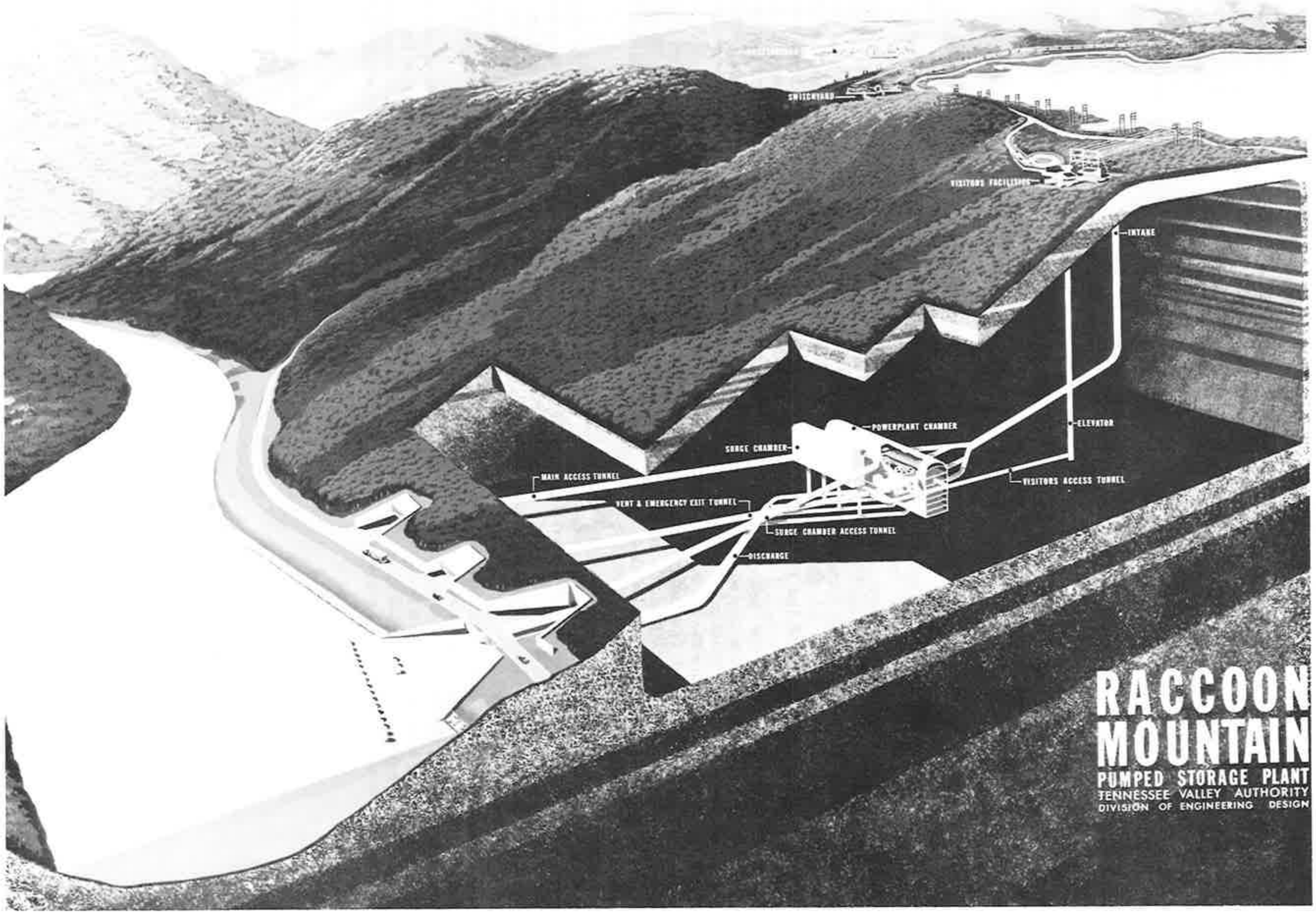

Figure 4. Architect's drawing of Raccoon Mountain Pumped-Storage Plant.

RACCOON MOUNTAIN PUMPED-STORAGE PLANT

Basically, the Raccoon Mountain Pumped-Storage Plant consists of reversible pump-turbines, an upper reservoir, and a lower reservoir. Power is generated by water from the upper reservoir flowing through the turbines and discharging into the lower reservoir. The upper reservoir is then recharged by reversing the turbines and pumping water from the lower reservoir back to the upper. More power is required to fill the upper reservoir than can be produced by flowing this same water through the turbines. Approximately 4 kilowatt-hours of energy are needed to store enough water required to generate 3 kilowatt-hours of energy. Economically, the advantages come from converting low-cost, off-peak energy into high-value, on-peak energy. Power produced from fossil fuel and nuclear generating plants during low-consumption hours is used to store water in the upper reservoir for generation during high-value, high-consumption hours.

Location and Description

Raccoon Mountain Pumped-Storage Plant is approximately 6 miles (9.7 km) west of Chattanooga, in Marion County. It is 26.4 river miles (42.5 km) downstream from the Chickamauga Dam and 19.9 river miles (32.0 km) upstream from the Nickajack Dam. At the time of this writing, the plant was in the final stages of construction and had not yet begun operation.

The plant consists of an upper reservoir containing approximately 38,000 acre-feet of storage volume, a silo-like intake structure located within an intake channel 180 feet (54.9m) wide and 1,382 feet (421.2m) long at the bottom, and an L-shaped impervious core rockfill dam 8,500 feet (2,591m) long with a maximum height of 230 feet (70.1m). Nickajack Lake is incorporated as the lower reservoir. Underground workings consist of a powerhouse chamber 72 feet (22m) wide, 165 feet (50m) high, and 490 feet (149m) long; a surge chamber 52 feet (15.8m) in maximum width and 305 feet (93m) in maximum length; and a transformer vault 55 feet (16.8m) wide, 48 feet (14.6m) high, and 385 feet (117.3m) long. There are approximately 12,000 feet (3,658m) of combined total shafts and tunnels ranging from 8 to 35 feet (2.4 to 10.7m) in diameter. Maximum operating head is 1,040 feet (317m) with a normal range of about 896 to 1,040 feet (273 to 317m). There are four modified Francis, vertical-shaft, reversible pump/turbines rated at 525,000 hp at 1,020 feet (311 m) of head in the generating mode, each with a capacity of 4,265 cubic feet per second at 940 feet (286.5m) of head in the pumping mode. Each motor/generator is capable of producing 382,500 kilowatts of energy in the generating mode or 540,000 hp in the pumping mode. Figure 4 shows the architect's conception of the Pumped-Storage Plant. Figure 5 gives the general plan of the project.

General Geology

Raccoon Mountain is located on the eastern edge of the Cumberland Plateau physiographic province. The rocks underlying this region represent a major sequence of nearly flat Paleozoic strata ranging in age from Cambrian to Pennsylvanian. The plateau is capped by Pennsylvanian sandstones and conglomerates, whereas the base and

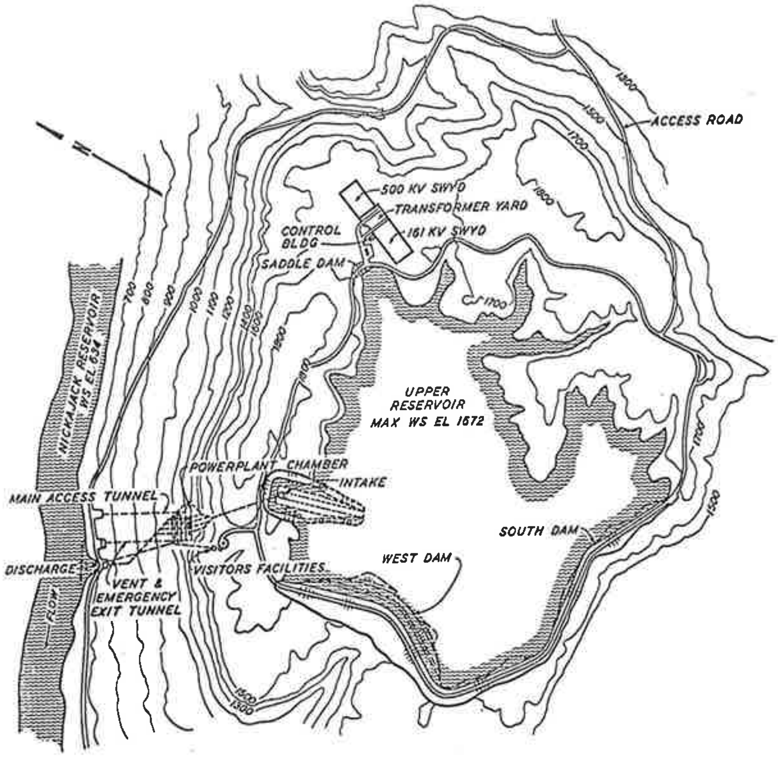

Figure 5. General plan of Raccoon Mountain Project.

lower valleys are underlain by limestones and shales of Mississippian age or older.

Very limited structural deformation has occurred near the site. The average strike and dip are N. 12° E. and 4° W-NW.

Site Geology

The uppermost or youngest formation encountered in excavation was the Sewanee Conglomerate, parts of which were excavated in the intake channel at the north edge of the reservoir.

The Signal Point Shale, which underlies the Sewanee Conglomerate, comprises about 50 percent of excavated rock in the intake channel. Along the alignment of the dam axis the Signal Point Shale was encountered in the northwest part only.

Underlying the Signal Point Shale is the Warren Point Sandstone. This formation was excavated to an elevation of 1,445 feet (440m) in the intake channel and extended in the intake shaft to an approximate elevation of 1,380 feet (412m). It was encounterd along the dam axis in the Laurel and McNabb Branch area and along the eastern parts of the dam.

Below the Warren Point Sandstone is the Raccoon Mountain Formation, which was encountered only in the intake and cable shafts and at a small saddle dam at the northeast end of the reservoir.

The Pennington Formation underlies the Raccoon Mountain Formation and was involved only in the excavation of the intake shaft and cable shaft.

All of the underground excavation, except for the two shafts, was exclusively in the Bangor Limestone, which lies beneath the Pennington Formation. The Bangor provided excellent structural stability for the tunnels and chambers located within Raccoon Mountain (see figures 6 and 7)

Exploration

Prior to construction, an exploration program was carried out from July 1963 through July 1964. All tunnel alignments were explored from 10 to 25 feet (3.0-7.6 m) below invert grade, and the intake channel was drilled to proposed bottom grade. Holes beneath the main dam and saddle dam were drilled 40 to 60 feet (12.2 to 18.3 m) into rock. Four deep holes establishing stratigraphic control were drilled from 260 to 1,190 feet (79-363 m) into rock. In all, 81 wire line core drill holes all Nx (approximately 2-1/4 inch) size were drilled for a total of 13,679 linear feet of core.

An exploration tunnel at the north foot of Raccoon Mountain was started in July 1968 and completed in March 1969. The adit sloped downward for the first 1,800 feet (549m) at a 9 percent grade, and then sloped at a 5 percent grade for another 200 feet (61m). From this point a 50° inclined shaft was driven approximately 50 feet (15.2m) up to an elevation of 600 feet (183m), where a horizontal drift was driven along the axis of the powerplant chamber parallel to the river for 400 feet (122m). Several test stations were established along the tunnel where core drilling was done for further examination of the surrounding rock.

Tests to determine static mechanical properties in the exploratory tunnel included stress relief overcoring and radial jacking surface deformation rosettes. As a result of

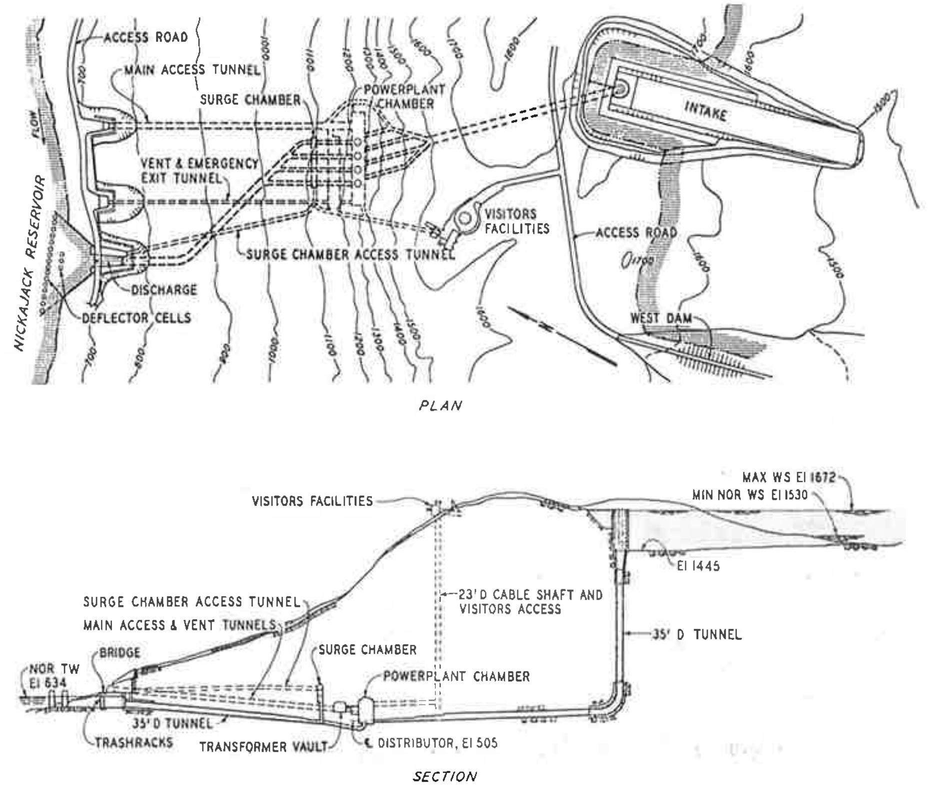

Figure 6. Power facilities at Raccoon Mountain Pumped-Storage Plant. (Courtesy of TVA).

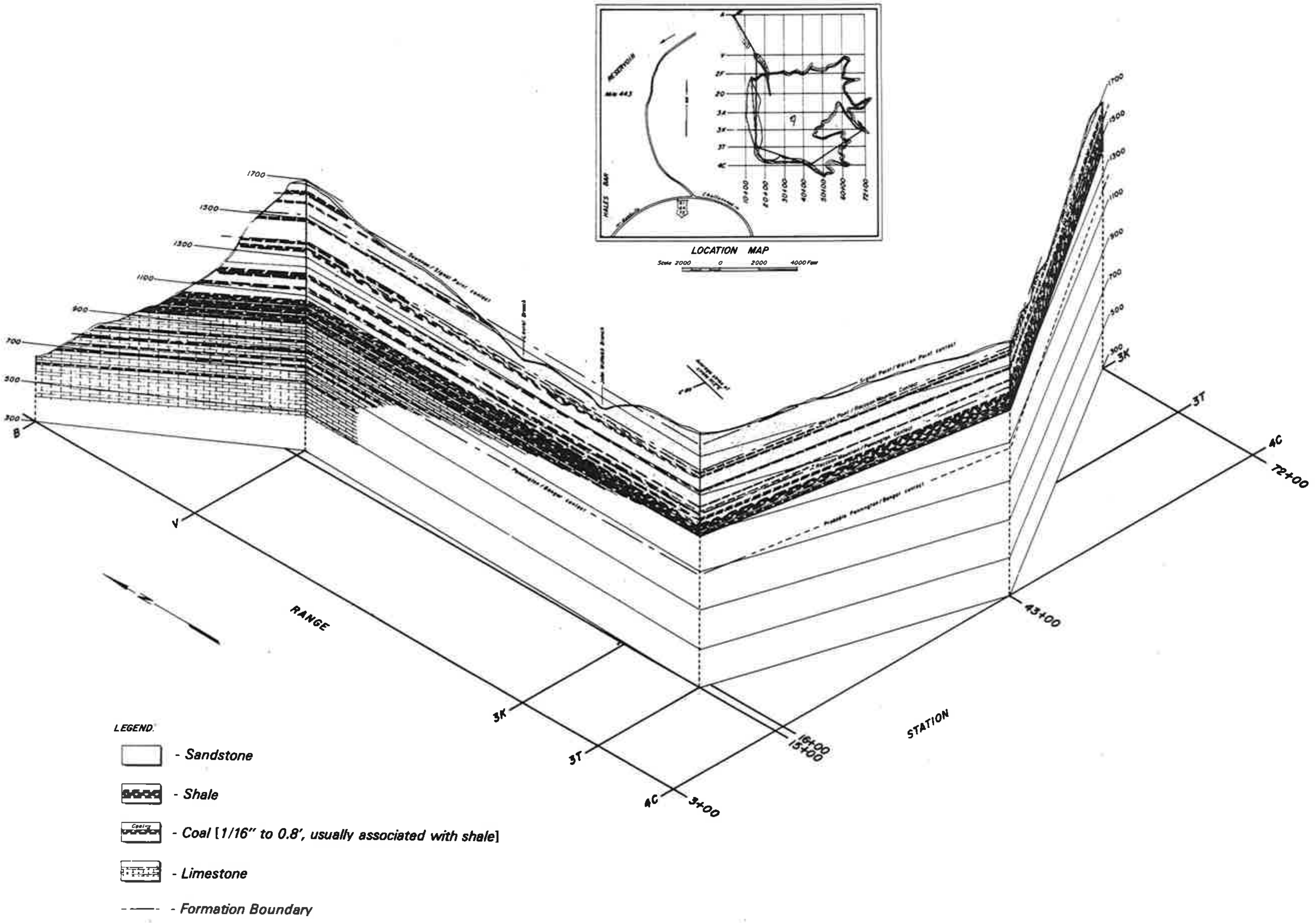

Figure 7. An isometric section of Raccoon Mountain.

these tests the orientation of the underground chambers was changed. Natural gas was encountered in several core holes drilled from test locations in the tunnel. In one hole the pressure of the gas flow amounted to 55 psi. Borehole television indicated that the gas was flowing from either joints, shears, bedding planes or vugs. The gas was allowed to escape, while the tunnel was evacuated, until no traces of the gas (80 percent methane and 20 percent ethane) were found.

Exploration in the form of core drilling, pit excavation, and tunneling continued throughout construction in order to supplement geologic information for the project. Geophysical logging of core holes was performed in holes in the surge chamber to establish geophysical characteristics of the foundation rock.

Foundation Treatment

Curtain grouting beneath the main dam and saddle dam consisted of one to two lines of cap holes drilled from 17.5 to 25 feet (5.3 to 7.6 m) into rock on 4-foot (1.22 m) centers and grouted through a 5-foot (1.52 m) standpipe. This was done in areas where top-of-rock conditions warranted an adequate cutoff along open and weathered bedding planes and joints near the surface, providing a cap so sufficient pressure could be maintained on deeper holes.

Following these lines of cap holes, percussion-drilled holes inclined 30° from the vertical and extending to a depth equal to one-half the maximum pool depth above the hole were drilled on 40-foot (12.2 m) centers and grouted in 25-foot (7.6 m) stages using a pressure equal to 0.5 psi per vertical foot of hole depth. Next, these holes were spilt-spaced to 20-foot (6.1m) centers and again to 10-foot (3.05m) centers, and the above grouting procedure was followed. All holes which took more grout than that required to fill the hole were again split-spaced and grouted, using the above procedure. In most areas, another line of holes, angled in the opposite direction 4 to 9 feet (1.22 to 2.74m) upstream from the first line, was drilled and grouted in the same manner. Approximately 19,600 bags of cement grout were injected into 165,501 linear feet (50,445m) of holes beneath the main dam, and 159 bags of cement grout into 2,796 linear feet (852m) of holes beneath the saddle dam.

From the north end of the main dam for approximately 2,000 feet (610 m) a single line of percussion-drilled holes on 20-foot (6.1 m) centers angled 30° from the vertical and drilled to an elevation of 1,620 feet (494m) were grouted to treat any open areas within the bedrock beneath the rim. All holes were pressure grouted in two stages using pressures equal to 0.5 psi per vertical foot of hole depth. Isolated takes were encountered and split-spaced holes on 10- to 5-foot (3.05 and 1.25m) centers were grouted. The total amount of grout injected was 2,227 bags into 14,327 linear feet (4,300m) of holes.

In the discharge structure area, grouting was done to provide a water seal to reduce river flow to the discharge structure excavation. A complicated series of percussion and core holes, both angled and vertical, was drilled in front of and perpendicular to the discharge tunnel. About 25,000 bags of cement grout were pumped into 15,345 linear feet (4,677 m) of holes in this area to keep water seepage to a minimum during the discharge structure excavation.

During underground excavation of the tunnels and chambers, roof falls were held to only one minor incident by installing rock bolts both in the roofs and in the walls. Borehole extensometers were installed in strategic locations throughout the underground excavation, and data were gathered and plotted weekly. In one location the extensometers indicated unusual downward movement of the roof and made it necessary to install additional rock bolts. This stopped the movement.

Water leakage into the tunnels was not a problem except in the discharge tunnel about 300 feet (91.4 m) from the portal. Water was routed from open bedding planes into pipes, which were tied together and surfaced through the concrete liner. After the concrete liner had cured, cement grout was pumped into the pipes and to the source of the water, stopping the flow.

Geologic work at the Raccoon Mountain Pumped-Storage Plant is essentially completed; however, during reservoir filling, rim investigations will be made daily. The Raccoon Mountain Pumped-Storage Plant will provide visitor access to the underground powerplant, the upper reservoir, and the lakeshore below. Although no water sport activities will be allowed in the upper reservoir, visitors will be welcome to picnic in the grounds and hike the scenic nature trail that will be provided on top of the mountain.

MINERAL RESOURCES (EXCLUSIVE OF COAL) OF HAMILTON COUNTY, TENNESSEE

BY
STUART W. MAHER[1]

INTRODUCTION

The known mineral resources and mineral products of Hamilton County consist almost entirely of materials formed by sedimentary processes and sedimentary materials altered by surficial weathering. Bauxite, cement, clay, chert, coal (discussed separately), hematite (iron ore and pigment), limestone, sand and gravel, and sandstone (dimension and refractory) have all been produced. One barite deposit of epigenetic origin is known. Industries processing imported materials included a coke and chemical plant and a rare earth and thorium plant.

Hamilton County was established in 1819 with Dallas as the county seat. The site of Chattanooga was occupied by Indians until 1837. Chattanooga was incorporated as a town in 1841 and in the years preceding the War Between the States rapidly developed as a rail center and river port. During the war the town and surrounding country were devastated. However, the proximity of iron ore and coking coal to transportation inspired investors to begin rebuilding Chattanooga as an iron and coal center. The gorge of the Tennessee River (through Walden Ridge) provided a route westward for coal. Also, the topography favored transportation routes to Atlanta, another major market for coal. So the physiography and resources had a significant influence on Chattanooga's development. (It is noteworthy that in the late 1860's the iron industry shifted from charcoal to coke in blast furnace charges).

The reserves of iron ore in Hamilton County were possibly overestimated in the post-war boom, and growth in demand for iron and steel was probably underestimated. But in the context of the economy of 1870 a hundred-ton-per-day iron furnace was large. Killebrew reported that in 1873 Chattanooga received, and either used or forwarded, 1,193,000 tons of coal (about 1,085,000 tonne) and that 29,000 tons (26,363t) of pig bar and railroad iron were shipped. (Killebrew and Safford, 1874, p. 523).

The Chattanooga Iron Company was incorporated in 1874 and operated at various periods until 1919. The Citico furnace was put in blast in April of 1884, and operated until 1918. (Chamberlain, M., ms., 1942).

Killebrew listed the Chattanooga Foundry and Machine Works, the Vulcan Works, the Wason Car and Foundry Company, and a rolling mill of Roane Iron Company as working in 1874. (Killebrew and Safford, 1874, p. 524-525).

Yarbrough (1963) says the first known commercial brick plant in Tennessee was the J. Wells Brick Company of Chattanooga, organized in 1871, and that at one time there were seven clay-working operations in Chattanooga. Key James Brick Company, New Citico Brick Company, and Chattanooga Brick Company, in addition to J. Wells, produced common and face brick. The Soddy-Daisy area was long a leading clay-working center. Shortly after the Civil War the B. Miflin Hood Company began production of heavy red stoneware near Daisy. Not long after this, the Herty Turpentine Cup Company began producing cups for the collection of pine sap. Eventually the products of this area included roof, floor, wall and drain tiles, and acid tower clay rings. (Yarbrough, R.E., 1963, thesis, UTK). Brick is currently produced by the General Shale Corporation.

The local availability of coal, clay and cement-grade limestone resulted in the construction of a cement plant by the Signal Mountain Cement Company (since 1947 a division of General Portland Cement Company) in 1922-23.

Just when stone production began in Hamilton County is not known. But limestone was used in early blast furnaces, and Cumberland Plateau sandstone was quarried for furnace liners and hearths. Eli Whitney Blake invented the rock crusher in 1858, a machine promptly used to produce railroad ballast and aggregate for macadam roads. It is probable that crushed stone was produced in Hamilton

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[1] Chief Geologist, Tennessee Division of Geology.

TABLE 1. LOCATION OF BAUXITE IN HAMILTON COUNTY, TENNESSEE BY TENNESSEE COORDINATE SYSTEM

Map No.	Mine or prospect	Tennessee Coordinates	Comments
		Daisy quadrangle, 112-NW	
Al 216	Hixson Mine	279,500N., 2,246,200E.	No data; termed mine by Dunlap and others, 1965; prospect by McIntosh, 1949.
	Harrison prospect (Holcomb)	278,600N., 2,243,600E.	No data.
		East Chattanooga quadrangle, 112-SW	
Al 219	Nixon prospect	262,000N., 2,232,300E.	No data; Dunlap and others, 1965, map. Not shown by McIntosh, 1949. Near trace of Missionary Ridge fault.
Al 217	Isabella Stewart (Perry) Mine	243,700N., 2,226,500E.	Largest mine; about 200,000 tons (182,000t). Site of discovery of bauxite (Ashley, 1911, p. 212; Dunlap and others, 1965, p. 11-13). Operated 1907-1924.
Al 218	Brannon and Montague mine	242,000N., 2,225,300E.	Mined 1920 to 1926 intermittently. 3,248 tons (2,953t) recorded. Two main open cuts, third cut of smaller size.
		Chattanooga quadrangle, 105-SE	
	Wilcox (Bucholz prospect)	238,700N., 2,224,250E.	Body 80 feet (24 m) by 40 feet (12 m), 70 feet (21 m) maximum depth; drilled by USBM-USGS 1942-43 (Dunlap and others, 1965, p. 15-17; McIntosh, 1949).
Al 221	Hornville mine	236,200N., 2,224,400E.	Small mine worked by Perry at time he operated Isabella Stewart mine.
Al 223	McCallie Tunnel prospect	232,300N., 2,222,650E.	Small deposit (3 to 5 tons or 2.7-4.5t) discovered 1906. Reported by Whitlatch (1939, p. 3) as discovery site in district.
AL 224	Bennett mine	222,800N., 2,218,500E.	Two pits; 800 to 1,000 tons (725-910t) production reported (Dunlap, and others, 1965, p. 18).
AL 225	Bennett prospect	222,400N., 2,218,400E.	Shallow pits; regarded favorable by Dunlap and others (1965, p. 19).
		Ooltewah quadrangle, 112-SE	
AL 220	Smith prospect	247,100N., 2,262,900E.	Two shafts, pits and trenches. Discovered about 1936. Drilled by USBM-USGS 1942-43 (Dunlap and others, 1965, p. 21-23; McIntosh, 1949).
AL 222	Willie Moore prospect	239,200N., 2,262,900E.	Pits; drilled 1938, 1942-43. Hard bauxite and kaolin (Dunlap and others, 1965, p. 19-21; McIntosh, 1949).

County for such purposes prior to 1860. Many road surfacing materials have been produced from residual chert accumulations associated with residuum of the Knox Group, the Ft. Payne, and other Mississippian units. In addition, sand and gravel, the latter containing much chert, has been dredged from the Tennessee River and mined along the flood plains.

Bauxite was discovered along the slope of Missionary Ridge in 1904, and subsequently at a total of 12 places. Six of these deposits produced and shipped bauxite between 1907 and 1926. It is estimated that about 300,000 tons (273,000t) were produced from the district. The bauxite was used chiefly for alum manufacture and to a smaller extent for polishes and fillers. (Dunlap and others, 1965).

This brief sketch is designed to illustrate that physiography and mineral resources played major roles in Hamilton County's development. Today these elements continue to influence the region's transportation patterns and its economy. Although iron and coal from local sources are not as significant as they once were, cement, brick, crushed stone, and gravel contribute some $25,000,000 annually to the county's economy.

BARITE

The only known occurrence of barite in Hamilton County is the Shofner prospect, immediately southeast of I-75, 3,000 feet (914 m) southwest of the Shallowford Road interchange. Construction of I-75 obscured this prospect.

Little is known of the history of development, but no production seems to have occurred here. Earlier, several small pits in residual clays were visible and lumps of barite in the clay, mixed with chert, could be seen. This deposit overlies bedrock of the upper Knox Dolomite and is analogous to those in the well-known Sweetwater district. Dunlap (1945, Abs.) reports this deposit is in residual clay from the Copper Ridge Dolomite.

Shofner prospect: Map no. Ba 226, 112-SW., 235,500 N., 2,250,750 E.

BAUXITE

According to tradition, bauxite was discovered in the Chattanooga district during construction of the McCallie Avenue tunnel in 1906 (whitlatch, 1939, p.3). However, Dunlap and others (1965, p.11) reported information from local sources to the effect that it was first found in a well on the Isabella Stewart property in 1904. Ashley (1911, p. 212) lends support to this by stating that in 1911 the Isabella Stewart mine was the only mine operating, and that, "The bauxite was found at this point in a well, which may still be seen on the east side of the pit."

The deposits all occur in unconsolidated materials overlying the Copper Ridge Dolomite of Cambrian age, and all appear to be part of the filling material in old sinkholes developed in that formation. Ten of the twelve known deposits composing the Chattanooga district are along the east side of a 12-mile (19.3 km) strike ridge, Missionary-Big Ridge, above the Missionary Ridge fault. The other two deposits are about 4.5 miles (7.2 km) northeast on the higher ground called Summit Knobs near Summit community. These deposits also occupy sinks in the Copper Ridge Dolomite.

Dunlap's (1965) cross sections clearly show the deposits are generally funnel-shaped, have sharp boundaries with the residual clays, and are mixed with quartz sands and chert-free clays not similar to residuum derived from the Copper Ridge Dolomite. These data confirm the sinkfilling mode of occurrence, and strongly suggest the source materials were derived elsewhere. Bridge (1950, p. 195) suggested aluminous rocks and clays from the Blue Ridge province to the east were carried by streams, and eventually were deposited in sinkholes developed in Cretaceous to Tertiary time, and weathered therein to kaolin and bauxite. The Hamilton County bauxite deposits also contain iron oxides, and lignite or lignitic materials occur in some deposits.

Ashley (1911, p. 212) noted the Missionary Ridge deposits are along a topographic bench and especially at the western edge of the bench: an observation confirmed by Dunlap and others (1965). Ashley speculated that this bench might be controlled by a fault subsidiary to the Missionary Ridge fault. McGavock (1941, p. 226) recognized a deformed zone in the Copper Ridge near Chickamauga Dam along the strike of the bench. Its association with the sinkholes and bauxite deposits is, however, conjectural.

Two general varieties of bauxite have been observed: a soft earthy type (major type), and a hard pisolitic type. The alumina content is higher in the hard ore, and appears to range inversely with silica. Both varieties range from white to cream, to dark-red, depending on iron oxide content. Generally, the iron is highest at the margins of the deposits. The alumina content of the district ores averages 50 percent, silica averages 21 percent, iron oxide and titania 2.5 percent each. Alumina ranges from 25 to 55 percent, silica from 5 to 52 percent, and iron oxide from slightly over 1 to 23 percent.

The largest known deposit, the Isabella Stewart or Perry, was 250-300 feet (76-91m) in diameter and as deep as 100 feet (30m). It is reliably reported to have produced 175,000 to 200,000 tons (160,000 to 180,000t) of ore (Dunlap and others, 1965). All of the production was used for chemical purposes, rather than for metal. Unless additional deposits are discovered in less developed areas, a revival of bauxite mining in the county is improbable (see Table 1).

CLAY AND SHALE

Hamilton County has long been a center for the manufacture of clay and shale products. Reserves of suitable argillaceous raw materials, coal gas for fuel, and transportation facilities combined to favor heavy clayware manufacturing. The proximity to iron-working plants, the post-Civil War construction boom in Chattanooga, and the turpentine industry in nearby states (clay cups were used to collect pine sap) provided good markets.

Beginning in the 1870's the alluvial clays along the Tennessee River and underclays from nearby coal mines were used for common brick and fire brick. Subsequently, shales were mined from the Rockwood (Silurian) and Pennington (Mississippian) formations, as were kaolin clays of probable Tertiary age (see bauxite).

Clay for cement manufacture was obtained from alluvium when the Signal Mountain cement plant was built in 1922. Clay for construction fill has been obtained at various times from the weathered mantle above the Ft. Payne, Rockwood, Chickamauga Group and Knox Group.

Bloating and ceramic tests were conducted by the U.S. Bureau of Mines in cooperation with the Tennessee Division of Geology. These indicate there are possible resources of shale suitable for both face brick and lightweight aggregate manufacturing in Hamilton County.

R.E. Yarbrough (1963, thesis, UTK) states that the J. Wells Brick Company organized in 1871 in Chattanooga. was the first commercial brick plant in East Tennessee. This operation was followed by the Chattanooga Brick Company, New Citico Brick Company, and Key James Brick Company at Chattanooga. An atlas of Chattanooga published by G.M. Hopkins of Philadelphia about 1889 (see Table 2) shows Montague Tile Works and Montague Fire Brick Works with 21 kilns and 5 kilns, respectively, on the riverfront west of the present end of West Ninth Street. Also shown with 6 kilns is the Howard-Park Brick Company on the river at the southern end of Tannery Flats. Two kilns of the Chattanooga Press Brick Company stood on the north side of Citico Creek about half a mile (0.8km) east of the mouth of the creek. Kilns not identified as to ownership are shown on the river bank at the present site of the Manker Patten Tennis Center. A few hundred feet to the east of these last kilns the J.F. Wright Brick Company's kilns are shown.

Hopkins' atlas also shows the Chattanooga Tile Company on the east side of South Market Street at West Main; the Chattanooga River Brick Company on the east bank of the river near the present pumping station; and the Spink-Genter Brick Company on Chattanooga Creek east of South Market near the present pumping station. No kilns are indicated at these sites.

The W. S. Dickey Clay Manufacturing Company operated a plant on the river flood plain adjacent to the present site of Combustion Engineering Company until 1962. This company began operations in Tennessee not long after the Civil War. Clay was mined from deposits of the Pennington near Graysville, Rhea County, and shipped by rail to Chattanooga. The company produced flue pipe, tile pipe, sewer pipe, and various kinds of drain tile. Fire brick was also manufactured from a bed of clay below a coal bed near Montague, Rhea County. The plant closed in 1962.

The B. Miflin Hood Company opened a clay processing plant at Daisy not long after the Civil War. This operation also closed in the early 1960's. Nearby were plants of the Herty Turpentine Cup Company and the Federal Ceramics Corporation. Various heavy ware products, including floor tile, acid tower rings and red stoneware were produced. The Soddy-Daisy area was well-known for its clay turpentine cups. The principal producer was Herty Turpentine Cup Company which closed following a fire in 1941 (Gildersleeve, 1946). (See Table 2.)

TABLE 2. CLAY-BASED PLANTS IN CHATTANOOGA AREA (ATLAS OF CHATTANOOGA, G. M. HOPKINS, 1889)[1]

Montague Tile Works and Montague Fire Brick Works: 105-SE, 240,000N., 2,202,800E.; 21 and 5 kilns, respectively. This appears to be the site later used by W. S. Dickey Clay Manufacturing Company.

Chattanooga Tile Company: 105-SE, 239,400N., 2,207,400E. East of South Market at West Main Street. No kilns explicitly shown.

Chattanooga River Brick Company: 105-SE, 234,700N., 2,203,400E. East edge of Tannery Flats between rail spur and I-124.

Howard-Park Brick Company: 105-SE, 233,000N., 2,202,600E. On Tannery Flats south of Chattanooga River Brick Company. Six kilns marked.

Spink-Genter Brick Company: 105-SE, 230,900N., 2,207,300E. On Chattanooga Creek (old channel) near pumping station south of I-24. No kilns shown.

Chattanooga Press Brick Company: 105-SE, 241,800N., 2,215,400E. On the north bank of Citico Creek about one-half mile (0.8km) below its mouth. 2 kilns marked.

J. F. Wright Brick Yard: 105-SE, 241,400N., 2,211,300E. This approximate location is on the south bank of the river near the WDXB radio tower.

Unknown Company: 105-SE, 241,300N., 2,210,500E. The Atlas shows several brick kilns at the present site of the Manker Patten Tennis Court. Ownership is not given.

Clay industries that can be located include:

W. S. Dickey Clay Manufacturing Company Plant: 105-SE, 239,200N., 2,202,800E. Mine: Graysville, Rhea County.

B. Muffin Hood Company (Federal Ceramics): 112-NW, 311,700N., 2,241,700E., and 310,750N., 2,243,400E., closed in 1960's. Map number 154 (kilns), Map numbers 158, 163, 164, 165 (clay or shale pits).

General Shale Products Corporation: 106-NE, 221,400N., 2,204,700E. Brick plant and shale quarry in Rockwood Formation. Formerly Key-James Brick Company.

Herty Turpentine Cup Company: Near Hood Company (see above). Closed in 1940's.

Clay Producers whose locations are not known:

J. Wells Brick Company: Appears in producer's lists into the early 1940's.

Chattanooga Brick Company: Appears in producer's lists into the early 1940's.

Missionary Ridge Brick Company: Known as a fire-brick manufacturer in the early 1920's. This company probably utilized materials associated with the bauxite deposits nearby. (Case, 1925, p. 80).

New Citico Brick Company: No information available.

Clay for Cement Manufacture:

Clay pits: Approximately 105-SE, 258,900N., 2,197,300E.

The Signal Mountain Division, General Portland, Inc., mines alluvial clay along the Tennessee River near the plant.

Clay for Construction Fills:

Two pits were supplying clay for construction fills in 1964, and two recently operated pits were noted in Chattanooga (Finlayson, 1964).

Active (1964):
105-SE, 242,700N., 2,223,400E. Chickamauga Group residuum.
105-SE, 225,500N., 2,201,650E. Mixed Rockwood, Chattanooga and Ft. Payne residuum.

Abandoned (1964):
105-SE, 225,250N., 2,217,900E.
105-SE, 223,450N., 2,221,400E.
Both in Knox Group residuum.

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[1] Locations are approximate; street names are those used in Atlas.

SHALE RESOURCES

Cooperative studies of the suitability of various shales for lightweight aggregate and ceramic uses have been conducted by the U. S. Bureau of Mines, Division of Geology, and Tennessee Valley Authority. These studies were regional and preliminary, but they should be useful in the search for shales having commercial possibilities.

Samples of shales ranging in age from Cambrian to Pennsylvanian were collected and fired in a rotary kiln to evaluate the lightweight aggregate potential. Extent and temperature of expansion, crushing strength, etc., were measured (Hollenbeck and Tyrrell, 1968). Positive results for samples from formations in or adjacent to Hamilton County are tabulated in Tables 3 and 4.

TABLE 3. FORMATIONS CONTAINING POSSIBLE BLOATING SHALE, IN VICINITY OF HAMILTON COUNTY [1]

Formation	Results[2]	
	Satisfactory	Marginal
Vandever	✓	✓
Whitwell	✓	✓
Signal Point	✓	✓
Raccoon Mountain	✓	✓
Pennington	✓	
Rockwood	✓	

[1] For locations, method of testing, and detailed results see Hollenbeck and Tyrrell, 1968.

[2] Some samples from some of these units were unsatisfactory.

TABLE 4. FORMATIONS CONTAINING POSSIBLE RESERVES OF SHALE SUITABLE FOR CERAMIC USE IN VICINITY OF HAMILTON COUNTY [1]

Formation	Results[2]
Vandever	Face brick, wall tile
Whitwell	Face brick
Raccoon Mountain	Face brick
Pennington	Face brick
Rockwood	In use for brick
Conasauga	Face brick

[1] For locations, method of testing, and detailed results see Hollerbeck and Tyrell, 1968.

[2] Some samples from some of these units were unsatisfactory.

LIMESTONE AND DOLOMITE

Hamilton County contains very large resources of limestone and dolomite east of the Cumberland Plateau (see Tables 5 and 6). Altogether some 53 quarries are known in rocks ranging in age from Ordovician to Mississippian. The largest number of quarries are in the Chickamauga Limestone of Middle Ordovician age. The Vulcan Materials Company quarry near the Chattanooga airport is producing stone in part from this unit. The quarry has a capacity of approximately 2 million tons (1,818,100t) per year.

The second largest source of stone is the Monteagle Limestone of Mississippian age. The large quarry of the Stone Man, Inc., near I-75 at Tiftonia produces over 500,000 tons (454,545t) per year from this formation.

Formerly the Signal Mountain Division of General Portland Cement Company operated a large surface and underground quarry on the east bank of the Tennessee River at the foot of Signal Mountain. The quarry rock is the Bangor Limestone of Mississippian age. The quarry is over 1,500 feet (457 m) long, 500 feet (152 m) wide, and includes three drift entries. The highwall is 80 (24m) to 100 feet (30m) or more high. This quarry was abandoned (1956) in favor of a new site farther down the river in Marion County. The old quarry supplied limestone to a plant with a rated capacity of 1,750,000 bbls. of cement per year.

TABLE 5. LOCATIONS OF LIMESTONE AND DOLOMITE QUARRIES IN HAMILTON COUNTY, TENNESSEE BY TENNESSEE COORDINATE SYSTEM

Map No.	*Tennessee Coordinates*	*Formation*		*Comments*
		Daisy quadrangle, 112-NW		
100	280,700N., 2,244,500E.	Och	Chickamauga Limestone	Opened, 1962, Operator: Boyd Hutton
99	282,000N., 2,246,500E.	Och	Chickamauga Limestone	Abandoned
101	279,900N., 2,234,000E.	Och	Chickamauga Limestone	Abandoned 1959
98	304,300N., 2,229,500E.	Mn	Newman Limestone	Abandoned
97	310,200N., 2,244,300E.	Mn	Newman Limestone	
		Chattanooga quadrangle, 105-SE		
106	259,400N., 2,194,000E.	Mb	Bangor Limestone	Cement rock; abandoned; both underground and surface
	244,300N., 2,223,000E.	Och	Chickamauga Limestone	Very old quarry - about 1880
112	246,600N., 2,215,400E.	Och	Chickamauga Limestone	Abandoned
118	240,800N., 2,223,100E.	Och	Chickamauga Limestone	Abandoned
117	240,200N., 2,220,900E.	Och	Chickamauga Limestone	Abandoned (includes 3 ft. bentonite; used to adulterate candy [2]
120	226,500N., 2,218,100E.	Och	Chickamauga Limestone	Abandoned
121	225,500N., 2,216,600E.	Och	Chickamauga Limestone	Abandoned; bentonite
		Hooker quadrangle, 106-NW		
123	221,200N., 2,179,200E.	Mn	Newman Limestone	Large. About 580,000/tpy Stone Man Co.
124	216,850N., 2,170,900E.	Mm?	Monteagle Limestone	Symbol on quad -- no other data.
		Ooltewah quadrangle, 112-SE		
116	240,100N., 2,285,500E.	Mn	Newman	Abandoned
108	258,000N., 2,288,000E.	Oh- Ocu	Hermitage and Upper Carters Formation	Abandoned
		East Chattanooga quadrangle, 112-SW[1]		
119	238,250N., 2,238,350E.	Ochl	Lower Chickamauga Limestone	
114	244,600N., 2,238,850E.	Och	Chickamauga Limestone	Very old; evidence of hand tools. Ls.
	241,000N., 2,238,000E.	Och	Chickamauga Limestone	Vulcan Materials. About '54, '55, Active (2 million/metric tpy)
113	245,650N., 2,225,675E.	Och	Chickamauga Limestone	
115	245,000N., 2,241,850E.	Oma	Mascot Dolomite	
111	248,600N., 2,225,800E.	Och	Chickamauga Limestone	
122	223,400N., 2,253,600E.	Єcu	Upper Conasauga Limestone	
105	266,300N., 2,233,200E.	Och	Chickamauga Limestone	TVA, for Chickamauga Dam 1938. 1,199,539 tons (1,088,222t)
107	257,600N., 2,232,600E.	Och	Chickamauga Limestone	TVA
109	255,700N., 2,230,900E.	Och	Chickamauga Limestone	
110	252,900N., 2,232,300E.	Och	Chickamauga Limestone	
		Snow Hill quadrangle, 112-NE[1]		
102	276,250N., 2,266,600E.	Єcr	Copper Ridge Dolomite	TVA quarry.
103	271,850N., 2,276,300E.	Ok	Knox Group	WPA quarry.
	313,700N., 2,298,300E.	Oma	Mascot Dolomite	Corps of Eng.
93	313,350N., 2,269,800E.	Ochl	Lower Chickamauga Limestone	
104	272,150N., 2,285,000E.	Ochl	Lower Chickamauga Limestone	
		Birchwood quadrangle, 119-SW[1]		
	317,200N., 2,299,800E.	Oma	Mascot Dolomite	Small

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[1] Data from R.L. Wilson, in preparation.

[2] A.R. Leamon, personal communication.

TABLE 6. LIMESTONE AND DOLOMITE QUARRIES SHOWN ON THE 30-MINUTE CHATTANOOGA FOLIO (HAYES, 1894).[1]

Tennessee Coordinates	Formation	Use
	Chattanooga quadrangle, 105-SE	
245,500N., 2,221,200E.	Chickamauga	"Road stone"
237,200N., 2,207,700E.	Chickamauga	"Road and building stone"
231,900N., 2,215,600E.	Chickamauga	"Road stone"
230,400N., 2,196,100E.	"Bangor"	"Road stone"

[1] Quarries cannot be precisely located to modern maps, nor in some instances is there evidence on the ground. Therefore, the locations given are approximate.

SAND AND GRAVEL

The Dixie Sand and Gravel Company dredges the Tennessee River and operates a mill in Chattanooga. The company began operations as the Bible Sand and Gravel Company in 1900, and has changed ownership several times. The mill is on the east bank of the river on Moccasin Bend (Tennessee Coordinates 241,300N., 2,203,000E.). The dredged material is screened and most of the gravel crushed in a rod mill. Some gravel is sold for aggregate (Finlayson, 1964, p. 3). Capacity is about 500,000 tons per year.

Finlayson (1964, p. 3) reported that the Southern Sand and Gravel Company began dredging in 1962. However, this company does not appear in the 1975 Directory of Tennessee Mining Operations, nor in the Mineral Yearbooks for 1962 to date.

Whitlatch (1939, p. 10-11) reported that foundry sand was being produced near St. Elmo in 1922 or 1923. An unpublished manuscript (T.D.G. files) by J. H. C. Martens describes two deposits consisting of residuum and talus along the east slope of Lookout Mountain. Martens states that W. J. Bradford was operating these pits, one "on his property directly east of the street car terminus" in St. Elmo, and the other "from a bank 1/4 mile (0.4km) south, at the Georgia state line . . . ." Martens' undated manuscript describes the pit at St. Elmo as "a quarter mile long" parallel to the base of the mountain, and "relatively narrow." He reports a highwall up to 25 feet (7.6m) high. This may be the site reported as a pit for fill by Finlayson (1964, p. 7) at Tennessee Coordinates 227,500N., 2,201,650E.

Sand and gravel have also been produced from unconsolidated deposits along Chickamauga Creek in the vicinity of Hixson. Swingle and Luther (1964) list two operating and two idle pits about a mile (1.6km) north of Hixson. The larger active pit was operated by M.N. Hartman in 1964. Operations began in 1930 and have continued intermittently since that date. Test drilling reportedly showed an average thickness of 20 feet (6.1m). The pits covered 5 to 7 acres (2 to 3 hectares), and had produced about 200,000 tons (182,000t). The Hartman pit is alluvial material related to Chickamauga Creek. It is at Tennessee Coordinates 281,100N., 2,231,000E.

The inactive (1964) pits were smaller and less information as to thickness, size, etc. could be obtained. Swingle (1964, p. 10) noted two terrace levels: a lower, more sandy one approximately 20 feet (6.1m) above the creek level; and a higher strath 25 to 30 feet (7.6-9.1m) above water level, but more clayey and less productive of sand. The inactive pits are at Tennessee Coordinates 299,200N., 2,234,400E. and 286,500N., 2,228,900E.

Jimmy Walker was producing sand and gravel from Chickamauga Creek in 1964. This operation was about half a mile (.8km) downstream from the U.S. Highway 27 bridge over the creek, where the stream channel is choked with Pennsylvanian sandstone alluvial detritus.

Walker was removing material from the channel and crushing it in a mill on the creek bank. Pea gravel and sand were produced by the mill. The capacity was 200 tons per day. (Swingle, 1964, p. 12). This operation was at Tennessee Coordinates 300,500N., 2,233,900E.

Luther and Swingle (1964) found an operating sand pit 1-1/2 miles (2.4km) north of Fairmount (Tennessee Coordinates 295,300N., 2,206,250E.). The pit was opened in 1955, and sand and minor amounts of gravel were extracted from the Needleseye Member of the Vandever Formation.

There are numerous other small pits in various places on the Plateau part of Hamilton County. Nothing is known of their history or production. They are small, generally overgrown, and are not regarded as significant.

The numerous residual chert sources (discussed under the heading "Chert"). fine crushed limestone, and stone sand, have provided adequate, economical sources for aggregate and other uses in Hamilton County. Hence there has been little incentive to produce silica sand for these purposes.

CHERT

Chert has been produced and widely used in Hamilton County. The Copper Ridge, Chepultepec and Longview formations of the Knox Group are particularly siliceous. The Mascot Dolomite also produces abundant chert on weathering. The chert-charged residual clays above these units have supplied most of the chert used. The Fort Payne of Mississippian age is an extremely siliceous rock and has supplied chert in some places. Much of the gravels in streams of the county are chert fragments rather than vein quartz pebbles (see Sand and Gravel).

The Knox Group is the most widely exposed unit in Hamilton County. It crops out over about 40 percent of the area. Its areal extent, coupled with weathering to depths of over 150 feet (46 m) results in abundant, readily available supplies of chert. It is used for road surfacing, fill material, and concrete aggregate.

Seven chert pits were identified as "active" by the Tennessee Division of Geology in the 1960's and 1970's. Numerous other "idle" or "abandoned" pits (Table 7) were also identified.

TABLE 7. LOCATIONS OF CHERT PITS IN HAMILTON COUNTY, TENNESSEE, BY TENNESSEE COORDINATE SYSTEM

Tennessee Coordinates	Remarks
Chattanooga quadrangle, 105-SE	
233,200N., 2,224,400E.	Active, 1963, Knox
222,900N., 2,219,800E.	Active, 1963, Knox
221,200N., 2,202,500E.	Active, 1963, Knox
240,400N., 2,199,500E.	Abandoned, Ft. Payne
264,500N., 2,216,900E.	Abandoned, Knox
261,700N., 2,218,000E.	Abandoned, Knox
261,800N., 2,214,100E.	Abandoned, Knox
254,500N., 2,213,100E.	Abandoned, Knox
252,900N., 2,212,700E.	Abandoned, Knox
249,300N., 2,208,400E.	Abandoned, Knox
249,000N., 2,210,200E.	Abandoned, Knox
Fairmount quadrangle, 105-NE	
283,250N., 2,223,300E.	Abandoned, Knox
273,450N., 2,218,050E.	Abandoned, Knox
Graysville quadrangle, 111-NE	
361,200N., 2,262,250E.	Abandoned, Ft. Payne
Soddy quadrangle, 111-SW	
341,300N., 2,254,000E.	Abandoned, Copper Ridge
Daisy quadrangle, 112-NW	
274,000N., 2,226,700E.	Abandoned, Knox
281,900N., 2,229,450E.	Abandoned, Knox
280,000N., 2,247,800E.	Abandoned, Newman
288,700N., 2,224,800E.	Abandoned, Ft. Payne
307,100N., 2,240,700E.	Abandoned, Newman May be alluvial in part
Snow Hill quadrangle, 112-NE[1]	
272,475N., 2,264,400E.	Active, 1975, Knox
311,775N., 2,284,775E.	Active, 1975, Knox
272,150N., 2,264,800E.	Inactive, Knox
270,800N., 2,265,150E.	Inactive, Knox
300,200N., 2,284,150E.	Inactive, Knox
288,050N., 2,279,300E.	Inactive, Knox
Ooltewah quadrangle, 112-SE[1]	
234,775N., 2,268,300E.	Intermittent production, Knox
Ringgold quadrangle, 113-NE[1]	
221,100N., 2,262,275E.	Intermittent production, Chepultepec
220,950N., 2,262,100E.	Intermittent production, Chepultepec
220,450N., 2,264,175E.	Intermittent production, Chepultepec
221,150N., 2,297,975E.	Intermittent production, Copper Ridge
Birchwood quadrangle, 119-SW[1]	
339,200N., 2,302,300E.	Inactive, Chepultepec
East Chattanooga quadrangle, 112-SW[1]	
235,000N., 2,245,650E.	Active, Knox
259,450N., 2,247,850E.	Active, Knox
233,300N., 2,244,150E.	Inactive, Knox
227,275N., 2,243,400E.	Inactive, Knox
240,750N., 2,230,900E.	Inactive, Knox
239,275N., 2,229,500E.	Inactive, Knox
238,000N., 2,227,500E.	Inactive, Knox
247,350N., 2,230,150E.	Inactive, Knox
249,075N., 2,234,100E.	Inactive, Knox
239,350N., 2,226,000E.	Abandoned, Knox
239,800N., 2,227,400E.	Abandoned, Knox
241,050N., 2,228,075E.	Abandoned, Knox
249,350N., 2,229,050E.	Abandoned, Knox
East Ridge Quadrangle, 113-NW[1]	
221,400N., 2,261,950E.	Inactive, Knox

[1] R. L. Wilson, in preparation.

IRON

Deposits of hematite in the Rockwood Formation (Silurian), nearby Pennsylvanian coking coals, and limestones of Mississippian age attracted much attention to Hamilton County following the Civil War. As early as 1849 the Chattanooga Foundry and Machine Works was developed on the Tennessee River's southeast bank near the present site of the Southern Railway's yards. (Killebrew and Safford, 1874, p. 524).

Killebrew (1874, p. 519) states that, "During the Civil War nearly all the business houses and private dwellings [in Chattanooga] were destroyed . . . The close of the war left Chattanooga nothing but a military post . . ." The iron industry, both primary and secondary, was a major element in the post-war recovery. In 1873 Killebrew listed the Chattanooga Foundry, the Vulcan Works, Wason Car and Foundry Co., Roane Iron Company's rolling mill (railroad iron), Chattanooga Iron Co. (blast furnace), and the Citico furnace (blast furnace, under construction) as important industries. (1874, p. 524-526.)

The Chattanooga Coal and Iron Company's furnace was built in 1874, and rebuilt in 1885. The original furnace had a capacity of 25 tons (22t) per day. It was built to produce pig iron for conversion to Bessemer steel. Brown ores from Georgia and Alabama were blended with locally mined hematite. However, scarcity of high quality ore in adequate volume made this plan unworkable. The company was reorganized in 1885 and a furnace of 80-tons (72t) daily capacity was built to make high phosphorus, foundry pig iron. Between 1895 and 1911 the furnace operated intermittently under various owners. Profitability was restricted due to high costs for imported ore and coke. In 1911 the properties were bought by the "the Lacey-Buek interests," who built a 200-ton (180t) per day furnace, and developed new ore deposits in Georgia and new coke ovens in Sequatchie County, Tennessee. This furnace operated until 1919 when the financial decline caused a sharp drop in pig iron prices. The furnace was sold and scrapped in 1928 (Chamberlain, 1942, ms.).

The site of these furnaces is the east bank of the Tennessee River west of Riverfront Parkway, the present location of Combustion Engineering Corporation.

The Citico Furnace Company was incorporated in 1882, and a furnace erected and placed in production in April, 1884. The furnace was rebuilt in 1895 with a capacity of 40,000 tons (36,363t) per year. Foundry pig iron was produced. Chamberlain says that over 80 per cent of the iron was sold to local foundaries. Coke from Hamilton (Soddy area), Sequatchie, and Marion counties, Tennessee, and from Georgia, and hematite from mines in Roane and Rhea counties, Tennessee, supplied the furnace. Originally the iron ore was shipped on river vessels, but after 1911 by rail. In 1901 hematite mines north of Gadsden, Alabama, were bought, and in 1910 property near Attalla, Alabama, was added. The new Soddy Coal Company, source of the Citico furnace's fuel supply was sold in 1911; and the furnace was scrapped and not replaced. Citico furnace was on the south bank of the Tennessee River between the railroad and Citico Creek near the mouth of the creek.

Iron mining in Hamilton County was in four outcrop belts of the Rockwood Formation of Early Silurian age. The Rockwood crops out along the Cumberland Plateau Escarpment, with the exception of an interval of about 6 miles (10km) from near Daisy to just north of Chickamauga Creek. In this distance the Rockwood is missing because of faulting. Other outcrops are on either limb of the Lookout Valley anticline, on the Stringers Ridge anticline, and on the western limb of the Whiteoak Mountain syncline. The Rockwood contains two to four seams of hematite. The ore zones are separated by beds of shale. Burchard points out that the thickness ranges considerably: for example, the Lookout Valley belt showed 5 inches to 33 inches (13-84cm) of hematite. The beds on Stringers Ridge range from 2½ feet to 3½ feet (.8-1.1m), but are much folded. Where weathered and leached the ores contained over 50 percent iron, but where fresh and unleached the iron content was about 30 percent. (Burchard, 1913, p. 83).

Both surface and underground mining methods were used. One such mining area was the Kuntz and Ryan mine, active in 1906, which supplied the Citico furnace. Burchard locates these operations ".85 miles northwest of Hill City (North Chattanooga)—Chattanooga bridge." (1913, p. 90, and Plate II). This is probably an entry on the north side of the railroad spur on the south side of Stringers Ridge, 0.1 mile (0.16 km) west of the I-124 Manning Avenue interchange. Here Burchard found ore seams totaling 3 feet 5 inches (.9 m 13 cm), 2 feet 9 inches (.6 m 23 cm), and 2 feet 5 inches (.6 m 13 cm), dipping 55 degrees northwest.

Elsewhere, high quality ore was collected as detrital pebbles eroded from the ore beds, or mined from outcrops of the seams, as near Ooltewah, and used for paint pigment. Ores for pigment were restricted to deeply leached, very friable hematite.

The U. S. Department of Interior (1959) estimated Hamilton County produced 6,331 tons (5,755t) of red iron ore from 1881 to 1957. Most of the ore smelted in the Citico and Chattanooga Iron Company furnaces was mined in Rhea and Roane counties, Tennessee, or northwestern Georgia and northern Alabama.

DIMENSION STONE

Several formations have supplied dimension stone for local use in Hamilton county. The Chickamauga Group limestones were used for footings, chimneys, walls, and for flagging. Hayes (1894) reported use of the "lower part of the Chickamauga" for dimension stone, particularly, and cited quarries "near Hickson" (sic). He also noted the use of sandstone from the Rockwood and Pennsylvanian for foundations.

Swingle and Luther (1964) reported removal of boulders of Pennsylvanian sandstones from the valley of Chickamauga Creek near Daisy. Some of these orthoquartzite cobbles were used for field stone. Swingle reported that the largest boulders were 24 inches (61cm) in diameter, and most ranged from 3 inches to 12 inches (8 to 30cm) in diameter.

Swingle and Luther locate an abandoned dimension stone quarry "on the slope of Freeman Ridge (Tennessee Coordinates 284,300N., 2,190,800E.)" (1963, p. 10). The Newton Sandstone was quarried here, and resembles the "Crab Orchard" stone of the Crossville area. The beds are flaggy, orthorquartzitic, various shades of buff to brown, and quite durable.

REFRACTORY SANDSTONE (BAUKITE)[1]

A quarry was developed in 1924 one mile (1.6km) west of Apison by a Knoxville group, the American Baukite Company (Wilson, R.L., in prep.; Anon., 1927). The quarry rock is a fine-grained sandstone unit in the Hartselle Formation of Mississippian age.

R. E. Davison, president of the company, described the deposit as 100 to 150 feet (30-45 m) thick, extending a mile and a half to two miles (2.5-3km) along the strike, and dipping 35 degrees southeast. Davison reported that "soft sedimentary materials or deposits which seem to be the result of trituration of the baukite rock, redeposited at the lower edge of the . . . deposit" and mixed with ground sandstone yielded a superior refractory (1927, p. 185). The material was used for lining steel ladles, crucibles, furnaces, and for saggers.

The term "baukite" is said to derive from the Bau district, Austria. The cartographers of the Ooltewah quadrangle undoubtedly misnamed "Bauxite Ridge."

Production continued from 1924 until about 1949. The quarry is on the Ooltewah quadrangle, 112-SE , at Tennessee Coordinate location 230,150N., 2,287,100E., and shows as map number 215 on Plate 1.

TABLE 8. ANALYSIS OF BAUKITE (DAVISON, 1927)

SiO_2	96.19 %
Al_2O_3	1.86
Fe_2O_3	.29
TiO_2	.91
CaO	.07
MgO	.10
Loss	.58

OIL AND GAS WELLS

BY

ROBERT C. MILICI

Two oil tests were drilled in Lookout Valley west of Red Bank-White Oak. Well No. 1 (Bunch, A.J. No. 1; Map No. 229) was completed sometime in the 1920's and went to a depth of approximately 1200 feet (365.8m). It is reported that the well had a strong show of gas at 800 feet (243.8m). The well, now called C.E. Phillips No. 1, was drilled deeper in 1971 and 1972 to 2,585 feet (788m) and ended in the Knox Group. According to the lessee, the well tested 124 Mcf/d from a depth of 680 to 700 feet (207-213m) after acid treatment, and is currently shut in.

The C. E. Phillips No. 2 well (Map No. 228) was drilled in 1972 to a total depth of 1,162 feet (354 m). The well had shows of gas at 555 to 560 feet (169-171m), and 922 to 934 feet (281-285m). According to records filed with the Tennessee Division of Geology, these zones were acidized and sand fractured, but no test was filed. The well apparently ended in the Stones River Group and is considered dry and abandoned.

Small amounts of natural gas were encountered in a diamond drill hole sunk by the Tennessee Valley Authority into Mississippian strata beneath Raccoon Mountain during foundation explorations for the Raccoon Mountain pumped-storage project. The gas apparently was contained in porosity in oolitic zones in the limestone.

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[1] H.M. Payne (1927) reported baukite fused at cone 32 to 33.

[2] Chief Geologist, Tennessee Division of Geology, when this report was prepared.

COAL MINING IN HAMILTON COUNTY, TENNESSEE

BY
A. RAY LEAMON[1]

INTRODUCTION

Hamilton County is located at the southeast corner of the Tennessee coal field and is one of the 22 counties that contain coal reserves. Coal measures are present in parts of the Graysville, Brayton, Soddy, Henson Gap, Daisy, Fairmount, Ketner Gap, Wauhatchie and Chattanooga 7½-minute quadrangle maps, all of which are in the western half of the county.

The entire county is drained by the Tennessee River and its tributaries, which are principally Suck Creek, Falling Water Creek, Chickamauga Creek, Little Soddy Creek, Possum Creek, Rock Creek, and McGill Creek. All of the streams draining Walden Ridge have cut deep gorges along many of which the coal seams have been opened and mined.

The coals that occur in the county lie below the Rockcastle Conglomerate and are in the Crab Orchard Mountains and Gizzard Groups.

The major coal operations of Hamilton County for the years 1943-1977 are listed in Table 1 of this chapter. Table 2 lists drill holes, and Table 3 is a detailed listing of Hamilton County's coal mines.

EXPLORATION

A large part of the coal-producing area of Hamilton County was owned by Durham Coal and Iron Company until 1931, when it was sold and later divided into three tracts, which are the Lahiere-Hill property, Wharton property and the Lacey property. Most of the prospecting in the county in recent years has been done on these three tracts of land.

Before selling the property, Durham Coal and Iron Company drilled 27 holes to determine the extent and quality of the reserves. Several companies have drilled coal-bearing areas in Hamilton County since the Durham Coal and Iron Company ceased operations in 1931.

Over the past seven years the Belle-Terre Quebec Mines, Ltd. of Canada; Fuqua Energy Corp.; Eastern Coal Associates of Beckley, West Virginia; Transco of Houston, Texas; Southeast Coal and Gas; and Ashland Oil Company have drilled the area. Also, in 1952 the State of Tennessee drilled 5 holes in the area, and TVA is presently drilling south of Rock Creek.

PRESENT COAL OPERATIONS

With the exception of Russell Mining Company (map no. 12), which operated mines in the area from 1955 to 1973, not much coal has been mined in the county since 1930. At the present time one surface mine and two underground mines are active in the county. The surface mine is west of Bakewell, and is in the Number 12 seam. At this mine the seam dips about 30° to the northwest. Although some deep mining has been done in the area, no mine maps are available. The coal averages about 30 inches (76cm) in thickness. The mine is operated by Coffee Coal Company (map no. 1).

One underground mine is in the Sewanee seam 2 mi. (2.3km) northwest of Soddy and is operated by M.C. Coal Company (map no. 2). The coal averages about 40 inches (102cm) in thickness and is relatively low in sulfur and ash content.

The other underground mine (map no. 3) is also in the Sewanee seam. This mine is operated by the Signal Coal Company.

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[1] Geologist III, Tennessee Division of Geology.

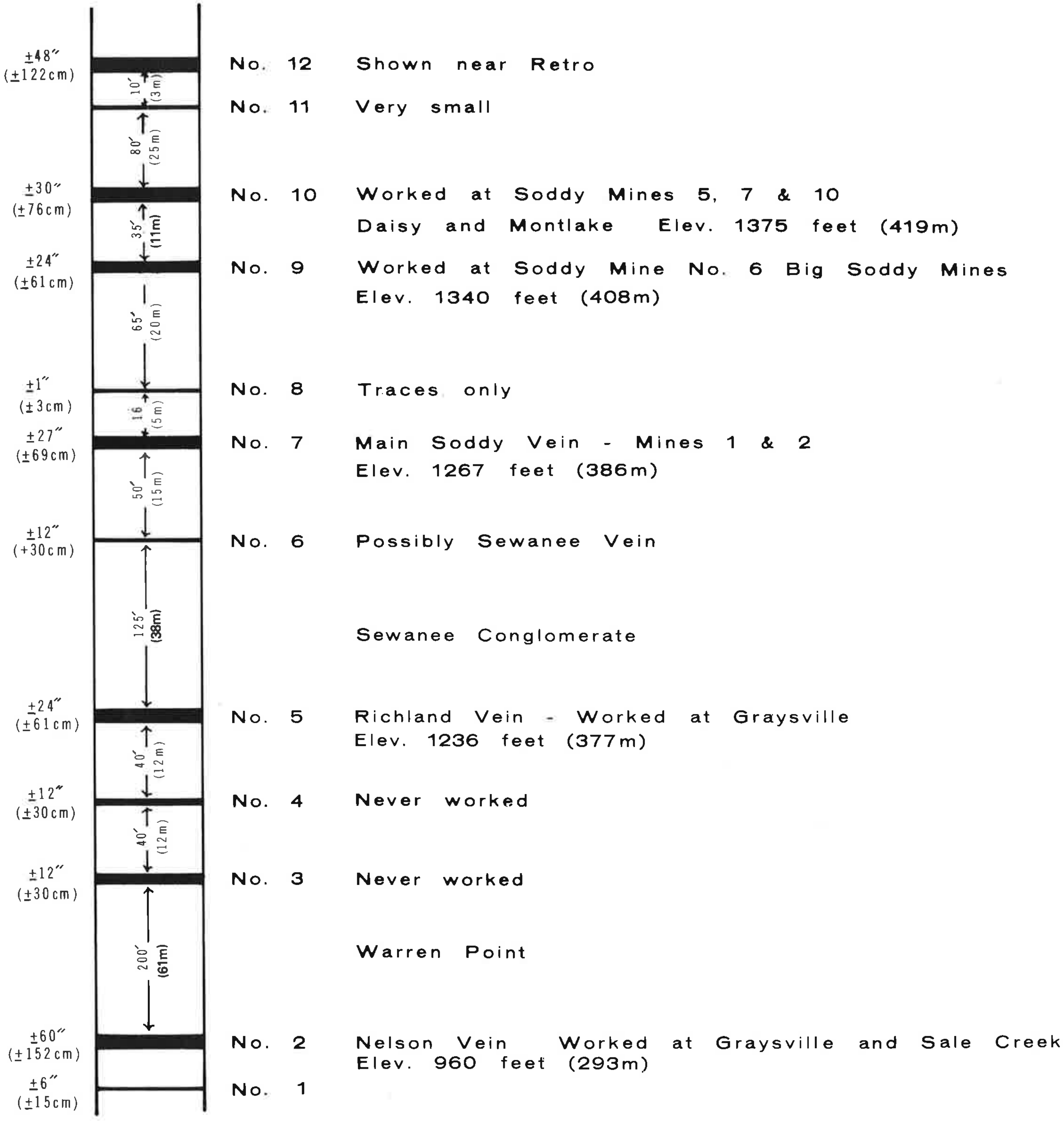

Figure 1. Shown is a general coal section in the area of Soddy, Tennessee, copied from an original made by the Durham Coal and Iron Company. One major difference in their section as compared to the correlations presently used by the Tennessee Division of Geology is the position of the Richland Seam No. 5 under the Sewanee Conglomerate; while the TDG correlates the Richland with No. 7, and places the coal above the conglomerate.

TABLE 1. MAJOR COAL OPERATIONS IN HAMILTON COUNTY, TENNESSEE.

Map No.[1]	Operating Company	Mine Name	Seam	Remarks
1	Coffee Coal Co.	No. 7 Strip	No. 12	Active-opened 4-77
2	M. C. Coal Co.	No. 1 deep	Sewanee	Active-opened 1976
3	Signal Coal Co.	Unknown	Sewanee	Underground Mine
4	Unknown	Unknown	Lantana	Abd. strip pit
5	Serodina Coal Co.	Serodino	Lantana	Abd. strip pit
6	New Daisy Coal Co.	Daisy	Sewanee	Operated 1866-1910
7	Montlake Coal Co.	Montlake	Sewanee	Operated 1903-1931
8	Montlake Coal Co.	Montlake	Sewanee	Operated 1903-1931
9	Unknown	Unknown	Sewanee	Abd. strip pit
10	Unknown	Unknown	Sewanee	Abd. strip pit
11	Unknown	Unknown	Morgan Springs	Mined 1970
12	Russell Coal Co.	Russell	Sewanee	Operated 1955-1973
13	Durham Coal & Iron	Big Soddy No. 7	Sewanee	Operated 1903-1924
14	Durham Coal & Iron	Big Soddy No. 3	Sewanee	Operated 1903-1924
15	Hamilton Coal Co.	Retro	Richland	Operated 1903-1908
16	Durham Coal & Iron	Soddy No. 1	Richland	Operated 1866-1931
17	Durham Coal & Iron	Soddy	Richland	Operated 1866-1931
18	Durham Coal & Iron	Soddy	Richland	Operated 1866-1931
19	Durham Coal & Iron	Sale Creek	Nelson	Operated 1843-1931
20	Unknown	Unknown	Nelson	Abd. underground mine

[1] See Plate 1 for map number location.

TABLE 2. DRILL HOLES IN HAMILTON COUNTY, TENNESSEE
(TENNESSEE VALLEY AUTHORITY, 1959)

Map No.[1]	Exploration Company	No.	Approx. Surface Elev. (ft.)	[m]	Coal Depth (ft-in)		[m]	Seam	Thickness (ft-in)		[m]	Remarks
21	Southeast Coal, Oil & Gas	8	1300	396	108 320 329 340 463 508	4 11 0 3 7 8	33 98 100 104 141 155	? ? Nelson ? ? ?	0 0 2 0 0 0	5 3½ 5 7 7 7	.125 .095 .735 .175 .175 .175	Drilled 1974 Total depth 701'0"
22	Transco CP-25		1850	564	no log							Drilled 1976
23	Transco CP-24		1720	514	no log							Drilled 1976
24	State of Tenn.	2	1760	526	135	0	41	?	2		.61	Drilled 1952 T.D.=191'0"
25	Transco CP-23		1890	576	no log							Drilled 1976
26	Transco CP-16		1910	582	no log							Drilled 1976
27	Belleterre	4	950	290	118 154 215	0 0 0	36 47 65	? Nelson[2] Goodrich	1 2 0	4 8 7	.405 .810 .175	Drilled 1976 T.D.=290'
28	Transco CP-19		1730	527	no log							Drilled 1976
29	Belleterre	3	935	285	96 128 160 194	5 7 5 8	29 39 49 59	? Nelson ? ?	0 3 0 1	9 3 3 0	.225 .985 .075 .305	Drilled 1973 T.D. 317
30	Durham Coal & Iron	2	882	269	81	0	25	Nelson	2	4	.710	Drilled 1906 T.D.=204'8"
31	Durham Coal & Iron	1	882	269	Drilled below crop of Nelson							Drilled 1906 T.D.=190'6"
32	Belleterre	2	996	304	162 185 195 207 222 266	0 9 3 1 9 7	49 57 59 63 68 81	? Nelson ? ? ? ?	1 2 0 0 0 0	2 3 10 5 6 11	.350 .685 .250 .125 .150 .275	Drilled 1973 T.D.=305'0"
33	Belleterre	1	870	265	60 88 106 124 177	7 0 4 4 6	18 27 32 38 54	? Nelson ? ? ?	2 1 0 0 0	4 0 6 5 5	.720 .305 .150 .125 .125	Drilled 1973 T.D. 252'
34	Transco CP-8		1715	523	no log							Drilled 1976
35	Transco CP-4		1720	524	no log							Drilled 1976
36	Durham Coal & Iron	20	1640	500				12 Sewanee	2 1	0 11	.610 .575	Drilled 1911
37	Durham Coal & Iron	15	1810	552				Sewanee Richland	1 3	9 4	..525 1.015	Drilled 1911
38	Durham Coal & Iron	11	1580	482				Lantana Sewanee Richland	0 2 0	4 0 5	.100 .610 .125	Drilled 1911

Note. — See footnotes for Table 2 on page 102.

Table 2. Drill Holes (continued)

Map No.[1]	Exploration Company	No.	Approx. Surface Elev. [ft]	[m]	Coal Depth (ft-in)	[m]	Seam	Thickness (ft-in)	[m]	Remarks
39	Durham Coal & Iron	12	1330	405			Sewanee	1 6	.450	Drilled 1911
40	Durham Coal & Iron	13					Lantana Sewanee Richland	0 10 1 2 1 6	.250 .350 .450	Drilled 1911
41	Ashland Oil Co. E-4		1725	526	no log					Drilled 1976
42	Durham Coal & Iron	10	1540	469			2_{10} Sewanee Richland	1 0 1 10 0 4	.305 .550 .100	Drilled 1911
43	Durham Coal & Iron	8	1440	439			Lantana 2_{10} Sewanee	2 0 1 2 3 6	.610 .350 1.065	Drilled 1911
44	Durham Coal & Iron	14	1600	488			12 Lantana 2_{10} Sewanee Richland	4 0 2 0 1 8 2 2 0 6	1.225 .610 .505 .660 .150	Drilled 1911
45	Durham Coal & Iron	7	1470	448			Sewanee Richland 2_6	2 0 0 7 0 2	.610 .175 .050	Drilled 1911
46	Durham Coal & Iron	9	1430	436			Sewanee Richland	2 0 2 10	.610 .860	Drilled 1911
47	State of Tenn.		1590	485			12 Sewanee Richland	3 8 2 7 0 7	1.115 .785 .175	Drilled 1952
48	Fuqua Energy	16	1453	443	no log					Drilled 1977
49	Durham Coal & Iron	4	1410	430			Sewanee 2_9 Richland 2_6 2_5 Nelson	1 2 0 3 1 10 1 0 0 3 1 6	.350 .075 .550 .305 .075 .450	Drilled 1977
50	Fuqua Energy	23	1442	438	no log					Drilled 1977
51	Fuqua Energy	22	1405	428	no log					Drilled 1977
52	Ashland Oil Co. E-10		1680	512	no log					Drilled 1976
53	Fuqua Energy	21	1718	524	no log					Drilled 1977
54	Fuqua Energy	15	1417	432	no log					Drilled 1977
55	Durham Coal & Iron	5	1390	404			Sewanee 2_8 Richland	2 2 0 8 1 0	.660 .200 .305	Drilled 1911
56	Durham Coal & Iron	1	1610	491			Lantana Sewanee Richland	0 4 2 5 1 0	.100 .735 .305	Drilled 1911
57	Durham Coal & Iron	6	1510	460			Sewanee Richland	2 0 1 3	.610 .385	Drilled 1911
58	Durham Coal & Iron	2	1400	427			Sewanee Richland 2_6	2 0 1 8 1 4	.610 .505 .405	Drilled 1911
59	Fuqua Energy	26	1493	454	no log					Drilled 1977

Table 2. Drill Holes (continued)

Map No.[1]	Exploration Company	No.	Approx. Surface Elev. (ft)	[m]	Coal Depth (ft-in)	[m]	Seam	Thickness (ft-in)	[m]	Remarks
60	Fuqua Energy	25	1456	444	no log					Drilled 1977
61	Durham Coal & Iron	3	1000	305			Nelson	3 3	.985	Drilled 1911
62	Eastern Associates	4	860	262	no log					Drilled 1973
63	Fuqua Energy	24	1422	433	no log					Drilled 1977
64	Durham Coal & Iron	17	1500	457			Sewanee Richland	1 4 1 3	.400 .375	Drilled 1977
65	Eastern Associates	3	1340	408	no log					Drilled 1973
66	Durham Coal & Iron	16	1430	436			Sewanee Richland	2 6 2 0	.760 .610	Drilled 1911
67	Fuqua Energy	45	1498	456	no log					Drilled 1977
68	Ashland Oil E-7		1710	521	no log					Drilled 1976
69	State of Tenn.		1640	500			[2]10 Sewanee	0 6 1 1	.150 .325	Drilled 1952
70	Durham Coal & Iron	18	1470	448			[2]10 Sewanee Richland	1 6 2 5 2 11	.450 .735 .885	Drilled 1911
71	Ashland Oil E-8		1650	503	no log					Drilled 1976
72	Durham Coal & Iron	3	1690	515			12 Lantana Sewanee Richland	1 3 0 5 2 8 0 10	.375 .125 .810 .250	Drilled 1911
73	Eastern Associates	2	1690	515	no log					Drilled 1973
74	Fuqua Energy	41	1729	527	no log					Drilled 1977
75	Fuqua Energy	37	1750	533	no log					Drilled 1977
76	Fuqua Energy	39	1721	525	no log					Drilled 1977
77	Durham Coal & Iron	2	1685	514	no log					Drilled 1911
78	State of Tenn.		1700	518			12 Lantana Sewanee Richland	0 6 2 0 3 6 1 1	.150 .610 .985 .325	Drilled 1952
79	Durham Coal & Iron	19	1500	457			Lantana Sewanee	0 5 1 6	.125 .450	Drilled 1911
80	Ashland Oil E-11		1560	475	no log					Drilled 1976
81	Durham Coal & Iron	4	1720	524			12 Lantana Sewanee Richland	1 0 0 9 2 0 1 3	.305 .225 .610 .375	Drilled 1911
82	Fuqua Energy	34	1742	531	no log					Drilled 1977
83	Ashland Oil E-6		1740	530	no log					Drilled 1976
84	Durham Coal & Iron	1	1680	512	no log					Drilled 1911
85	State of Tenn.		1690	515			Sewanee Richland [2]7	3 0 0 7 0 5	.915 .175 .125	Drilled 1952
86	Ashland Oil E-9		1630	497	no log					Drilled 1976
87	Ashland Oil E-5		1760	536	no log					Drilled 1976
88	Fuqua Energy	49	1938	591	no log					Drilled 1977
89	Fuqua Energy	33	1645	501	no log					Drilled 1977
90	Eastern Associates	1	1500	457	no log					Drilled 1973
91	Fuqua Energy	12	1828	557	no log					Drilled 1977
92	State of Tenn.		1855	565	31 0 56 6 242 6	9 17 74	Lantana Richland	0 6 0 2 1 5	.150 .050 .425	Drilled 1952 T.D.=275'2"

[1] See Plate 1 for map number locations.

[2] Not included in map legend.

TABLE 3. COAL MINES IN HAMILTON COUNTY, TENNESSEE

Mine	Opened	Closed	Type Mine	Operator
Alexander	1910	1913	UG[1]	T. A. Alexander
Alexander	1939	1946	UG	A. J. Alexander
Allen Smith (Millsaps)	1939	1942	UG	Allen Smith
Alexander	1940	1942	UG	Daisy Coal Company
Alexander No. 5	1943	1945	UG	C. B. Alexander
Alexander No. 10	1943	1945	UG	C. C. Alexander
Alexander Bros. (Chickamauga)	1944		UG	Yather Coal Company
Aetna (Serdino)	1946	1952	S[2]	V. P. Serdino
Alexander No. 48	1948	1949	UG	Alexander Coal Company
Alexander	1953		UG	Flat Top Coal Company
Aaron No. 9	1956	1958	UG	Aaron Coal Company
Bunker Hill	1889	1899	UG	New Soddy Coal Company
Big Soddy No. 1	1903	1924	UG	Durham Coal & Iron
Big Soddy No. 2	1904	1920	UG	Durham Coal & Iron
Big Soddy No. 3	1904	1924	UG	Durham Coal & Iron
Big Soddy No. 4	1904	1920	UG	Durham Coal & Iron
Big Soddy No. 7	1910	1914	UG	Durham Coal & Iron
Byran	1922	1925	UG	M. M. Ruth
Big Soddy No. 6	1923	1924	UG	Durham Coal & Iron
Bean	1939	1944	UG	Bean Bros.
Bishop	1944	1945	UG	W. A. Bishop
Board Fork	1944	1945	UG	Board Fork Coal Company
Bowers-Carey	1944	1945	UG	Board Fork Coal Company
Black No. 1	1945	1947	UG	J. C. Black
Black No. 2	1945	1946	UG	J. C. Black
Byron Harris	1945	1946	UG	Harris Coal Company
Boulevard No. 1	1945	1956	UG	Boulevard Coal Company
Boulevard No. 2	1945	1956	UG	Boulevard Coal Company
Battle	1946	1947	UG	Battle Coal Company

ote. — See footnotes for Table 3 on page 113.

(continued)

Table 3. Coal Mines (continued)

Mine	Opened	Closed	Type Mine	Operator
Blair & Miller	1950	1952	UG[1]	Blair & Miller Coal Co.
Beasley	1951	1956	UG	M. E. Beasley
Bowman No. 1	1951	1952	UG	Bowman & Scott Coal Co.
Bowman No. 2	1951	1952	UG	Bowman & Scott Coal Co.
Big Fork	1951	1952	UG	
Big Staub	1953	1954	UG	Walker Coal Company
Boulevard No. 3	1955	1956	UG	Boulevard
Beene No. 1	1956	1959	UG	Beene & Northrup Coal Co.
Bradford No. 3	1956	1958	UG	Earl Bradford Coal Co.
Bradford No. 10	1957	1958	UG	Bradford & O'Mary Coal Co.
Bradford No. 8	1957	1959	UG	Earl Bradford Coal Co.
Bradford No. 3A	1958	1960	UG	Earl Bradford Coal Co.
Bradford No. 4	1958	1962	UG	Earl Bradford Coal Co.
Beene No. 1	1959	1962	UG	J. W. Beene Coal Company
Beene No. 2	1959	1960	UG	J. W. Beene Coal Company
Bradford No. 6	1960	1962	UG	Earl Bradford Coal Co.
Burchard No. 1	1960	1964	UG	Wayne Burchard Coal Co.
Brewer No. 2	1964	1965	UG	Lloyd Brewer Coal Co.
Bear Cat No. 1	1971	1972	S[2]	Bear Cat Mining Company
Cherokee No. 1	1933	1934	UG	P. T. Parker
Connor Creek	1935	1936	UG	R. C. Hassler
Card	1939	1944	UG	Card Coal Company
Couch	1944	1946	UG	Aaron Couch
Campbell	1945	1946	UG	C. F. Campbell
Connor & Sunderland	1945	1946	UG	Connor & Sunderland
Cedar Point No. 12	1945	1946	UG	V. P. Serdino
Clements	1947	1948	UG	Clements Coal Company
Crabtree	1947	1948	UG	Crabtree Coal Company
Chapman	1947	1948	UG	Chapman Coal Company
Crawley (Ledford)	1947		UG	Crawley Coal Company

continued

Table 3. Coal Mines (continued)

Mine	Opened	Closed	Type Mine	Operator
C & N	1950	1952	UG[1]	C & N Coal Company
Coal	1951	1952	UG	Norman Coal Company
Chancy	1953		UG	Chancy Coal Company
Cash	1953	1953	UG	Soddy Cash Coal Company
Carey No. 1	1957	1959	UG	Demps Carey Coal Company
CR & B No. 14	1968	1969	UG	CR & B Coal Company
Chickamauga No. 1	1971	1972	UG?	Chickamauga Mining Company
Daisy	1881	1910	UG	New Daisy Coal & Coke
Dunning	1923	1925	UG	Rostin, Montgomery, Dunning
Durham	1933	1934	UG	W. R. Milligan
Daughtrey	1941	1943	UG	
Davis	1941	1943	UG	Pendergrass & Cunnie
Dempsey	1942	1945	UG	Mary Glen Mining Company
Dykes	1945	1946	UG	Clark A. Dykes
Dye	1945	1947	UG	Willie F. Dye
Dill No. 1	1954	1959	UG	Carlos Dill Coal Company
Dean No. 9	1956	1958	UG	Dean & Smith Coal Company
Dill No. 2	1958	1965	UG	Carlos Dill Coal Company
Dunwoody No. 1	1966	1969	UG	Dunwoody Coal Company
Elliot	1944	1945	UG	W. B. Elliott Coal Company
Everett	1946	1947	UG	Pickett & Roberts
Edwards Point	1953	1954	UG	Hoodenpyl Coal Company
Furman	1919	1920	UG	Durham Coal & Iron
Flat Rock	1935	1936	UG	Joe Crooks
Flat Top No. 1	1939	1943	UG	Pikeville Coal Company
Fraiser	1947	1948	UG	Frank Fraiser
Franklin	1947	1950	UG	John Franklin
Ford	1952	1953	UG	W. F. Ford Coal Company
Frizzell	1954	1965	UG	David Frizzell Coal Co.
Frizzell	1954	1956	UG	Walter Frizzell Coal Co.

continued

Table 3. Coal Mines (continued)

Mine	Opened	Closed	Type Mine	Operator
Flynn No. 4	1957	1959	UG[1]	Flynn & Brookman Coal Co.
Frizzell No. 6	1959	1960	UG	Walter Frizzell Coal Co.
Flag Stone No. 1	1963	1965	UG	Flag Stone Coal Company
Grant	1945	1946	UG	Grant & Mayes
Graves	1945	1946	UG	Graves-Cagle Coal Company
Grayson	1945	1947	UG	William L. Levi
Griffith	1947	1948	UG	Luther Griffith Coal Co.
Gothard & Coleman	1947	1948		
Gothard No. 1	1954	1958	UG	Gothard Coal Company
Golston No. 1	1959	1960	UG	Golston Coal Company
Gravitt No. 1	1959	1960	UG	Herbert Gravitt Coal Co.
G & D No. 1	1964	1965	UG	G & D Coal Company
Green No. 1	1966	1969	UG	Green Coal Company
Howard	1941	1943	UG	Wess Howard
Hunt	1942	1949	UG	C. N. Hunt
Hessler	1945	1946	UG	Hunt and Jenkins
Harris	1946	1946	UG	Bryon Harris
Higdon	1948	1949	UG	Ernest Coal Company
Harvey	1950	1953	UG	Harvey Coal Company
Howard	1950	1956	UG	G. W. Howard Coal Company
Hawkins	1951		UG	Hawkins Coal Company
Hunkapiller	1952		UG	Hunkapiller Coal Company
Hatfield No. 1	1953		UG	Hatfield & Luttrell Coal Co.
Hensley No. 1	1956	1960	UG	William Hensley Coal Co.
Hickey	1958	1960	UG	Hickey & Teeters Coal Co.
Hunziker No. 3	1959	1960	UG	C. P. Hunziker Coal Co.
Istock (King)	1956	1958	S[2]	Nick Istock, Inc.
Jones	1947	1948	UG	W. B. Jones
Jaco	1952	1953	UG	Jaco Coal Company
Johnson	1952	1953	UG	Otis Johnson

continued

Table 3. Coal Mines (continued)

Mine	Opened	Closed	Type Mine	Operator
Johnson & Johnson (Millsaps)	1955	1959	UG[1]	Johnson & Johnson Coal Co.
Jellico Ind. No. 1	1969	1971	S[2]	Jellico Industries
Jellico Ind. No. 2	1969	1970	S	Jellico Industries
King	1922	1925	UG	C. H. King
Keef	1940	1940	UG	Lon Keef
Kelly	1950	1952	UG	Kelly Coal Company
Kilgore No. 1 (Ruth)	1952	1959	UG	Kilgore Coal Company
Kilgore No. 4	1953	1955	UG	Kilgore Coal Company
Kilgore No. 3	1954	1956	UG	Kilgore Coal Company
Kilgore No. 2 (Powell)	1954	1962	UG	Kilgore Coal Company
Keener No. 1	1957	1959	UG	Ervin Keener Coal Co.
King No. 1	1957	1958	UG	Silas King Coal Company
Kilgore No. 2 (Harvey)	1961	1962	UG	J. M. Kilgore Coal Co.
Lewis & Alexander	1975	1906	UG	Northside Land Company
Lewis & Hatfield	1907	1909	UG	Durham Coal & Iron
Ledford	1935	1946	UG	J. H. Ledford
Levi	1941	1950	UG	Levi Bros.
Lancaster	1944	1945	UG	Ike Lancaster
Lettles	1944	1947	UG	Lloyd Lettles
Layne	1952	1953	UG	Lidge Layne Coal Company
Ledford	1952	1953	UG	Ledford Coal Company
Laymon	1953	1954	UG	Laymon Coal Company
Levi & Christian	1953	1954	UG	Levi & Christian Coal Co.
Louis	1953	1954	UG	Ridge & Louis Coal Company
Little Staub	1953	1954	UG	Walker Coal Company
Lewis No. 5	1954	1955	UG	Grover Lewis Coal Company
Lewis No. 6	1954	1956	UG	Grover Lewis Coal Company
Lewis No. 7	1954	1956	UG	Grover Lewis Coal Company
Lewis No. 8	1954	1956	UG	Richard Lewis Coal Company
Lewis No. 8	1955	1958	UG	Grover Lewis Coal Company
Luttrell No. 5	1960	1961	UG	Paul Luttrell Coal Co.

continued

Table 3. Coal Mines (continued)

Mine	Opened	Closed	Type Mine	Operator
Luttrell No. 6	1962	1963	UG[1]	Paul Luttrell Coal Co.
Little No. 1	1962	1963	UG	Little Coal Company
Morgan	1898	1898	UG	
Montlake No. 1 (Rope)	1903	1931	UG	Montlake Coal Company
Montlake No. 2	1903	1906	UG	Montlake Coal Company
Montlake No. 10	1911	1923	UG	Montlake Coal Company
Middlecreek	1922	1925	UG	Middle Creek Coal Company
Montlake No. 4	1922	1924	UG	Signal Mtn. Coal Company
Montlake No. 5	1927	1927	UG	Durham Coal & Iron
Montlake No. 3	1927	1927	UG	Durham Coal & Iron
Melville	1928	1930	UG	Staub Coal Company
Marler	1933	1939	UG	I. W. Marler
Millsaps	1933	1946	UG	A. G. Millsaps
Millsaps	1939	1941	UG	Will Smith
Mary Glen	1940	1940	UG	Mary Glen Mfg. Company
Montlake No. 10	1941	1942	UG	George Yother
Millsaps	1943	1944	UG	C. C. Alexander
Milligan	1944	1950	UG	Wallace Milligan
Merman	1945	1947	UG	Walter Clements
McHone	1945	1946	UG	Harley McHone
Merman No. 1	1946	1947	UG	Walter Clements
Millsaps	1947	1953	UG	W. R. Millsaps
Miller	1948	1949	UG	Chester Miller
Murphy	1948	1959	UG	Murphy Coal Company
Mulligan	1949	1960	UG	Luther Mulligan
Morrison	1949	1950	UG	Morrison & Levon Coal Co.
Mays	1941	1942	UG	Joe Mays
Manning	1952		UG	W. A. Manning Coal Co.
Mitchell	1952	1953	UG	Kilgore Coal Company
Montgomery	1952	1953	UG	Montgomery Coal Company
Murry	1952	1953	UG	Murry Coal Company

continued

Table 3. Coal Mines (continued)

Mine	Opened	Closed	Type Mine	Operator
Moore No. 3	1953		UG[1]	Charles Moore Coal Co.
Milligan	1953		UG	D. R. Milligan
Meeks No. 1				
Miller	1955	1960	UG	Forrest Miller Coal Co.
Murphy No. 9 (Sewanee)	1955		UG	Murphy Coal Co.
Myers	1955		UG	Waldo Myers Coal Co.
Mickells	1959	1960	UG	Willie Mickells Coal Co.
Moore No. 1	1959	1961	UG	Moore & White Coal Co.
Milligan No. 1 (Powell)	1962	1963	UG	Milligan Coal Co.
Meek 1-A	1963	1964	UG	Meeks Coal Co.
Milligan No. 2	1963	1965	UG	Milligan Coal Co.
Metzler	1971	1972	S[2]	Metzler Mining Co.
New Bank	1898	1898	UG	
Nolan	1945	1946	UG	George Nolan
Norman	1952	1953	UG	Norman Coal Company
Northrup No. 1	1957	1958	UG	L. J. Northrup Coal Co.
Nolan No. 1	1963	1965	UG	Nolan & Son Coal Co.
O'Mary No. 4	1956	1958	UG	O'Mary & Bradford Coal Co.
Oak Hill No. 2	1964	1965	UG	Oak Hill Coal Company
Perkins	1944	1949	UG	L. W. Perkins
Priddy	1944	1945	UG	Jim Priddy
Parker	1945	1946	UG	C. C. Parker
Phillips	1945	1946	UG	J. T. Phillips
Pickett	1945	1946	UG	W. C. Pickett
Pilot	1945	1947	UG	Pilot Coal Company
Pine Hill	1946	1947	UG	C. C. Parker
Powell	1948	1953	UG	Powell Coal Company
Patton	1949	1950	UG	Earl Patton Coal Company
Prichard	1952	1953	UG	Prichard Coal Company
Pickett	1953	1954	UG	Clint Pickett Coal Company
Payne No. 2	1955	1956	UG	Calvin M. Payne Coal Co.

continued

Table 3. Coal Mines (continued)

Mine	Opened	Closed	Type Mine	Operator
Payne No. 3	1955	1956	UG[1]	Calvin M. Payne Coal Co.
Payne No. 4	1955	1956	UG	Calvin M. Payne Coal Co.
Payne No. 5	1956	1958	UG	Calvin M. Payne Coal Co.
Perkins	1958	1959	UG	Perkins Coal Company
Perkins 1-A	1960	1962	UG	Perkins & White Coal Co.
Patton (Millsaps No. 1)	1963	1964	UG	Leon Patton Coal Company
Retro	1903	1908	UG	Hamilton Coal Company
Rickett	1933	1946	UG	Will Rickett
Reynolds	1943	1945	UG	C. C. Alexander
Reel	1944	1945	UG	Roy Reel
Rutherford	1944	1945	UG	W. A. Rutherford
Renfro	1945	1952	UG	T. C. Renfro
Reynolds	1946	1948	UG	Hobert D. Reynolds
Rounsville No. 3	1946	1947	UG	A. C. Rounsville
Rutherford	1948	1949	UG	Jack Rutherford
Ray	1952	1953	UG	Ray Houser Coal Company
Reynolds	1952	1955	UG	Pickett Coal Company
Roberts	1952	1958	UG	Roberts Coal Company
Russell (Lakeview)	1955	1973	S[2]	Russell Mining Company
Rutherford No. 1	1956	1957	UG	J. M. Kilgore Coal Co.
Sale Creek	1843	1875	UG	Sale Creek Coal & Coke
Soddy	1866	1897	UG	New Soddy Coal Company
Shoal	1874	1974	UG	
Soddy No. 1	1885	1931	UG	New Soddy Coal Company
Soddy No. 3	1892	1923	UG	New Soddy Coal Company
Soddy No. 2	1892	1931	UG	New Soddy Coal Company
Soddy No. 5	1903	1910	UG	Durham Coal & Iron
Soddy No. 4 (Davis)	1904	1914	UG	Durham Coal & Iron
Shale	1904	1905	UG	Dixie Portland Cement Co.
Soddy No. 7	1905	1913	UG	Durham Coal & Iron

continued

Table 3. Coal Mines (continued)

Mine	Opened	Closed	Type Mine	Operator
Soddy No. 8	1906	1906	UG[1]	Durham Coal & Iron
Soddy No. 10	1907	1910	UG	Durham Coal & Iron
Soddy No. 9	1908	1910	UG	Durham Coal & Iron
Soddy Slope	1912	1912	UG	Durham Coal & Iron
Skiles Hollow	1921	1922	UG	Durham Coal & Iron
Staub No. 1	1922	1927	UG	Staub Coal Company
Staub No. 2	1923	1925	UG	Staub Coal Company
Sunshine	1924	1926	UG	Durham Coal & Iron
Summit	1925	1927	UG	Georgia-Tenn. Coal Co.
Suck Creek	1933	1943	UG	Hamilton Coal Mining Co.
Simons	1935	1936	UG	Bill Simons
Soddy No. 12	1939	1940	UG	W. B. Goodson
Spangler	1939	1949	UG	W. S. Spangler
Spurlin No. 2	1939	1940	UG	Rosa Spurlin
Soddy	1940	1944	UG	Pikeville Coal Company
Soddy No. 4	1940	1943	UG	W. B. Goodson
Shadwick No. 1	1940	1945	UG	John Shadwick
Shadwick No. 2	1941	1942	UG	John Shadwick
Stub No. 7	1941	1942	UG	Yather & Sons
Smith	1943	1945	UG	C. C. Alexander
Soddy No. 7	1943	1944	UG	Yather Coal Company
Spurling	1944	1945	UG	R. R. Spurling
Sequatchie No. 3	1945	1946	UG	Sequatchie Coal Mining Co.
Sexton	1945	1946	UG	Sequatchie Coal Mining Co.
Simmons	1946	1947	UG	Fred Simmons
Simpson	1946	1947	UG	Norman & Everest Simpson
Stewart	1947	1948	UG	M. M. Stewart
Shadwick	1949	1956	UG	John Shadwick
Sharp	1950	1951	UG	Johnson & Tallent Coal Co.
Sprangler	1952	1955	UG	Dock Sprangler Coal Co.
Stewart	1952	1953	UG	Nathan Stewart Coal Co.

continued

Table 3. Coal Mines (continued)

Mine	Opened	Closed	Type Mine	
Sunshine	1952	1953	UG[1]	Sunshine Coal Company
Spangler No. 1	1953	1956	UG	C. D. Spangler Coal Co.
Spangler No. 3	1953	1954	UG	D. S. Spangler & Son Coal Co.
Smithers	1953	1954	UG	Smithers Coal Co.
Scott	1954	1958	UG	Scott Coal Company
Serdino	1954	1956	S[2]	Serdino, Inc.
Spangler No. 2	1955	1962	UG	D. S. Spangler Coal Co.
Smith No. 2	1957	1958	UG	Smith Coal Mining Co.
Smart No. 1	1959	1963	UG	Tom Smart Coal Company
Salvage (Millsaps)	1960	1963	UG	J. L. Savage Coal Company
Smith No. 1	1961	1963	UG	Paul Smith Coal Company
Soddy Mining	1970	1971	UG?	Soddy Mfg., Inc.
Thomas	1935	1936	UG	H. R. Thomas
Thomas No. 1	1943	1952	UG	Thomas Coal Company
Thomas No. 2	1943	1944	UG	Thomas Coal Company
Terry	1947	1948	UG	Terry Coal Company
Thomas	1953	1954	UG	Vandergriff Coal Company
Tentex (N. McGill)	1966	1967	UG	Tentex Coal Corp.
Tentex (P. S. No. 1)	1966	1968	UG	Tentex Coal Corp.
Tentex No. 3	1966	1967	UG	Tentex Coal Corp.
Varnell	1922	1925	UG	G. W. Coal Company
Vaughn	1945	1946	UG	Louie Vaughn
Vaughn No. 2	1945	1946	UG	W. D. Walker
Vandergriff	1952	1958	UG	Paul Vandergriff Coal Co.
Walker	1922	1925	UG	S. J. Coal Company
Wagon	1926	1929	UG	Montlake Coal Company
Walden Ridge	1940	1940	UG	Walden Ridge Coal Corp.
Walker	1944	1949	UG	Paul Walker
Wilson	1944	1945	UG	W. H. Wilson
Whitlow No. 1	1945	1955	UG	Dewey Whitlow Coal Company

continued

Table 3. Coal Mines (continued)

Mine	Opened	Closed	Type Mine	Operator
Williams	1947	1948	UG[1]	Williams Coal, Inc.
Wilcox	1952	1953	UG	R. B. Wilcox Coal Company
White No. 1	1954	1956	UG	Andrew White Coal Co.
Whitlow No. 2	1955		UG	Dewey Whitlow Coal Co.
Whitlow No. 3	1955		UG	Dewey Whitlow Coal Co.
Whitlow No. 4	1955	1958	UG	Dewey Whitlow Coal Co.
Walden Ridge	1956	1958	S[2]	Walden Ridge Coal Company
Whitlow No. 5	1957	1958	UG	Dewey Whitlow Coal Co.
Whitlow No. 6	1958	1959	UG	Whitlow Coal Co.
Walters No. 1	1959	1960	S	John Walters Coal Co.
Yather	1939	1940	UG	Yather Bros.
Yather	1947	1959	UG	Yather Coal Company

[1] UG - Underground.

[2] S - Strip.

EARLY COAL OPERATIONS

Coal mining in Hamilton County began in the mid 1800's, and the earliest mining was on the Nelson coal seam just west of Sale Creek, in the northwest part of the county. From 1853 to 1930, the area between Chickamauga Gulch and Sale Creek produced a large part of the coal that was mined in the state.

Most of the early mining was by Sale Creek Coal and Coke Company, Soddy Coal Company, Montlake Coal Company, and New Daisy Coal and Coke Company. The above companies were purchased by Durham Coal and Iron Company in 1910 and operated until the company shut down operations about 1931.

The Sale Creek mine (the oldest mine in the county), the Soddy mine, the Montlake mine, the Retro mine, and the Daisy Mine were the largest and probably the most important operations in the county. They are described on the following pages. The history of these mines was taken from early accounts of the operations written by various geologists and mine inspectors who visited the mines when the companies were active.

Surface mining has been done in the county from the Middle 1950's to the present. Most of the mining was on the Sewanee seam, although scattered openings have been made on the Morgan Springs and Lantana seams. The mining on the higher seams was primarily on Richey Ridge where the No. 12 seam is presently being mined.

RETRO MINES (*Map No. 15*)

Several coal openings were made on both sides of Possum Creek when Durham Coal & Iron Company purchased the mines. Some of these mines are not located on the map because of lack of accurate records. Eight different seams were found on the property, but only the Nelson, Richland, and No. 12 proved to be of sufficient thickness and quality to justify additional exploration.

The Nelson was found on the north side of Possum Creek, ranging in thickness from 30 inches (76 cm) to 7 feet (2.13 m). It was believed by Durham Coal & Iron that a large reserve of workable Nelson seam was present between this prospect and the Sale Creek mine, 2 miles (3.2km) to the north. According to early reports, the continual drain on the finances of the corporation resulted in the abandonment of this prospect in 1920.

The main opening at Retro was in the Richland seam on the south slope of Possum Creek, where the coal averaged 42 inches (107.0cm) in thickness. After mining began, the coal proved to be irregular and structurally disturbed, and confined to a basin about 400 feet (122m) wide. This mine was abandoned in 1920 after the main entry had been driven for more than 4,000 feet (1219m) into coal that thinned to a few centimeters.

The No. 12 seam was opened and a slope driven 300 feet (91m) into the mountain, where the coal thickness ranged from 14 inches (36cm) to 44 inches (112cm). The initial installation would have necessitated two inclines, two tram roads, and a bridge over Possum Creek; this made the cost of producing coal prohibitive in a competitive market.

SALE CREEK MINE (*Map No. 19*)

The Sale Creek mine, opened in 1843, is located on the north bank of Sale Creek (Rock Creek), under an outlying spur of Walden Ridge. Mining was on the Nelson, or No. 2 seam, which (according to earlier reports) averaged about 42 inches (107cm) in thickness. According to reports by the Durham Coal and Iron Company, the coal contained two bands of impurities, each about 2 inches (5cm) thick, resulting in a dirty product with a 25 percent washer loss.

The coal seam dipped from the portal elevation of 975 feet (297 m) to an average elevation in the mine of 785 feet (239 m). The upkeep on the mine was less costly than at other mines in the area, primarily because of the good roof and lack of gas. This also made it one of the safest mines in the area.

Mining was the double entry, room and pillar method, and production reached a rate of 400 tons (364t) per day. Sufficient local labor was available and no serious labor trouble ever occurred.

It was estimated that approximately 1,000,000 tons (909,000t) of Nelson coal was mined from the Sale Creek mine before 1926. Very little activity has taken place in the area since that time. The Nelson seam is a high-volatile (32-33%), medium-to-high ash (9-26%) and low sulfur (.40-.70%) coal.

BIG SODDY MINES (*Map Nos. 13 & 14*)

The Big Soddy mines were opened in 1904 on the north slope of Big Soddy Creek, approximately 1.3 miles (2.1km) northwest of Soddy. The mines were not in continuous operation, but were worked during peak market periods until 1923 when operations ceased due to a high wage scale and a depressed demand for the coal. However, some mining was done in the area after 1923, primarily surface mining during the period from 1950 to 1972.

These mines were opened on the No. 9 Richland and Sewanee seams. However, most of the tonnage was mined from the Sewanee seam, because the other two seams proved to be inconsistent in thickness. The No. 9 seam was opened by 5 mines along the face of the slope of Big Soddy Creek, at an elevation of 1,250 feet (381m). The coal has an even sandstone bottom, but the roof is rolling shale that results in variation in the thickness of the seam. Nine holes were drilled and numerous test pits were dug along the outcrop to determine the quality and reserves of the coal seams in the area. Analysis of the Sewanee seam shows the coal to be high-medium volatile and low sulfur coal, with high ash content.

The mines were producing 400 tons (364t) per day when operations ceased in 1923. Mining was on the double entry, room and pillar method, although this was varied to meet any peculiar coal conditions that might occur. The usual plan was to drive the entries at right angles to the squeeze, thereby permitting the driving of a room in good coal as long as the seam thickness permitted.

SODDY MINES (*Map Nos. 16, 17 & 18*)

The mines at Soddy were opened in 1868 by a cooperative of Welsh miners. They operated the mines until 1884, and coal was shipped to Chattanooga on river barges. In 1884 the Queen and Crescent Railroad was built and the mines were bought by a stock company.

The mines lying on both sides of Little Soddy Creek were the largest producers of coal on Walden Ridge, and had the most extensive development and the highest mining cost. Most of the coal produced from these mines came from the Richland seam, although limited mining was done on the Sewanee seam.

When washed, the Richland seam was considered to be the highest grade coal in Walden Ridge. It analyzed 27 to 30 percent volatile matter, 4 to 8 percent ash, and 1.2 percent sulfur.

These mines were extensively worked because of the extent and uniformity of the Richland seam. Mining was systematic and the double entry, double room method was used. Haulage was 1,200 feet (366m) by mules, 3,200 feet (975m) by tail rope, 9,100 feet (2,774m) by electric locomotive to the portal and 6,600 feet (2,012m) by wire rope down an incline to the tipple at the railroad tracks. More than 15 miles (24km) of track were in the mine during the peak of operations. During 1926 the entire output of washed nut and slack coal was sold under contract to the Tennessee Products Corp. at a price of $2.45 per short ton (F.O.B. mines) for use in the by-product ovens at Chattanooga.

Between 1884 and 1910 the Soddy properties were operated by two or three different companies. The last before the Durham Company was the New Soddy Coal Company, controlled by D.P. Montague and H.S. Chamberlain. The Durham Coal and Iron Company was organized in 1910 and operated the property until 1931 (Table 1). The property containing the Soddy mines is presently owned by Joseph Lahier of Chattanooga, Tennessee. There is one active mine on the property at the present time.

DAISY MINES (*Map No. 6*)

The Daisy mines were opened about 1865, near Daisy, about 18 miles (29 km) northwest of Soddy-Daisy. The coal averages 42 inches (107 cm) in thickness and dips slightly to the west. The Tabler Crudup Coal and Coke Company operated the mines until 1881, when the Daisy Coal and Mining Company was organized and took over the operations.

The mine is at an elevation of 1,300 feet (396m) and is in the Sewanee seam. Bad roof conditions were encountered but never corrected because the miners worked on contract, and neither the miners nor the management would spend money to have the roof properly timbered.

Fifty-two persons were employed in the mine in 1891, and 25,000 tons (22,727t) of coal were produced. Analyses of the coal showed 28 to 30 percent volatile matter, 6 to 10 percent ash, and .9 percent sulfur.

MOUNTLAKE MINE (Map Nos. 7 & 8)

The Montlake mines lie on the north side of North Chickamauga Creek, approximately 4½ miles (7km) southwest of Soddy. The mines were in the Sewanee seam 900 feet (274m) above North Chickamauga Creek. The original mine opening was on the point of the ridge where the cropline turns parallel to North Chickamauga Creek. Two entries were driven into the point and then turned to parallel the creek about 300 feet (91m) from the outcrop; after driving about 1,200 feet (366m), the main entries were stopped and two main entries driven at right angles to the first entry. During the operations at the Montlake mine several entries were driven to develop the coal and make the haulage as short as possible. Coal was shot off the solid, with no mining machines at the mine.

The Montlake lease totaled 2,700 acres, 1,650 acres of which contained minable Sewanee coal. About 250 acres were mined out up to 1926. For the purpose of making a reserved estimate of the Montlake lease, the Durham Coal and Iron Company used 14 measured sections from the Montlake mine, and several cropline thicknesses. These showed an average thickness of 34 inches (86cm). Information from the Durham Coal and Iron Company report indicates the mine recovered about 65 percent of the inplace reserves.

The Sewanee seam is a hard bituminous coal, containing some sulfur as pyrite, but otherwise clean except for inherent ash. The roof is a black shale and the bottom a hard fire clay.

A typical analysis taken from the Montlake mine shows the coal to contain 24 to 28 percent volatile matter, 9 to 11 percent ash, and 2.2 to 3.3 percent sulfur. The sulfur is as pyrite and can be reduced some by picking before shipping.

COKE OVENS

The decline in the steel industry in Tennessee has virtually eliminated the need for coke in Hamilton County. There are at the present time no mining companies operating coke ovens. However, there are old coke ovens still standing in many areas of the county, such as the ones to be seen near Soddy and Sale Creek.

GROUND–WATER RESOURCES
OF
HAMILTON COUNTY, TENNESSEE

BY
ROBERT LAKE WILSON[1]

INTRODUCTION

PRESENT INVESTIGATIONS

The first systematic investigation of ground water in Hamilton County, Tennessee, was done in 1956 under the joint sponsorship of the U. S. Geological Survey and the Tennessee Division of Geology.

The present report generally describes the ground-water resources of Hamilton County. It presents information gained from a study carried out by students in an Environmental Studies course offered in the spring of 1977 by The University of Tennessee at Chattanooga. The Chattanooga Area 208 Waste Management Program also provided assistance in the completion of this project.

PREVIOUS INVESTIGATIONS

CLIMATE

Hamilton County has a climate that can best be described as humid-temperate. It is characterized by cool winters and warm summers. According to data from the U.S. Weather Bureau's climatic summaries the winter weather is changeable and alternates between cool spells with an occassional cold period. Temperatures fall as low as the freezing point on about one-half of the winter days. Temperatures below zero have occurred only 14 times since 1879. From year to year the snowfall is greatly variable. Some winters have little or none. Heavy snowfalls have occurred, but any appreciable accumulation of snow seldom remains on the ground more than a few days. Ice storms of freezing rain or glaze are not uncommon. On occasion, mid-winter icing has been severe enough to cause considerable property damage to the higher elevations in the county. The average annual temperature is 60.4°F (15.8°C).

Summer high temperatures normally range from the high eighties to the low nineties. Temperatures of 100°F (38°C) or higher are unusual, having occurred in less than one-fourth of the years since the turn of the century. Afternoon temperatures are frequently modified by thunderstorms and may drop 10° to 15°F (6°-8°C) in a matter of minutes.

The annual precipitation of 51.8 inches (131cm) in Hamilton County is fairly well-distributed throughout the year, with the greater amounts in the winter when cyclonic storms from the Gulf of Mexico reach the area with greater intensity and frequency. A second peak rainfall period generally occurs in July, principally from thunderstorms that move into the area from the south and southwest.

The growing season averages 228 days in the lowlands. Records of the past 30 years show an average date of latest freezing temperature in the spring to be March 26, and the all-time latest, April 12. The average date of the first freezing temperature in the fall is November 9 and the earliest on record is October 27.

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TOPOGRAPHY

Hamilton County is a part of the Appalachian Highlands physiographic division. The western quarter of the county lies within the Cumberland Plateau while the eastern three-fourths is a part of the Valley and Ridge.

That part of the Cumberland Plateau in the western part of the county is called Walden Ridge. Although plateau-like when viewed from the valley below, the name "mountain" aptly applies. The name, Signal Mountain, is given to the southernmost extension of Walden Ridge. The gently rolling uplands are about at a 1,900 feet (579m) elevation. A steep eastward-facng escarpment 1,100 feet (335m) high separates the mountains from the valley below. Lookout Mountain and Raccoon Mountain are prominent mountains south of the Tennessee River.

The eastern three-fourths of the county consists of a series of valleys and ridges that trend generally northeast-southwest. These ridges, for the most part, rise to elevations of between 900 and 1,100 feet (274 and 335m). The highest, Whiteoak Mountain, averages nearly 1,500 feet (457m) in elevation, its crest forming a large part of the county's eastern boundary.

The Tennessee River, which flows generally southward for some 48 miles (77km), covering almost the entire length of the county, is an important geologic feature in Hamilton County.

SURFACE WATER

The principle river of Hamilton County is the Tennessee. It enters the county in the northeast corner and flows southward toward Lookout Mountain, near which it is deflected to the northwest and flows westward into the "Grand Canyon of the Tennessee."

The western half of the county is drained by a series of small streams that have their headwaters on Walden Ridge. All these streams have eroded deep canyons into the eastern escarpment of Walden Ridge. Where they emerge from the plateau margin they have formed broad alluviated valleys. From north to south these are McGill, Rock, Possum, Soddy, North Chickamauga and Falling Water Creeks. Grasshopper and Wolftever Creeks are the major westward-flowing streams that have their headwaters along the slopes of Whiteoak Mountain. The major northward-flowing stream is South Chickamauga Creek. Its headwaters are in North Georgia along the western slopes of Taylor Ridge, which is the continuation of Whiteoak Mountain in Georgia.

Annual precipitation in Hamilton County totals about 60 inches (152cm). About 22 inches (56cm) is runoff, 8 inches (20cm) goes underground and passes into the ground-water system before being discharged into streams, and the remaining 30 inches (76cm) is lost to the atmosphere through evapo-transpiration.

Stream flow records indicate that the maximum flow of the Tennessee River at the U.S. Geological Survey stream gauge (Rivermont Golf and Country Club - Mile 467.6) since 1936 was 267,000 cubic feet per second on March 17 and 18, 1973. The minimum daily flow during that period was 1,200 cfps on November 1, 1953, and the mean annual flow was 35,393 cfps. Stream flow records are also available for South Chickamauga, Wolftever, Falling Water, North Chickamauga, Soddy, Possum, Rock and McGill Creeks (Table 1.)

TABLE 1. CHARACTERISTICS OF SELECTED STREAMS DRAINING HAMILTON COUNTY[1]

Stream	No. of years Records Kept	Drainage Area Square Miles (Square Kilometers)		Average Discharge Cubic Feet per Second (Cubic Meters per Second)	
S. Chickamauga	47	428	(1,109)	699	(19.8)
Wolftever	11	18.8	(48.7)	33.8	(0.957)
Rock	12	38.1	(98.7)	[1]0-51.7	(1.46)
McGill	4	13.0	(33.7)	[1]0-14.4	(0.407)
Possum	7	22.7	(58.8)	[1]0-13	(0.367)
Soddy	19	50.5	(130.8)	[1]0-60.3	(1.706)
N. Chickamauga	16	62.6	(162.1)	[1]0-56.9	(1.61)
Falling Water	6	13.2	(34.2)	[1]0-45.6	(1.29)

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[1] Minimum and maximum discharge.

GROUND WATER

AVAILABILITY

Unconsolidated rocks in Hamilton County include alluvium, colluvium, and residuum. Alluvium is found along the streams in the area and is composed principally of clay, silt, and scattered rock fragments ranging up to boulder size. It has an average thickness of around 3 to 6 feet (1-2m) and does not constitute an important source of ground water.

Colluvium is locally much thicker than the alluvium, but confined to the steeper slopes of Walden Ridge, Lookout, Raccoon, and Whiteoak Mountains. The colluvium consists of clay, sand, silt and rock fragments and (like the alluvium) has a rather low water yield.

The thickest and most extensive unconsolidated rock material in Hamilton County is the residuum. It overlies the limestones and dolomites of the area. Its thickness may range from a few feet to over 150 feet (46 m). Where the residuum overlies limestone it is composed mainly of clay, and in general has a very low permeability and low water yield. However, over the Knox Group it contains larger angular fragments (mostly chert), and normally will yield water sufficient for most domestic purposes. The most productive zone appears to be at the contact of the residuum and the underlying bedrock.

Consolidated sediments such as shale, sandstone, limestone, and dolomite have quite variable water-bearing properties.

Shales, which are composed mainly of clay and silt-sized particles, have very low permeability. Unless some type of secondary opening such as fracturing is present, their water yield is very meager. However, calcareous shales may have fractures and bedding planes that have been enlarged through ground-water movement. Most shales in Hamilton County, however, are poor aquifers. Yields of more than 5 gallons per minute are rare.

The sandstone beds of the Rome and Rockwood Formations have only a limited area of outcrop since they are commonly steeply dipping. Permeabilities are normally very low since the openings between the sand grains are partially filled with ferruginous or siliceous cement. On the other hand, the Pennsylvanian sandstones may contain permeable zones that could yield water for domestic purposes at a maximum rate of 60 gpm. The average yield, however, is between 5 and 10 gpm. The water quality for most wells is satisfactory in most instances. In general, in the shallow aquifers the water is somewhat acid, high in iron or magnesium, and with a low average hardness.

The amount of water produced by wells in limestone or dolomite is dependent upon the number and size of solution cavities encountered in drilling. These cavities are most abundant in the first 250 feet (76 m). If a sufficient quantity is not found within that zone, it is advisable to drill deeper. The average depth of the 250 wells listed in this survey was only 140 feet (43m).

There is good evidence that solution has been very active along the flood plains of the major streams in the area. Wells drilled close to large rivers or streams can obtain large quantities of ground water. It is possible that in many cases the solution channels are connected with surface streams and actually allow river water to flow into the wells. In Table 2 the water-bearing characteristics of the various geologic formations in Hamilton County are listed.

TABLE 2. WATER-BEARING CHARACTERISTICS OF THE GEOLOGIC FORMATIONS OF HAMILTON COUNTY

SYSTEM	GROUP	FORMATION	THICKNESS [IN FEET]	THICKNESS [IN METERS]	WATER-BEARING CHARACTERISTICS
PENNSYLVANIAN	Crab Orchard Mountains Group	Rockcastle Conglomerate	100	30	Conglomerate and sandstone beds yield small quantities of water sufficient for farm and domestic use. Water commonly high in iron. Shale formations are relatively impermeable and yield little or no water.
		Vandever Formation	262-492	80-150	
		Newton Sandstone	59-131	18-40	
		Whitwell Shale	59-200	18-60	
		Sewanee Conglomerate	59-200	18-60	
	Gizzard Group	Signal Point Shale	49-137	15-42	
		Warren Point Sandstone	302	92	
		Raccoon Mountain Formation	148-400	45-122	
MISSISSIPPIAN		Pennington Formation	295-492	90-150	Shales have low permeability, yield little or no water to wells or springs. Limestones yield moderate quantities of water from solution channels or intersecting joints. No data available for the Hartselle Formation.
		Bangor Limestone	295-394	90-120	
		Hartselle Formation	10-49	3-15	
		Monteagle Limestone	295-394	90-120	
		St. Louis Limestone	100	30	
		Warsaw Limestone	0-72	0-22	
		Fort Payne Formation	249	76	Yields moderate to large quantities of water from solution cavities, intersecting joints, and residuum. An excellent aquifer.
DEVONIAN		Chattanooga Shale	13-49	4-15	Very poor aquifer, impermeable, water quality not good.
SILURIAN		Rockwood Formation	597	182	Minor quantities of water from fractured and weathered zones, water commonly has high iron content.

Table 2. Water-Bearing Characteristics (continued)

SYSTEM		GROUP		FORMATION	THICKNESS [IN FEET]	THICKNESS [IN METERS]	WATER-BEARING CHARACTERISTICS
ORDOVICIAN				Sequatchie Formation	246	75	Poor aquifers, yield small amounts of water only from fractured or weathered zones.
				Shellmound Formation	0-114	0-35	
				Leipers Limestone	0-344	0-105	
	Chickamauga Supergroup			Inman Formation	39-69	12-21	
		Nashville Group		Catheys Formation	197	60	Poor aquifers, yield small amounts of water. Many wells contain traces of hydrogen sulfide.
				Cannon Limestone	197	60	
				Hermitage Formation	98-119	30-36	
		Stones River Group		Carters Limestone	295	90	Yield moderate amounts of water to wells that penetrate solution cavities.
			Jewell Bluff Formation[1]	Lebanon Limestone	197	60	
				Ridley Limestone	457	140	
				Murfreesboro Limestone	344	105	
				Pond Spring Formation	354	108	
		Knox Group		Mascot Dolomite	457-590	140-180	Best aquifer in the county. Water yield is high, springs numerous. Many dug wells obtain water from the siliceous residuum.
				Kingsport Formation	249	76	
				Chepultepec Limestone	984	300	
CAMBRIAN				Copper Ridge Dolomite	984	300	
		Conasauga Group		Maynardville Limestone	312	95	Numerous springs in limestone.
				Conasauga Undivided	1,509	460	Poor aquifer, weathered zones locally supply small quantities of water to dug wells. Drilled wells commonly unsuccessful.
				Rome Formation	1,312	400	Wells yield only minor amounts of water normally high in iron. Fair to poor aquifer.

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[1] New Formation

Figure 1. Water service distribution area: approximate location and areal extent of each district.

WATER QUALITY

Precipitation is only slightly mineralized, but as it percolates through the soil and rocks beneath the earth's surface it begins to dissolve minerals and accumulates suspended organic material. The chemical quality of ground water depends in large measure upon the composition of the rocks through which it has flowed and the amount of time that the water has been in contact with the rocks. The salts of calcium, magnesium, sodium, iron and aluminum are the most common dissolved constituents.

Calcium is one of the principle constituents responsible for hardness in water. It is highest in wells drilled into limestone. Analyses of well water in the Chattanooga area indicate a range of 14 to 141 parts per million (ppm).

Magnesium is abundant in dolomite rocks. Dolomite may be dissolved by carbonated water, but it does not precipitate from water in which it has been dissolved. Along with calcium, it causes hardness in water. The concentration of magnesium in the wells of Hamilton County ranges from 0.5 to 32 ppm.

Sodium in natural waters is often reported, along with potassium. Wells from sandstone areas like Walden Ridge will have a slightly higher content of sodium and potassium than those in the limestone areas of the valley. Chemical anaylses indicate a range of 0.6 to 51 ppm. High concentration of sodium may indicate contamination by sewage.

Iron occurs chiefly as a ferrous bicarbonate in the ground water of the Chattanooga area. Iron concentrations in excess of a few hundredths of a part per million may stain clothes and plumbing, and have a distinct taste. Samples of some selected wells in Hamilton County indicate a range of from .01 to .77 ppm.

Aluminum is one of the most abundant metals in Hamilton County. It occurs in shales and in clays that overlie limestones and dolomites. Most of the aluminum, however, occurs as an aluminum silicate in the form of clay minerals or mica, and is almost completely insoluble in the ground water. A few wells had 0.02 to 0.16 ppm of aluminum.

The total hardness of water in the county as indicated by the analyses supplied ranges from 21 to 28 ppm. Water having a hardness of less than 50 ppm is considered soft. A hardness greater than 120 ppm is very noticeable, especially in the consumption of soap. If the hardness exceeds 220 ppm, a commercial water softener is recommended.

UTILITY DISTRICTS

In addition to domestic wells, the major water needs of Hamilton County are supplied by some eleven water utility districts. Figure 1 gives the approximate location and areal extent of each district. The following is a brief summary of each of these districts in terms of water source and quantity.

Tennessee-American Water Company (1)

This is the largest single supplier of water to the City of Chattanooga and several adjacent communities. It provides, on the average, about 56 million gallons a day that are derived from wells located on the flood plain of the Tennessee River a short distance upstream from its processing plant on Riverside Drive.

Hixson Utility District (2)

The second largest district in the county with 13,849 meters installed, it serves the Hixson and Middle Valley area. Water is obtained from wells inside Cave Springs, located in the Knox at the base of Cave Springs Ridge. It produces over 5,500 gallons per minute.

Eastside Utility District (3)

The third largest district in the county, with approximately 6,260 customers, serves the communities of Summit, Collegedale, Ooltewah, East Brainerd, and Apison. Three wells less than 100 feet (30 m) deep located near Carson Springs on Shorttail Springs Road in the Kingsport Formation of the Knox Group yield from 500-1000 gpm.

Savannah Valley Utility District (4)

Centered around the Snow Hill area in east central Hamilton County the Savannah Valley Utility obtains water from a series of wells drilled into the Mascot Dolomite and the Kingsport Formation. Some 12 wells in all were drilled with an average depth of 166 feet (51 m) and with a yield ranging up to 350 gpm. At present, this district serves about 1000 customers.

Union Fork-Bakewell Utility Districts (5)

Located along U. S. Highway 27 in the northern part of the county these districts have just over 300 customers and derive water from a single 450-foot (137-m) well into the Knox Dolomite with a discharge of 200 gpm.

Soddy-Daisy-Falling Water Utility District (6)

Water in this district is produced from two wells, one at Falling Water drilled 203 feet (62 m) into Mississippian limestones, and the second a 200-feet (61m) deep well at Soddy-Daisy located in the Knox Dolomite. Both wells produce about 200 gpm. Currently the district serves about 3,000 homes.

Walden Ridge Utility District (7)

This district serves a large area (some 1500 customers) on Walden Ridge beyond the town of Signal Mountain. Water is supplied by two wells 171 and 140 feet (52 and 43m) deep. These wells are drilled into the Monteagle Limestone below Buzzard Point at the foot of Walden Ridge and produce between 250 and 400 gpm.

Sale Creek Utility District (8)

This is the smallest utility district with only 300 customers. It is located in the extreme northern end of the county. Water is produced from two shallow wells drilled into Mississippian limestones. Both wells yield about 200 gpm.

Mowbray Mountain Utility District (9)

The water supply for the Mobray Mountain area is unique. Two large pumps were placed into Montlake (a natural depression in the Sewanee Conglomerate) near the edge of the Chickamauga Gulch. This depression is about 500 feet (152m) in diameter and some 200 feet (61m) deep (see Figure 2). Under normal conditions the lake contains around 73 million gallons of water. The district serves about 385 customers.

OTHER UTILITY DISTRICTS (10, 11)

The remaining two utilities, The Signal Mountain Water System (10) with some 2,000 customers, and the Lookout Valley Utility District (11) with 1,900 customers, both obtain their supply of water from the Tennessee-American Water Company.

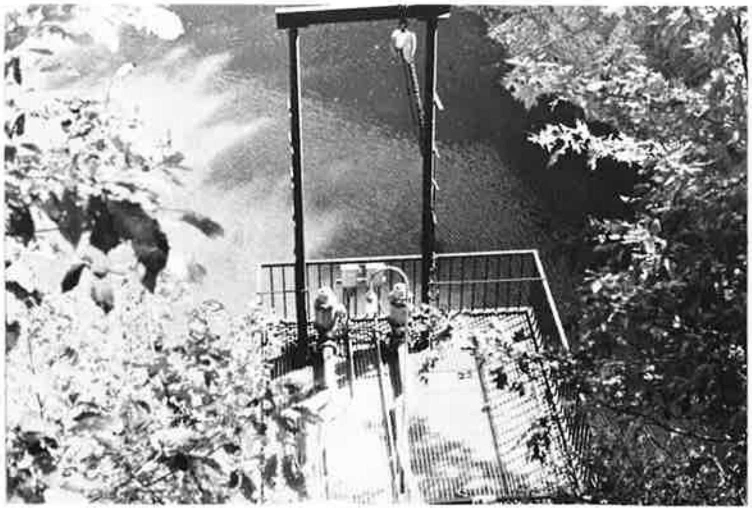

Figure 2. Twin pumps lift water for use by Mowbray Mountain Utility District.

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