# Stratigraphy and Uranium Content of the Chattanooga Shale in Northeastern Alabama Northwestern Georgia and Eastern Tennessee

By LYNN GLOVER

CONTRIBUTIONS TO THE GEOLOGY OF URANIUM

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# STRATIGRAPHY AND URANIUM CONTENT OF THE CHATTANOOGA SHALE IN NORTHEASTERN ALABAMA, NORTHWESTERN GEORGIA, AND EASTERN TENNESSEE

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By Lynn Glover


## ABSTRACT

In northeastern Alabama, northwestern Georgia, and eastern Tennessee, the Chattanooga shale of Late Devonian age ranges in thickness from 0 to more than 40 feet. Most of the shale is of the Gassaway member, though the Dowelltown member is present in part of eastern Tennessee. Beds of Dowelltown age were found in a small area in Alabama and Georgia, but the member is not recognized there. The Chattanooga shale and the overlying Maury formation, which is chiefly of Mississippian age, are progressively overlapped in the vicinity of Birmingham, Ala.

Along the eastern margin of the late Chattanooga sea, which coincided roughly with the region studied, stable shelf conditions prevailed, but the degree of stability was somewhat less than that to the west in the Eastern Highland Rim area. This difference is indicated in the east by the somewhat more silty and sandy sections, intraformational conglomerates, greater range in thickness of the shale, and in a few places by preservation of basal conglomerate. Phosphate nodules and minor amounts of chert were deposited in the east, and the distribution of each is areally and stratigraphically distinct. The chert probably accumulated in quieter water than did the phosphate.

Occasional influxes of greater than usual amounts of inorganic material produced the gray beds common in the Chattanooga. These beds have more clay and less organic matter than do the black beds.

The Maury formation in Georgia and southeastern Tennessee contains lentils of black shale; and in central-eastern Tennessee where the typical greenish Maury lithology is absent, beds equivalent in age to the Maury are of black and gray shale.

Less stable conditions of deposition and wide distribution of phosphatic black shale account for the generally low uranium content (less than 0.005 percent) of the Chattanooga shale in the region studied.


## INTRODUCTION

Since 1944 the U.S. Geological Survey has conducted field investigations of the Chattanooga shale, a potential low-grade source of uranium, for the Atomic Energy Commission. This report is the result of a reconnaissance study of the shale in the folded rocks of eastern Tennessee, northwestern Georgia, and northeastern Alabama during July 1954 to March 1955. The objectives of the project were to study the stratigraphy of the Chattanooga shale and related rocks with emphasis on environment of deposition, source of sediments, lithic character, thickness, distribution and correlation of stratigraphic units, distribution and concentration of uranium in the shale, and the character of stratigraphic control (if any) on the concentration of uranium, to detect radioactivity anomalies in the shale by means of a scintillation counter, and to sample the shale for uranium analyses.

The region studied (pl. 14) includes the southern Appalachians and the eastern margin of the Cumberland Plateau; it is bounded to the east and south by the limits of the Chattanooga outcrop, to the north by 36° latitude (approximately Knoxville, Tenn.), and to the west by a line of extension of the Sequatchie Valley. During the investigation, all roads that crossed the outcrop of the shale were traversed, all observed outcrops were spotted on maps, and the best exposures were measured and described in detail. An average scintillation-counter reading is herein recorded for each section or part of a section where a reliable reading could be taken. Twenty-eight samples of shale were collected for analysis from eight of these sections, and 11 faunal collections were made.

Data on shale localities examined by others are included in this report. These include outcrops described (all by written communications) by Slaughter and Clabaugh in 1945, Butler and Chesterman in 1945, Nelson and Brill in 1947, Robeck and Brown in 1950, Robeck and Conant in 1951, and Swanson and Kehn in 1955. Most of these investigators described only one or two localities in the folded belt, but Swanson and Kehn described seven outcrops east of the Sequatchie Valley in Tennessee and Alabama. Pertinent data from these investigations are incorporated in the present report.

## ACKNOWLEDGMENTS

This investigation was facilitated by the help of many people. Dr. Walter B. Jones, State geologist of Alabama, and Mr. Hugh D. Pallister, senior geologist of the Alabama Geological Survey, offered encouragement and unlimited use of the facilities of the State Core Library. Capt. Garland Peyton, State geologist of Georgia, provided information on undescribed localities in northwestern Georgia. Mr. Stuart W. Maher, Tennessee Division of Geology, and Robert A. Laurence, U.S. Geological Survey, spent a day in the field with the writer reviewing the stratigraphy of the Chattanooga shale in eastern

Tennessee. Faunal identifications were made by W. H. Hass, of the U.S. Geological Survey, and G. A. Cooper, of the U.S. National Museum. Uranium and trace elements analyses were made by the U.S. Geological Survey.

## GENERAL GEOLOGIC AND STRUCTURAL SETTING

The outcropping rocks in the region are mainly well-indurated Paleozoic sedimentary rocks that range in age from Cambrian to Pennsylvanian. These rocks were folded and faulted during the formation of the Appalachians, so that they now form long arcuate folds traceable on the surface as far south as Centreville, Ala. In the vicinity of Centreville, Paleozoic rocks are overlapped by poorly indurated sedimentary rocks of Cretaceous age.

The regional geology is described by Butts (1926), Butts and Gildersleeve (1948), and Rodgers (1953) and is shown on the State geologic maps of Alabama, Georgia, and Tennessee.

## STRATIGRAPHY AND SEDIMENTATION

### CHATTANOOGA SHALE

The Chattanooga shale is a black organic pyritiferous marine shale that is generally very fine grained and sparsely fossiliferous. It is part of a persistent terrane of black shale deposited over much of the interior of North America during Middle Devonian, Late Devonian, and Early Mississippian time.

In the southern Appalachians and along the folded margin of the Cumberland Plateau, the Chattanooga unconformably overlies at least six formations that range in age from Middle Ordovician to Middle Devonian. It is apparently conformably overlain by the Mississippian Maury formation south of the latitude of Knoxville, Tenn., except in the narrow belt of outcrop along the western margin of the Great Smoky Mountains. There, and to the northeast of Knoxville, the Chattanooga interfingers with and is overlain by clastic geosynclinal sedimentary rocks.

As the Chattanooga is one of the more incompetent formations in the region, it was severely folded and faulted during the formation of the Appalachians. It commonly crops out where folds have been truncated by erosion, though some exposures are along the eroded edges of fault blocks. The shale is more widely distributed in the folded margin of the Cumberland Plateau than in the Valley and Ridge province farther east where most of it has been removed by erosion.

### DOWELLTOWN AND GASSAWAY MEMBERS

A well-exposed section of the Chattanooga shale in the Eastern Highland Rim along State Highway 26 at the east approach to Sligo Bridge near Smithville, DeKalb County, Tenn., was designated by Hass (1956, p. 13) and by Conant and Swanson (written communication) as the standard section of the Chattanooga. This outcrop, which has both the Dowelltown and the Gassaway members, is better suited for stratigraphic studies than the poorly exposed, thin, incomplete, and faulted rocks at the type locality of Hayes (1894) on Cameron Hill in the city of Chattanooga, Tenn. Only the Gassaway member is present at Cameron Hill, and the outcrop is typical only of the few thin exposures in the vicinity of the city.

Table 1 shows the system of nomenclature adopted by the U.S. Geological Survey for the Chattanooga shale in central Tennessee.

Breaking the monotony of the black shale succession are the middle unit of the Gassaway member and the upper unit of the Dowelltown member, which consist of alternating thin gray and black beds. This allows the 2 members to be divided into a total of 5 units. A thin bed of sandstone, the Bransford sandstone of Campbell (1946, p. 884), generally is present at the Dowelltown-Gassaway contract in east-central Tennessee. Near the top of the Dowelltown is a thin bed of bentonite (Hass, 1948), which has been traced over much of the Eastern Highland Rim and as far east as Dayton, Tenn. (loc. 11P–1, pls. 14, 18).

Previous investigations by Robeck and Brown (written communication, 1950) and Glover have shown that both members of the Chattanooga shale are present in the northern part of Sequatchie Valley,

TABLE 1.—*Stratigraphic nomenclature of the Chattanooga shale and Maury formation in central Tennessee*

<table>
<tr><th>System</th><th colspan="3">Formal name</th><th colspan="2">Informal name</th></tr>
<tr><td>Lower Mississippi Plan</td><td colspan="3">Maury formation</td><td colspan="2"></td></tr>
<tr><td rowspan="5">Upper Devonian</td><td rowspan="5">Chattanooga shale</td><td rowspan="3">Gassaway member</td><td>Upper unit</td><td rowspan="3">Upper black shale</td><td>Top black shale</td></tr>
<tr><td>Middle unit</td><td>Upper gray beds</td></tr>
<tr><td>Lower unit</td><td>Middle black shale</td></tr>
<tr><td rowspan="2">Dowelltown member</td><td>Upper unit</td><td colspan="2">Middle gray beds</td></tr>
<tr><td>Lower unit</td><td colspan="2">Lower black shale</td></tr>
</table>

but that the Dowelltown is absent, probably because of overlap, in northern Alabama and in Tennessee south of hole WR-48 (pl. 14). In corroboration the typical alternation of thin gray and black beds of the upper unit of the Dowelltown member was observed during this reconnaissance only at localities 11P-1 and 10P-1 (pl. 18), both of which are north of the latitude of hole WR-48. Farther south, however, Hass identified conodonts of Dowelltown age from the lower 1 foot of the outcrop at locality 6N-53 (pls. 14, 17), Menlo, Ga., and from the basal sandstone at locality 4J-3 (pl. 16), Etowah County, Ala. As the difference in lithology of beds of Dowelltown and Gassaway age at these localities in Alabama and Georgia is insufficient to warrant separating the formation into members, the term Chattanooga is herein applied to all of the Devonian black shale south of Chattanooga, Tenn., where the terms Gassaway and Dowelltown are useful in a time sense only.

The outcrops that contain beds of probable Dowelltown age (6N-53 and 4J-3) are both in areas of thick shale section (pls. 14, 15). It seems reasonable to assume that the entire area of thick shale contains beds of Dowelltown age at the base, although the beds may not be separable lithologically. This assumption is the basis for the distribution of shale of Dowelltown age in Alabama and Georgia as shown in figure 16.

### OVERLAP

The thickness of the Chattanooga shale (pl. 15) and the distribution of the beds of Dowelltown and Gassaway age (fig. 16) show that the general direction of overlap in the region was to the south and east. A slightly high area seems to have existed along the southern Tennessee State line (pl. 15) because there the section is thin and only shale of Gassaway age is present. Another high area was in the vicinity of Birmingham, Ala., and farther east, where the Chattanooga (loc. 3H-2, pl. 16) and the overlying Maury (loc. 3J-2) are progressively overlapped.

### BASAL SANDSTONE

A basal sandstone was found at all localities at which the bottom unit of the Chattanooga shale was exposed (except loc. 8N-3) (pl. 15). The sandstone has an average thickness of 0.78 foot for 31 localities, and a maximum thickness of 5.0 feet in core RO-11 (pls. 14, 16), southwest of Birmingham. Characteristically, the sandstone is composed of well-rounded poorly sorted quartz grains ranging in size from silt to pebble, but averaging coarse sand (0.5-1.0 mm.). The matrix consists of organic matter, pyrite, and abundant phosphatic fossils that may have been in part reworked from older beds.

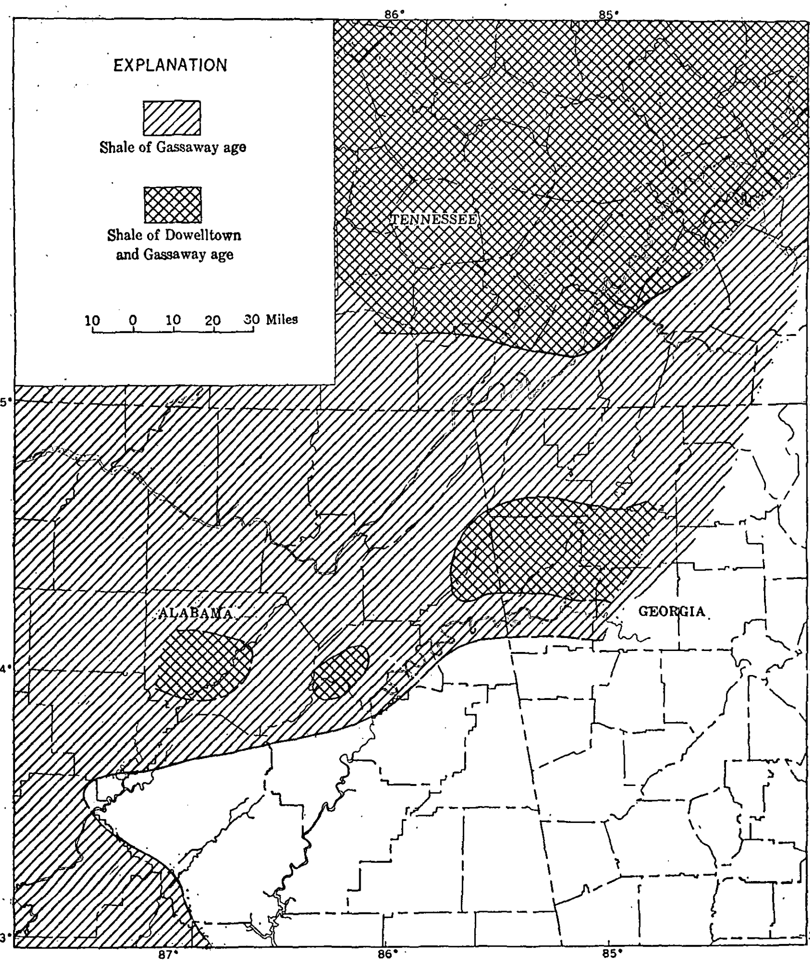


FIGURE 16.—Distribution of beds of Dowelltown and Gassaway age in the Chattanooga shale of northeastern Alabama, northwestern Georgia, and eastern Tennessee.

Conglomerate or conglomeratic sandstone is the basal unit at localities 4J–3, AL–66, 7N–52, and RO–11 (pl. 14). The pebbles have a maximum diameter of 0.13 foot, and at the first three places are subrounded to well rounded. At the last place, core RO–11 (fig. 19), the pebbles are angular pieces of chert eroded from the underlying cherty limestone. Pebbles are present where the basal sandstone is relatively thick and appear to be associated with thick shale sections and less stable areas of deposition.

Considering that the Chattanooga is underlain by six formations in this region, the identity of all pebbles with underlying rocks shows that the pebbles have not been transported far. The roundness of many of the pebbles indicates that they must have undergone considerable wave action before final deposition.

The basal sandstone is a time-transgressing unit ranging in age from early Dowelltown (early Late Devonian) in the general latitude of Knoxville, Tenn. (35°), to Maury (Early Mississippian) near Birmingham, Ala.

### LITHOLOGY

Although the Chattanooga shale in this region closely resembles the shale in central Tennessee, it differs lithologically in several respects. In general it is coarser grained and contains much disseminated coarse sand, scattered chert beds, and intraformational conglomerates.

#### SAND AND SILT

Several thin beds of coarse-grained sandstone are present in the Chattanooga shale in this region. At localities 4J–5 and 4J–6 (pls. 14, 16) in Alabama a 0.2-foot bed of poorly sorted sandstone with silt- to granule-size quartz particles was found about 0.5 foot below the top. At localities 7N–52 (pl. 17) in Georgia, and 9P–2 (pl. 18) and 11T–1 (pl. 18) in Tennessee, poorly sorted coarse-grained sandstone is present, but none of these can be traced beyond its own exposure. Because these sandstone beds are of small areal extent, poorly sorted, and coarse grained, they are believed to be lag concentrates of the disseminated coarse sand deposited in the Chattanooga sea.

Well-sorted fine sand is common in the eastern outcrops of the Chattanooga shale. At localities 6M–2 and 6M–4 (pl. 17) in Alabama, the upper 18 to 21 feet of the outcrops is practically all black siltstone and fine-grained sandstone. The silt and sand in these sections slumped before consolidation, and much of the original bedding was destroyed. Rich (1951, p. 2023) maintained that all true sand beds in the shale are lag concentrates of material that has been rafted in, but such quantities of silt and sand as are found at 6M–2 and 6M–4 could hardly have been rafted in but must have been transported by current action. In core RO–11 (pls. 14, 18) microcrossbedding in the silt near the top of the Chattanooga also indicates that currents were active in the deposition of the shale.

#### GRAY BEDS

Beds of gray claystone, gray silty claystone, or gray shale are common to most outcrops of the Chattanooga in the region studied. The gray beds in the Dowelltown member at 11P–1 and 10P–1 (pls. 14, 18) are part of a unit that can be found over a large area of east-central Tennessee. However, in the vicinity of Chattanooga, Tenn., and farther south, the gray beds seem to be more lenticular.

The gray beds of the Chattanooga in most places have more clay and less organic matter than the black shale, and in many of the eastern outcrops they are somewhat silty or sandy. When compared with the surrounding black shale, the gray beds are also less perfectly sorted and bedded. These features, with the exception of the small amounts of silt and sand, seem to agree with the general characteristics of the gray beds in the Chattanooga shale along the Eastern Highland Rim. Conant (1952, p. 22) has suggested a process of postdepositional oxidation of the organic matter to produce these gray beds in the Highland Rim area. However, by such a process the percentage increase of all other components should bear a constant relation to the amount of organic matter destroyed, and this does not seem to be true. Within the area of this study, less perfect sorting, general absence of well-defined bedding, and disproportionately greater amounts of clay in the gray beds indicate that these beds are probably the result of an increased supply of inorganic material rather than oxidation of organic muds. Consequently, the gray beds are interpreted by the writer to represent faster deposition than the black beds.

#### PHOSPHATE AND CHERT

Phosphate nodules are widely distributed in the Chattanooga shale of northwest Georgia and east Tennessee (fig. 17). In the northern Sequatchie Valley and northern part of the Eastern Highland Rim, the nodules are confined to the upper few feet of the Chattanooga; but in the easternmost exposures in Georgia and Tennessee, they are found in intervals throughout the shale in both gray and black beds. The nodules range in size from small spheres 0.05 foot in diameter to large lenses about 2 feet in length near the Highland Rim, but in the easternmost outcrops they are only about 0.1 to 0.2 foot in greatest diameter.

Beds of chertified black shale were discovered in the Chattanooga in northeast Alabama and northwest Georgia (fig. 17). The chert beds are from 0.02 to 0.20 foot thick and give a spectacular shower of sparks when struck with a hammer. At 7N–52 (pl. 17) the thickness of individual beds is constant for an exposed distance of 25 yards, yet the beds cannot be correlated between outcrops. Analysis of a sample of the chert showed 85 percent silica, much of it as chalcedony. Normally the Chattanooga shale contains about 30 percent silica, mostly as quartz grains.

Figure 17 shows that the phosphate and chert in the Chattanooga shale tend to be areally segregated. In five outcrops near the Alabama-Georgia line, 6M–1, 6M–2, 6M–4, 7N–2, and 7N–52 (pls. 14, 17), both

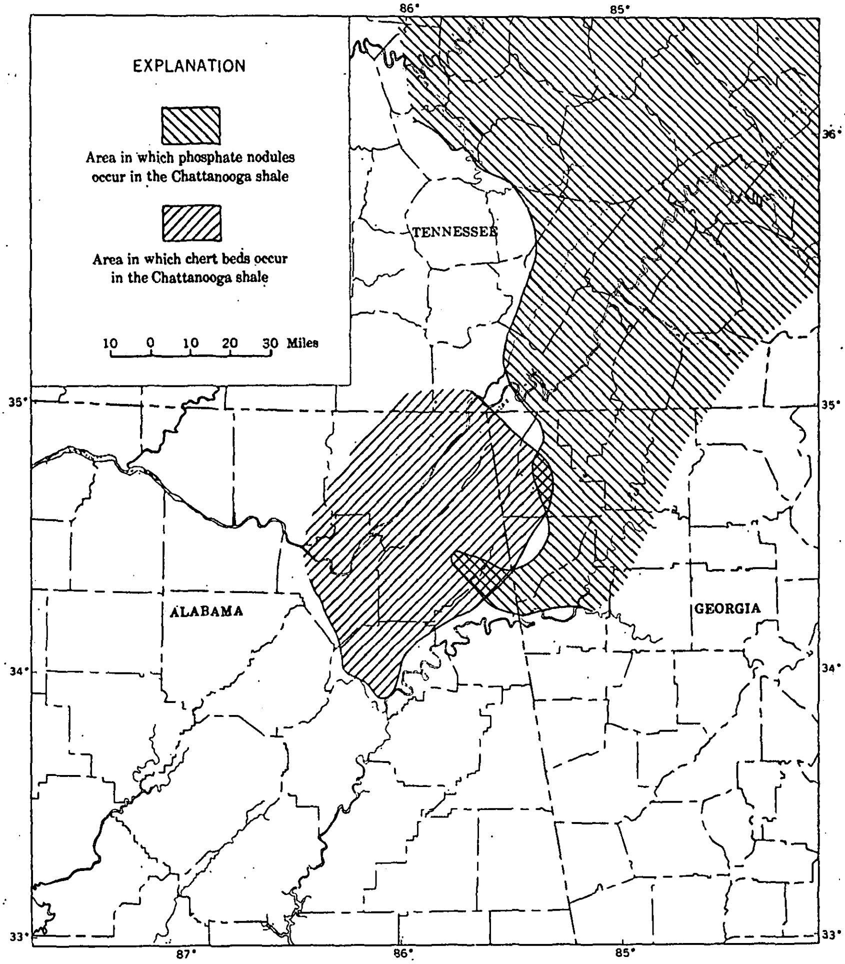


FIGURE 17.—Distribution of phosphate and chert in the Chattanooga shale of Alabama, Georgia, and Tennessee.

phosphate and chert are present. At each place the chert-bearing unit is below the bed containing phosphate nodules, and in general the chert is in the finer grained part of the outcrop. Because of the fine-grained impervious nature of the Chattanooga shale, it is believed that chertification took place at the time of deposition or soon after. Apparently the environment that favored the formation of phosphate nodules did not favor the formation of chert as the two have not been found in the same bed. The fine grain of the chert-bearing shale suggests that quieter water and the availability of dissolved silica may have been factors that favored formation of chert rather than phosphate.

### INTRAFORMATIONAL CONGLOMERATES

Intraformational conglomerate occurs in a 1-foot interval in the Chattanooga shale at locality 8P-3 (pls. 14, 18) in northwestern Georgia where it contains many balls and flakes of gray silty claystone in a matrix of black shale. These fragments of silty claystone are mostly subrounded, but some have sharp edges. Quartz grains ranging in size from silt to coarse sand are scattered through the unit, which has poorly defined bedding and breaks into irregular pieces. The rocks in this interval are also notable for the impressions of articulate brachiopod shells. Normally these calcareous shells would have been dissolved by the acidic environment of the organic mud before they could be covered by sediment; hence, the preservation of such impressions implies sudden burial. Apparently semiconsolidated mud was stripped up, presumably by current action, and transported a short distance to its present site.

Such intraformational conglomerates may be a widespread occurrence in the Chattanooga. For example, most of the Bureau of Mines diamond-drill cores (pl. 14, WR-48, WR-49, WR-50) that contain the upper unit of the Dowelltown member show that the contacts between the light- and dark-gray layers are not as definite as they seem at the outcrop. Rather, the lighter layers contain blebs, lenses, stringers, and flakes of darker claystone, and vice versa. Some of these inclusions of lighter material in darker layers or darker inclusions in lighter layers can be explained by flowage during compaction, but others are isolated, angular, and obviously clastic.

The idea that some of these flakes have been transported by current action is further strengthened by the fact that many of the individual light and dark layers are actually lenses that cannot be correlated even between nearby outcrops. Normally such fine sediment as that in the gray and black layers of the Chattanooga would be deposited as beds over large areas. Therefore the lenticularity of these beds suggests that they are preserved patches of widespread blankets of sediment. Presumably wave action reworked parts of these beds, destroying many of the original layers of the sediment by mixing and finally depositing the material elsewhere. In this manner inclusions of one type of sediment would be deposited in a bed of another type.

Conant (1952, p. 16, 19) cites the paper-thin laminae and thick shale section in the Flynn Creek cryptovolcanic structure to show the oft-repeated agitation of the sediments. From the evidence of lenticular bedding and intraformational conglomerates found in the region of the present study, it seems certain that the Chattanooga shale was not deposited in such deep water that simple and almost uninterrupted settling could explain the stratigraphic features preserved. Instead, there must have been infrequent periods of bottom scouring that redistributed the muds, so that the floor of the sea was well graded most of the time.

## MAURY FORMATION

The Maury formation is a widespread thin bed of claystone that is commonly green, glauconitic, pyritiferous, and locally silty or sandy and contains phosphate nodules. The formation was named by Safford and Killebrew (1900, p. 141–142) for exposures in Maury County, Tenn. Outside of the Central Basin of Tennessee the name has not been widely used, though the literature records the presence of greenish beds at the top of the Chattanooga. Hass (1956, p. 7, 13) pointed out that the Glendale shale of Swartz (1924, p. 24), named for an exposure near the old Glendale station in North Chattanooga, Tenn., is the Maury formation. In Alabama and Georgia the Maury has generally been considered part of the Chattanooga shale.

In the region studied the thickness of the Maury ranges from 0.3 to about 7.5 feet, and the average thickness in 54 sections east of the Sequatchie Valley is 3 feet. Both the range in thickness and the average thickness are about 50 percent greater than in central Tennessee. The Maury appears to be present throughout the region except in the area east of Birmingham (pl. 15) where it is overlapped by the Fort Payne chert.

### BIRMINGHAM HIGH

In a large area around Birmingham, Ala. (pl. 15), only the Maury formation is generally present between the overlying Fort Payne chert and underlying formations that range in age from Ordovician to Early Devonian. On three sides of this area, the Chattanooga shale wedges out by progressive overlap, and east of Birmingham (loc. 3J–2, pls. 14, 16) the Fort Payne chert rests directly on the Frog Mountain sandstone of Early or Middle Devonian age. Thus these outcrops indicate that the latest shorelines of both the Chattanooga and the Maury seas were in the Birmingham area and were not far apart.

Where the Maury overlies the black Chattanooga, it retains its characteristic greenish color; and the unweathered iron compounds are usually sulfides, as at outcrops 4J–5, 4J–6, and 4H–1 (pls. 14, 16), northeast of Birmingham. However, on the Birmingham high near the wedge edge of the Chattanooga, at localities 2F–2, 3H–1, 3H–2, 4K–1, and 4L–1 (pls. 14, 16), red shale is present in the lower part of the Maury. At greater distances from the edge of the Chattanooga, as at localities 3H–4, 3H–3, 3J–1, 4K–2, and 4L–2 (pls. 14, 16), red claystone and silty claystone make up most, or all, of the Maury. The only feature common to the Maury in these outcrops, and to the Maury in the more normal succession that overlies the Chattanooga elsewhere, is a very thin layer of dark-green silty material, which is probably glauconitic, at the Fort Payne-Maury contact. No sulfides of iron are apparent in the red shale, although sulfides are common in the thin overlying green claystone where it is present. Phosphate nodules are also absent in the red shale.

The Maury contains a basal conglomerate at outcrops 3H–1, 4K–1, and 4L–1 (pls. 14, 16), just south of the edge of the Chattanooga. This conglomerate is made up of subangular cobbles and pebbles of sandstone in a matrix of quartz sand and red clay. "Landward" from the edge of the Chattanooga shale, the Maury does not have a basal sandstone or conglomerate.

Red coloring in the basal Maury formation is probably due to finely divided hematite. The red iron ores of the underlying Silurian rocks would provide a good supply of hematite which normally would have been reduced to sulfides in the poorly aerated Maury sea. Oxygen must have been plentiful enough during the early stages of Maury deposition in this area to keep the iron from being reduced, implying a near-shore, aerated environment of deposition.

### BLACK SHALE

Throughout most of the region wherever the Maury formation lies on the Chattanooga shale, the Maury is typically a greenish claystone. However, in the northeastern half of the region at localities 6M–4, 6M–2, (pls. 14, 17) 8N–4, 8N–1, 9N–1, and 12S–1 (pls. 14, 18), the Maury contains a bed of black shale that is almost indistinguishable from the black shale of the Chattanooga; and at locality 8N–6 (pls. 14, 18) it contains two beds of black shale. Plate 14 shows that these black shale localities are oriented geographically in an arcuate linear pattern suggesting some sort of relation among them. However, many intervening localities do not show black shale. It may be that they are part of 1 or 2 widespread blankets of black shale that were partly removed by submarine beveling.

At localities 9P–2 (pls. 14, 18), east of Chattanooga and east of these black shale lentils, 2.7 feet of normal greenish claystone of the Maury is underlain by 3.7 feet of black shale crowded with round phosphate nodules. This black shale unit has a thin basal sandstone which rests on buff silty claystone. Hass (1956, p. 11) states that the phosphatic nodule-bearing black shale contains a conodont fauna of Early Mississippian (Maury) age and that the underlying buff silty claystone has another conodont fauna equivalent in age to the Upper Devonian

(Gassaway) strata below the phosphate nodule unit in exposures along the Eastern Highland Rim. Without the paleontological evidence one would place the top of the Chattanooga shale at the top of the phosphatic black shale unit. However, if one reasons that the basal sandstone is a lag concentrate of the phosphatic black shale unit and that it indicates erosion before its deposition, it is possible that the typical greenish claystone of the Maury and some of the upper part of the Chattanooga were removed and that a black shale lentil of the Maury was deposited directly on the gray claystone of the Chattanooga. This would result in the problematical succession seen at the outcrop. Hence, tentatively, the Maury-Chattanooga contact at locality 9P–2 is here placed at the base of the phosphatic black shale unit of Maury age.

### BACON BEND SECTION

Strata of Maury age at locality 11T–1 (pls. 14, 18) bear little resemblance to the greenish claystone generally found overlying the Chattanooga shale in this region. Here in a roadcut near the Bacon Bend of the Little Tennessee River in Monroe County is an outcrop of shale that may be transitional between the "three-fold" black shale succession of northeast Tennessee and the Chattanooga-Maury succession in the vicinity of the city of Chattanooga. The section begins at the base with a Middle Ordovician bentonite-like clay that is overlain disconformably by 12 feet of black shale of probable Late Devonian age. Proof of the age of this black shale awaits the discovery of conodonts in this part of the outcrop; and the tentative Late Devonian assignment is based on thickness trends, physical similarity of the strata, and stratigraphic position. About 11 feet of beds equivalent in age to the Maury formation are next above the Devonian(?) black shale. The lower 8 feet of this interval is a silty claystone, light gray in color, that contains a megafossil fauna identified by G. A. Cooper as of Early Mississippian age. (See section on paleontology.) The upper 3 feet of the interval is black shale containing conodonts of Early Mississippian Maury age according to W. H. Hass. (See section on paleontology.) The paleontological evidence is in good agreement as to the Maury age of the 11-foot interval of rock, but the typical greenish, phosphate-nodule-bearing claystone of the Maury seems to have been supplanted by rocks more akin to the Chattanooga.

The Grainger shale overlies the uppermost black shale, and this contact is probably equivalent to the Fort Payne chert-Maury formation contact found elsewhere in the region studied.

## FORT PAYNE CHERT

The Fort Payne chert, a cherty limestone of Mississippian age, overlies the Maury formation at most places in the part of the folded belt covered in this report. Because the thick basal beds of the Fort Payne are generally the most cherty, the contact with the Maury formation usually is easily picked. At localities 7P–1, 7P–2 (pls. 14, 17), and 3J–2 (pls. 14, 16), however, the basal 1 or 2 feet is not cherty, and the limestone has weathered to a clayey residuum. Also at 9P–4 (pls. 14, 18) the lower Fort Payne strata are green siltstone. In every case the contact can be picked by applying one or all of the following criteria:

1. The lowest chert bed is Fort Payne.
2. Phosphate nodules are not present in the Fort Payne.
3. A thin layer of very dark-green glauconitic siltstone usually marks the Maury-Fort Payne contact.

At 9P–4, east of Chattanooga, a small "algal reef" at the base of the Fort Payne is in contact with the underlying Maury. If the reef is truly algal, the maximum depth of the sea at the end of Maury time at this locality would be the greatest depth at which algae can carry on photosynthesis.

The Fort Payne chert is supplanted by the Grainger shale at locality 11T–1 (pls. 14, 18). The exact relation between the two formations has not been worked out, but they are at least partly time equivalents.

## PRE-CHATTANOOGA UNCONFORMITY AND ITS RELATION TO THE ORIGIN OF THE SHALE

The unconformity at the base of the Chattanooga shale is one of the greatest in terms of time in the Paleozoic rocks of the Southeastern States. A proper interpretation of the nature of this contact is important to any theory of origin of the Chattanooga shale; hence, it has received much attention in previous investigations. This study supports in general the interpretation by Conant (1956a, p. 464–465; 1956b, p. 436) that the basal sandstone of the Chattanooga is a shallow-water deposit derived in part from the soil of a peneplain as the Chattanooga sea advanced. New evidence from this study suggests further that the sandstone was derived in a shoreward zone of moderate wave action. Constant agitation of the loose material in this zone, which must have transgressed a peneplained surface with phenomenal slowness, eventually abraded the rock surface below the zone of weathering virtually everywhere.

The pre-Chattanooga surface was formed on the rocks of three systems as shown on the highly generalized pre-Chattanooga geologic

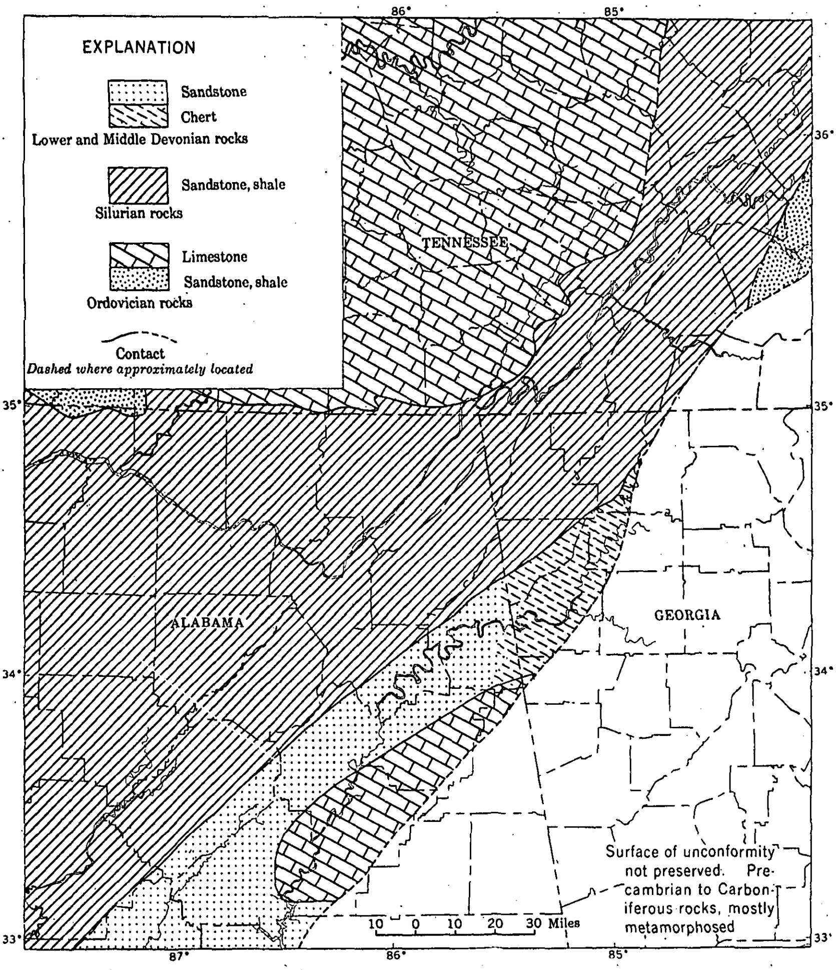


FIGURE 18.—Generalized pre-Chattanooga geologic map of northeastern Alabama, northwestern Georgia, and eastern Tennessee.

map (fig. 18); and, although many rock types are present, they are almost always beveled to the same degree of smoothness. In places an angular discordance of several degrees separates the Chattanooga and underlying rocks, but generally the beds are parallel. The smoothness of this surface is its most significant feature. No stretch of the imagination could envision such a surface to exist beneath the soil of even the most perfect peneplain. This rarity of irregularities at the surface of unconformity is in itself one of the most compelling evidences of submarine beveling that can be offered.

Further evidence of submarine erosion is afforded by the basal contact at locality 11T–1 (pls. 14, 18). Here the Chattanooga rests on a 4-foot bed of Middle Ordovician bentonite. If we assume that almost no beveling took place during inundation, then the bentonite must have been exposed to air by erosion at some time during the process of peneplanation. Surely the bentonite could not have withstood first the drying action of the air and then even the most gentle agitation of an advancing sea. Again the most reasonable hypothesis is that the erosion that exposed the bentonite was submarine, in which case the bentonite could act as a wet and very compact clay considerably more resistant to erosion than many sandstones.

Apparently, then, the pre-Chattanooga surface is the product of two different erosional processes: first, subaerial erosion that produced a peneplain, and second, a relatively minor amount of submarine erosion that removed the soil, the underlying weathered rock, and almost all minor irregularities of the surface.

But if the Chattanooga is mostly fine-grained shale with only a thin basal sandstone, where are the tools of erosion? The evidence is that the remains of the eroding agent are indeed to be found in the inch or so of sandstone at the base of the Chattanooga. Probably in the near-shore zone of erosion, the loose material was always coarser and more abundant than is immediately apparent from the thin bed of well-rounded sand that finally came to rest in the zone of permanent deposition as the sea slowly advanced. Some evidence for this is found in the conglomerates at the base of the Maury on the Birmingham high south of the thin edge of the Chattanooga shale. Apparently a relatively sudden deepening of the sea at the beginning of Maury time resulted in preserving locally some conglomerate before it was reduced to the usual sand-sized particles of the basal sandstone. Certainly time was an important factor in producing the relations now observed. The distribution of beds of Gassaway and of Dowelltown age (fig. 16) indicates that much of Late Devonian time was required to deposit a thin unit of black shale in a sea that transgressed in this time only a few tens of miles.

It has been difficult to prove that the surface of unconformity is in greater part a product of subaerial erosion. According to the deep-water theory as presented by Rich (1951, p. 2021) the principal beveling was pre-Devonian, and this was followed by deposition of some Lower and Middle Devonian strata. Rich thought that the unconformity between the Chattanooga and the underlying rocks was due to nondeposition rather than subaerial erosion. In this manner he could explain the absence of a shallow-water deposit at the base of the Chattanooga, which he felt should be present if the Chattanooga was deposited in a transgressing sea. The overlapping relations of such time-stratigraphic units as the members of the Chattanooga shale and the Maury formation do indicate however that the sea was transgressing. And the fact that the Chattanooga was the initial deposit of a transgressing sea indicates relatively shallow-water deposition. Further, it has been shown that the surface of unconformity must have been beveled to its present degree of smoothness during the process of transgression, which would have removed evidence of subaerial erosion and weathering.

At a few places, however, evidence of subaerial weathering has been found. This evidence is found in the basal contacts of cores from holes WR-48, WR-50 (pl. 14), and RO-11 (pls. 14, 16). In cores WR-48 and WR-50 the basal sandstone of the Chattanooga fills small crevices and cavities in the underlying limy shale of the Silurian Rockwood formation. In core RO-11 (fig. 19) several small solution cavities are present in the limestone to a depth of about 1 foot below the base of the Chattanooga. The cavities range between 0.1 and 0.2 foot in greatest diameter and in cross section show a very irregular outline. Most of the cavities are filled with the basal sand of the Chattanooga and one cavity has, in addition to the sandstone, a 0.02-foot layer of black shale. For about 1.7 feet below the Chattanooga the limestone has been reworked and weathered and is full of pyrite. Surely these cavities could not have been formed during the first period of erosion postulated by Rich (1951) and then have survived unfilled from the end of the Silurian to the Late Devonian. Instead, they must have formed during subaerial erosion just before deposition of the Chattanooga shale. The irregular outline of these cavities and their presence in limy shale and limestone leave little doubt that they were formed by solution; hence, the containing rock must have been not only out of the sea but, for a short time at least, it must have been above the water table. That these cavities in the weathered pre-Chattanooga rock escaped destruction by the beveling that took place during transgression is probably explained by their location in or near a historically unstable area, the Appalachian geosyncline.

## URANIUM

The average uranium content of 25 samples of Chattanooga shale taken from selected outcrops in the region investigated is about 0.005 percent. This value, however, is doubtless too high for a regional average because many of the outcrops were selected for sampling on the basis of relatively high scintillation-counter readings.

This low uranium content compared with that of the shale along the Eastern Highland Rim can probably be explained by the lithology of the shale. The beds of Gassaway age in the region studied are commonly thicker, nearly everywhere sandier and siltier, and in places phosphatic throughout. The indicated more rapid deposi-

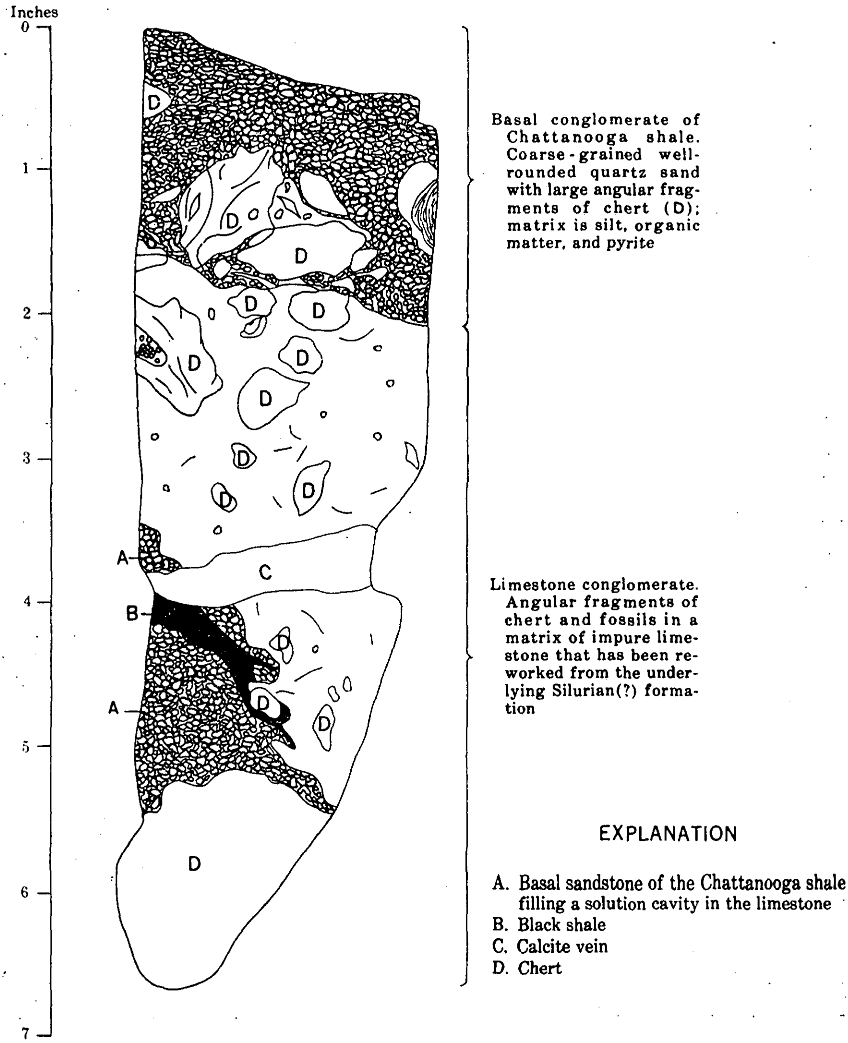


FIGURE 19.—Sketch of core from hole RO–11 showing solution cavity filled with Chattanooga shale; SE¼NW¼ sec. 23, T. 20 S., R. 5 W., Jefferson County, Ala.

tion, the consequent smaller percentage of finely divided carbonaceous material, and the presence of phosphate were probably the principal factors that caused the lower uranium content of the shale in this region.

The greatest concentrations of uranium were found at localities 7M–2 and 7N–52 (table 2). The outcrop at locality 7N–52 has 9.7 feet of shale that averages 0.007 percent uranium. The outcrop is near the north end of a syncline (Pigeon Mountain) that is bounded on the east side by a long reverse fault. All the shale outcrops in the area show moderate to intense faulting, and most of the outcrops have dips of more than 5°. One interesting feature of the section at locality 7N–52 (pls. 14, 17) is a 4-foot thickness of chert-bearing shale, the top of which is about 4 feet below the Chattanooga-Maury contact. A channel sample was taken of the whole chert-bearing thickness and a grab sample was taken of the chert alone. Analysis of the grab sample of chert shows 85.7 percent $SiO_2$, 0.30 percent $K_2O$, 0.10 percent $P_2O_5$, 0.013 percent eU, and 0.012 percent U. Much of the $SiO_2$ is in the form of chalcedony. An analysis of a channel sample of the chert-bearing shale showed only 0.006 percent U. This seems to indicate that the chert beds may run high in uranium, but this is uncertain because only one sample of chert was analyzed. The uranium content of the chert-bearing shale is significantly lower than the uranium content of the overlying and underlying noncherty shale beds that contain 0.008 and 0.007 percent U, respectively. Chert beds in other sections do not show higher than usual radioactivity as measured by a portable field scintillation counter, though this may be because they are thinner and more scattered than at locality 7N–52.

TABLE 2.—*Uranium content of some Chattanooga shale samples from northeastern Alabama, northwestern Georgia, and eastern Tennessee*

[Analyses by U.S. Geological Survey: R. Moore, Grafton Daniels, analyses; P. Moore, B. A. McCall, radiation measurements. Type of sample: A, channel; B, chip]

| Locality | Sample | Type | Thickness (feet) | eU (percent) | U (percent) | Remarks |
|---|---|---|---|---|---|---|
| 4J–3 | 1 | B | 16 | 0.008 | 0.003 | |
| 4J–4 | 1 | B | 5 | .006 | .003 | |
| 6N–53 | 1 | A | 5 | .008 | .006 | Avg. 0.005 percent U. |
| | 2 | A | 5 | .007 | .004 | |
| | 3 | A | 5 | .007 | .005 | |
| | 4 | A | 5 | .010 | .006 | |
| 6P–5 | 1 | A | 3 | .006 | .002 | |
| 7N–52 | 2 | A | 2.2 | .004 | .002 | |
| | 3 | A | 1.7 | .011 | .008 | 0.007 percent U. |
| | 4 | A | 4 | .009 | .006 | |
| | 5 | A | 4 | .009 | .007 | |
| | 6 | A | 4 | .008 | .006 | Duplication of sample 4. |
| 7P–2 | 1 | A | 5 | .007 | .003 | |
| | 2 | A | 5 | .007 | .004 | |
| 9P–2 | 1 | A | 4 | .006 | .003 | |
| | 2 | A | 1.6 | .006 | .004 | |
| | 3 | A | 2.5 | .007 | .004 | |
| 7M–2 | 1 | A | 2.2 | .006 | .004 | |
| | 2 | A | 2.2 | .005 | .004 | |
| | 3 | A | 2.2 | .007 | .005 | |
| | 4 | A | 2.2 | .009 | .007 | |
| | 5 | A | 2.2 | .016 | .009 | |
| | 6 | A | 2.2 | .011 | .0065 | |
| | 7 | A | 2.2 | .006 | .004 | |
| | 8 | A | 2.2 | .007 | .004 | |

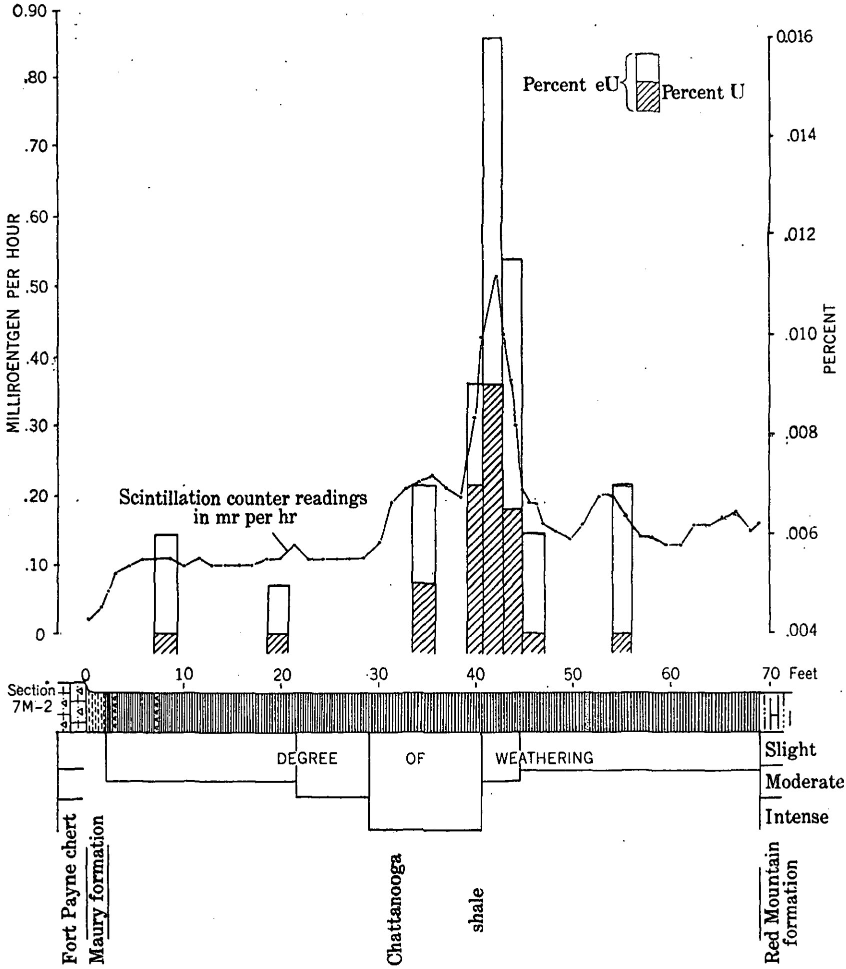


FIGURE 20.—Comparison of radioactivity and uranium content with degree of weathering at locality 7M–2.

In the faulted and weathered section at locality 7M–2 (pl. 14), an unusually high uranium content for the rocks in a 6-foot interval was indicated by field-scintillation-counter readings. Analyses showed that the uranium content of the rocks in the interval ranged from 0.0065 percent to 0.0090 percent. Disequilibrium was much greater than usual, the equivalent uranium ranging from 0.009 to 0.016 percent. As shown on figure 20, the greatest concentration of uranium is at the base of and just below the most highly weathered rocks in the shale. The rocks in this interval are weathered to light buff and tan colors in contrast to the chocolate brown of the less deformed and weathered rocks below. Because of the isolated nature of this unusually high uranium concentration in the shale, it is believed that the deep weathering and deformation are responsible for enrichment. McKelvey and others (1955, p. 471) state, "If the uraninite is associated with the iron sulfides, the $(U^{+6}O_2)^{+2}$ may be retained for some time at the outcrop by adsorption on the ferric oxide of the gossan. Under humid conditions, uranium is removed by ground and surface waters." This is significant because the Chattanooga shale contains about 10 percent pyrite and marcasite. If the rock in the most highly weathered interval has lost much of its iron to solution, as is suggested by its light color, then much of the uranium carried by ground water would be adsorbed by the rock in the next lower interval that contained appreciable amounts of iron compounds. This process may explain the relation of the highly uraniferous shale interval to the degree of weathering and deformation in the shale.

A grab sample of highly weathered coal from the Maury-Fort Payne contact at locality 8N–2 in Dade County, Ga. (pls. 14, 18), near Chattanooga, was analyzed and found to contain unusually high concentrations of rare earths (Breger and Deul, 1955, p. 186). The coal burns to 10 percent ash that contains all the rare earths except promethium. In the 1 to 5 percent range are yttrium, manganese, gadolinium, and neodymium. In addition 0.16 percent uranium was in the ash. At the outcrop the coal is present as several lenses as much as 10 feet long and 0.1 foot thick. It is probable that the coal represents burial of one or two isolated logs and as such would be of no commercial importance as a source of rare earths.

No area containing a combination of structural setting, shale thickness, and uranium content that would compare favorably to the area near Smithville, DeKalb County, Tenn., was found in the region studied. Nearly everywhere, the Chattanooga shale is moderately to intensely faulted and often complexly folded. In addition, about a third of the region is underlain by shale less than 15 feet thick. Structural features and thick overburden indicate that strip mining would not be feasible.

## PALEONTOLOGY

The following fossil collections, mostly conodonts, were identified by W. H. Hass, of the U.S. Geological Survey, except for the collection of megafossils from locality 11T–1 that was identified by G. A. Cooper, of the U.S. National Museum. Locality numbers refer to the localities shown on plate 14. Shale sections (pls. 16, 17, 18) show the location of the fossil collections in the sections.

All the following are quoted from written communications by Hass and Cooper.

4J–3

The conodonts in the material examined are weathered and for the most part poorly preserved. It is suggested that the basal sandstone of the Chattanooga shale at the Brothers Mill Gap locality is probably a part of the Dowelltown member.

*Ancyrodella* sp.
*Ancyrognathus englypheus* Stauffer
*Bryantodus* sp.
*Hindeodella* sp.
*Palmatolepis subperlobata* Branson and Mehl
    *subrecta* Miller and Youngquist
    sp.
*Polygnathus linguiformis* Hinde
    cf. *P. pennata* Hinde
*Prioniodus* sp.

Numerous fragments of bladelike, barlike, and platelike specimens

6P–1

The collection is considered to come from the Gassaway member of the Chattanooga shale. This opinion is based on an examination of approximately 50 conodont specimens that are preserved as molds.

*Bryantodus* sp.
*Palmatolepis glabra* Ulrich and Bassler
    *perlobata* Ulrich and Bassler
    *subperlobata* Branson and Mehl
    (impressions of fragmentary specimens)
*Polygnathus* sp.
*Prioniodus* sp.
*Spathognathodus inornata* (Branson and Mehl)
    sp.

Numerous impressions of fragmentary bladelike, barlike, and platelike conodonts.

*Lingula* sp.
*Orbiculoidea* sp.

Numerous impressions of brachiopods

6N–53

The collection [which is from topmost 0.1 foot] contained nothing of significance. Only a few specimens of *Hindeodella*, *Spathognathodus*, and *Lingula* were seen.

This collection [which is from 0.9 to 1.1 feet above the base of the section] is from the Dowelltown member of the Chattanooga shale. The rock is a light-gray to medium dark gray siltstone containing numerous "worm tubes" that are filled with light-gray siltstone. About 18 molds of conodonts were examined. The assignment to the Dowelltown is based chiefly upon the presence in the collection of several good specimens of *Palmatolepis subrecta* Miller and Youngquist. This species ranges throughout the Dowelltown of central Tennessee. It is also found in the lowermost beds of the overlying Gassaway member of the Chattanooga shale along the Eastern Highland Rim of central Tennessee where it is associated with a distinctive set of conodonts that are not in collection 6N–53.

*Ancyrodella* sp.
*Bryantodus* sp.
*Hindeodella* sp.

*Palmatolepis subrecta* Miller and Youngquist
cf. *P. unicornis* Miller and Youngquist
spp. (fragments)
*Prioniodus* sp.
Conodont fragments

7P–1

This collection is from the lower faunal zone of the Gassaway member of the Chattanooga shale. The rock is a pale-brown siltstone. About 24 specimens were examined.

*Foerstia* sp. (one specimen)
*Hindeodella* spp.
*Palmatolepis distorta* Branson and Mehl
*glabra* Ulrich and Bassler
*perlobata* Ulrich and Bassler
*Prioniodus* sp.
*Spathognathodus* sp.
Conodont fragments

9P–4

The collection is from a dark-gray shale that contains quartz sand grains. The collection consists of about 12 conodont molds and numerous specimens of the plant *Foerstia*. The collection comes from the lower faunal zone of the Gassaway member of the Chattanooga shale.

*Foerstia* sp. (numerous specimens)
*Palmatolepis glabra* Ulrich and Bassler
*perlobata* Ulrich and Bassler
*rugosa* Branson and Mehl
*Prioniodus* sp.
*Spathognathodus* sp.
Conodont fragments

8N–1

The collection contains the following genera and species. They are preserved chiefly as molds:

*Gnathodus* sp.
*Hindeodella* sp.
*Lonchodina* sp.
*Polygnathus communis* Branson and Mehl
*Prioniodus* sp.
*Spathognathus* sp.
Bladelike, barlike, platelike impressions of conodonts
*Orbiculoidea* sp.

It is the writer's opinion . . . that the dark-gray bed at St. Elmo [8N–1] should be placed in the Maury formation.

11T–1

This collection [from the base of the upper black shale, which is 2 to 3 feet thick] comes from a pale-brown siltstone that contains some quartz sand. About 24 conodont impressions were recognized. It is my opinion that the bed from which the collection came is from the Lower Mississippian. This opinion is based on the presence of *Siphonodella duplicata* (Branson and Mehl) and *Siphonodella duplicata* (Branson and Mehl) var. A. The latter has nodes rather than transverse ridges on the inner platform. *Siphonodella* is restricted to the Kinderhook and I have not found the above mentioned species very high up in the Kinderhook. The bed from which collection 11T–1 came should, in my opinion, be correlated with the Maury formation of the central Tennessee area.

*Bryantodus* sp.
*Hindeodella* spp.
*Siphonodella duplicata* (Branson and Mehl)
*duplicata* (Branson and Mehl) var. A
*Spathognathodus aciedentatas* (E. R. Branson)
*Spathognathodus* sp.
*Orbiculoidea* sp.

[The following material on megafossils from the middle gray silty claystone, is quoted from G. A. Cooper (written communication, 1956.)]

The fossils from the Little Tennessee River are difficult to date because they are chiefly immature or little known species. Of brachiopods there is a small *Ambocoelia*, a *Schuchertella*, small *Conetes*, a *Productella* suggesting *P. pyxidata*, and two genera of terebratuloid brachiopods: probably *Hamburgia* or *Dielasma* and a small shell suggesting *Romingerina*. A snail suggesting *Mourlonia* is present and a trilobite belonging to the Proetidae, possibly the genus *Exochops*, is also present.

Although some of the genera cited are commonly Devonian in occurrence, the general expression of the fossils in this collection is more like ones from Lower Missisippian rocks. The small *Ambocoelia* is suggestive of one in the Louisiana limestone and the terebratuloids are suggestive of the Mississippian. Dielasmoids are not known from the Devonian. The tribolite is definitely a Mississippian type.

My conclusion is that the collection is of early Mississippian age, possibly correlative to the fauna of the Hamburg oolite or that of the Louisiana limestone.

## CONCLUSIONS

1. Chattanooga shale of Late Devonian (Dowelltown) age is exposed in an elongate northeast-trending area in Alabama and Georgia, but there is not sufficient difference in lithology to warrant separation into members.
2. The shale east of the Sequatchie Valley is considerably coarser grained than it is to the west.
3. Large quantities of interbedded silt and fine sand in some outcrops indicate transportation by current action.
4. Gray beds in the Chattanooga are interpreted to be the result of greater than usual influxes of inorganic material, and so represent faster deposition than do the black beds.
5. Phosphate nodules and chert beds are present in the Chattanooga shale and seem to be areally and stratigraphically segregated.
6. Intraformational conglomerates and lenticular bedding in the Chattanooga shale indicate infrequent periods of bottom scouring.

7. The range in thickness and average thickness of the Gassaway member and the Maury formation are greater in the region studied than to the west.

8. The Chattanooga shale and Maury formation are overlapped and wedge out in the vicinity of Birmingham, Ala. The overlapping relations and the presence of red shale and a basal conglomerate in the Maury show that the latest shorelines of the Chattanooga and Maury seas were near Birmingham.

9. Black shale beds are present in many of the eastern exposures of the Maury; and at an outcrop near Bacon Bend of the Little Tennessee River, strata of Maury age consist entirely of black shale. This suggests that the Maury merges into black shale in northeastern Tennessee.

10. A shoreward zone in the transgressing Chattanooga sea probably was characterized by moderate wave action and no permanent deposition.

11. Indications are that the Chattanooga shale was the initial deposit of a sea that transgressed upon an extensive peneplain, and as such the shale must have been deposited in relatively shallow water.

12. No area, containing a combination of structural setting, shale thickness, and uranium content that would compare favorably to the area near Smithville, DeKalb County, Tenn., was found in the region studied.

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# LOCATION OF SHALE OCCURRENCES

*Location of shale occurrences*

| *Locality* | *County and State* | *Description* |
|---|---|---|
| 1F-1 | Bibb, Ala | Outcrop on north end of Big Mountain at Pratts Bluff on the Cahaba River, about 5 miles north of Centreville. |
| 2F-1 | Tuscaloosa, Ala | Cut of abandoned road in gap through Red Mountain 0.8 mile southeast of Alabama Great Southern Railway crossing at Tannehill. |
| 2F-2 | Jefferson, Ala | About 5 miles south of Bessemer in Owens Gap through Red Mountain. |
| 3H-1 | Jefferson, Ala | On road leading west from Palmerdale (Palmer); at bend in road about 1 mile west of intersection with Alabama Highway 38. |
| 3H-2 | Jefferson, Ala | About 0.6 mile south of road intersection at Clay; in cut on road leading to Trussville. |
| 3H-3 | Jefferson, Ala | At eastern boundary of Leeds; in roadcut along U.S. Highway 78. |
| 3H-4 | Jefferson, Ala | U.S. Highway 78; in gap through Red Mountain between Birmingham and Irondale. |
| 3H-5 | Jefferson, Ala | Cut on U.S. Highway 31 at Birmingham; about 2 miles south of Third Avenue, just south of the highway crest at Vulcan Park. |
| 3J-1 | Saint Clair, Ala | About 1.5 miles south of city limits of Odenville in roadcut along Alabama Highway 174. |
| 3J-2 | Saint Clair, Ala | 2 miles north of Pell City on Alabama Highway 25; in roadcut opposite E. S. Brown Grocery. |
| 4G-1 | Blount, Ala | At Blount Springs; about 0.5 mile east of U.S. Highway 31 on country road; roadcut. |
| 4H-1 | Blount, Ala | About 8 miles southwest of Oneonta; from bridge on Alabama Highway 38 across Blackburn Fork of Warrior River go northeast about 0.7 mile on Highway 38, then west on dirt road about 2 miles; outcrop in cut on north side of road near intersection with dirt road leading south. |
| 4J-1 | Blount, Ala | From junction of Alabama Highways 25 and 38 in Oneonta, 0.2 mile northwest on Alabama Highway 38; cut on west side of road. |
| 4J-2 | Saint Clair, Ala | About 1 mile west of Whitney; in roadcut on north side of Alabama Highway 25, 0.1 mile west of intersection with U.S. Highway 11. |
| 4J-3 | Etowah, Ala | Brothers Mill Gap in Greasy Cove; on road to Camp Sumatanga about 1.8 miles south of junction with Gallant road, near county line. SE cor. sec. 19, T. 12 S., R. 4 E. |

*Location of shale occurrences*—Continued

| *Locality* | *County and State* | *Description* |
|---|---|---|
| 4J–4 | Blount, Ala | About 0.5 mile west on Alabama Highway 38 from intersection with Alabama Highway 25 in Oneonta, then southwest on dirt road about 0.2 mile; outcrop at road fork near old house. |
| 4J–5 | Saint Clair, Ala | About 1.8 miles northwest along road that intersects U.S. Highway 11 at south edge of Springville; in roadcut opposite artificial lake. |
| 4J–6 | Saint Clair, Ala | About 1.5 miles northeast of city limits of Springville turn east on dirt road; outcrop in roadcut about 0.7 mile from U.S. Highway 11 and just south of fork in dirt road. |
| 4J–7 | Etowah, Ala | About 4 miles northeast of Gallant go north 1 mile on road crossing Louisville and Nashville Railroad; outcrop of shale in east road bank. |
| 4K–1 | Saint Clair, Ala | Cox Gap in Beaver Creek Mountain; about 4 miles southeast of Ashville; in roadcut. |
| 4K–2 | Calhoun, Ala | About 1 mile northwest of Ohatchee; in cut along road from Ohatchee to Ten Island Church. |
| 4K–3 | Etowah, Ala | On Dunaway Mountain south of Gadsden; from Morgans crossroad go southwest on U.S. Highway 411 about 0.5 mile, turn left on dirt road and continue south across crest of mountain; in roadcut just past first sharp turn to right. |
| 4L–1 | Calhoun, Ala | Alexander Gap in Colvin Mountain; in roadcut along U.S. Highway 241 about 0.75 mile southwest of Etowah-Calhoun County line. |
| 4L–2 | Calhoun, Ala | About 1 mile southeast of Ohatchee; in cut along road from Ohatchee to Alexandria. |
| 5H–1 | Blount, Ala | 3 miles west of intersection of Alabama Highways 128 and 38 at Blountsville, turn east from Highway 128 on dirt road; in roadcut 0.5 mile from intersection. |
| 5J–1 | Blount, Ala | Roadcut about 3.5 miles airline east of Summit in Hobson Gap in Dividing Ridge just south of Marshall County line. |
| 5J–2 | Blount, Ala | About 1.4 miles west of Brooksville; roadcut along Alabama Highway 74. |
| 5J–3 | Etowah, Ala | Near Altoona; from Blount-Etowah County line go 1.5 miles north on Alabama Highway 176; outcrop in roadcut at sharp bend in road. |

*Location of shale occurrences*—Continued

| *Locality* | *County and State* | *Description* |
|---|---|---|
| 5L-1 | Etowah, Ala | East side of Red Mountain; from intersection of U.S. Highways 11 and 241 in Attalla go northeast on Highway 11 about 5.4 miles, then go 0.55 mile west on dirt road. |
| 6K-1 | Jackson, Ala | From road intersection north of church at Langston go about 0.5 mile west-northwest to top of hill on trail road; outcrop in bank along road. |
| 6K-2 | Jackson, Ala | From railroad crossing at Hollywood east-southeast 3.6 miles; outcrop in roadcut on north side of road near edge of Guntersville Reservoir. |
| 6K-3 | Jackson, Ala | From courthouse at Scottsboro about 6.5 miles southwest on Alabama Highway 32; roadcut on northwest side of road 200 feet northeast of bridge crossing part of reservoir. |
| 6L-1 | DeKalb, Ala | From intersection of U.S. Highway 11 and Alabama Highway 68 in Collinsville, west on Highway 68 for 0.1 mile; outcrop at base of west-facing bluff. |
| 6M-1 | DeKalb, Ala | At Fort Payne; about 300 feet northwest of U.S. Highway 11 along Alabama Highway 35; cut on north side of road. |
| 6M-2 | Cherokee, Ala | In north road cut through Shinbone Ridge just north of Blanche. |
| 6M-3 | DeKalb, Ala | 1.4 miles southwest of Fort Payne city limits on U.S. Highway 11, turn west on dirt road 0.2 mile; in cut on north side of road. |
| 6M-4 | Cherokee, Ala | In south road cut through Shinbone Ridge just west of Blanche. |
| 6N-2 | Floyd, Ga | In roadcut on southeast side of Lavender Mountain; on road leading south from Crystal Springs to the Berry School in north Rome; less than 0.2 mile south of crest of mountain. |
| 6N-3 | Chattooga, Ga | Southeast slope of Taylor Ridge; 0.75 mile northwest of Gore in cut of U.S. Highway 27. |
| 6N-4 | Floyd, Ga | Near foot of Turnip Mountain; about 10 miles west of Rome in roadcut. |
| 6N-5 | Chattooga, Ga | About 6 miles south-southwest of Gore in roadcut just northeast of Silver Hill. |
| 6N-6 | Floyd, Ga | North side of Lavender Mountain; go 0.5 mile northeast from Sand Spring Church then take dirt road up mountain about 0.5 mile; outcrop is in sharp bend of road. |

*Location of shale occurrences*—Continued

| *Locality* | *County and State* | *Description* |
|---|---|---|
| 6N-53 | Chattooga, Ga | About 0.5 mile west of Menlo on Georgia Highway 48; 4.4 miles east of the State line and 2.8 miles southeast of Cloudland; cut on north side of road. |
| 6P-1 | Floyd, Ga | South of Turkey Mountain; about 50 yards south of intersection of Old Dalton Road and Staton Road. |
| 6P-2 | Floyd, Ga | Just west of Crystal Springs; outcrop is below the Mill Dam on Little Armuchee Creek. |
| 6P-3 | Floyd, Ga | West of Armuchee in cut along paved road; second bend in road across Armuchee Creek. |
| 6P-4 | Floyd, Ga | Horseleg (Mt. Alto) Mountain; 0.8 mile on Hanks Street south of intersection with Shorter Avenue. |
| 6P-5 | Floyd, Ga | East side of Turkey Mountain; on Old Dalton Road about 0.4 mile north of intersection with Staton Road. |
| 7M-1 | DeKalb, Ala | About 2.5 miles northwest of Valley Head in roadcut along Alabama Highway 58. |
| 7N-2 | DeKalb, Ala | In roadcut across Little Ridge about 15 miles north of Fort Payne. NE¼ sec. 6, T. 5 S., R. 10 E. |
| 7N-2 | Walker, Ga | About 2 miles west of LaFayette on north side of roadcut through Shinbone Ridge. |
| 7N-52 | Walker, Ga | Dug Gap; on Georgia Highway 193 about 6 miles northwest of LaFayette. |
| 7P-1 | Walker, Ga | Maddox Gap in Taylor Ridge about 8 miles east of LaFayette; in cut along Georgia Highway 143 at first sharp bend in road down east side of Taylor Ridge. |
| 7P-2 | Walker, Ga | Dick Ridge; in roadcut along Georgia Highway 143 on south side of road; about 2 miles east of 7P-1 at Maddox Gap. |
| 7P-3 | Gordon, Ga | About 5 miles west of Sugar Valley in roadcut across Horn Mountain. |
| 8N-1 | Hamilton, Tenn | Near St. Elmo; in gap through Hawkins Ridge about 0.3 mile north of Tennessee-Georgia State line. |
| 8N-2 | Dade, Ga | Abandoned chert quarry 0.5 mile south of Hooker. |
| 8N-3 | Walker, Ga | About 0.8 mile northwest of Cooper Heights; outcrop at crest of low ridge east of Lookout Mountain in roadcut along Georgia Highway 143. |
| 8N-4 | Dade, Ga | In roadcut 0.35 mile east of road intersection at Hooker, just south of the Tennessee-Georgia State line. |

*Location of shale occurrences*—Continued

| *Locality* | *County and State* | *Description* |
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| 8N-5 | Walker, Ga | Roncoe Hollow Mine site; from intersection of Chattanooga Valley Road and Grand Center Road 3.5 miles south of Flintstone, go south on Chattanooga Valley Road about 0.7 mile; at crest of hill go west on dirt road to end of road and walk to end of ravine (0.15 mile). |
| 8N-6 | Dade, Ga | On Georgia Highway 143 about 1 mile west of intersection of U.S. Highway 11 and Georgia Highway 143 at south edge of Trenton. |
| 8P-2 | Catoosa, Ga | "Cherokee Valley Phosphate Mine"; east flank of Whiteoak Mountain; outcrop in ravine 0.3 mile west of road intersection 1.5 miles south of Tennessee-Georgia State line, and 3.85 miles airline north-northeast of railroad crossing at Ringgold. |
| 8P-3 | Catoosa, Ga | About 1.25 miles airline east of railroad crossing at Ringgold and 0.2 mile north of intersection of U.S. Highway 41 and Cherokee Valley Road; outcrop of shale in west roadcut of Cherokee Valley Road. |
| 8P-4 | Catoosa, Ga | About 1.6 miles east by road of Ringgold on U.S. Highway 41, then south on dirt road 0.25 mile; outcrop in Nashville, Chattanooga, and St. Louis Railroad cut. |
| 9N-1 | Hamilton, Tenn | Wauhatchie Mine site; from Chattanooga west on U.S. Highway 11, turn off 0.75 mile beyond Tennessee Highway 41, then northwest on Cummings road to first sharp bend north; outcrop marked by several adits in side of hill. |
| 9N-2 | Hamilton, Tenn | First overpass west of north end of Lookout Mountain on U.S. Highway 11 just west of Chattanooga. |
| 9N-3 | Hamilton, Tenn | About 0.25 mile northeast of Glendale in roadcut through ridge north of Mountain Creek School on "W Road." |
| 9N-4 | Hamilton, Tenn | About 0.5 mile west of intersection at Red Bank main business district; outcrop in roadcut through Godsey Ridge. |
| 9P-1 | Hamilton, Tenn | About 0.8 mile southeast of Collegedale railroad station; cut on south side of Southern Railroad. |
| 9P-2 | Hamilton, Tenn | In cut along Apison Pike 1 mile airline southeast of Collegedale railroad station; outcrop is in cut on north side of road just east of bridge over Chestnut Creek. |

*Location of shale occurrences*—Continued

| *Locality* | *County and State* | *Description* |
|---|---|---|
| 9P-3 | Hamilton, Tenn | Just north of Collegedale railroad station on north side of creek in cut of a dead end road that heads west. |
| 9P-4 | Hamilton, Tenn | Dead Man Gap near Ooltewah; on U.S. Highway 11 1.4 miles east of intersection with Georgetown Pike at Ooltewah. |
| 9P-5 | Bradley, Tenn | About 6 miles airline west of Cleveland in roadcut along south fork of Harris Creek 0.9 mile airline southwest of Baugh Spring on west flank of Lauderback Ridge. |
| 9P-6 | Bradley, Tenn | About 0.5 mile south of Lauderback Springs on old abandoned road. |
| 9P-7 | Bradley, Tenn | About 0.5 mile north of 9P-6 and due east of Lauderback Springs. |
| 10P-1 | Hamilton, Tenn | Southern Railway cut just west of U.S. Highway 27; 1.5 miles north of Bakewell. |
| 11P-1 | Rhea, Tenn | 1.4 miles airline north of northernmost railroad crossing in Dayton; outcrop just north of intersection of two dirt roads. |
| 11T-1 | Monroe, Tenn | Near Bacon Bend of the Little Tennessee River; from the intersection of two unpaved roads southeast of the river bend go east about 0.25 mile to the third bend in the road; outcrop in roadcut. |
| 12R-1 | Roane, Tenn | Just north of Rockwood city limits in cut along road heading northeast toward Little Mission Church. |
| 12S-1 | Roane, Tenn | 5 miles about east-northeast of Harriman and just east of the community of Emory; outcrop on lake just south of Tennessee Highway 61. |
| 13S-1 | Roane, Tenn | About 3.2 miles southwest of Oliver Springs, turn northwest on dirt road; outcrop in roadcut about 1.5 miles from main road. |
| R-S1 | Sequatchie, Tenn | About 5 miles south of courthouse at Dunlap; 1 mile south of junction with Tennessee Highway 28 along Tennessee Highway 8; highway cut. |
| R-S2 | Marion, Tenn | From junction of Tennessee Highways 27 and 108 just south of Whitwell, about 4 miles east on Tennessee Highway 27 and 1.3 miles east of Powells crossroads; highway cut. |
| R-S3 | Bledsoe, Tenn | About 6 miles northeast of courthouse at Pikeville; 2.1 miles east along dirt road from its junction with northeast-southwest gravel road on east side of Sequatchie River; upper part of section is on east side of Beatty Creek, lower part is on northwest side of southwest fork of Beatty Creek. |

*Location of shale occurrences*—Continued

| *Locality* | *County and State* | *Description* |
|---|---|---|
| R–S6 | Bledsoe, Tenn | 2 miles east of road junction near Cedar Ridge; on southwest side of road, and on northeast side below the road. |
| R–S7 | Cumberland, Tenn | 16.7 miles north of Pikeville, a roadcut on northeast side of Tennessee Highway 28, opposite a farmhouse on southwest side of Sequatchie River. |
| R–S14 | Bledsoe, Tenn | 7.7 miles south-southwest of courthouse at Pikeville; from bridge over Sequatchie River, about 1 mile east on Pitt Gap road; northwest side of road. |
| R–S15 | Marion, Tenn | On U.S. Highways 41, 64, and 72, between Jasper and the Tennessee River, about 2.5 miles west of west end of bridge over Tennessee River; cut on northeast side of highway. |
| R–S16 | Bledsoe, Tenn | About 2 miles east of courthouse at Pikeville along Tennessee Highway 30; in old chert pit about 200 feet west of highway. |
| R–S17 | Bledsoe, Tenn | About 13.3 miles south-southwest of courthouse at Pikeville; from Stephen Chapel on east side of Sequatchie River, southwest about 2.5 miles, then east 0.7 mile; on north side of McWilliams Creek just north of road. |
| R–S18 | Hamilton, Tenn | Just northwest of Chattanooga, directly in back of cabin No. 14 at Glendale Tourist Court. |
| R–S19 | Hamilton, Tenn | About 0.5 mile west of junction of U.S. Highways 11 and 41; cut on north side of Highway 41. |
| AL–64 | Blount, Ala | Drillhole; from Brooksville 1.3 miles west on Alabama Highway 74; at intersection turn east-southeast on dirt road for 0.5 mile; hole on north side of road. |
| AL–65 | Blount, Ala | Drillhole; from Blountsville 2.3 miles northeast on Alabama Highway 38, then 1.4 miles east-southeast on dirt road; hole about 500 feet north of road intersection. |
| AL–66 | Blount, Ala | Drillhole; from Blountsville 3.1 miles west-southwest on Alabama Highway 38, then about 0.5 mile southeast on dirt road; hole on south side of road. |
| RO–11 | Jefferson, Ala | Drillhole; SE¼NW¼ sec. 23, T. 20 S., R. 5 W. |
| WR–47 | Marion, Tenn | Drillhole; near Tennessee Highway 27, east wall of Sequatchie Valley, about 1 airline mile south of Kelley Chapel, on jeep road leading southwest to the valley from hairpin turn on the highway. |

*Location of shale occurrences*—Continued

| *Locality* | *County and State* | *Description* |
|---|---|---|
| WR-48 | Sequatchie, Tenn | Drillhole; about 5 miles south of Dunlap, about 2,000 feet west of Tennessee Highway 8 on an abandoned road that descends to valley from a point on the highway about a quarter of a mile south of a limestone quarry and mine. |
| WR-49 | Bledsoe, Tenn | Drillhole; about 2 miles southeast of Pikeville, and about 1,200 feet south of prominent north bend in Tennessee Highway 30, along a dirt road on southside of a stream. |
| WR-50 | Cumberland, Tenn | Drillhole; in lowest part of sinkhole known as Grassy Cove, about 10 airline miles southeast of Crossville, about 900 feet N. 10° E. of road intersection at Grassy Cove community, and about 300 feet west of Tennessee Highway 68. |

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