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BLACK SHALE INVESTIGATIONS, BLOCK 3, TENNESSEE

by

R. C. Robeck and Andrew Brown

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ABSTRACT

The Chattanooga shale was studied and sampled in the general vicinity of the Sequatchie Valley, Tennessee, in February and March, 1948, as part of a larger study of the distribution of uranium in the shale in east-central Tennessee. For convenience this area has been designated Block 3. It extends north-northeast in Tennessee from the Alabama-Tennessee State line for a distance of about 65 miles, and has a width of about 15 miles. It includes the Sequatchie Valley, Walden Ridge, and the western edge of the Tennessee River Valley.

The Chattanooga shale crops out on both sides of Walden Ridge, which is about 9 miles wide and stands 1,000 to 1,500 feet above the valleys on either side. It is cut out by faults, however, along the west side of the Sequatchie Valley. The best exposures are on the western escarpment of Walden Ridge. The shale dips into the ridge at angles as high as 25° and at all outcrops is somewhat broken and disturbed.

The major lithologic units of the Chattanooga shale, the Upper Black shale, the Middle Gray siltstone, and the Lower Black shale, are present in the area. The undivided Upper Black shale of this area is equivalent to the Top Black shale, Upper siltstone, and Middle Black shale of the Eastern Highland Rim area farther west, and is present throughout Block 3 except at places where it has been concealed by faulting.

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The Lower Black shale is found only in the northern half of the Block, and the Middle Gray siltstone is absent in the extreme southern part. With one exception the bentonite bed, an important horizon marker, is present at all localities where the Middle Gray siltstone is present.

The general structure of the area is simple. It consists of an anticline that corresponds generally with the Sequatchie Valley and a broad syncline on which Walden Ridge is developed. The Sequatchie anticline is broken by a persistent thrust fault on the west flank. The fault and the major folds strike northeastward.

A total of 98 routine and 5 special samples was taken from 11 measured sections. The greatest concentration of uranium is in the Upper Black shale, which ranges from 7.87 to 15.47 feet in thickness and averages about 12 feet. This unit averages 0.0081 percent uranium, as compared with 0.0069 percent uranium for the 16-foot average thickness of the three upper units in Block 1 of the Eastern Highland Rim area. Reserves in Block 3 are estimated to be 965,000 tons of uranium.

The shale in Block 3 can be recovered only by underground mining, and because of the crumpled condition of the rocks, mining problems would probably be more serious in this area than in the Eastern Highland Rim.

INTRODUCTION

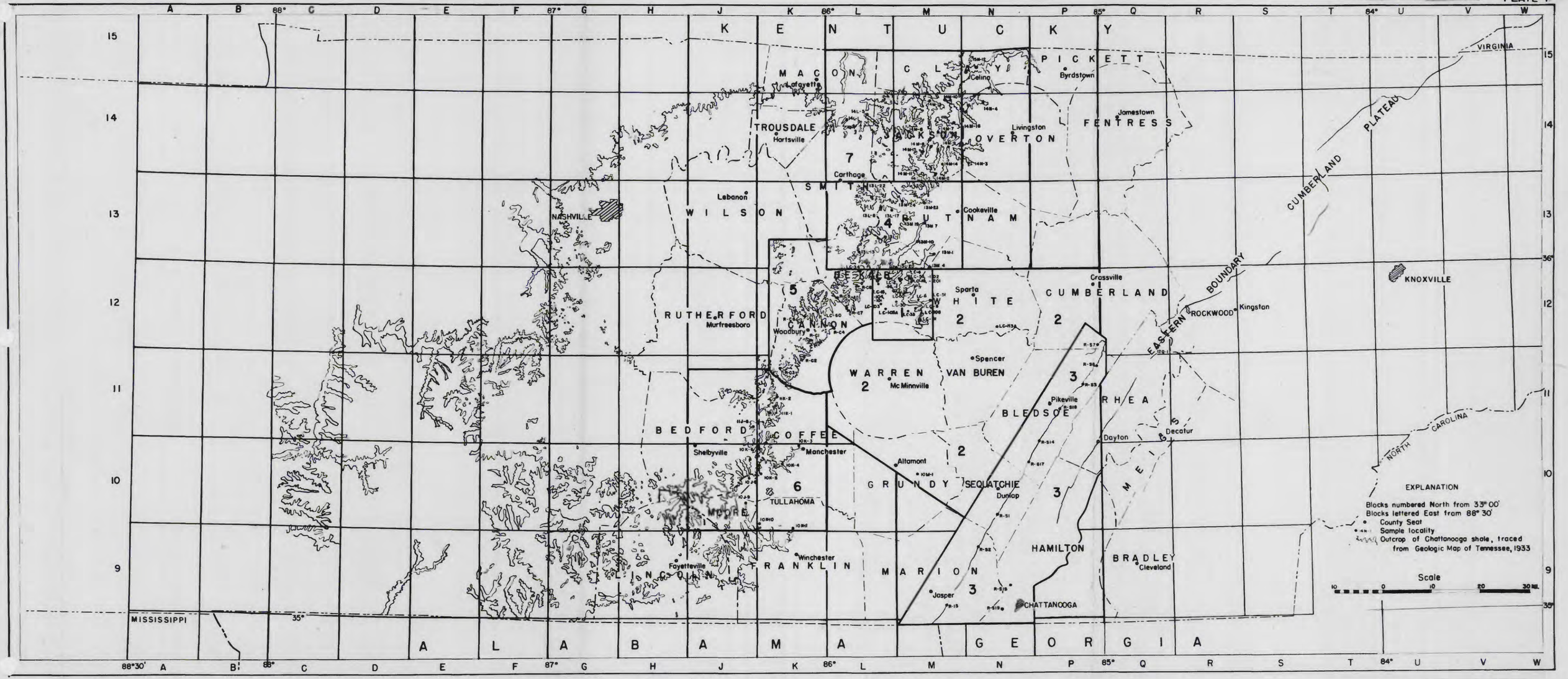
This report gives the results of investigations of the Chattanooga shale in Block 3, one of the subdivisions into which the large area underlain by that formation in east Tennessee was divided for convenience in study. Block 3 is east of the Eastern Highland Rim area; its general location is shown by plate 1.

A report on the Eastern Highland Rim, [1][1/] in which the earliest investigation of the shale was concentrated, is being submitted at about the same time as this report. The present report is to be considered a supplement to the more detailed report rather than a complete report in itself. To avoid unnecessary repetition, many aspects of the shale problem will be discussed herein only in general terms, emphasis being on important differences between conditions in Block 3 and those in the Eastern Highland Rim. Those differences are largely in the fields of stratigraphy, structure, and uranium content.

Field work in Block 3 was done in February and March 1948 by R. C. Robeck, assisted by C. E. Baker, Jr. W. H. Hass correlated the beds by studies of the conodonts and comparisons with the more thoroughly studied beds in the Eastern Highland Rim. The report was written largely by Andrew Brown. The mapping of the Chattanooga outcrop is taken generally from published folios. [2] The field work consisted mainly of detailed measurements of sections, Geiger counter readings at the outcrops, and routine and special sampling.

1/ Numbers in brackets refer to references at end of report.

PLATE I



LOCATION OF BLOCKS, EASTERN OIL SHALE., TENNESSEE

LOCATION

Block 3 extends north-northeast from the Alabama-Tennessee State line for a distance of about 65 miles. It includes the Sequatchie Valley, Walden Ridge, and the western edge of the Tennessee River Valley, and has an average width of about 15 miles. The area is shown on plate 2.

GEOGRAPHY

The largest towns in the Sequatchie Valley are Jasper (pop. 1,500), near the south end of Block 3, and Pikeville (pop. 760), about 45 miles up the valley from Jasper. No important towns are on Walden Ridge. In the Tennessee River Valley the city of Chattanooga (pop. 128,000) is near the south edge of the Block, and Dayton (pop. 1,870) is about 50 miles northeast of Chattanooga. Paved State Highway 28 traverses the Sequatchie Valley throughout its extent in Tennessee, and U. S. Highway 27 runs a few miles east of the foot of Walden Ridge in the Tennessee River Valley. Several good paved highways cross Walden Ridge, and continue westward across the Sequatchie Valley and the Cumberland Plateau.

A branch line of the Nashville, Chattanooga, and St. Louis Railway extends up the Sequatchie Valley from Bridgeport, Alabama, to its terminus at Pikeville. Chattanooga is served by several important rail systems, one of which, the Cincinnati, New Orleans, and Texas Pacific (Southern), roughly parallels U. S. Highway 27

to the northeast.

The valleys are underlain mostly by limestone and contain much good farming land. Walden Ridge is capped by Pottsville sandstone which produces a sandy soil of only fair agricultural value.

TOPOGRAPHY

Block 3 is essentially a long, narrow plateau (Walden Ridge) about 9 miles wide extending north-northeast throughout the length of the Block, and dropping sharply to deep valleys on either side. The Sequatchie Valley, which forms the western boundary, has been cut into the Cumberland Plateau along the line of the Sequatchie anticline to depths of 1,000 to 1,500 feet and a width of 3 to 5 miles. Walden Ridge, though bearing a separate name, is physiographically part of the Cumberland Plateau; the name "ridge" is a misnomer, as the area is a shallow syncline with a relatively flat top and drops to the valleys in steep escarpments. The western edge of the broad valley of the Tennessee River is within the Block, the eastern boundary of which may, for convenience, be taken as the river itself.

The area as a whole has a maximum relief of about 2,000 feet. The floor of the Sequatchie Valley drops from about 1,000 feet altitude at its northern end to 600 feet at the Alabama-Tennessee State line. Altitudes in the Tennessee River Valley

are somewhat less, the river at Chattanooga (Hales Bar reservoir) standing at about 629 feet, and the town of Dayton at about 707 feet. The top of Walden Ridge is 1,000 to 1,500 feet above the valley floors.

STRATIGRAPHY

The floors of the Sequatchie Valley and most of the Tennessee River Valley are limestones of Ordovician age. In the Eastern Highland Rim the Chattanooga rests directly on rocks of Ordovician age comparable to those exposed in the valleys; but in Block 3 the two groups are separated by the Rockwood formation of Silurian age, which is exposed near the foot of Walden Ridge, and is about 200 feet thick in the Sequatchie Valley and 300 feet thick on the Tennessee River side.

In both the Eastern Highland Rim area and in Block 3 the Chattanooga is directly overlain by the thin Maury shale, which in turn is overlain by the Fort Payne chert. The total cover, however, is far thicker in Block 3, where the Mississippian limestones which form the surface in the Eastern Highland Rim are overlain by several hundred feet of Pottsville (Pennsylvanian) sandstone. Thus the total overburden throughout much of Block 3 is on the order of 1,000 to 1,500 feet, as against a few hundred feet in the Eastern Highland Rim area.

Whereas the beds in the Eastern Highland Rim area are practically undisturbed and essentially flat, all of those in Block 3 are more or less distorted by the folding and faulting incident to formation of the Sequatchie and parallel anticlines (pls. 3 and 4). For this reason good exposures, which are the rule in the Eastern Highland Rim, are almost unknown in Block 3, and accurate measurements and careful stratigraphic studies are difficult. In addition, the crumpled rocks weather more deeply than the flat beds in the Eastern Highland Rim, introducing a further source of uncertainty in stratigraphic work and particularly in Geiger counter readings.

The stratigraphic section of the Chattanooga and the immediately underlying and overlying rocks in Block 3 is given below.

Partial stratigraphic section in Block 3

Mississippian
- Fort Payne chert
- Maury shale

Devonian or Mississippian
- Chattanooga formation
  - Upper Black shale (upper part, containing phosphatic nodules)

Devonian
- Chattanooga shale
  - Upper Black shale
  - Middle Gray siltstone
  - Lower Black shale

Silurian
- Rockwood formation

The Upper Black shale, which has not been subdivided in Block 3, is equivalent to the three upper units (Top Black shale, Upper siltstone, and Middle Black shale) of the Eastern Highland Rim area.

Rockwood formation

The Rockwood formation is named for Rockwood, Tennessee, where it contains workable iron ore. In Block 3, however, it is predominantly a gray-green or pinkish shale containing a few thin beds of limestone and has no present economic value.

Chattanooga shale

The Chattanooga in Block 3 differs from that in the Eastern Highland Rim area in three principal respects:

(1) The entire formation, and each of its members, is somewhat thinner.

(2) All units of the Chattanooga are present in most of the Eastern Highland Rim. In Block 3, however, the Lower Black shale is present only in the northern half (R-S17 and more northerly exposures), and the Middle Gray siltstone is present at all except the three southernmost outcrops.

(3) In the Eastern Highland Rim the Upper Black shale is divisible into three distinct lithologic units--the Top Black shale, the Upper siltstone, and the Middle Black shale. In Block 3 the Upper siltstone has not been identified either by

stratigraphic studies or by radiometric characteristics, and the entire upper unit, except for the phosphatic nodule layer at the top, is essentially homogeneous.

The thickness of the Chattanooga and its various units at all the outcrops measured and sampled in Block 3 are given in table 1.

Table 1.—Thicknesses of units of Maury and Chattanooga shales, Block 3, Tennessee (localities arranged from north to south; thicknesses in feet and hundredths)

Localities	Maury	Chattanooga				
		Upper Black	Middle Gray	Lower Black	Basal sand-stone	Total Chatta-nooga
12Q-1	(3.2)	(30.0)	(4.0)	(3.4)	-	(37.4)
R-S7	-	-	-	-	-	
R-S6	2.4	15.47	7.19	2.50	0.20	25.36
R-S3	1.40	11.41	c	c	c	
R-S16	2.65	12.87	c	c	c	
Dayton	(2.0)	(10.0)	(6.0)	(5.0)	c	(21.0)
R-S14	2.30	14.50	c	c	c	
R-S17	c	12.73	3.63	0.65	0.20	17.21
R-S1	2.82	14.47	1.09	-	0.64	16.20
R-S2	3.09	13.07	-	-	0.20	13.27
R-S18	2.86	11.15	0.48	-	0.70	12.33
Chattanooga	(4.5)	(6.0)	-	-	-	(6.0)
R-S19	3.20	7.87	-	-	0.23	8.10
R-S15	4.62	8.66	-	-	0.10	8.76
Average	2.82	12.22	3.08	1.57	0.32	14.46

- Unit missing.
c Unit partially or wholly concealed.
( ) Figures in parentheses not included in averages.

Table 1 also includes the type locality of the Chattanooga (in the city of Chattanooga), an unsampled locality near Dayton, and locality 12Q-1 (pl. 1) which is an exposure outside the area of investigation but which is mentioned several times in this report.

A thin basal sandstone (pl. 4) is present at the base of the Chattanooga shale in every complete section measured in Block 3. and in most sections in the Eastern Highland Rim area. Its thickness in Block 3 is 0.1 to 0.7 foot, as compared with a maximum of 0.2 foot in Block 1. It is a medium- to coarse-grained, poorly sorted, massive sandstone, iron-stained at many localities. Its presence at the base of the Chattanooga, where it underlies either the Upper Black shale, the Middle Gray siltstone, or the Lower Black shale, indicates that the bed transgresses time and hence cannot be properly assigned to any unit of the Chattanooga. Formerly it has been considered an eastern correlate of the Hardin sandstone of west Tennessee, but such a correlation now seems unlikely.

The Lower Black shale is similar in appearance and lithology to the same unit in the Eastern Highland Rim except that at most places in Block 3 it is badly broken, and shows slickensides which indicate faulting. The unit is missing in the five southernmost exposures (R-S15, R-S19, R-S18, R-S2, and R-S1) and is thin (0.65 foot) at R-S17. Its position is concealed at R-S14, R-S16,

and R-S3, but it is 2.5 feet thick at R-S6, near the northern end of the Sequatchie Valley. Where present, it is considerably thinner than in the Eastern Highland Rim area. At the Roddy exposure (12Q-1) in the Tennessee River Valley about 22 miles north-northeast of Dayton (pl. 1), a probable Lower Black shale is 3.4 feet thick.

The Middle Gray siltstone is a series of alternating gray and black beds which are about 0.1 foot thick, about a third of the beds being black slaty shale, the remainder dark-gray siltstone. It is absent at the two southernmost exposures (R-S15 and R-S19), thin (0.48 foot) at R-S18, and missing at R-S2. At R-S1 it is 1.09 feet thick, and northward the thickness increases (though the position of the unit is concealed at three exposures) to 7.19 feet at R-S6. At the Roddy exposure mentioned above the unit is 4.0 feet thick.

As only four complete sections include the Middle Gray siltstone, it is not possible to give a dependable average thickness. However, the unit appears to be considerably thinner in Block 3 than in the Eastern Highland Rim area.

The bentonite bed near the top of the Middle Gray siltstone is 0.13 to 0.14 foot thick (pl. 4), and is an excellent stratigraphic marker for correlating beds over a wide area. It is present in all measured sections which include the Middle Gray except R-S18.

The Upper Black shale in Block 3, as in the Eastern Highland Rim area, is the thickest and most uraniferous member of the Chattanooga. It is black and tough, but somewhat more fissile than corresponding beds to the west, perhaps because of the crumpling to which it has been subjected.

As previously stated, the three subdivisions of the Upper Black shale of the Eastern Highland Rim area cannot be identified in Block 3, where the entire sequence consists of black shale and has only a few thin sandstone or siltstone stringers not over 0.04 foot thick. These stringers increase slightly in thickness toward the south.

The Upper Black shale in Block 3 increases in thickness from south to north, ranging from 7.87 feet at R-S19 to 15.47 feet at R-S6. The average for 10 exposures is 12.22 feet, as compared with 16.40 feet for the same member in Block 1. At the Roddy exposure the Upper Black shale is 30 feet thick, this greater thickness corresponding with the northward thickening in the Eastern Highland Rim area and Block 3.

In Block 3 the phosphatic zone is thin or absent in the middle portion but thickens to the north and the south: it is 1.35 feet thick at R-S19 and 2.60 feet at R-S6. The nodules are as much as 6 inches long and 1 inch thick.

Maury shale

In Block 3 the gray-green Maury shale (pls. 5 and 6) has three recognizable subdivisions. The lowest of these contains scattered phosphatic nodules; the middle contains abundant nodules and is locally cherty; and the upper contains quartz geodes and a few phosphatic nodules. These subdivisions are absent or poorly developed in Block 1. The thickness of the Maury in Block 3 ranges from 1.4 to 4.62 feet, being thicker to the south. Its average thickness at nine outcrops is 2.82 feet, about 1 foot greater than in Block 1 where it averages only 1.86 feet.

The name "Maury" is used provisionally in this report for the unit which has been called the Glendale formation. Adequate correlations, however, have not been made between the true Maury of west Tennessee, the Maury of the Eastern Highland Rim, and the Glendale formation of east Tennessee.

Fort Payne chert

The Fort Payne in Block 3 is 75 to 200 feet thick, and in lithology is similar to the same formation in Block 1. It is a hard, siliceous limestone locally containing a considerable amount of chert.

STRUCTURE

Walden Ridge, the central part of Block 3, is structurally a shallow syncline along the flanks of which the rocks dip as much as 25°. The eastern part of the Block, which is the western edge of the Tennessee River valley, is considerably folded and faulted, though no one structure is of much importance to this report except a small unfaulted swell here referred to as the Glendale anticline, on which localities R-S18 and R-S19 are located.

The Sequatchie Valley, which forms the western part of the Block, is a deeply eroded anticlinal valley bounded on the west by a high-angle fault overthrust from the southeast and having a displacement of as much as 4,000 feet. On that side of the valley the Chattanooga has been cut out by the fault; on the eastern side, in the valley floor and on the slope of Walden Ridge, the shale dips into the ridge at an average angle of about 8°.

Nearly all beds in the area are deformed to some extent, and the Chattanooga, being particularly incompetent, has probably been disturbed and fractured more than any of the other formations (pl. 4). The Lower Black shale, where present in Block 3, is badly shattered, and the entire Chattanooga formation is so crumpled that measurements and identifications are subject to considerable error. Some of the units may have been cut out

locally by faulting, although it is more likely, in the light of observations in other areas, that the lower units are absent locally because of non-deposition.

No angular unconformities were seen either within or at the top or bottom of the Chattanooga. It is entirely possible, however, that the condition of the rock masks such unconformities, if they do exist.

COMPOSITION OF THE SHALE

No detailed studies have been made of the composition of the shale in Block 3. The rock appears to be essentially the same, lithologically, chemically, and mineralogically, as that exposed in the Eastern Highland Rim.

DEPOSITION OF THE SHALE

In the report on the Eastern Highland Rim area attention is called to the fact that the Lower Black unit of the Chattanooga occupies an east-west belt about 65 miles wide, and that the Middle Gray siltstone occupies a similar belt only a few miles wider. In Block 3 the Lower Black shale is present only in the northern half, indicating an eastward extension of that belt. The Middle Gray siltstone, however, is present nearly to the south limit of the Block, indicating that the sea was transgressing in that direction during Middle Gray time. The Upper Black shale appears to be present at all outcrops of the Chattanooga in Block 3. Similar widespread presence of the corresponding shale units in the Eastern Highland Rim area indicates that much larger areas were flooded during Upper Black time than during earlier Chattanooga times.

Inconclusive evidence seems to indicate that the Chattanooga shale accumulated in a relatively shallow sea.

METHOD OF STUDY

Stratigraphic investigations

The methods used in stratigraphic investigations in Block 3 were the same as those used in the Eastern Highland Rim area. As those methods are described in the report on that area, repetition here is unnecessary.

Of the 11 exposures measured and sampled in Block 3, 9 are on the east side of the Sequatchie Valley, and 2 (R-S18 and R-S19, pl. 2) on the Glendale anticline east of Walden Ridge. One exposure (R-S7) is only 1 foot thick and is disregarded in figuring thicknesses and grades.

The Chattanooga was examined at three different types of exposures: large highway cuts on the sides of the ridge (R-S1, R-S2, R-S6, R-S7, R-S14, R-S15, R-S18, and R-S19); road cuts in hills within the Sequatchie Valley (R-S3, R-S14, R-S16, and R-S17); and stream valley exposures (R-S6, R-S3, and R-S17). Some exposures, as duplications in the list above indicate, combine more than one type. Most creek-bed exposures (pl. 7B) in Block 3 are poor, as they are covered nearly everywhere by a heavy mantle of talus.

Geiger counter investigations

Work with the Geiger counter in Block 3 was hampered by the condition of the outcrops, the wet and cold weather, and trouble within the instrument during the latter part of the investigation.

The counts per minute for each of the lithologic units were practically the same in the Eastern Highland Rim and in Block 3, except that the absence of the Upper siltstone in Block 3 eliminated a zone of low readings found elsewhere. Thus the entire Upper Black unit is essentially one unit radioactively as well as lithologically.

The crumpled and weathered condition of most exposures in Block 3 affords few good reading faces, such as are common in the Eastern Highland Rim area. The weathering of the rocks leads to some surprising results; but as the counter registers total radioactivity rather than uranium content, it is understandable that some low readings were of sections which assay high in uranium, and vice versa. On the whole, the relationship between counter readings and chemical assays is less consistent in Block 3 than in the Eastern Highland Rim.

Practically all counter work was done on the Upper Black shale, which previous experience had shown was the only unit likely to be of economic interest. The Maury and Middle Gray were used in field scanning merely as reference units and as field checks on their uranium content. The Lower Black, which is

thin and local in the Sequatchie area, is of little economic interest.

Routine samples

Complete sets of samples were taken from nine outcrops on the east side of the Sequatchie Valley, and two on the Glendale anticline. The sampling and numbering system used in the Eastern Highland Rim was followed with these exceptions:

(1) As the Upper siltstone was not recognized in Block 3, the three-fold division of the upper units used in the Eastern Highland Rim was not applicable. Therefore all samples of the Upper Black shale were numbered in the 11-19 range and no samples were numbered in the twenties and thirties.

(2) In Block 3, sample no. 11 is merely the uppermost sample unit of the Upper Black shale, and is not confined, as it was in the Eastern Highland Rim, to beds containing phosphatic nodules.

(3) At some localities the basal sandstone was given the sample number 61, instead of being included in the lowest sample of the Lower Black as was done in the Eastern Highland Rim area. In the field notes this sandstone was often referred to as the Hardim sandstone, an assignment now believed to be erroneous.

Twenty-pound samples were taken of each sample unit, the total number of routine samples being 98. Only two of the exposures (R-S1 and R-S17) are reasonably fresh and undistorted;

R-S6 and part of R-S3 have undisturbed fresh rock in the middle of the Upper Black. Other sections are either badly distorted, badly weathered, or both. Though the weathered outcrops were cleaned off as much as time and weather permitted, most of the samples are not as fresh as those from the Eastern Highland Rim.

Special samples

Two sets of special samples were taken from Block 3 exposures. Two 200-pound samples were taken from R-S1 on March 30, 1948, the 2-foot interval containing parts of routine samples 15 and 16; one sample was sent to Battelle Memorial Institute, the other to the Y-12 research unit at Oak Ridge. Two 200-pound samples and one 50-pound sample were taken from routine sample interval 17 at R-S16 (pl. 7A), on July 7, 1948; the two large samples were shipped to Battelle and Y-12, the small one to the U. S. Geological Survey laboratory at Washington.

URANIUM IN THE SHALE

Previous investigations

Three exposures in the Sequatchie Valley were investigated by Nelson and Brill [3] during their reconnaissance work on the Chattanooga. Samples from the Upper Black at their locality BR-136 (R-S1 of this report) showed a uranium content of 0.006 percent; from BR-147 (R-S16), 0.010 percent; and from BR-148 (R-S7), 0.008 percent.

At R-S7, where Nelson and Brill reported a thickness of 7 feet, only 1 foot was found in 1948 (pl. 8A).

Vertical distribution

Overall distribution of uranium in the shale sequence is essentially the same in Block 3 as in the Eastern Highland Rim. Chemical assays of the Middle Gray siltstone (four exposures) average only about 0.0031 percent uranium; of the Lower Black shale (two exposures only, and these thin and broken), 0.0032 percent. Most of the uranium is in the Upper Black shale, where the average thickness of 12.22 feet assays 0.0081 percent. Breaking down the assays further, the average of the eight complete exposures in the Sequatchie Valley is 0.0085 percent, one exposure (R-S3) averaging 0.0064 percent, the others ranging from 0.0083 to 0.0093 percent (R-S7, assaying 0.006, is omitted from the averages because only 1 foot is exposed). The two

exposures on the Glendale anticline (R-S18 and R-S19) average only 0.0055 percent, bringing the average uranium content for the 11 exposures in the entire Block down to 0.0081 percent.

When allowance is made for the absence in Block 3 of the Upper siltstone, the uranium in the Upper Black shale is distributed vertically in essentially the same manner as in the Eastern Highland Rim area. The phosphatic beds at the top are commonly poor in uranium; below that zone the uranium content is highest in the upper two-thirds or three-fourths of the member.

Areal distribution

Assays of all samples taken from Block 3, which are given in table 2, show (1) that the uranium content on the Sequatchie Valley side of Walden Ridge is considerably higher than on the eastern side; and (2) that the Sequatchie Valley exposures have a remarkably uniform uranium content, with no evidence of important differences from south to north.

The uranium content of the Upper Black shale in Block 3 (0.0085 percent in the Sequatchie Valley, and 0.0081 percent over the entire Block) compares with 0.0069 percent for the same unit in Block 1 of the Eastern Highland Rim; the only Block in that area for which assays are available. This higher grade is probably attributable in part to the absence of the low-grade Upper siltstone in Block 3; but even after making that allowance,

Table 2.--Summary of thicknesses and assays, Block 3, Tennessee (thicknesses in feet and hundredths; all averages weighted)

	R-S1		R-S2		R-S3		R-S6		R-S7		R-S14		R-S15		R-S16		R-S17		R-S18		R-S19		Average
Sample no.	Thick-ness	Uranium (per-cent)	Thick-ness	Uranium (per-cent)	Thick-ness	Uranium (per-cent)	Thick-ness	Uranium (per-cent)	Thick-ness	Uranium (per-cent)	Thick-ness	Uranium (per-cent)	Thick-ness	Uranium (per-cent)	Thick-ness	Uranium (per-cent)	Thick-ness	Uranium (per-cent)	Thick-ness	Uranium (per-cent)	Thick-ness	Uranium (per-cent)	uranium (per-cent)
Maury																							
1	1.11	0.002	1.22	0.003	1.4	0.003	2.4	0.003			2.3	0.003	2.12	0.003	1.65	0.003			1.5	0.002	1.56	0.002	
2	1.71	.001	1.87	.001									2.5	.003	1.0	.002			1.36	.004	1.64	.003	
Total & ave.	2.82	0.0014	3.09	0.0018	1.4	0.003	2.4	0.003			2.3	0.003	4.62	0.003	2.65	0.0026			2.86	0.0030	3.20	0.0025	0.0026
Upper Black																							
11	1.0	0.007	2.0	0.006	2.11	0.003	2.6	0.007	1.0	0.006	2.0	0.003	1.65	0.011	2.0	0.008	2.0	0.010	1.81	0.005	1.35	0.006	
12	1.52	.007	2.0	.011	1.05	.007	1.64	.010			2.0	.005	2.0	.007	1.84	.007	2.0	.008	1.89	.005	2.0	.003	
13	2.0	.009	2.0	.011	0.9	.006	2.0	.012			2.0	.011	1.04	.003	1.48	.007	1.86	.010	1.1	.005	1.9	.005	
14	1.68	.010	2.0	.010	2.0	.009	1.94	.011			2.0	.011	1.12	.006	2.0	.010	1.9	.008	1.7	.008	0.93	.005	
15	2.0	.009	2.0	.011	1.69	.006	1.7	.005			2.0	.010	1.85	.007	1.55	.011	1.72	.010	1.45	.005	1.92	.004	
16	1.85	.009	2.0	.009	1.63	.005	0.99	.009			1.5	.010	1.10	.012	2.0	.010	1.34	.005	1.2	.009			
17	2.0	.008	1.27	.003	2.03	.009	2.3	.007			1.5	.011			2.0	.010	1.91	.008	2.0	.007			
18	0.93	.008					2.3	.009			1.5	.007											
19	1.49	.007																					
Total & ave.	14.47	0.0087	13.07	0.0087	11.41	0.0064	15.47	0.0088			14.5	0.0093	8.66	0.0083	12.87	0.0091	12.73	0.0085	11.15	0.0062	7.87	0.0044	0.0081
Middle Gray																							
41	1.09	0.002					1.56	0.003									1.41	0.003	1.18	0.006			
42							1.63	.002									2.22	.003					
43							2.0	.003															
44							2.0	.003															
Total & ave.	1.09	0.002					7.19	0.0028									3.63	0.003	1.18	0.006			0.0031
Lower Black																							
51							2.7	0.003									0.85	0.004					0.0032
61	0.64	0.004	0.20										0.10								0.23		

the richest part of the Block 1 sequence, the Top Black shale, averages only 0.0078 percent, slightly less than the 0.0081 average of the entire Upper Black shale in Block 3.

Possible discrepancies in chemical assays, which are discussed in the Eastern Highland Rim report, do not appear to be of much importance in Block 3, where the assays are consistent within themselves and agree in main details with other evidence. It seems likely that the higher assays actually represent a higher and more uniform uranium content. This is readily explained on the basis of the hypothesis referred to in the Eastern Highland Rim report, that concentration of the metal is greater in thinner sections of uranium-bearing formations than in thicker sections that represent the same time interval. In this particular case, the 12.22 feet of Upper Black shale in Block 3 contains, at 0.0081 percent, nearly as much uranium as the 16.40 feet of the comparable beds, at 0.0069 percent, in Block 1.

In comparing assays of samples from Blocks 1 and 3, it should be remembered that the Block 1 exposures are undisturbed and relatively fresh, whereas those in Block 3 are normally tilted, somewhat fractured, and nearly always deeply weathered. As the effect of weathering on the uranium content of the shale is at present not known, it is possible that samples taken underground in the Block 3 area might give assays somewhat different from those obtained at the surface. Assays of routine samples taken in Block 3 are shown in table 2.

[redacted]

Reserves

A cubic foot of black shale in place weighs about 140 pounds. A 1-foot bed of such shale over a square mile contains about 1,951,488 tons of shale. At 0.0081 percent uranium, the average for the Upper Black in Block 3, a 1-foot bed over a square mile contains about 158 tons of uranium, and the average 12.22-foot thickness of the unit would thus contain 1,930 tons.

The Chattanooga in Block 3 underlies Walden Ridge which has an average width of at least 9 miles. The length of the ridge in the Block, from the gorge of the Tennessee River on the south to the end of the Sequatchie Valley on the north, is about 55 miles. Therefore the shale underlies approximately 500 square miles in the Block. At a uranium content of 1,930 tons per square mile, there would be a total uranium tonnage in the area of about 965,000 tons. Between the Tennessee River and the Alabama State line is an additional area of about 60 square miles underlain by shale which, based on two outcrops (R-S15 and R-S19), is only about 8 feet thick and has a uranium content of about 0.006 percent. No tonnages are given for this area.

The tonnage of uranium in the Chattanooga shale underlying the Cumberland Plateau west of the Sequatchie Valley, and at a depth of approximately 2,500 feet, has not been calculated, but must be vast.

[redacted]

By-product possibilities

Possible by-products are discussed in the report on the Eastern Highland Rim, and no additional information was gained in the Block 3 investigations. The oil yield of the shale is probably about the same as in Block 1, and there are probably few differences in the other constituents.

MINING CONDITIONS

Stripping

The heavy cover of Walden Ridge would prohibit any stripping over most of Block 3. The only areas where the shale might be recovered by this method are the small hills in the Sequatchie Valley such as that in which R-S16 is exposed, and hills like the one shown in plate 9B. The maximum stripping area in such places, however, would be confined to a few acres and would not be economically attractive.

Underground mining

As long as more favorable places such as the Eastern Highland Rim area are available, underground mining in Block 3 would hardly be feasible because of the unpredictable underground conditions. The general distortion of the shale at the outcrops on both sides of Walden Ridge, coupled with the synclinal structure of the ridge itself, indicates that the shale in the area is likely to be badly broken, particularly near the outcrops. How much the distortion of the Chattanooga would be reflected in the Fort

Payne, which forms a good roof in the undisturbed Eastern Highland Rim area, is unknown.

The situation in the Eastern Highland Rim area and in Block 3, from a mining standpoint, may be summarized by saying that approximately the same tonnage of uranium, oil, and other by-products, or possibly a little more, can be recovered from a 16-foot bed in Block 1 than can be taken from a 12-foot bed in Block 3. When it is considered that conditions in Block 1 are in the main known or at least predictable, whereas those in Block 3 are unknown and largely unpredictable, the advantages of the first area over the second are obvious.

REGISTER OF LOCALITIES

Sequatchie Valley

R-S1 Sequatchie Co., Daus quadrangle, on Highway 8, 1 mile southeast of junction of State Highways 28 and 8 (pls. 3, 4, 5).

R-S2 Marion Co., Keltner Gap quadrangle, on State Highway 27, 1.3 miles east of Powells crossroads.

R-S3 Bledsoe Co., Melvine quadrangle, about 8 miles northeast of Pikeville, 2.1 miles east of junction with north-south gravel road. Upper part of section is on east side of Beatty Creek, lower part is on northwest side of southwest fork of Beatty Creek.

R-S6 Bledsoe Co., Melvine quadrangle, 2 miles east of road junction near Cedar Ridge. Outcrop is on southwest side of road, and on northeast side below the road.

R-S7 Cumberland Co., Vandever quadrangle, 16.7 miles north of Pikeville, a road cut on northeast side of State Highway 28, opposite a farmhouse on southwest side of Sequatchie River (pl. 8A).

R-S14 Bledsoe Co., Brayton quadrangle, on northwest side of Pitt Gap road about 1 mile east of bridge over Sequatchie River (pl. 8B).

R-S15 Marion Co., Sequatchie quadrangle, 2.5 miles west of west side of Tennessee River bridge at Haletown, 1.9 miles west of Rankin Cave school on northeast side of Highway 41 where it cuts through Anderson hill (pl. 6B).

R-S16 Bledsoe Co., Pikeville quadrangle, 2 miles east of Pikeville on northwest side of State Highway 30 in old chert pit about 200 feet west of highway (pl. 7A).

R-S17 Bledsoe Co., Mt. Airy quadrangle, on north side of McWilliams Creek 0.7 mile east of main north-south gravel road (pl. 7B).

Glendale anticline

R-S18 Hamilton Co., directly in back of cabin No. 14 at Glendale Tourist Court (pl. 9A), near Chattanooga.

R-S19 Hamilton Co., Wauhatchie quadrangle, on north side of U. S. Highway 41 about half a mile west of junction with U. S. Highway 11 (pl. 6A).

[redacted]

REFERENCES

1. Conant, L. C., Brown, Andrew, and Hass, W. H., Chattanooga shale of the Eastern Highland Rim, Tennessee: Trace Elements investigations report 62, 1950.

2. Hayes, C. W., U. S. Geol. Survey Geol. Atlas Folios: Kingston (no. 4, 1894), Chattanooga (no. 6, 1894), Sewanee (no. 8, 1894), and Pikeville (no. 21, 1895).

3. Nelson, J. M., and Brill, K. G., Radioactivity of the Chattanooga shale east of the Mississippi and south of the Ohio Rivers: Trace Elements investigations report 22, 1947.

[redacted]

Abbreviations used on Plates 3-9

FP	Fort Payne
Dc	Chattanooga shale
M	Maury
Ph	Phosphatic zone
UB	Upper Black shale
B	Bentonite bed
MG	Middle Gray siltstone
LB	Lower Black shale
BS	Basal sandstone
Miss.	Mississippian Rocks
Dev.	Devonian Rocks
Sil.	Silurian Rocks
Ord.	Ordovician Rocks

Plate 3

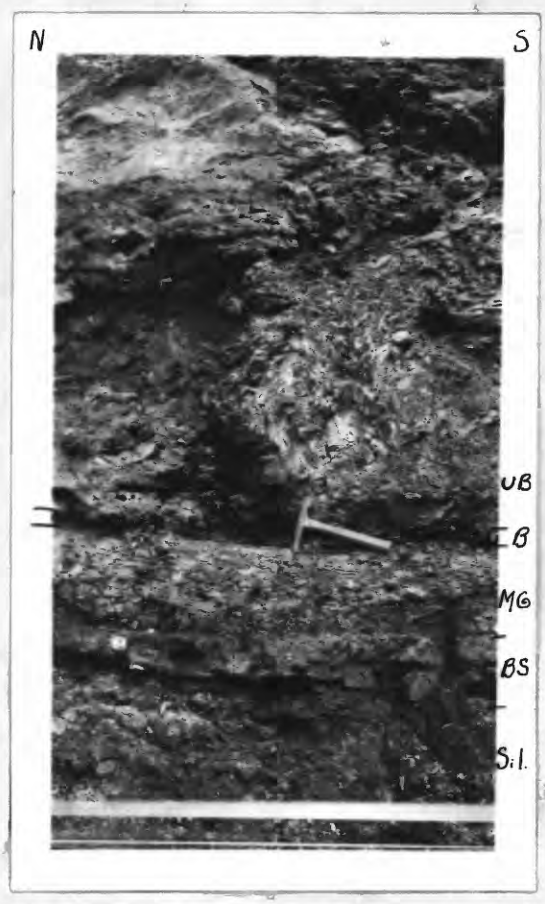
A. Cut on Tennessee Highway 8. R-S 1

220

B. Bentonite Bed at R-S 1

220

Plate 4



A. Tight folds in the Upper Black. R-S 1

220

B. Middle Gray cut out by intraformational folding. R-S 1

220

Plate 5

A. Upper Black and Maury at R-S 1

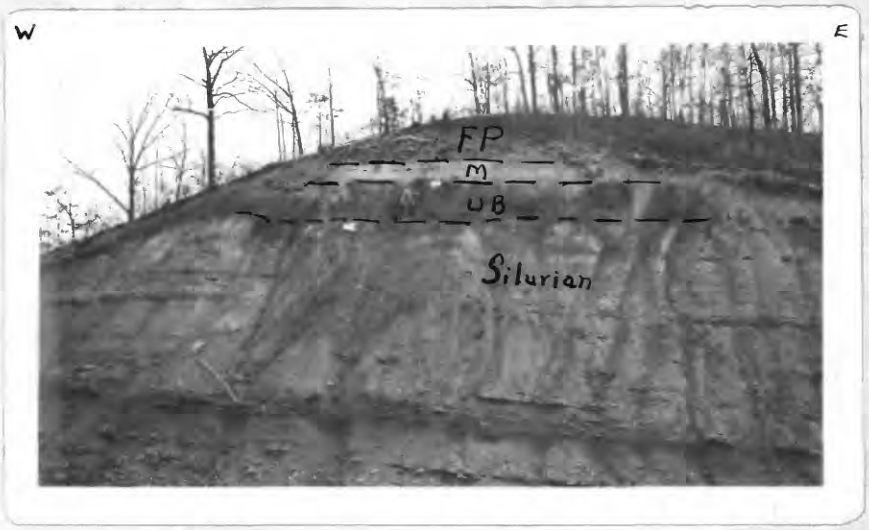
270

B. Phosphate zone of Upper Black. R-S 1

270

Plate 6

A. U. S. Highway 41. R-S 19



B. U. S. Highway 41. R-S 15

222

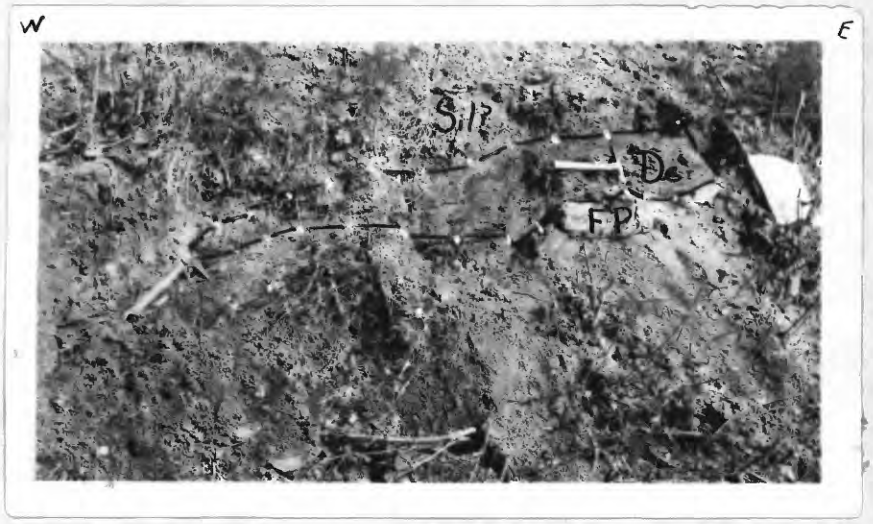
A. Tennessee Highway 30 E. of Pikeville. R-S 16

217 -

B. McWilliams Creek. R-S 17

219

Plate 8

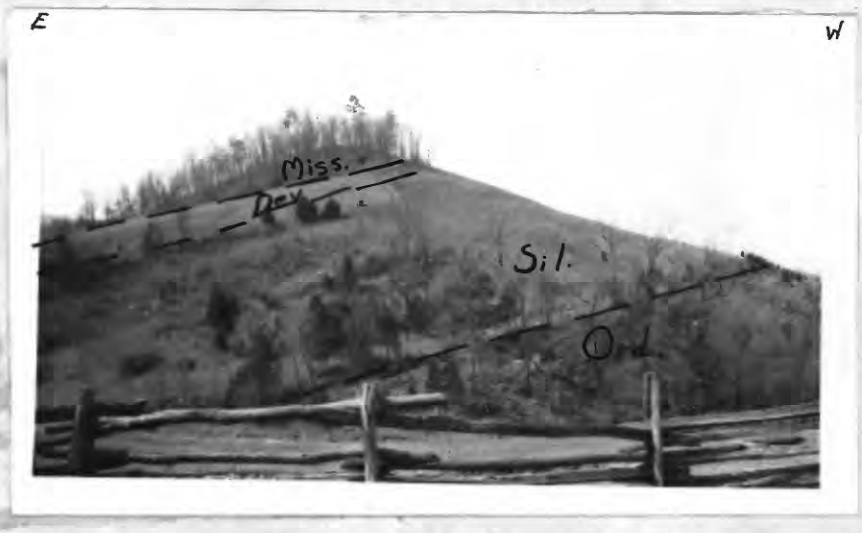


A. Tennessee Highway 28. R-S 7

B. Pitt Gap road. R-S 14

Plate 9

A. Glendale. R-S 18



B. Isolated hill type of Chattanooga exposure near R-S 14