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GEOLOGICAL SURVEY

# CHATTANOOGA SHALE OF THE EASTERN HIGHLAND RIM, TENNESSEE

by

L. C. Conant, Andrew Brown, and W. H. Hass

August 1950

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Trace Elements Investigations Report 62



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## ABSTRACT

The Chattanooga shale of the Eastern Highland Rim area of Tennessee was studied by the U. S. Geological Survey in 1947, 1948, and 1949 to determine its availability as a source of uranium. The work included detailed stratigraphic studies, collection and assay of many samples, core drilling, Geiger-counter scanning, and the driving of a 100-foot adit.

Where studied the shale is 4 to 37 feet thick, the average for the entire area being about 27 feet. Five lithologic units have been recognized, the upper three of which (Top Black shale, Upper siltstone, and Middle Black shale) may be of possible value as future sources of uranium. The aggregate thickness of these three upper units ranges from 4 to 22 feet and averages about 16 feet. The shale is overlain at most places by so thick a cover of Fort Payne chert as to prevent large-scale stripping operations and necessitate underground mining if the shale is ever to be utilized.

The form and association of the uranium in the shale are not known, though a number of possibilities have been investigated.

Assays of samples from Block 1, near the center of the area investigated, indicate that the three upper units contain about 0.0069 percent uranium and that the Top Black shale (6.35 feet thick in this block) contains about 0.0078 percent. It seems likely that the uranium content of the shale in adjoining blocks is similar to that in Block 1, though available assays are

inconsistent: assays of all large and some small samples indicate a grade equal to that in Block 1, others indicate a lower grade.

Present information indicates that the 93.5 square miles of Block 1 for which assays are available contain about 200,000 tons of metallic uranium in the three upper units. Insufficient evidence is at hand to warrant estimates of grade and tonnage in other areas, though it is known that the shale has a fairly consistent thickness over many thousand more square miles, mostly at depths of 150 to 3,000 feet, and it is probable that the uranium content in much of that area is comparable to that of Block 1. It is certain that vast quantities of uranium are present, most of it probably having a concentration of less than 0.01 percent.

# INTRODUCTION

## Purpose of work

Reconnaissance studies from 1944 to 1947 [11, 16] 1/ showed that the Chattanooga shale of Tennessee contains as much as 0.01 percent metallic uranium in some areas. Despite this relatively low content, the tremendous tonnage of the shale over wide areas appeared to warrant further investigation.

The general purpose of the project was to learn as much as possible about the uranium content of the shale, more specific objectives being:

(1) The origin of the uranium in the shale.

(2) The association of the uranium with other mineral or organic constituents of the shale.

(3) The vertical distribution of the uranium in the several layers of the shale formation.

(4) The areal distribution of the uranium in the shale.

(5) The uranium reserves of various grades.

To attain these objectives, the investigations included geologic mapping, detailed measurements and study of lithologic features at many exposures, local and regional paleontologic and stratigraphic studies, systematic collection of many samples for assay, tests with the Geiger-Mueller tube and cyclotron register, core drilling, and the driving of a 100-foot adit.

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

## Personnel

The work here reported was done by members of the Fuels Branch of the Geological Survey. Field investigations were under the general supervision of L. C. Conant. Andrew Brown was in charge of drilling and adit work, and W. H. Hass was particularly responsible for the paleontology and regional stratigraphy. Most of the sampling was done by Andrew Brown, R. C. Robeck, R. E. Smith, and W. A. Heck, who were assisted by several other geologists assigned to the project for short periods. Geologic mapping in Block 1 was largely by Conant; in Block 4 by Smith; and in Blocks 5, 6, and 7 by Robeck. Radioactivity measurements at outcrops of many of the sampled localities were made by Robeck. All these men have contributed materially to the information in this report.

## AREAS OF INVESTIGATIONS

Most of the investigations were along the Eastern Highland Rim of east-central Tennessee, chiefly because earlier reconnaissance had indicated higher uranium content in that general region. Some work was done in other regions, but this report covers only that northeasterly trending belt which extends south from the Kentucky-Tennessee line almost to the Tennessee-Alabama line (see map, pl. 1).

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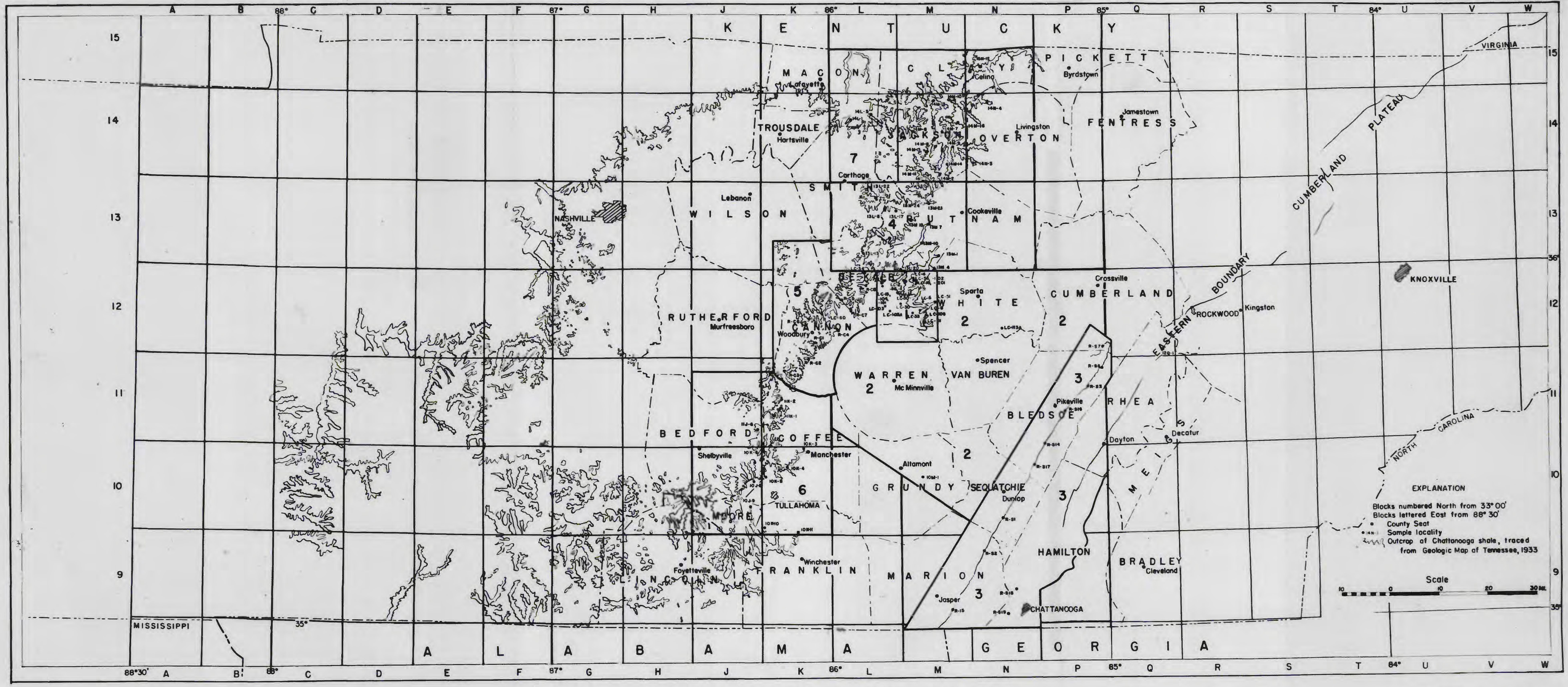
PLATE I




LOCATION OF BLOCKS, EASTERN OIL SHALE., TENNESSEE

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Designation of blocks

The outcrop area of the Chattanooga shale in Tennessee and nearby states was divided by coordinates into 15-minute quadrangles measured north and east from latitude 33° N. and longitude 88°30' W. These quadrangles were numbered from south to north and lettered from west to east (pl. 1). Exposures which were studied along the Eastern Highland Rim of Tennessee on the present project are in 14 quadrangles bearing numbers from 10 to 15 and letters from J to N. This area was also divided into five blocks based on the quadrangle system but not following it in its entirety. The sizes and locations of these blocks are shown in plate 1. The northernmost, Block 7, includes the Northeastern Highland Rim and that part of the Cumberland River Valley within the State of Tennessee. Blocks 4, 5, and 6 include the western edge of the Eastern Highland Rim as far south as 35°15' N. latitude. Block 1, in which the first and most intensive studies were made, is east of Block 5 where the Caney Fork River and its tributaries have cut a deep re-entrant into the Highland Rim.

Southeast of the areas described above, the Chattanooga is buried for about 40 miles to the place where it crops out on the east side of the Sequatchie Valley. East of this valley it underlies Walden Ridge and is exposed at intervals on its east flank. The Sequatchie Valley-Walden Ridge area is designated as Block 3; the large area between it and the Highland Rim blocks, where only a small amount of subsurface information is available, is designated Block 2. This report covers investigations in Blocks 1, 2, 4, 5, 6, and 7. Because of different geological conditions in the Walden Ridge area, Block 3 is discussed in a separate report. [13]

Sampled localities in Blocks 1 and 2 are designated by the prefix LC-, followed by a number assigned to the exposure (e. g., LC-10, LC-55). Those in Block 5 bear the prefix R-C (e. g., R-C2, R-C8) except for two localities (LC-34 and LC-60) which carry the Block 1 prefix. In Blocks 4, 6, and 7, the prefixes are the designations of the quadrangles in which the outcrops are located (e. g., 13M-10).

## Geography

The area embraced by this report is essentially that in which the dissected escarpment between the Highland Rim and the Central Basin of Tennessee is present. This area includes parts or all of Clay, Macon, Overton, Jackson, Putnam, Smith, White, DeKalb, Cannon, Coffee, Moore, and Franklin Counties, Tennessee. The principal towns are Livingston, Gainesboro, Carthage, Cookeville, Sparta, Smithville, Woodbury, Manchester, and Tullahoma.

Because of the rugged topography along the escarpment and the comparatively poor soil, the area as a whole is sparsely inhabited. The only railroads crossing the area are the Tennessee Central Railway connecting Knoxville and Nashville through

Carthage and Cookeville, the Nashville, Chattanooga, and St. Louis Railway between Chattanooga and Nashville; and a branch line of the Nashville, Chattanooga, and St. Louis which leaves the main line at Tullahoma and passes through Manchester and McMinnville to Sparta. Highway transportation is fairly good: U. S. 70N passes through Carthage and Cookeville; U. S. 70S passes through Woodbury, McMinnville, and Sparta; and several good state highways cross the area both north-and-south and east-and-west. Many of the county roads are well maintained, and nearly all the localities shown on the maps can be reached in any except the worst weather.

The climate is generally pleasant, though much cold weather and snow must be expected during the winter months. Records from Cookeville show that the average temperature for January is 40.4°, and for July is 76.7°, and that the average annual rainfall is 53.38 inches. January is the wettest month, and September the driest.

Center Hill and Dale Hollow Reservoirs.--Two large reservoirs in the area have been impounded by the Corps of Engineers of the U. S. Army as parts of the Cumberland River flood control project: the Dale Hollow Reservoir (Block 7, pl. 6) and the Center Hill Reservoir (Blocks 1 and 4, pls. 2 and 3). These reservoirs might be of great importance in any exploitation of the shale deposits, both as means of transportation and as sources of water and electric power. The Center Hill Reservoir is particularly well located with reference to the shale deposits in Block 1 and the southern part of Block 4. It was filled after most of the geologic work in Blocks 1 and 4 was completed. Localities LC-108 and LC-11 are now under water; LC-8 and LC-51 can be reached only during low-water periods. Gauging records [1] show that the average flow of the Caney Fork River, at a point near the south edge of Block 4, has been about 3,543 cubic feet per second during the 22 years of record. The range has been between 25 and 178,000 cubic feet per second; the minimum figure has been affected by the Great Falls Dam; the maximum represents the largest flood known on the river.

## TOPOGRAPHY

The Chattanooga shale is exposed along the escarpment between the Nashville Basin and the Eastern Highland Rim. The Basin is about 125 miles long and 60 miles wide, extends across the State of Tennessee in a northeasterly direction, and is surrounded by the Highland Rim. Though topographically a basin, it is structurally part of a gentle swell, the Cincinnati arch, the higher parts of which have been removed by erosion. At present the Basin is a relatively level lowland about 500 feet above sea level, and floored by Ordovician limestones.

The Highland Rim is a relatively smooth upland which surrounds the Basin, is some 25 miles or more wide, and is probably the remnant of an ancient peneplain that once extended across the present Basin. In the area covered by this report the Rim is approximately 1,000 to 1,100 feet above sea level, thus being 500 to 600 feet higher than the Basin. It is capped by the Fort Payne chert.

Because of the resistant nature of the Fort Payne, the slopes along the escarpment and in the stream valleys cutting back into the Rim are normally about $30^{\circ}$ or more, and some, especially near the bottoms of narrow valleys, range from $45^{\circ}$ to vertical in cliffs 200 feet high. The best exposures of the Chattanooga are in road cuts on the slopes and at waterfalls in small streams (figs. 1 and 2).

To the north (Block 7) the Fort Payne is more shaly, erodes more readily, and develops somewhat gentler slopes.

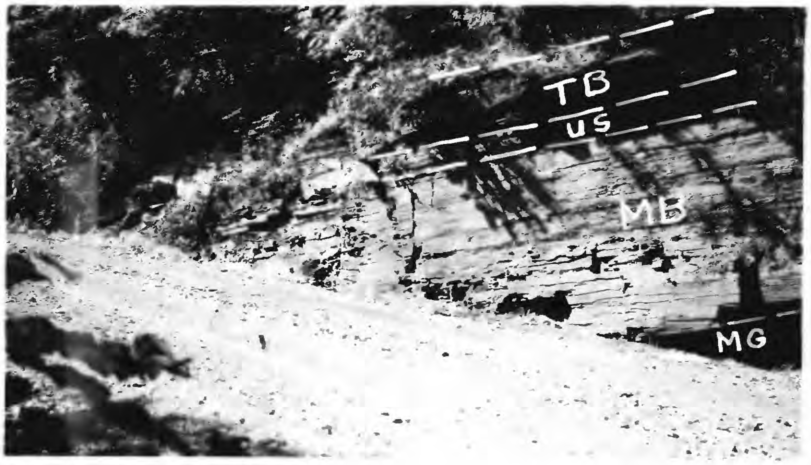
## STRATIGRAPHY

### Rocks underlying the Chattanooga

At nearly all places along the Eastern Highland Rim the Chattanooga lies directly on limestones of Ordovician age. In the northern part of Block 7, in Macon County (quadrangle 15L, pl. 1) and near the eastern edge of Clay County (quadrangles 15N and 15P), thin beds of Silurian rocks separate the Ordovician from the Chattanooga. These underlying rocks have not been studied in detail in this project.

Figure 1


A. English Falls at locality R-C7 in Block 5. The Chattanooga shale is well exposed at many such falls in the Highland Rim area. Visible below the Fort Payne chert are: a re-entrant formed by the Maury shale; undifferentiated Top Black shale, Upper siltstone, and Middle Black shale (UB); Middle Gray siltstone (MG); Lower Black shale (LB); and Ordovician limestone (Ord). 1948.




B. Typical fresh road cut in the Chattanooga shale at locality R-C2 in Block 5. Seen here are the slightly overhanging Top Black shale (TB), the Upper gray siltstone (US), the Middle Black shale (MB), and the position of the Middle Gray siltstone (MG). Several special samples were taken from near the middle of the Top Black shale. 1948.

Figure 2


A. - Locality LC-10 on old Highway 26, near Sligo, Block 1, showing Fort Payne chert (FP), Maury shale (M), Top Black shale (TB) being sampled, and Upper siltstone (US). Weathering has developed a fissility not apparent in fresh exposures of the shale. March 1948.


B. - Locality R-Ç1, on Highway 53 about 2½ miles south of Woodbury, Block 5. Below the poorly exposed Fort Payne chert and Maury shale (M) are the Top Black shale (TB), Upper siltstone (US), Middle Black shale (MB), and lower units not well seen in photo. 1948.

## Chattanooga shale

Introduction.--The Chattanooga shale is exposed over large areas in Tennessee, southern Kentucky, northern Alabama, and northwest Georgia. In the area covered by this report, it is 4 to 37 feet thick, being thinnest in the southern part (Block 6) and thickest in the three central blocks (1, 4, and 5). It is composed almost entirely of tough black shale and light- to dark-gray siltstone or claystone. Scattered phosphatic nodules are present in the upper part of the formation throughout the northern half of the area.

The fresh black shale appears nearly massive (fig. 1B) and often breaks with a conchoidal fracture. Laminae of silt, iron sulphides, and microgranular material, however, give the rock a stratified appearance. Upon weathering the shale develops a conspicuous fissility (fig. 2). At old outcrops a thin coating of yellow-brown iron oxide is the rule; where much weathered the black shale locally becomes dark brown. The siltstone or claystone weathers to a soft, hackly rock stained various shades of yellow and green.

The Chattanooga is divisible lithologically into several units, which are shown in the following section.

Table 1.--Thicknesses of units of Maury and Chattanooga shales, Eastern Highland Rim, Tennessee
(Localities arranged from north to south; thicknesses shown in feet and hundredths)

| Locality | Maury | Chattanooga | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Top Black shale | | | | | | | | | |
| | | Phosphatic layer b | Phosphatic zone | Non-phosphatic shale | Total Top Black | Upper siltstone | Middle Black | Total three upper units | Middle Gray | Lower Black | Total Chattanooga |
| **Block 7** | | | | | | | | | | | |
| 15N-12 a | 0.80 | 0.30 | 12.71 a | 3.64 a | 16.65 a | 1.18 a | - | 17.83 a | - | - | 17.83 |
| 14N-4 | 1.20 | - | 5.10 | 8.82 | 13.92 | 4.53 | - | 18.45 | - | - | 18.45 |
| 14M-10 | 1.25 | 0.80 | 5.54 | 5.80 | 12.14 | 5.28 | - | 17.42 | - | - | 17.42 |
| 14M-13 | 1.30 | 0.65 | 1.35 | 11.00 | 13.00 | 5.00 e | - | 18.00 e | - | - | 18.00 e |
| 14L-5 | 1.80 | - | 8.93 | 4.30 | 13.23 | 5.41 | - | 18.64 | - | - | 18.64 |
| 14L-1 | 3.15 | 1.83 | - | 13.84 | 15.67 | - | - | 15.67 | - | - | 15.67 |
| 14M-16 | 1.30 | 0.40 | 3.45 | 10.00 | 13.85 | 7.97 | - | 21.82 | - | - | 21.82 |
| 14M-7 a | 1.40 | 0.45 | 2.55 a | 9.53 a | 12.53 a | 7.80 a | - f | 20.33 a | - | - | 20.33 |
| 14M-6 | 2.00 e | 0.30 | 1.79 | 8.36 | 10.45 | 6.51 | - f | 16.96 | - | - | 16.96 |
| 14M-9 | 1.60 | 0.70 | 2.30 | 12.61 | 15.61 | 4.98 | - f | 20.59 | - f | - f | 20.59 |
| 14M-8 | 1.87 | 0.35 | 2.66 | 11.77 | 14.78 | 5.50 | - f | 20.28 | - | - | 20.28 |
| 14M-15 | 2.05 | 0.40 | 1.17 | 9.57 | 11.14 | 2.60 | 2.24 | 15.98 | 2.77 | 4.05 | 22.80 |
| 14N-3 | 0.89 | 0.74 | 1.26 | 9.83 | 11.83 | 3.14 | 3.66 | 18.63 | 1.38 | 4.90 | 24.91 |
| 14M-14 | 1.20 | 0.60 | 3.88 | 16.23 | 20.71 | 1.55 | 5.37 | 27.63 | - f | - f | 27.63 |
| 14M-11 | 2.10 | 0.30 | 1.75 | 8.23 | 10.28 | 2.18 | 2.09 | 14.55 | 6.97 | - f | 21.52 |
| 14M-2 | 1.04 | 1.25 | 1.75 | 7.78 | 10.78 | 4.63 | 1.93 | 17.34 | 3.29 | 4.94 | 25.57 |
| Average* | 1.56 | 0.65 | 3.74 | 9.46 | 13.54 | 4.55 | 3.06 | 18.76 | 3.60 | 4.63 | 20.53 |
| **Block 4** | | | | | | | | | | | |
| 13L-22 | 2.15 | 1.04 | 3.59 | 7.24 | 11.87 | 3.02 | 2.00 | 16.89 | 5.29 | 6.04 | 28.22 |
| 13M-23 | 0.27 | 0.50 | 2.19 | 8.57 | 11.26 | 2.82 | 3.85 | 17.93 | 5.01 | 4.57 | 27.51 |
| 13M-24 | 1.53 | 0.40 | 2.25 | 7.77 | 10.42 | 3.70 | 2.51 | 16.63 | 4.38 | 4.24 | 25.25 |
| 13L-8 | 0.80 | 0.58 | 0.61 | 7.81 | 9.00 | 3.05 | c | } 16.39 | c | c | } 28.73 |
| 13L-17 | c | c | c | c | c | | 4.34 | | 6.23 | 6.11 | |
| 13M-19 | 1.30 | 0.44 | 1.68 | 9.25 | 11.37 | 1.67 | 4.21 | 17.25 | 6.04 | 4.72 | 28.01 |
| 13M-7 | 1.06 | 2.10 | - | 8.87 | 10.97 | 2.87 | 5.75 | 19.59 | 5.81 | 5.15 | 30.55 |
| 13L-11 | 1.57 | 0.46 | 2.42 | 7.11 | 9.99 | 2.63 | 4.65 | 17.27 | 8.07 | 6.05 | 31.39 |
| 13M-10 | 1.50 | 0.96 | 2.95 | 9.47 | 13.38 | 3.00 | 6.08 | 22.46 | 8.07 | 6.49 | 37.02 |
| 13L-13 | 0.80 | - | - | 5.23 | 5.23 | 2.96 | 2.95 | 11.14 | 7.57 | 5.40 | 24.11 |
| 13M-1 | 1.00 | 0.72 | 1.98 | 9.68 | 12.38 | 2.84 | 7.01 | 22.23 | 8.03 | 5.59 | 35.85 |
| 13L-20 | 2.37 | 0.75 | 0.90 | 6.60 | 8.25 | 3.22 | 6.12 | 17.59 | 8.93 | 6.53 | 33.05 |
| 13M-5 | 1.71 | 0.55 | 1.00 | 5.48 | 7.03 | 2.69 | 6.67 | 16.39 | 8.38 | 6.55 | 31.32 |
| 13M-4 | 1.63 | 0.65 | 1.91 | 7.38 | 9.94 | 3.06 | 8.42 | 21.42 | 9.39 | 6.71 | 37.52 |
| Average* | 1.36 | 0.76 | 1.95 | 7.73 | 10.08 | 2.89 | 4.97 | 17.94 | 7.02 | 5.70 | 30.66 |
| **Block 1** | | | | | | | | | | | |
| LC-15 | 1.32 | 0.50 | - | 6.94 | 7.44 | 1.97 | 6.18 | 15.59 | 8.98 | 6.10 | 30.67 |
| LC-4 | 2.07 | 0.30 | - | 7.69 | 7.99 | 2.87 | 7.67 | 18.53 | 9.77 | 6.77 | 35.07 |
| LC-17 | 1.97 | 0.10 | - | 7.00 | 7.10 | 2.36 | 7.55 | 17.01 | 9.29 | 5.95 | 32.25 |
| LC-55 | 1.80 | 0.80 | - | 6.80 | 7.60 | 2.10 | 7.70 | 17.40 | 8.50 | 5.70 | 31.60 |
| LC-102 | 3.30 | 0.25 | - | 5.85 | 6.10 | 2.50 | 7.10 | 15.70 | 10.35 | 5.75 | 31.80 |
| LC-2 | 2.30 | 0.26 | - | 6.69 | 6.95 | 2.49 | 7.19 | 16.63 | 9.45 | 12.24 | 38.32 |
| LC-56 | 2.50 | - | - | 6.25 | 6.25 | 2.50 | 7.65 | 16.40 | 8.82 | 6.28 | 31.50 |
| LC-1 | 2.50 | 0.50 | - | 5.95 | 6.45 | 2.45 | 7.40 | 16.30 | 9.35 | 6.35 | 32.00 |
| LC-10 | 2.06 | 0.50 | - | 6.70 | 7.20 | 3.35 | 7.90 | 18.45 | 9.70 | 4.80 | 32.95 |
| LC-12 | 1.95 | 0.15 | - | 6.72 | 6.87 | 2.19 | 7.31 | 16.37 | 9.00 | 6.74 | 32.11 |
| LC-50 | 1.80 | - | - | 5.67 | 5.67 | 2.57 | 10.05 | 18.29 | 10.76 | 7.05 | 36.10 |
| LC-51 | 1.24 | - | - | 5.53 | 5.53 | 2.98 | 8.44 | 16.95 | 10.51 | 6.70 | 34.16 |
| LC-6 | 0.95 | 0.37 | - | 4.90 | 5.27 | 2.84 | 8.73 | 16.84 | 10.65 | 6.72 | 34.21 |
| LC-30 | 1.88 | - | - | 4.96 | 4.96 | 2.50 | 7.73 | 15.19 | 9.27 | 6.50 e | 30.96 e |
| LC-103 | 1.60 | - | - | 6.60 | 6.60 | 1.10 | 7.00 | 14.70 | 9.00 | 6.40 | 30.10 |
| LC-8 | 1.10 | - | - | 6.25 | 6.25 | 2.49 | 8.70 | 17.44 | 11.68 | 2.50 | 31.62 |
| LC-33 | 1.37 | - | - | 5.12 | 5.12 | 2.85 | 8.53 | 16.50 | 10.43 | 6.47 | 33.40 |
| LC-105A | 1.55 | - | - | 5.00 | 5.00 | 1.35 | 7.65 | 14.00 | 9.60 | 5.85 | 29.45 |
| LC-11 | 2.03 | - | - | 6.38 | 6.38 | 3.67 | 3.37 | 13.42 | 5.71 | 10.38 | 29.51 |
| Average* | 1.86 | 0.37 | - | 6.16 | 6.35 | 2.48 | 7.57 | 16.40 | 9.51 | 6.59 | 32.51 |
| **Block 5** | | | | | | | | | | | |
| LC-34 | 4.30 | 0.85 | - | 6.94 | 7.79 | 2.17 | 4.22 | 14.18 | 7.93 | 5.09 | 27.20 |
| R-C8 | 2.16 | - | - | 6.17 | 6.17 | 1.85 | 5.54 | 13.56 | 8.60 | 5.11 | 27.27 |
| R-C5 | 3.40 | - | - | 4.66 | 4.66 | 1.50 | 5.99 | 12.15 | 8.23 | 4.71 | 25.09 |
| R-C7 | 3.20 | - | - | 3.15 | 3.15 | 1.77 | 6.16 | 11.08 | 9.15 | 5.90 | 26.13 |
| LC-60 | 4.21 | - | - | 5.56 | 5.56 | 2.29 | 6.17 | 14.02 | 8.49 | 6.40 | 28.91 |
| R-C6 | c | - | - | 6.02 | 6.02 | 1.22 | 6.11 | 13.35 | 7.82 | 7.33 | 28.50 |
| R-C4 | 3.52 | - | - | 4.12 | 4.12 | 1.93 | 8.00 | 14.05 | 7.35 | 4.77 | 26.17 |
| R-C1 | 4.00 | - | - | 4.50 | 4.50 | 1.34 | 7.90 | 13.74 | 9.00 | 9.50 e | 32.24 e |
| R-C2 | 3.10 | - | - | 3.94 | 3.94 | 1.22 | 7.10 | 12.26 | 9.45 | 6.48 | 28.19 |
| R-C3 | 3.60 e | - | - | 2.00 | 2.00 | 1.24 | 6.46 | 9.70 | 7.40 | 8.89 | 25.99 |
| Average* | 3.50 | 0.85 | - | 4.71 | 4.79 | 1.65 | 6.37 | 12.81 | 8.34 | 6.42 | 27.57 |
| **Block 6** | | | | | | | | | | | |
| 11K-2 | 1.14 | - | - | 2.80 | 2.80 | 2.24 | 4.42 | 9.46 | c | c | |
| 11K-1 | 2.20 | - | - | 4.22 | 4.22 | 2.75 | 5.81 | 12.78 | 10.48 | 7.81 | 31.07 |
| 11J-6 | 1.76 | - | - | 3.90 | 3.90 | 3.02 | c | } 12.07 | c | c | } 26.69 |
| 10K-6 | c | - | - | c | c | c | 5.15 | | 8.72 | 5.90 | |
| 10K-3 | 2.34 | - | - | 4.95 | 4.95 | 1.43 | 6.23 | 12.61 | 5.13 | 8.93 | 26.67 |
| 10K-4 | 2.75 | - | - | 7.43 | 7.43 | 0.86 | 6.75 | 15.04 | 3.71 | 6.27 | 25.02 |
| 10K-5 | 2.11 | - | - | 7.17 | 7.17 | 0.79 | 5.68 | 13.64 | 2.52 | 7.33 | 23.49 |
| 10J-8 | 1.35 | - | - | 8.62 | 8.62 | 0.73 | 6.32 | 15.67 | 3.98 | 1.07 | 20.72 |
| 10J-9 | 0.90 | - | - | 7.38 e | 7.38 e | - | 5.62 e | 13.00 | 0.42 | - | 13.42 |
| 10K-10 | 1.18 | - | - | 4.27 | 4.27 | - | - | 4.27 | - | - | 4.27 |
| 10K-11 | 0.60 | - | - | 9.40 | 9.40 | - | - | 9.40 | - | - | 9.40 |
| Average* | 1.63 | - | - | 6.01 | 6.01 | 1.69 | 5.75 | 11.79 | 4.99 | 6.22 | 19.02 |
| **Eastern Highland Rim, ave.*** | 1.88 | 0.62 | 2.99 | 7.00 | 8.46 | 2.83 | 6.06 | 16.04 | 7.64 | 6.16 | 26.86 |

* Averages for units not everywhere present determined only for those outcrops where present.
\- Unit missing.
a Samples at 14M-7 and 15N-12 may be partially assigned to incorrect units.
b Phosphatic layer here included in Chattanooga shale, though recent studies suggest it belongs in the Maury.
c Unit partially or wholly concealed.
e Thickness estimated.
f Later information suggests unit is present, but is included in measurements of higher units.

19

Divisions of the Chattanooga shale

| Age | Formation | Subdivision | Description |
|---|---|---|---|
| Lower Mississippian or Upper Devonian | Chattanooga shale | Top Black shale | **Black shale, scattered phosphate nodules; northern part of area only.** |
| Upper Devonian | | | **Black shale; most widespread of all the subdivisions.** |
| | | Upper siltstone | **Black shale having a few claystone or siltstone beds; varved siltstone at base.** |
| | | Middle Black shale | Black shale. |
| | | Middle Gray siltstone | Gray claystone or siltstone and black shale, interbedded; bentonite bed near top. |
| | | Lower Black shale | Black shale. |
| | | Basal sandstone | Conglomeratic sandstone, commonly 2 inches or less thick; where Lower Black shale is absent, is commonly at base of lowest unit present. |

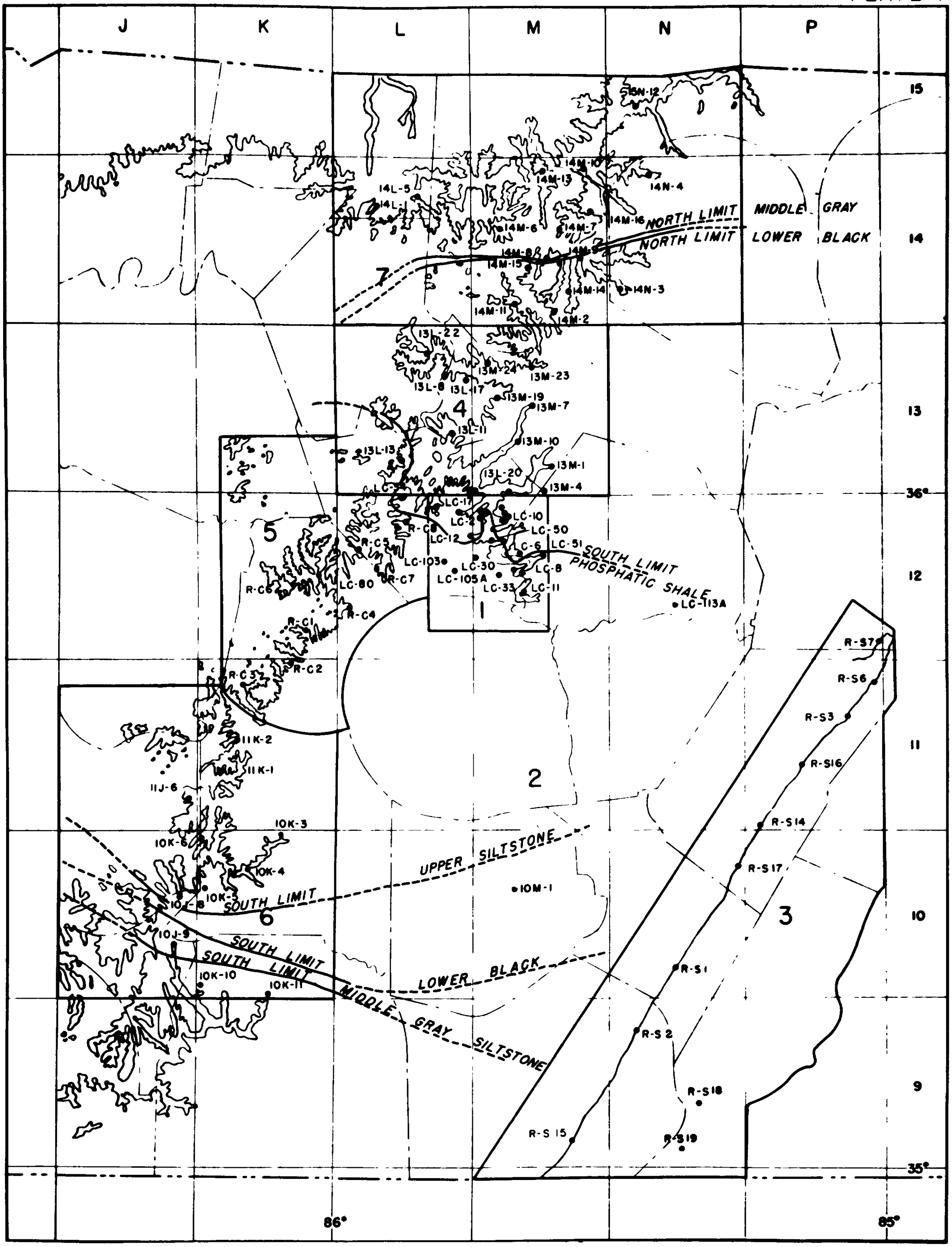
Thicknesses of these and the overlying Maury shale units at all measured exposures in the area investigated are given in table 1.

Basal sandstone.--At most exposures the basal 2 inches or less of the Chattanooga is a sandstone or fine-grained conglomerate composed of rounded quartz grains and water-worn fragments of shells, bones, and conodonts. The fresh sandstone is commonly dark gray and contains grains or seams of pyrite or marcasite. Regardless of the thickness of the Chattanooga section, or of which unit may be at the base of a particular exposure, the sandstone is commonly present and in places grades into the overlying shale. It appears, therefore, that the sandstone represents the working over of whatever detritus was available as the sea spread over the land, and is a basal sandstone or conglomerate of whatever part of the formation was deposited first. Some workers have considered this a thin equivalent of the Hardin sandstone which underlies the Chattanooga shale of southwest Tennessee, but as its equivalence with that formation is at least questionable, the term basal sandstone is preferable.

Lower Black shale.--This unit is dominantly black shale, and only a few thin partings and beds of siltstone or claystone are present. Throughout the Eastern Highland Rim its average thickness is about 6 feet, and it is present everywhere except at the three southernmost localities in Block 6, and in the northern two-thirds (pl. 7) of Block 7. Its thickness is more irregular within short distances than that of the other units, because of the somewhat irregular surface on which it accumulated.

Confidential

PLATE 7




DISTRIBUTION OF LOWER BLACK SHALE, MIDDLE GRAY SILTSTONE, UPPER SILTSTONE, AND PHOSPHATIC UNITS OF CHATTANOOGA SHALE, EASTERN HIGHLAND RIM, TENNESSEE

10 0 10 20 30 40 Miles

1950

Confidential

Middle Gray siltstone.--The Middle Gray siltstone is a series of interbedded black shale and gray siltstone or claystone beds. It is as much as 11 feet thick, averages about 9 feet in Blocks 1 and 5, and thins toward both the north and south. It is absent at the two southernmost localities in Block 6, and probably in the northern two-thirds of Block 7 (pl. 7). The unit is distinctly layered at all outcrops. The beds are light to dark gray and at old outcrops are stained yellow and brown. Some, especially in the upper part of the unit, have a distinct bluish-green cast. The upper and lower thirds of the thicker sections of the Middle Gray siltstone contain beds of black shale which have a maximum thickness of 0.2 foot.

A bentonite bed which averages about 0.1 foot in thickness is an important stratigraphic marker in the Middle Gray siltstone and is 0.1 foot to 1.5 feet below the top of the unit. It has recently been described by Hass.[9] This bed is present throughout Blocks 1 and 4, in the southern part of Block 7, in the northern part of Block 6, and in Block 5 except an area of about 100 square miles in the vicinity of Woodbury. It is thus present for about 80 miles along the Highland Rim, has been found in cuttings from wells in Block 2, has been seen in measured sections in the Sequatchie Valley (Block 3), and has been found south of Nashville on an outlier in the southwest corner of quadrangle 12H. This bentonite appears to reflect a fall of volcanic ash whose remnants are now present throughout more than 4,000 square miles in east-central Tennessee.

Middle Black shale.--This unit is similar to the Lower Black shale. It is thickest in Block 1, where it averages about 7.5 feet, and it thins to the north and south. The unit is missing at the two southernmost exposures in Block 6 and perhaps in the northern part of Block 7. In Block 7, however, it is probably more widespread than was supposed at the time of the field work or than is indicated in table 1, but sufficient field re-checks and laboratory studies have not yet been made to determine its distribution. The uncertainty results from the similarity of this unit and the Top Black shale, two units which are commonly differentiated in the field only by the presence of the intervening Upper siltstone. Where that intervening unit is absent, the two upper shale units can be differentiated only with difficulty, if at all. The distribution of the Middle Black shale is believed to be somewhat more widespread than the Middle Gray or Lower Black units.

Upper siltstone.--Though consisting largely of beds of black shale similar to those in the black shale units, the Upper siltstone is distinguished from them by a series of thin beds of gray siltstone or claystone which give it a distinctly layered appearance.

The Upper siltstone unit is about 2 or 3 feet thick throughout most of Blocks 1 and 4, is thinner in Block 5, and is absent in the southern part of Block 6 (pl. 7). To the north, it is about 4 feet thick in the southern part of Block 7, but a few miles farther north, in the vicinity of Gainesboro (pl. 6), the unit cannot be identified with certainty, either because it is absent or, more likely, because the distinctive siltstone and claystone beds are missing. The thicknesses of the unit in the northern part of Block 7 that are given in table 1 are taken from field notes at the time of sampling, but it now seems likely that many of them are incorrect owing to misidentification of the beds at a time when field work consisted chiefly of collecting samples for uranium assays, and little time was available for stratigraphic studies.

The base of the Upper siltstone at most outcrops is a distinctive varved bed averaging about 0.2 foot thick. Where unweathered, the bed consists of alternating paper-thin layers of pyritic light-gray silty material and of black shale; where weathered, it has a rusty brown color. The silt layers are thicker and coarser at the base and become finer and thinner upward until the varved bed merges imperceptibly into the black shale. The areal distribution of the varved bed, which is a serviceable key for stratigraphic work, is essentially the same as that of the bentonite bed in the middle gray siltstone. In general it is better developed in more western outcrops, and is poorly developed or absent in the eastermost outcrops of the Highland Rim area, suggesting a western source.

Top Black shale.--Like the other black shale units, the Top Black is essentially free of gray claystone beds, has a few partings of very fine siltstone, and can be recognized from the others in the field only by the presence of the intervening siltstone or claystone units. It is probably the toughest and most massive of the black shale units, is commonly 4 to 8 feet thick, and is the most widespread of any of the units. Because of its toughness it tends to project slightly and overhang the other units in many outcrops (fig. 1B). The uranium content of this unit is consistently the highest of any part of the formation. To distinguish this part of the formation from the next higher unit, it is here referred to as the non-phosphatic part of the Top Black shale.

Overlying the massive non-phosphatic part of the Top Black shale is a similar black shale which contains scattered nodules of phosphate and marcasite, and which is referred to here as the phosphatic shale of the Top Black shale. It is present only in the two northern Blocks, 4 and 7, and is thickest in the more northern block. The nodules are roughly spherical and are commonly about 0.1 foot in diameter, but some are as large as about 0.4 foot. The nodules compose only a small part of the total mass of the shale, which is otherwise similar to the non-phosphatic part of the Top Black shale. No sharp break between the phosphatic and non-phosphatic beds of the Top Black shale was found, division in the field being made arbitrarily at the lowest horizon where nodules were found. The Maury shale and a phosphate layer of the Maury rest directly on the phosphatic shale where that is present, elsewhere on the non-phosphatic Top Black shale. At most places the contact is sharp, though locally the phosphatic Top Black shale seems to grade into the Maury shale. As the Maury rests on both the phosphatic and non-phosphatic parts of the Top Black shale, its base seems to be an unconformity. Isopach maps showing the thicknesses of the entire Chattanooga formation and of the three upper units are presented in plates 8 and 9 (in both maps the phosphatic nodule layer at the base of the Maury is included in the Chattanooga). Some of the thicknesses of the phosphatic unit shown in table 1 are probably too great, as later field work indicates that early field identifications were probably wrong. Adequate field checks have not yet been made, but some of the probable errors were compensated for in plate 9.

## Rocks overlying the Chattanooga shale

Maury shale.--The Maury (locally pronounced Murray) has long been considered by many to be the uppermost member of the Chattanooga shale, probably because there is less contrast between those two materials than between the Maury and overlying Fort Payne chert. The present investigations show that it contains a completely different assemblage of fossils (conodonts) which, together with evidence of an unconformity at its base and its different lithology, is a strong argument for considering it a separate formation.

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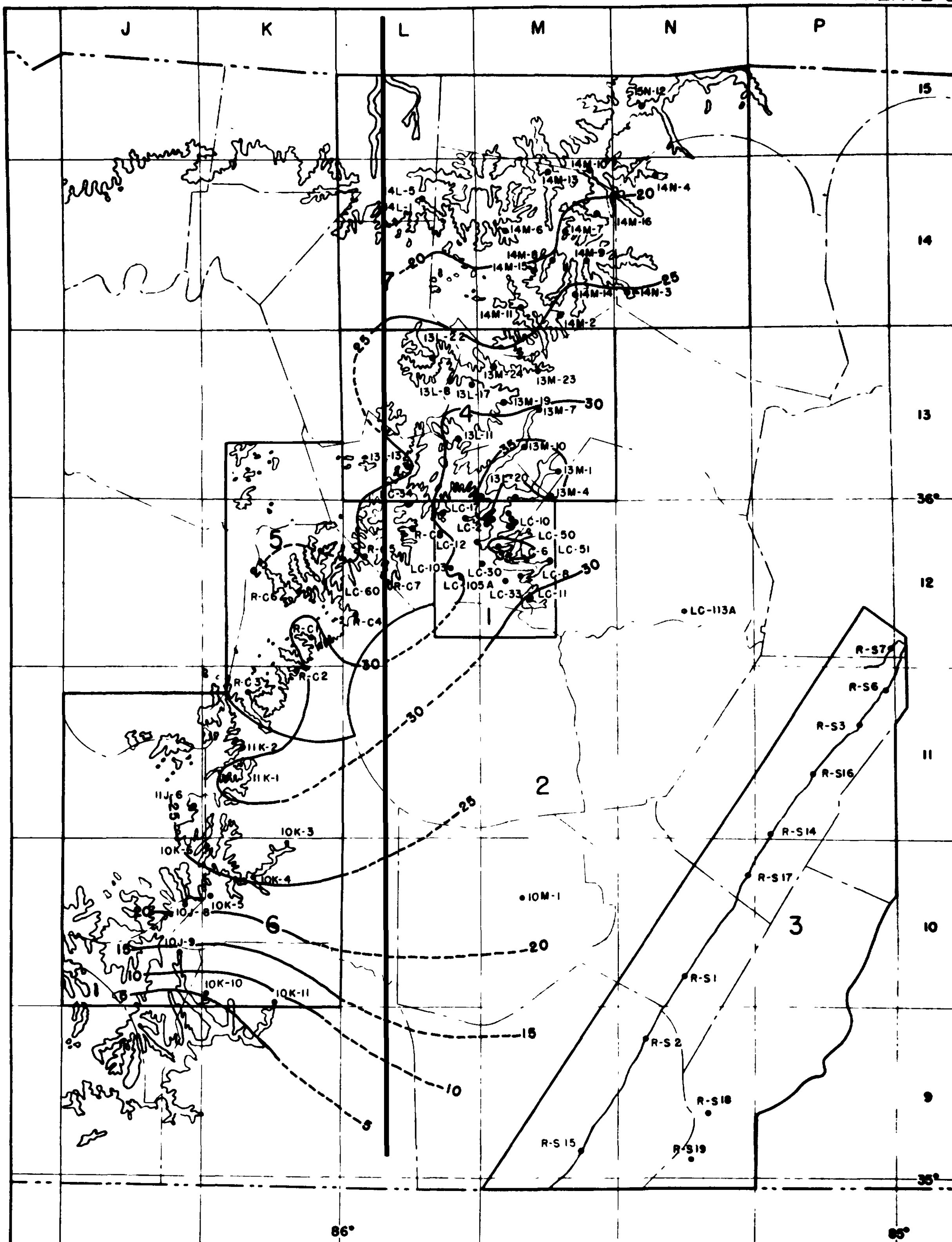
PLATE 8




ISOPACH MAP SHOWING THICKNESS OF CHATTANOOGA SHALE, EASTERN HIGHLAND RIM, TENNESSEE

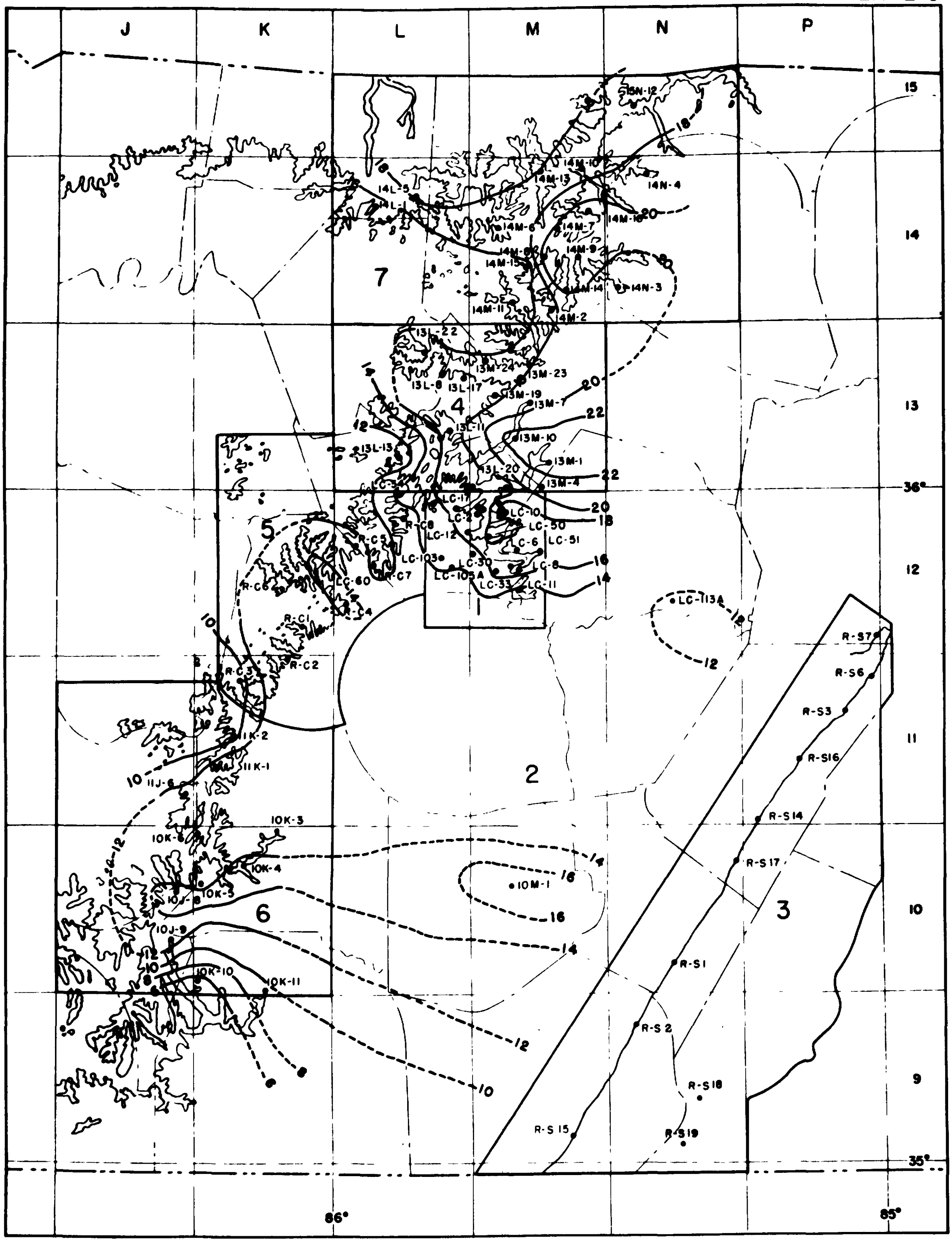
Contour interval 5 feet

10 0 10 20 30 40 Miles

1950

Confidential

PLATE 9



ISOPACH MAP SHOWING THICKNESS OF THREE UPPER UNITS OF CHATTANOOGA SHALE, EASTERN HIGHLAND RIM, TENNESSEE

Contour interval 2 feet

10 0 10 20 30 40 Miles

1950

The Maury has characteristically been considered to be an interval of about 1 to 3 feet of blue-green shale or claystone which weathers readily to a semi-plastic clay. It now appears, however, that a layer of large crowded phosphate nodules in a black shale matrix, where present, should be considered part of the Maury instead of the Chattanooga. Accordingly, two units of the Maury are here recognized--the phosphate nodule layer and the overlying blue-green shale. The phosphate nodule layer commonly contains only enough black shale to bind the nodules together. The nodules are normally flattened and kidney-shaped, and about half a foot in length (fig. 3B), though locally they are as much as 1.8 feet in length. This bed extends a few miles farther south than the phosphatic part of the Top Black shale, and is present in most outcrops along the north and northwestern sides of the Nashville Basin. At a few localities a thin bed of Maury-type greenish shale underlies the nodule layer; at a few other localities only the nodule layer is present between the Chattanooga black shale and the still higher Fort Payne chert. The nodule layer is irregular in thickness, a few outcrops showing it to range from about half a foot to 2 feet in thickness within a distance of 100 feet. For some reason not yet understood, this highly phosphatic bed of black shale is lower in uranium content than are the non-phosphatic black shale units of the Chattanooga. During the field work this layer was considered part of the Chattanooga shale, and was commonly sampled with the underlying phosphatic part of the Top Black shale.

Figure 3

A. Fort Payne chert showing bedding and massive chert. At locality LC-10 in cut for old Highway 26, near Sligo, Block 1. 1948.

B. Phosphate nodule layer about 1 foot thick showing irregular contacts with overlying Maury shale and underlying Top Black shale of the Chattanooga. In cut for new Highway 56, about 2 miles north of Hurricane Creek bridge over Center Hill Reservoir, Block 4. 1949.

In order to keep the various tables and maps of this report consistent, the phosphate nodule layer is shown in table 1 as part of the Top Black shale, as it is impossible to separate it from the other phosphatic unit with which it was included in many of the samples.

The blue-green shale is commonly about 1 to 3 feet thick. It has been described as being glauconitic, but no glauconite has been found in it in the area of these investigations. The contact with the overlying Fort Payne chert is commonly knife sharp, but in a very few places appears to be gradational in an interval 2 or 3 inches thick.

Fort Payne chert.--The Fort Payne is a siliceous limestone containing, particularly in the basal 60 feet, many bands of chert (fig. 3A). At some localities in the southern part of the area the basal unit consists of as much as 50 feet of greenish crinoidal limestone and greenish silty shale. The Fort Payne is about 200 feet thick, and is so difficult to drill that it is a formidable obstacle to stripping operations, but it makes a fairly good roof for underground mining.

In Block 7, the northern part of the area, the Fort Payne becomes less cherty and more shaly, grading northward into the New Providence shale.

Overlying the Fort Payne are limestones of Warsaw and St. Louis age. As these rocks are of no interest to the present work, only their presence is noted.

## STRUCTURE

The Chattanooga of the Eastern Highland Rim has a regional dip to the east and southeast of about 30 feet to the mile. [19] Many undulations, however, are present, so that dips of as much as 5° in various directions are seen locally (fig. 4). The structural conditions are shown on the block maps (pls. 2 to 6) by structure contours drawn on the top of the Chattanooga. The greater structural irregularity shown on the Block 7 map is due partly, but probably not entirely, to the fact that much more subsurface information is available for part of that area. [7]

One thrust fault has been noted in Block 1 about 2 miles upstream from LC-11 where all but 2 or 3 feet of Chattanooga has been cut out between the underlying and overlying limestones.

Figure 4

View looking downstream (north) from near Sligo bridge, showing local dips in rocks underlying the Chattanooga shale. Fort Payne chert caps the small knob at left center; Chattanooga shale crops out in the saddles on either side of the knob, and is marked by ink line on the photograph. Flood plain has since been inundated by Center Hill Reservoir. January 1948.

## COMPOSITION OF THE SHALE

The black shales, as distinguished from the siltstones, are extremely fine grained and, as their color suggests, contain much organic matter. Silt and finely divided mica are present, especially along the bedding planes. Pyrite and marcasite are abundant as grains, nodules, thin layers, and lenses. Asphaltic pyrobitumen, similar to albertite or impsonite (identified by F. J. Flanagan, Report F 44, 1947) is present as disseminated grains and as seams ranging from microscopic films up to lenses several hundredths of a foot in thickness. At two localities a little disseminated galena was found in the Top Black shale.

When freshly broken the black shales give off a strong petroliferous odor. The oil yield and uranium content of the rock are discussed in later sections.

Beds of fine-grained gray material interbedded with the black shale have commonly been referred to during the field work as gray siltstone. In reality the beds are probably better described as gray claystone, but as they have been repeatedly referred to in earlier reports on this project as gray siltstone, it seems best to retain that terminology in this report. No petrographic or chemical analyses have been reported on these beds. They contain much less uranium than do the black shales.

Thin sections of three core samples from LC-103 were studied by the branch of Geochemistry and Petrology of the Geological Survey, and the results are given below.

Roughly estimated volumetric mineral composition
of black shale, in percent

| | LC-103-13 (Top Black) | LC-103-31 (Middle Black) | LC-103-52 (Lower Black) |
|---|---|---|---|
| Quartz | 20-30 | 20-30 | 20-30 |
| Pyrite | 5-10 | 10-15 | 5-10 |
| Calcite | 2- 5 | 10 | 2- 5 |
| Muscovite and sericite | 2 | 2 | 2 |
| Clay minerals | 5-10 | 5-10 | 5-10 |
| Kerogenous material | 40-50 | 35-45 | 40-50 |

Several chemical analyses of the black shale have been made by Battelle Memorial Institute, [3, 5, 6] and four of them are quoted below. Of the samples, LC-15-C and LC-201-113 are from Block 1, 13L-22 is from Block 4, and 14M-2 is from Block 7.

Chemical analyses of Top Black shale

| Locality no.<br>B. M. I. no. | 13L-22<br>(BR-154-46)<br>1090-1 | 14M-2<br>(S100-46)<br>1090-4 | LC-15-C<br><br>1207-100 | LC-201-113<br><br>1207-117 |
|---|---|---|---|---|
| Ign. loss | 23.4 | 24.9 | 23.0 | 23.0 |
| $SiO_2$ | 46.00 | 48.60 | 49.30 | 47.90 |
| $TiO_2$ | - | - | (0.69) a | 0.62 |
| $Al_2O_3$ | 11.60 b | 10.40 b | 11.40 b | 10.00 |
| $Fe_2O_3$ | 10.70 | 9.90 | 9.60 | 9.82 |
| MgO | 0.95 | 0.78 | 1.22 | 1.52 |
| CaO | 1.46 | 0.21 | 0.36 | 1.59 |
| $Na_2O$ | - c | - c | 0.33 | 0.40 |
| $K_2O$ | 3.79 | 3.40 | 4.03 | 3.33 |
| $P_2O_5$ | 0.96 | 0.27 | 0.12 | 0.65 |
| $CO_2$ | 0.20 | 0.10 | 0.31 | 0.48 |
| S | 6.80 | 5.90 | 6.90 d | 7.70 e |
| C | 14.50 | 14.60 | 14.30 | 13.40 |
| H | 1.60 | 1.00 | 1.55 | - |

a Included with $Al_2O_3$.
b Includes $TiO_2$, $ZrO_2$, $V_2O_5$.
c Included with $K_2O$.
d Separate analyses give: 0.8% organic sulphur; 0.3% sulphate; 5.7% pyrite (= 10.7% $FeS_2$).
e Separate analyses give: 0.94% organic sulphur; 0.16% sulphate; 6.6% sulphide [= 12.3% $FeS_2$].

At Battelle Memorial Institute [5] a study of the mineral composition of the shale from LC-201-113 (the adit) by use of the microscope and by other means indicated that the shale contains the clay mineral illite [hydro-mica]. Recalculation of the chemical analysis gave those workers the following indicated mineral composition, in percent:

| | | | |
|---|---|---|---|
| quartz | 25 | feldspar | 10 |
| illite | 23 | chlorite | 7 |
| organic matter | 20 | calcite and dolomite | 1 |
| pyrite and marcasite | 12 | other | 2* |

* clay, iron oxide, tourmaline, zircon, and others.

## DEPOSITION OF THE SHALE

No attempt is made in this report to discuss the deposition of the Chattanooga shale as a whole; only that part of the widespread outcrop area between the Central Basin and the folded Appalachians and south of the Kentucky-Tennessee State line is considered. The area is about 120 miles long northeast and southwest, about 70 miles wide, and lies between the site of the old continent of Appalachia and the Cincinnati arch.

At the time deposition of the Chattanooga began, Appalachia was a low land mass situated somewhere east of the present folded Appalachians. [14] Much of the Cincinnati arch area was probably above water during much of the Silurian and Devonian periods [18], and the region was reduced to the almost level limestone surface on which the shale lies. [18] A subsidence in Upper Devonian time produced an inland sea or embayment having undetermined connections with the open ocean. In this sea the Chattanooga shale was deposited.

Plate 7, which is based largely on the data in table 1, shows that the oldest part of the Chattanooga - the Lower Black shale - was deposited in a belt about 75 miles wide from north to south, extending eastward toward the Sequatchie Valley, where it is also present. [13] Because of widespread erosion in the Central Basin, the original extent of the Lower Black shale to the west is not known. The next higher unit in the Chattanooga, the Middle Gray siltstone, covers only a slightly wider area; and, as the thicknesses of the units are roughly comparable over the entire region of this report, it appears that during Middle Gray time the sea transgressed only slightly farther to the north and south.

The distribution of the higher units is not yet certain, as the Top Black and Middle Black shales can only be separated with certainty by paleontologic evidence or by the presence of the intervening Upper siltstone. Paleontologic studies are insufficiently advanced at this writing to indicate the distribution of those beds. The Upper siltstone is not recognized south of the position shown on plate 7, nor has it been definitely recognized north of the approximate limit of the Middle Gray siltstone. It may well be that black shale equivalents of the Upper siltstone are present outside those boundaries, but that has not been demonstrated. It seems likely that the Middle Black shale extends only some 10 or 20 miles farther south than the Middle Gray, but northward it may extend much or all of the way to the Tennessee-Kentucky line. The Top Black shale is believed to be the thin shale, some 5 to 8 feet thick, which extends south to the Tennessee-Alabama line; it is also believed to extend northward into Kentucky. This greater extent of the Top Black is especially interesting as that unit has the consistently highest uranium content. The phosphatic zone of the Top Black shale extends from the southern part of Block 4 into Kentucky.

Black shales can accumulate in either deep or shallow water and are being formed today in both environments. [12] The chief requirements for their formation and preservation seem to be (1) poor bottom circulation in the water, which condition normally requires a more or less landlocked sea, and (2) an abundance of organic matter, usually plants, which are preserved because the bottom conditions are such that normal animal life, with its attendant scavenger action, cannot exist. It is probable that these conditions prevailed while the Chattanooga shale was being deposited.

## METHOD OF STUDY

### Previous investigations

Between 1944 and 1946 Slaughter [16] and Brill [11] did reconnaissance work on the Chattanooga shale and visited and sampled a number of localities in the area covered by this report. Most of their assays were radiometric (Geiger counter readings in either the field or the laboratory), though a few chemical assays were made. This earlier work was of much assistance to the later investigations.

Most of the Slaughter and Brill localities within the area of the present investigation were re-sampled and are shown on the block maps (pls. 2 to 6) by this project's numbers. Other localities that were not sampled during the present project are shown by their original numbers. The Slaughter and Brill localities are listed below:

Slaughter and Brill localities in Eastern Highland Rim area

| Block | Original number | Present project number |
|---|---|---|
| 1 | S-101 | LC-11 |
| 1 | BR-114 | LC-15 |
| 1 | BR-153 | LC-10 |
| 4 | BR-154 | 13L-22 |
| 4 | BR-155 | 13M-19 |
| 4 | BR-156 | 13L-20 |
| 4 | BR-156A | - |
| 5 | BR-150 | R-C6 |
| 5 | BR-115 | R-C1 |
| 5 | BR-120 | R-C3 |
| 6 | BR-146 | - |
| 6 | BR-116 | 11K-1 |
| 6 | BR-144 | - |
| 6 | BR-145 | - |
| 6 | BR-140 | - |
| 6 | BR-143 | 10K-11 |
| 6 | BR-143A | - |
| 7 | BR-110 | - |
| 7 | BR-111 | - |
| 7 | BR-112 | - |
| 7 | BR-176 | - |
| 7 | BR-113 | - |
| 7 | S-100 | 14M-2 |
| 7 | S-102 | 14M-15 |

Stratigraphic investigations

Mapping.--Geologic maps showing the line of outcrop of the Chattanooga shale were made on the best base maps available. No attempt was made to identify the overlying and underlying formations. In Blocks 1 and 4 a considerable part of the area was mapped on the Corps of Engineers' excellent topographic maps of the Center Hill Reservoir. Published U. S. Geological Survey topographic maps were used as bases for parts of Blocks 5, 6, and 7. Aerial photographs were used in Blocks 1, 4, and 5, for locating exposures and mapping the contacts.

The Block 1 map (pl. 2) was compiled on a scale of 1:20,000 (1 inch = 1,667 feet). The other maps (pls. 3-6) were compiled on a scale of 1:63,360 (1 inch = 1 mile), county road maps being used as bases except in a few places where standard topographic maps are available. In Blocks 5, 6, 7, the geology is taken in part from published maps and reports. [2]

Contours on the top of the Chattanooga shale are shown on all the block maps; these are based on outcrop elevations and on elevations of stratigraphic horizons determined from drill-hole logs. Because of the numerous irregularities in the surface of the shale, the contours are general only, except for part of Block 7.

Isopach lines showing the thickness of the entire Chattanooga formation and of the three upper units are shown on plates 8 and 9.

Study of individual exposures.--In all, 67 sections along the Highland Rim escarpment and the Caney Fork and Cumberland River valleys were sampled and measured. Locations of those outcrops are shown on the detailed block maps (pls. 2-6), most of them are shown on the regional map (pl. 1), and they are described in the register of localities appended to this report.

Most of the sampled and measured outcrops in Block 1 are 2 to 3 miles apart. In the other blocks, the spacing is 4 to 6 miles. In the vicinity of Sligo in Block 1, a number of outcrops (LC-1, LC-10, LC-55, LC-56, LC-2, and LC-102) within about a mile of each other were investigated to study short-range differences in the shale. At LC-1 three separate sets of samples were taken at horizontal intervals of about 100 feet for similar comparisons.

All sample localities in Block 1, and two in each of Blocks 4, 5, 6, and 7, were measured in detail. At those places most beds more than one-hundredth of a foot thick were numbered consecutively and their distinctive features noted, measurements being in tenths and hundredths of a foot. As the Chattanooga shale is almost invariably some shade of gray, each bed was compared with the Munsell series of graduated hues ranging from 1 (black) to 9 (white). Fissility was estimated and expressed on a scale ranging from 1 (extremely poor fissility) to 5 (well-developed fissility), but as this feature is dependent largely on weathering it probably has little significance. Other sampled outcrops were measured in less detail and marked off for sampling, care being taken to obtain accurate over-all measurements for each of the main units.

## Drilling

Several drill holes were put down in Blocks 1 and 2 (pls. 1 and 2) in order to study the shale at depth, where it had not been subjected to weathering. Nominal 2-inch or, later, 3-inch cores were taken (fig. 5), and these were studied in much the same manner as the surface outcrops, then were divided into sample units. All drill holes carry the prefix LC- and are numbered from 100 up. Data on the drilling are given below.

Data on drill holes in the Chattanooga shale

| Hole no. | Rock bitted (feet) | 2-inch cores | | 3-inch cores | | Core recovery (percent) | Total depth |
|---|---|---|---|---|---|---|---|
| | | Cored (feet) | Recov. (feet) | Cored (feet) | Recov. (feet) | | |
| LC-100 | 75.0 | | | | | | 75.0 a |
| LC-101 | 124.5 | 7.5 | 5.5 | | | 73.3 | 132.0 |
| LC-102 | 140.8 | 32.8 | 30.7 | | | 93.6 | 173.6 |
| LC-103 | 139.4 | 30.6 | 28.1 | | | 91.8 | 170.0 |
| LC-104 | 53.9 | 35.6 | 20.5 | | | 57.6 | 89.5 |
| LC-105 | 136.0 | | | | | | 136.0 a |
| LC-105A | 136.6 | | | 30.7 | 30.7 | 100.0 | 167.3 |
| LC-108 | 21.5 | | | 8.9 | 8.1 | 91.0 | 30.4 |
| LC-108A | 25.5 | | | 8.8 | 7.8 | 88.6 | 34.3 |
| LC-108AA | 30.5 | | | 8.3 | 7.8 | 94.0 | 38.8 |
| LC-108B | 23.0 | 15.5 | 3.7 | | | 23.9 | 38.5 |
| LC-113 | 25.0 | | | | | | 25.0 a |
| LC-113A | 359.7 | | | 25.3 | 24.8 | 98.0 | 385.0 |
| Totals | 1297.9 | 122.0 | 88.5 | 82.0 | 79.2 | 82.2 | 1495.4 |

a Hole lost by contractor.

Figure 5

A. Drill at LC-108. April 1948.

B. Three-inch core from LC-105A. June 1948.

## Geiger-counter investigations

All sampled outcrops in Blocks 1, 4, and 5 were scanned with a Geiger-Mueller tube and cyclotron register. No work of this type was done in Blocks 6 and 7.

Field counter readings were normally made at 1-foot intervals, occasionally at 0.5 foot. The readings obtained, although not considered to be quantitatively accurate, gave indications of relative uranium content and were of much assistance in choosing localities for special samples, especially before many chemical assays were available.

## Sampling

Routine samples.—Sample intervals were laid out within each unit of the Chattanooga shale, most of the intervals being not more than 2.0 feet thick or less than 0.5 foot except where the entire unit is thinner. Efforts were made to break the samples at conspicuous bedding planes if possible, but this could not always be done, and many of the intervals were picked arbitrarily.

To facilitate comparisons of assays from different exposures, a series of numbers was allotted to each lithologic unit, making it possible to tell from the sample number what part of the formation it represents. The system used is given below.

Numbering of samples of Chattanooga shale

| Stratigraphic unit | Allotted numbers | Remarks |
|---|---|---|
| Maury shale | 1-10 | Usually only one sample. |
| Phosphatic beds | 11 | Not used where phosphate nodule beds are missing. Where such beds are thick, letters (A, B, etc.) are added. |
| Top Black shale (non-phosphatic) | 12-20 | |
| Upper siltstone | 21-30 | |
| Middle Black shale | 31-40 | |
| Middle Gray siltstone | 41-50 | Base of sample 41 usually base of bentonite. |
| Lower Black shale | 51-60 | Lowest sample includes basal sandstone. |

The total number of routine samples taken from outcrops and drill holes in Blocks 1, 2, 4, 5, 6, and 7 was exactly 1,000. Distribution of the samples by blocks and by stratigraphic units is given in table 5 in the appendix. All the routine samples are listed by blocks in tables 7 to 11 in the appendix, together with information on their uranium content, where available.

The small number of samples taken of the Maury and Middle Gray in most of the blocks reflects information gained during early stages of the investigation, when it was learned that those two units are of little or no economic interest. They were, therefore, sampled at only a few localities outside of Block 1.

All field sampling was done by hand. A pneumatic jackhammer was used for some of the work (fig. 2A), but was too light to be effective under the conditions encountered.

Special samples.--As assays of routine samples became available, the laboratories working on the shale occasionally requested special samples. Most such samples were taken in sets of three, 200 pounds being sent to Battelle Memorial Institute, 200 pounds to Y-12 at Oak Ridge, and 40 pounds to the Geological Survey laboratory in Washington. Several larger samples of 1 to 15 tons were also collected. In all, 40 such samples were taken, and are listed in table 6 in the appendix together with 10 smaller samples taken at one locality for preliminary assays on larger samples.

## Adit

In order to obtain large samples of fresh shale for laboratory tests, both stripping operations and underground mining were considered. The overburden of Fort Payne chert in the Eastern Highland Rim area is so thick and tough that large scale stripping of the shale is impracticable, so an adit was driven into the Top Black unit of the shale to obtain both fresh samples and information on the mining qualities of the rock.

The adit-driving operation has been described in the report "Experimental adit in the Chattanooga shale", [8] so only a brief summary will be given here. The adit was driven from a small ravine about 140 feet north of LC-10, near Sligo in Block 1, DeKalb County, Tennessee (pl. 2). Its direction is N. 52° E., its length is 100.2 feet, its height 8.5 feet, and its minimum width 5 feet (fig. 6). Rocks removed were the Top Black shale of the Chattanooga and the Maury formation, which here consists of the basal phosphate nodule layer 0.5 foot thick and the overlying Maury blue-green shale which is 1.75 feet thick. The roof is Fort Payne chert, the floor the uppermost gray bed of the Upper siltstone. A comparatively deep facing cut was made, the portal being 27 feet behind the original ground surface at floor level.

The material removed for sampling was the 6.25-foot bed of Top Black shale. After it was found that the phosphate nodule layer of the Maury made a satisfactory temporary roof, that bed and the overlying blue-green shale were left in parts of the adit to test their suitability as a roof (pl. 10).

The adit was advanced in 5- and 6-foot rounds, with a standard "bottom round" drilling pattern. The number of holes per round was 12 to 19, and considerable experimenting was done on the best combination of holes and charges. The most effective charge was 38 sticks of 40 percent gelatin dynamite per round; with this loading about 1.2 tons of rock per pound of explosive were broken out.

The shale is highly abrasive, and only tungsten carbide bits cut it effectively. Actual cutting speed of the bits was about 30 feet per hour; drilling speed, including changes in the rather cumbersome bar-set-up, was 15 to 17 feet per hour. Dust conditions were extremely bad except when water was used in the drilling; because of the high silica content of the rock,

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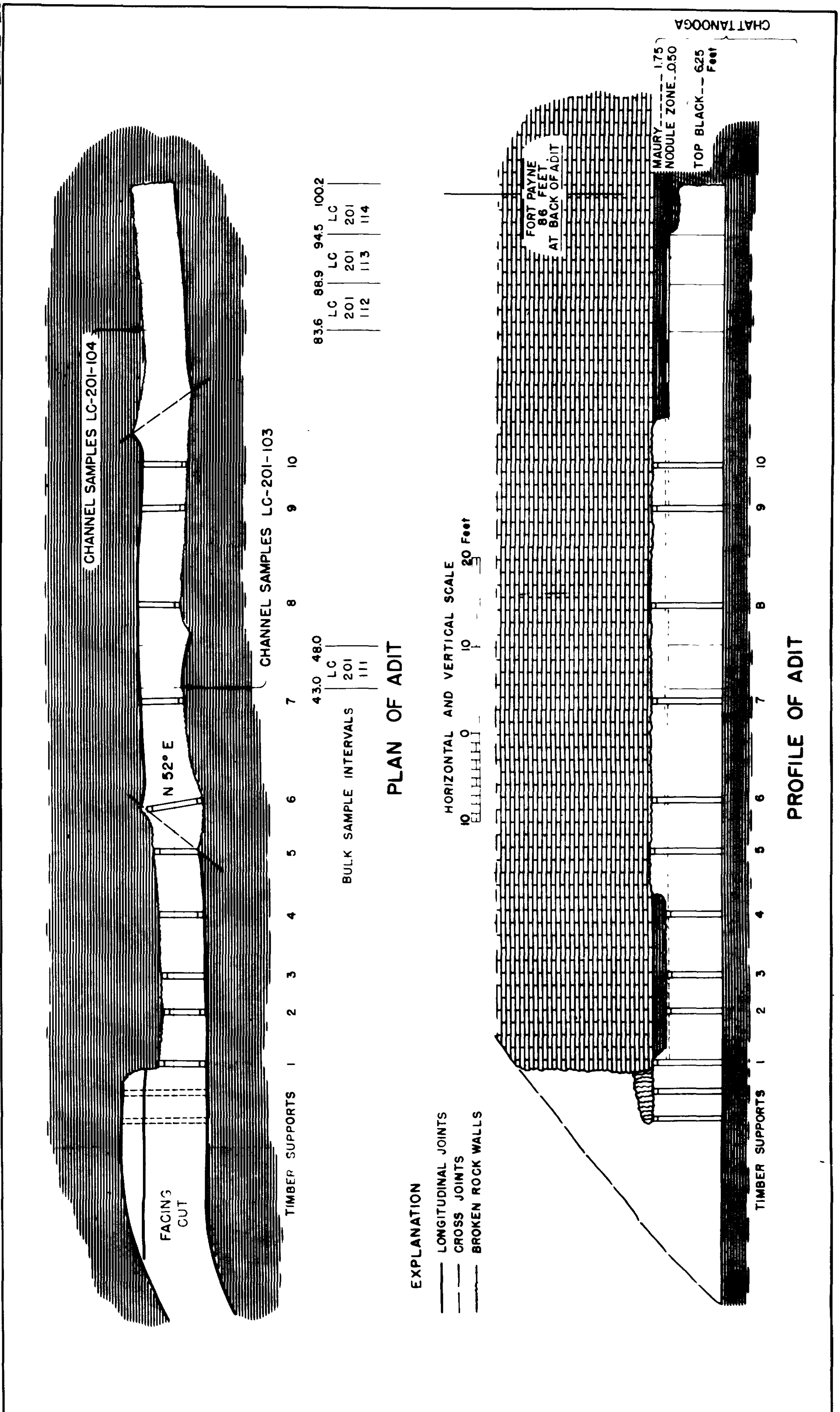
PLATE 10




PLAN AND PROFILE OF SLIGO ADIT, DE KALB COUNTY, TENNESSEE

Figure 6

A. Portal of adit during construction. January 1949.

B. Face of adit. Note joint on right side. Visible roof is phosphatic layer. January 1949.

respirators were used at all times as a precaution against silicosis.

Roof support problems were not serious. The 10 sets of supports used in the adit, made of heavy white oak timbers, were probably more than were actually necessary. As the floor of the adit is essentially level, drainage problems were negligible.

The locality number of the adit is LC-201. Four large (10- to 20-ton) samples were taken. With one exception, the samples were shot from under the phosphate nodule layer and represent the 6.25-foot interval of Top Black shale. The exact positions from which the samples were taken are shown on plate 10 and in table 6 in the appendix.

## URANIUM IN THE CHATTANOOGA SHALE

### Origin of the uranium

As uranium is present in sea water, it is probable that the immediate source of the radioactive material in the black shales was the water itself, and the initial source was the surrounding lands from which streams drained into the sea. Much of the clastic material deposited in the Eastern Highland Rim area probably came from Appalachia. Some of this material was undoubtedly derived from granitic rocks which are normally comparatively rich in disseminated uranium. [10]

The form and association of the uranium in the black shale are still unknown, but fragmentary evidence suggests that it might be associated with (1) carnotite, (2) sulphides, which are abundant in the shale, or (3) organic ingredients of the shale. These and other possible associations of the uranium are discussed further in the following pages.

### Association with other constituents and characteristics of the shale

The manner of precipitation of the uranium after it reached the sea is not known. No uraniferous mineral has been found in the shale, and the form of the metal is unknown. The most likely possibilities are that it is present (a) in a definite mineral form; (b) in an organic compound; or (c) in disseminated form in organic or clay minerals, to which it became attached by some kind of adsorption or base-exchange process. It may also be present in more than one form.

Some apparent relationships have been noted in the field and laboratory between the uranium content and some other physical and chemical characteristics of the shale. As these may lead some day to more definite conclusions, they are summarized below.

Thickness of the deposits.--It has been stated [10] that in nearly all uranium-bearing black shales, the highest grades are in areas where a thin formation represents much geologic time.

It is known, for example, that the formation in Tennessee, where it is relatively thin, is higher grade than in Kentucky, where it is thicker. This general relationship between thickness and grade applies only to places where comparable beds are present, and is not applicable to areas, such as the southern edge of Tennessee, where a thin section is present because the area was submerged for only a part of Chattanooga time. Where sedimentary accumulation is extremely slow, an appreciable concentration of uranium apparently can develop. Conversely, more rapid sedimentation probably causes dilution of the uranium precipitates. In this connection, it is perhaps significant that assays of samples taken during the present project from Blocks 1 and 3 suggest that the Block 3 (Walden Ridge) exposures, which seem to represent the same stratigraphic intervals but are somewhat thinner than those in Block 1, are of a little higher grade. Geological conditions in the two areas are so different, however, that direct comparison is not warranted.

Toughness and blackness of the rock.--These two characteristics of the black shale usually go together and are so treated. Before assays were available, field workers noted that the Top Black unit of the shale, which is thick-bedded and black, was more difficult to sample than the other units. Later, when special samples were called for, it was noticed that the units selected were likely to be the toughest beds of the exposure; and assays of routine samples showed that the tough Top Black unit was almost invariably the highest in uranium. The blackness is largely an index to the organic content, and the toughness is in large measure governed by the abundance of thin silt layers. It appears, therefore, that those beds which are composed almost entirely of black shale, having fewer or thinner silt partings, are the richest in uranium.

Degree of weathering.--Although most samples were taken from apparently unweathered exposures, the wide variations in uranium assays from comparable beds at different localities suggest that some or all of the outcrops have been subjected to leaching or enrichment. Though such alterations probably do not extend far underground and hence would have little effect on the grade of ore in the area as a whole, they are of significance in interpreting the assays of outcrop and drill-hole samples. The subject is discussed further in the section on "Areal distribution of the shale".

Bitumen.--In the alum shales of Sweden the highest uranium contents are reported [10] to be in beds of practically pure bitumen. That the same may be true in the Chattanooga shale is suggested by assays of two small samples of bitumen, in which the uranium content was found to be somewhat higher than in the enclosing shale. These assays are shown below.

Uranium content of bitumen and associated shale

| Sample number | Uranium in bitumen (percent) | Uranium in shale (percent) |
|---|---|---|
| LC-51-WM1 | 0.008 | 0.005 |
| LC-201-71 a | 0.011 | |
| LC-201 b | | 0.008 |

a Sample of bitumen collected from adit dump; exact horizontal and vertical position unknown, but undoubtedly from Top Black shale.

b Average of 8 assays of the 6.25 feet of Top Black shale in the adit.

Recent studies at Battelle Memorial Institute [5] on the composition of the shale do not entirely bear out the above indications that the uranium content may be greater in the bitumen. Those studies indicated that the only constituents of the shale that contain greater than average amount of uranium are pyrite and marcasite. As these conclusions refer to the entire organic content rather than to the bitumen only, they may not negative the indications that the bitumen contains more uranium than do the other constituents.

Conodonts.--The Chattanooga shale contains numerous conodonts, which are fossil remains of structural parts of an unknown marine animal and which have been used to determine the age relationships of the different units of the formation. Conodonts in the shale are composed of the mineral apatite, and collections are being prepared for a uranium assay. It seems unlikely, however, that they contain any appreciable concentration of uranium.

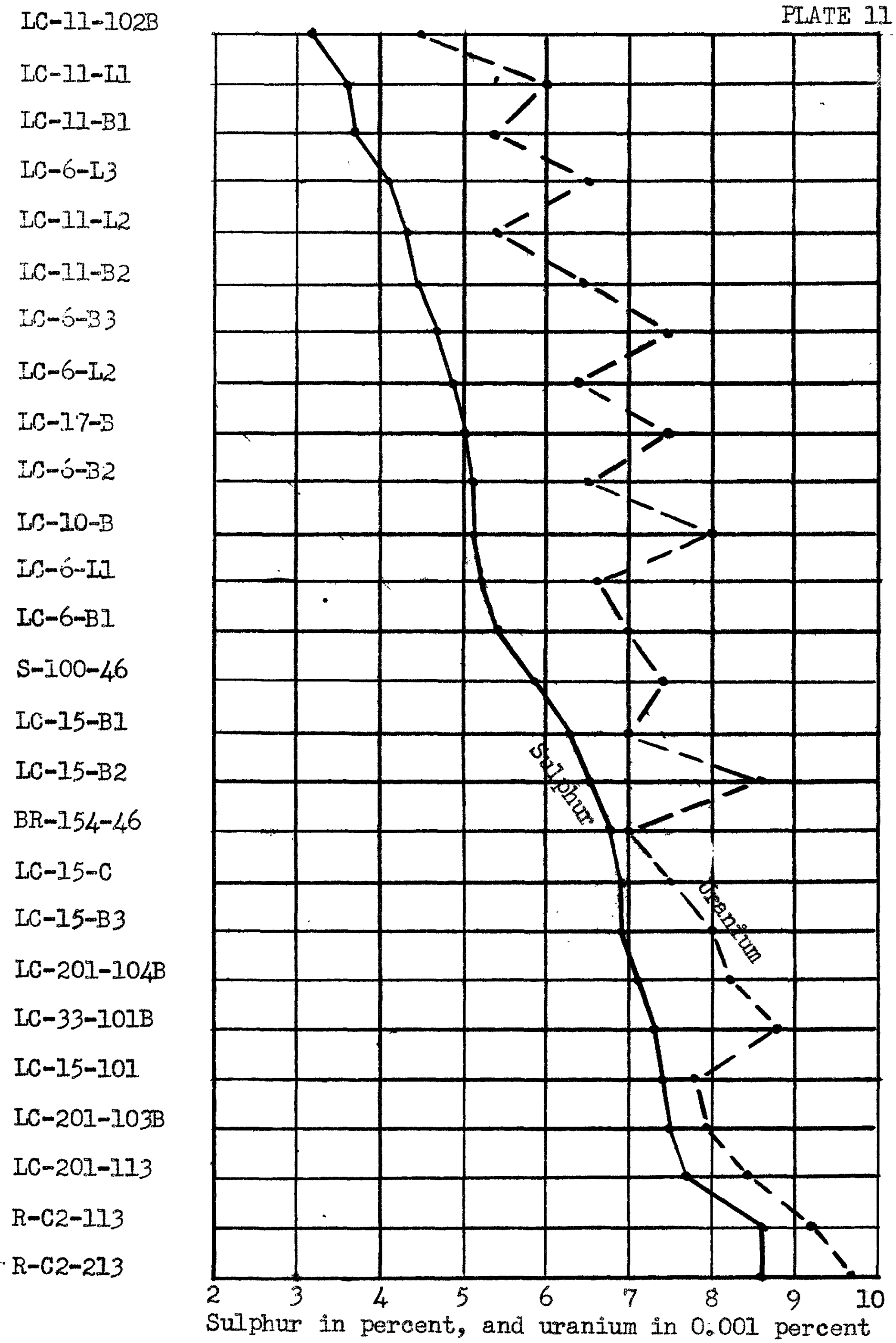
Phosphate.--Although a number of phosphatic formations contain considerable amounts of uranium, [10] the phosphate-bearing black shale beds of the areas here reported appear to contain a smaller percentage of uranium than do the non-phosphatic shales (tables 2, 7, 8, and pl. 12).

Ratio of vanadia and urania.--A few complete chemical analyses show that the ratio of $V_2O_5$ to $U_3O_8$ is approximately the same (about 8:1) in the Chattanooga shale as it is in the carnotite ore from the Colorado Plateau. This suggests the possibility that the uranium-bearing constituent of the Chattanooga may be a disseminated form of carnotite, though more determinations of the $V_2O_5$ content of the shale would be needed to verify this theory.

Carbonates.--The general rule that carbonates and uranium do not go together is borne out by study of the Chattanooga. The amount of uranium is appreciably less in the presence of even a small amount of carbonate. [10]

Sulphides.--The Chattanooga black shales are reported by Battelle Memorial Institute [5] to contain about 12 percent sulphides, marcasite appearing to be more abundant than pyrite. A suggestive though somewhat variable relationship between the uranium and sulphur contents has been noted in the available analyses. This is shown on the chart (pl. 11), which includes

PLATE 11




RELATIONSHIP OF SULPHUR AND URANIUM IN THE CHATTANOOGA SHALE,
EASTERN HIGHLAND RIM, TENNESSEE
(Data chiefly from Battelle Memorial Institute and Y-12 reports.)

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samples from widely separated localities. It appears, therefore, that further information on the sulphide content would be desirable in any future study of the uranium association in the shale.

Vertical distribution of uranium in the shale

The distribution of uranium vertically in the Chattanooga has been determined more definitely than any other aspect of its distribution. Average assays of samples from Block 1 (table 7) fall into a definite pattern, which is shown in tabular form in table 2 and graphically in plate 12. Though the sample intervals do not represent exactly the same interval at different localities, they probably correspond closely enough to warrant comparisons.

Study of the data shows that the Maury blue-green shale, the phosphate-nodule layer, and the Middle Gray siltstone are of such low grade that they may be dismissed from consideration. In addition, it is arbitrarily assumed that any rock containing less than 0.005 percent uranium would not be considered worth mining under any circumstances. With this assumption, the Lower Black shale is eliminated, but even if its uranium content were somewhat higher than it is, the difficulties of mining such a thin bed would be serious. The possible economic units are, therefore, the non-phosphatic Top Black shale, the Upper siltstone, and the

Table 2.--Uranium content, by stratigraphic units and sample intervals, Block 1, Tennessee

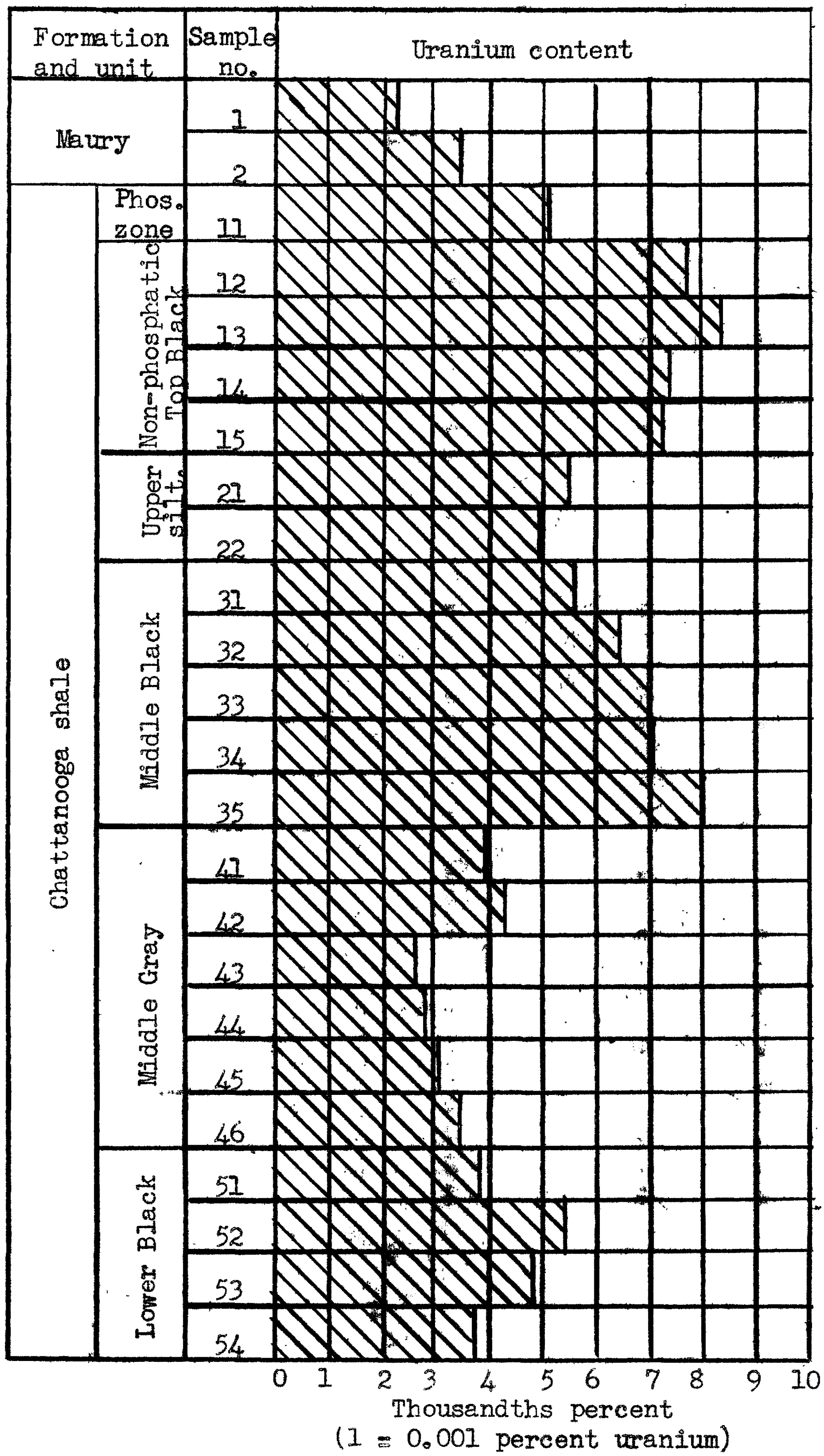
| Unit | Sample no. | No. of samples | Uranium content * | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | High | | Low | | Average percent | Group average (weighted) |
| | | | Loc. | percent | Loc. | percent | | |
| Maury shale | 1 | 15 | (2) | 0.004 | 105A | 0.001 | 0.0023 | 0.0025 |
| | 2 | 4 | 1A | .006 | 2 | .002 | .0035 | |
| Phosphatic layer a | 11 | 7 | 56 | .011 | 102 | .003 | .0051 | 0.0051 |
| Top Black shale | 12 | 19 | (2) | .011 | 1A | .003 | .0076 | 0.0077 |
| | 13 | 19 | 10 | .012 | 17 | .005 | .0083 | |
| | 14 | 19 | (2) | .011 | (4) | .005 | .0074 | |
| | 15 | 9 | 10 | .013 | 105A | .004 | .0072 | |
| | 16 | 1 | 4 | | | | .0070 | |
| Upper siltstone | 21 | 21 | 50 | .009 | 105A | .003 | .0055 | 0.0053 |
| | 22 | 16 | 50 | .007 | 1 | .002 | .0049 | |
| Middle Black shale | 31 | 20 | 50 | .009 | (2) | .003 | .0056 | 0.0066 |
| | 32 | 20 | (2) | .009 | 105A | .004 | .0064 | |
| | 33 | 18 | (2) | .009 | 17 | .005 | .0070 | |
| | 34 | 17 | 50 | .010 | (2) | .004 | .0071 | |
| | 35 | 9 | 50 | .011 | 1A | .002 | .0080 | |
| Middle Gray siltstone | 41 | 18 | 4 | .006 | 10 | .001 | .0029 | 0.0029 |
| | 42 | 18 | 33 | .005 | 105A | .001 | .0033 | |
| | 43 | 18 | 1 | .006 | (2) | .001 | .0026 | |
| | 44 | 18 | 1 | .008 | 105A | .001 | .0028 | |
| | 45 | 16 | (5) | .004 | (2) | .001 | .0031 | |
| | 46 | 8 | 2 | .004 | 50 | .001 | .0024 | |
| | 47 | 2 | 4 | .003 | 6 | .002 | .0024 | |
| Lower Black shale | 51 | 19 | 1 | .006 | 11 | .001 | .0038 | 0.0045 |
| | 52 | 18 | 17 | .008 | (3) | .003 | .0054 | |
| | 53 | 17 | (2) | .008 | 105A | .002 | .0048 | |
| | 54 | 12 | 2 | .005 | (6) | .003 | .0037 | |

* Only chemical assays included.

a The phosphatic layer in Block 1 is the nodule layer presently believed to be basal Maury.

Figures in parentheses in Loc. columns indicate number of localities represented by the assays given.

PLATE 12




URANIUM CONTENT BY SAMPLE INTERVALS, BLOCK 1

Middle Black shale; fortuitously, these are three successive units which could be worked as one. In these three units the grades are highest at the top of the Top Black shale, somewhat lower in the Upper siltstone, and increasingly higher in the Middle Black shale (pl. 12). Tables 1, 3, 7, and 8 show the total thicknesses and the average uranium content of these three units under the caption "Three upper units." Exclusion of the fractional foot of the phosphate-nodule layer would alter the totals and averages only slightly.

The lower grade of the Upper siltstone (pl. 12) may be attributed to the presence of thin silt beds in that unit. The higher grades toward the top of the Top Black and toward the bottom of the Middle Black seem noteworthy but are not readily explainable; they may be related in some way to the presence of unconformities below the Middle Black and above the non-phosphatic Top Black shale in Block 1. In the Lower Black shale the highest grades are in the middle of the unit.

Nearly complete assays of the samples from Block 4 (table 8) show the same relative uranium content of the different units, but the reported grades are distinctly lower. These assays are discussed at the end of the next section.

Areal distribution of uranium in the shale

The areal, or horizontal, differences of uranium content of the black shale are by no means as clear as are the vertical differences which have just been discussed. Discrepancies in the assays, even minor ones, may indicate apparent but such misleading differences in grade from place to place that it seems necessary to consider such discrepancies.

Two kinds of uranium assays - physical and chemical - have been made of the shale samples during the present project. The physical assays are based on Geiger-counter readings made in the field or laboratory and reflect the total radioactivity of the shale rather than its true uranium content. Most of the assays made by Slaughter [16] and Brill [11] are of this type. Chemical assays were made by fluorimetric, colorimetric, or other methods, and are usually, though not always, lower than the physical assays. The grades used in compiling this report are based on chemical assays wherever those are available, and unless stated otherwise (tables 6 to 11 in the appendix).

High and low assays of various sample intervals differ so greatly (e. g., 0.003 to 0.013 for interval 13, 0.002 to 0.011 for interval 35, table 2) that possible explanations must be considered. Most of the assays of each outcrop are commonly consistent with each other, but assays from one locality tend to run high, whereas those from nearby localities from rock that appears identical may be low.(Good examples are LC-1 and

LC-56). Such differences may well be due to one or more of the following causes: (1) Effects of weathering on the rock; (2) sampling errors; (3) analytical errors; or (4) true differences in uranium content.

(1) The uranium content of the shale is readily soluble in dilute acids, a fact well established by the workers who have studied possibilities of its extraction. It is quite possible, therefore, that ground water, containing $CO_2$ from the atmosphere and organic acids from the soil, would leach the uranium at one place and cause enrichment at another. A possible example of such enrichment is the area near the adit (LC-201). Samples of the Top Black at LC-10, a 20-year old road outcrop 140 feet from the adit, show a grade of 0.011 percent uranium. The same unit in the adit, about 70 feet back of the original surface, shows 0.0085 percent; and cores from drill hole LC-102, 1,500 feet north of LC-10, show 0.0074 percent uranium. It was noted in driving the adit that the drilling and blasting qualities of the rock changed about 40 feet back of the original outcrop, suggesting that some alteration may extend that far back from the outcrop.

An example of possible leaching is at LC-6, a bluff exposure in which the Top Black contained only 0.0057 percent uranium. At the other extreme, suggesting possible enrichment, is LC-50, which is in the bed of an intermittent stream. Here the entire three upper units assayed 0.010 percent, the Top Black alone, 0.0117 percent. Such erratic assays suggest that the grades at any one outcrop may be influenced by leaching or enrichment, but over the entire area they probably tend to balance each other and give a fair average figure.

(2) Sampling in such rocks as the Chattanooga shale, even when done carefully, introduces certain variables. For example, if the uranium is associated with bitumen films, which are as much as a quarter of an inch thick, a given sample could run high or low depending on whether or not it included a bitumen film at the exact point where the sample was taken. Aside from such possibilities as this, sampling errors were probably not serious, except possibly for the three sets of samples taken from LC-1, which were obtained before uniform methods had been developed.

(3) For such low-grade material as the black shale, analytical errors are likely and even expectable. The laboratories state that assays are to be considered accurate only within 0.001 or 0.002 percent, so it can readily be seen that when this probable error is applied to a sample containing about 0.006 percent uranium it makes a significant difference. The practice adopted during the present project was to ask that the samples be re-run when assays were apparently inconsistent. The higher priority of other work, however, has prevented adequate re-assays.

(4) Evaluation of the true differences in uranium content must await evaluation of the other variables. If the uranium is

found to be definitely associated with other constituents of the shale, such as bitumen or sulphides, some local variations are to be expected, as these materials do not appear to be distributed uniformly throughout the shale. The apparent uniformity of the shale over large areas, and the probable sea-water source of the uranium therein, make it improbable that the uranium content of a particular bed of fresh rock differs much over distances of a few miles.

Statements in the following section regarding uranium reserves in the Eastern Highland Rim are made with the understanding that assays from individual outcrops may not reflect the true uranium content throughout the area represented by that outcrop, and that averages over large areas are probably more reliable. In Block 1 the average uranium content of the Top Black shale is 0.0077 percent and of the three upper units (Top Black, Upper siltstone, and Middle Black) 0.0069 percent. Assays for each locality in the block are given in table 3, in which localities are arranged roughly in order of grade, the Middle Gray and Lower Black being omitted as presumably having no economic value. Localities close together have been grouped and averaged (LC-10, LC-55, and LC-102 in one group, LC-1, LC-2, and LC-56 in another). Only localities for which chemical assays are available are included.

Table 3.--Thicknesses and uranium content of the upper units, by localities, Block 1, Tennessee

| Locality | Top Black | | Three upper units | |
|---|---|---|---|---|
| | Thickness (feet) | Uranium (percent) | Thickness (feet) | Uranium (percent) |
| LC-50 | 5.67 | 0.0110 | 18.29 | 0.0100 |
| LC-10 | 7.20 | .0114 | 18.45 | .0091 |
| -102 | 6.10 | .0074 | 15.70 | .0071 |
| -55 | 7.60 | | 17.40 | |
| Ave., LC-10, -102, -55 | 6.97 | 0.0094 | 17.18 | 0.0081 |
| LC-103 | 6.60 | 0.0089 | 14.70 | 0.0077 |
| -33 | 5.12 | .0091 | 16.50 | .0072 |
| -8 | 6.25 | .0081 | 17.44 | .0072 |
| LC-56 | 6.25 | 0.0096 | 16.40 | 0.0078 |
| -1B | 6.45 | .0077 | 16.30 | .0067 |
| -2 | 6.95 | .0069 | 16.63 | .0065 |
| -1 | 6.45 | .0073 | 16.30 | .0063 |
| -1A | 6.45 | .0070 | 16.30 | .0062 |
| Ave., LC-1, -1A, -1B, -2, -56 | 6.51 | 0.0077 | 16.39 | 0.0067 |
| LC-4 | 7.99 | 0.0080 | 18.53 | 0.0066 |
| -17 | 7.10 | .0065 | 17.01 | .0062 |
| -11 | 6.38 | .0065 | 13.42 | .0061 |
| -30 | 4.96 | .0068 | 15.19 | .0060 |
| -6 | 5.27 | .0061 | 16.84 | .0058 |
| -15 | 7.44 | .0058 | 15.59 | .0056 |
| -105A | 5.00 | .0065 | 14.00 | |
| -12 | 6.87 | | 16.37 | |
| -51 | 5.53 | | 16.95 | |
| Average all localities | 6.35 | 0.0077 | 16.40 | 0.0069 |

The only information on Block 2 is from a deep well drilled by the Magnolia Company at Gruetli, Grundy County (10M-1, pl. 1), and from drill hole LC-113A (pl. 1). At Gruetli the three upper units are 15 feet thick and assay 0.0082 percent uranium. At LC-113A, on the other hand, the same units are 11.5 feet thick and assay only about 0.0036 percent. This figure, which is the average of three sets of fluorimetric assays, is not understood; it may indicate a buried area of unusually low uranium content, or there may be some unknown factor which causes these inconsistently low assays. Assays of samples from the Sequatchie Valley, Block 3, [13] are comparable with those of the Gruetli well, so it seems likely that much of the buried shale southeast and east of Blocks 1, 5, and 6 has a uranium content comparable to that in the Eastern Highland Rim area, but the evidence is too meager and inconsistent to be conclusive.

For Block 4, chemical assays have been reported for nearly all samples (table 8), but those are so different from the assays of samples from the adjoining Block 1 that they must be viewed with doubt. It is seen from table 8 that all units of the shale seem to have a much lower uranium content than do the same units in Block 1, though the ratios of the uranium contents of the several units are about the same. Comparison of tables 3 and 8 shows that the Block 4 samples (13L-20 and 13M-4) which are closest to Block 1 apparently have a surprisingly lower uranium content than any outcrop in Block 1.

Further question concerning the validity of the Block 4 assays is raised by consideration of assays of special samples from localities S-100 and R-C2. S-100 is just north of Block 4, yet assays reported on two special samples (table 6) are well within the range of assays of the Top Black shale in Block 1 (table 3). At R-C2 in Block 5 four special samples were collected from sample interval 13. Assays of three of these (table 6) show 0.0090, 0.0092, and 0.0[illegible]7 percent uranium, and an assay of the routine sample by radiometric method (table 9, R-C2-13) also shows 0.009 for the same interval; fluorimetric assays of the same routine sample, however, showed only 0.007 and 0.004 percent uranium. Similar low fluorimetric assays have been reported for most other routine samples submitted after completion of field work in Blocks 1 and 3. Geiger-counter scanning of the Block 5 outcrops, although not here considered to be reliable quantitatively, also indicated uranium contents comparable with those in Block 1. Whether these discrepancies indicate changing standards in the laboratory or real differences in the samples submitted cannot be stated with certainty. It is possible that the first samples taken, in the routine work, were slightly weathered, but that special samples taken later represent fresher rock of higher uranium content. Re-assays which have been requested to check these possibilities are not yet available in sufficient quantity. As the physical appearance and the thicknesses of the units are essentially the same in Blocks 1 and 4, and as all geologic reasoning suggests that the uranium content should be similar, the acceptance of these low assays does not seem warranted at present.

Assays of samples from Blocks 5, 6, and 7 (tables 9-11) are too few to permit evaluation of the uranium content of those areas.

## Reserves

On the basis of several specific-gravity determinations it is assumed that a cubic foot of shale in place weighs 140 pounds. A 1-foot bed of such rock occupying an acre contains 3,049 tons of shale, and the same bed over a square mile contains 1,951,488 tons. At 0.0069 percent uranium, which is the average of the three upper units in Block 1, a 1-foot bed over 1 square mile contains 134.6 tons of uranium. For the purpose of the following calculations, this figure is rounded out to 135. The average thickness of 16.4 feet of the three upper units of the black shale in Block 1 is estimated to contain about 2,214 tons of uranium per square mile. Thus, in the 93.5 square miles underlain by Chattanooga in the part of Block 1 for which information is available (see map, pl. 13), there would appear to be about 207,000 tons of uranium.

Only a slightly different figure is obtained by calculating the reserves using the polygonal areas shown on plate 13. Boundaries of the polygons near the edges have been chosen somewhat arbitrarily, and conservative assumptions have been made in several instances where data are lacking or incomplete. Reserves which have been calculated for each polygon are given in table 4, and total about 196,000 tons of uranium. It seems reasonably safe to conclude, therefore, that the three upper units of black shale in the 93.5 square miles of Block 1 for which information is available contain about 200,000 tons of metallic uranium.

Reserves in Block 2 are problematical as to grade because of the differences between assays from drill hole LC-113A and the Gruetli well. It seems safe to state that about 1,500 square miles between the Sequatchie Valley and Blocks 1 and 6 are probably underlain at depths of 300 to 2,000 feet by some 12 to 17 feet of shale representing the three upper units, and that the average grade of most of this shale is probably as high as in the outcrops of Block 1. No tonnage estimates appear warranted.

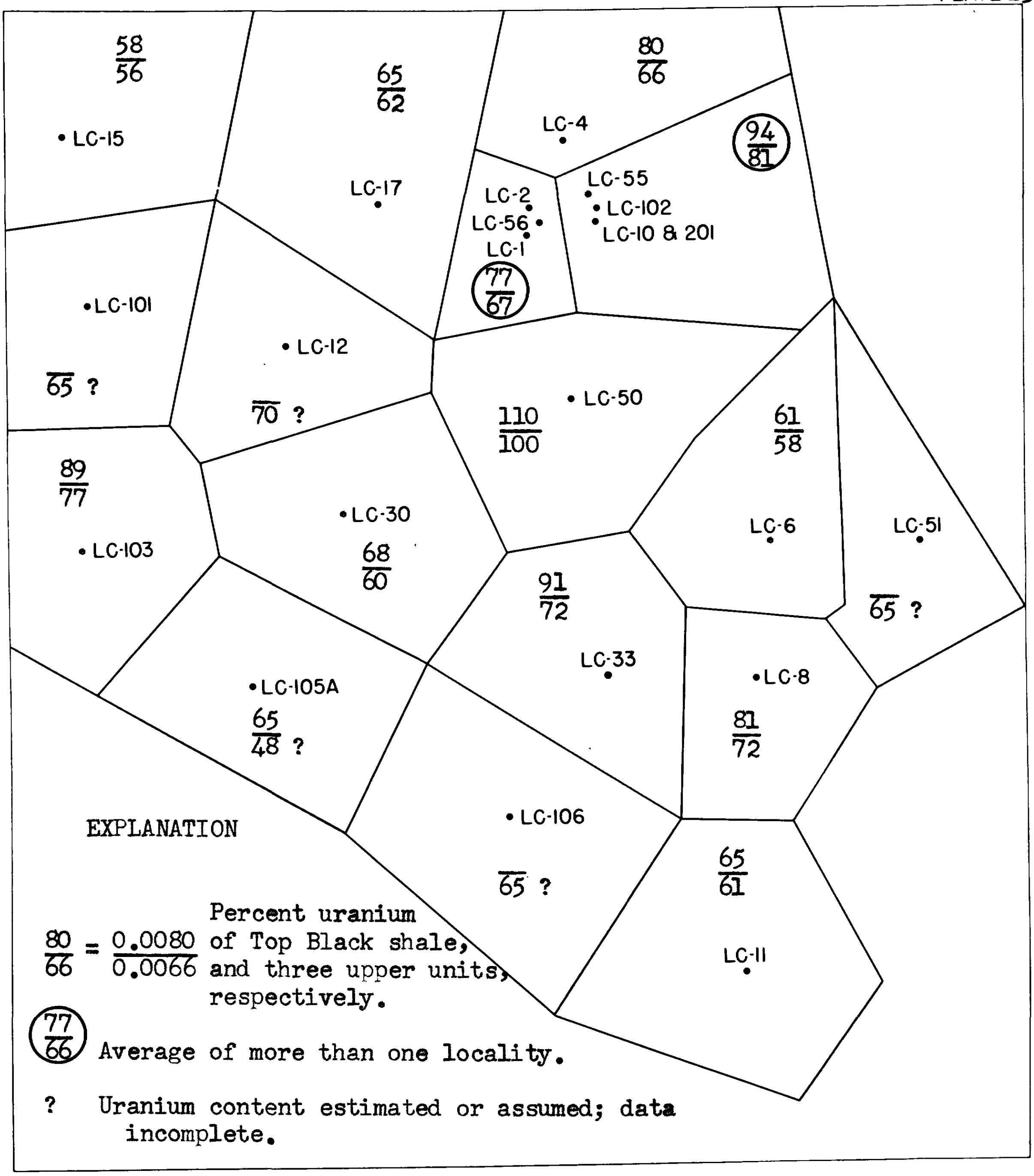
Assays of samples from Block 4 are so low, as has already been pointed out, that it has not seemed worth while to make tonnage estimates of the uranium content of that area. Assays of several special samples from Block 5 (table 6) indicate a uranium content comparable to Block 1, but routine fluorimetric assays again indicate a lower grade. The fragmentary and conflicting data at hand (tables 6 and 9) do not warrant conclusions regarding grade or tonnage in that area. Assays of samples from Blocks 6 and 7 are still more fragmentary (tables 10 and 11) and do not permit such estimates.

Table 4.--Tonnage estimates by polygons of the three upper units

| Locality number (LC-) | Square miles represented | | Thickness (feet) | Shale (millions of tons) | Grade | Uranium (short tons) |
|---|---|---|---|---|---|---|
| | Total | Underlain by shale | | | | |
| 50 | 7.8 | 4.5 | 18.29 | 160.62 | 0.010 | 16,062 |
| 10,55,102 | 7.0 | 6.7 | 17.18 | 224.63 | .0081 | 18,195 |
| 33 | 6.4 | 5.8 | 16.50 | 194.56 | .0072 | 14,008 |
| 103 | 5.8 | 5.8 | 14.70 | 166.38 | .0077 | 12,812 |
| 8 | 4.5 | 4.2 | 17.44 | 142.94 | .0072 | 10,292 |
| 4 | 5.2 | 2.7 | 18.53 | 97.63 | .0066 | 6,444 |
| 17 | 9.2 | 7.0 | 17.01 | 232.36 | .0062 | 14,407 |
| 30 | 7.2 | 6.8 | 15.19 | 201.57 | .0060 | 12,094 |
| 11 | 8.1 | 7.0 | 13.42 | 183.32 | .0061 | 11,183 |
| 1,2,56 | 2.6 | 0.6 | 16.39 | 19.19 | .0067 | 1,286 |
| 6 | 6.1 | 6.1 | 16.84 | 200.46 | .0058 | 11,627 |
| 15 | 6.7 | 5.7 | 15.59 | 173.42 | .0056 | 9,711 |
| 105A | 6.8 | 6.8 | 14.00 | 185.78 | a | 8,918 |
| 12 | 5.5 | 5.5 | 16.37 | 175.70 | b | 12,299 |
| 51 | 5.0 | 4.5 | 16.95 | 148.85 | c | 9,675 |
| 106 | 8.3 | 8.3 | 15.00 d | 242.96 | d | 15,792 |
| 101 | 5.5 | 5.5 | 15.50 e | 166.36 | e | 10,814 |
| Total | 107.7 | 93.5 | | 2916.73 | | 195,619 |

a Estimated on basis of incomplete assays to be about 0.0048.
b Estimated on basis of incomplete assays to be 0.007.
c No chemical assays available; assumed on basis of adjoining polygons to be 0.0065.
d Area not sampled; estimated on basis of adjoining polygons to have 15 feet at 0.0065.
e Estimated on basis of two samples from Top Black that 15.5 feet would assay 0.0065.

PLATE 13




POLYGONS USED FOR BLOCK I CALCULATIONS

1 0 1 2 3 Miles

## BY-PRODUCT POSSIBILITIES

### Oil and gas

The Chattanooga has long been known as a potential oil shale, but most tests of its oil yield have indicated that in the Eastern Highland Rim area it is of low grade. If, however, the shale were to be mined and processed for uranium, the oil and gas by-products would be important and might determine the feasibility of extracting the uranium. Oil assays by the modified Fischer retort method have been made on three sets of samples from Block 1 by the U. S. Bureau of Mines laboratory at Laramie, Wyoming, and the results are shown in table 12 in the appendix. Other samples of the shale have been assayed likewise by the U. S. Geological Survey laboratory at Washington, and the results of these assays are shown in table 13 in the appendix. From these tables it is seen that the oil yield of the different shale units is not correlative with the uranium content. In general, the fragmentary data indicate that the Middle Black shale yields the most oil, and the Lower Black shale, which is consistently low in uranium, yields nearly as much oil as does the Middle Black. The Top Black shale, which contains the most uranium, appears to have a somewhat lower oil yield.

It is possible, according to oral statements by workers at Battelle Memorial Institute, that about 50 percent more oil can be obtained than indicated by the modified Fischer assays; this, however, might require higher temperatures than would permit maximum extraction of the uranium. Experiments at Battelle Memorial Institute indicate, moreover, that enough carbonaceous matter might still remain in the shale after removal of the oil to supply the fuel requirements for extraction of the uranium. Various aspects of the possibility of recovering by-product fuels from the shale have been discussed in reports of investigations at Battelle Memorial Institute. [4, 6]

### Sulphuric acid

The pyrite and marcasite of the shale are reported by Battelle Memorial Institute to be in excess of that required to supply the sulphuric acid presumed to be needed in extraction of uranium. If such is the case, the excess sulphuric acid might be a salable by-product.

### Alumina

Research on the metallurgical problems of uranium extraction indicates that much of the alumina in the shale would be leached with the uranium and would, therefore, be in the uranium-bearing liquors. The possibility of precipitating this alumina and reclaiming it as another by-product has apparently been only partially investigated, owing to curtailment of research on uranium extraction from black shale.

## Light-weight concrete aggregate

It has been suggested that the shale tailings could be used for light-weight aggregate. As many other shales and clays are suitable for this purpose, it would appear that the market for such aggregate would be largely a local one, perhaps extending as far as Knoxville, Chattanooga, and Nashville which range in airline distance from the adit, from about 65 to 100 miles.

## Potash

Several samples of the shale were found by the Geological Survey laboratory to contain 3 to 4 percent $K_2O$. It has been suggested that some of this potash could be extracted as another by-product.

## Molybdenum

Studies of the Chattanooga shale at Battelle Memorial Institute [6] have indicated that molybdenum is a potential by-product which is present in about the same quantity as the uranium, and would be extracted along with the uranium.

## Carbon

A small industry has been operated for several years on the Western Highland Rim, and has been described by the Tennessee Planning Commission. [17] This company produces from the shale, after the oil has been extracted, several grades of black pigments and fillers which are used in the manufacture of typewriter ribbons and carbon paper, in linoleum, as coloring matter for mortar, and in other ways. A short article [15] on this industry is here quoted.

Pay Dirt

[From Industrial and Engineering Chemistry, vol. 40, pp. 22A-24A, Dec. 1948, presumed to be by W. H. Shearon, Jr.]

In Tennessee, a few miles from the city of Franklin, there is a rock stratum known as the Chattanooga shale, an oil-bearing shale black and slatelike in appearance. To give a slight geological orientation, this stratum of rock is Devonian-Mississippian in age and its upper member is the Murray [sic] green shale which is characterized by phosphatic nodules. On the farm of William A. Johnson, engineer, farmer, and native of the area, in a layer 8 to 10 feet thick and at a very uniform depth, lie an estimated several million tons of this shale. In 1927 the valuable nature of the mineral became evident when he accidentally threw a piece of the rock on a fire, and noticed that it began to burn. On investigating he found a high kerogen content, and becoming interested in its possibilities as an oil source he built a crude retort and successfully obtained oil. Costs of production of this oil from the shale effectively dampened what enthusiasm he had along this line, however, particularly since in 1927 crude oil from petroleum was selling at $1.30 a barrel. It is interesting therefore to follow the story of a man who "turned the tables" and has made a successful venture by ignoring the oil.

As is so often the case, the direction in which an experiment ends may be far from that in which it started. So with the Chattanooga shale. From the bottom of the retort Johnson recovered about 80% of the original weight of the shale as a black residue. This residue proved a very satisfactory pigment, and what started as an oil project turned into a pigment manufacturing operation. He named his "pay dirt" Carbsil, as it is largely carbon and silica.

Dull tools may be an anathema to some, but to Johnson they are better than sharp ones. He uses discarded rock bits for drilling, reducing blowing of the dust, and finds that a dull bit will cut the deposit faster.

In producing Carbsil, the shale is blasted from the formation and hauled a short distance to an incline from which it is fed into the tops of retorts, or burners. The original method consisted in retorting the shale in an oxygen-deficient atmosphere; this resulted in a "soft-burned" pigment. During the war customers' requirements dictated a "dead-burned" pigment, obtained by actually burning the shale instead of retorting it, and the retorts were converted to burners. Johnson is still operating with burners, but plans to rebuild the equipment to "dead-burn" part of it in a shell surrounding the retort and at the same time to provide the heat for the inside retorting operation which produces the soft-burned pigment. Vapors will be pulled off the top of the retort by vacuum, and the pigment residue drawn continuously from the bottom. With the present batch method about 5 tons per day of dead-burned shale can be produced per burner; capacity of the continuous unit will be 15 tons per burner.

The pigment residue is quenched, passed through hammer-mills, and then sent to a ball mill (capacity 1.5 tons per hour) where it is pulverized. Regular grades of Carbsil pass 99.1% through a 325-mesh screen; dead-burned Carbsil passes 98%. Depending on the method of production and mixing, Carbsil is available in four grades, in which the carbon content varies from 12 to 25% and the ash (silica, alumina, and iron oxides) from 88 to 75%. All of these blacks are in the very low oil absorption range, about one tenth that of an ordinary grade of carbon black. Therefore they are wet readily by all types of vehicles and allow the use of higher loadings in paint formulations, with final products of low viscosity. Specific gravity ranges from 2.30 to 2.68.

Carbsil finds many uses: in the manufacture of carbon paper and typewriter ribbons; for undercoatings and auto top dressings; to bleach paraffin; and as a linoleum filler and bleach. Mixed with a small amount of carbon black or graphite it makes a durable and elastic metal paint. Using the dead-burned pigment, a rubdown finish can be obtained. During the war Carbsil was extensively used in camouflage paints.

At present, the volatiles from the retorts are being exhausted to the air, but they afford a potential source of oil, gas, and ammonium sulfate. When retorted at about 900° F., a yield of 35 to 45 gallons of oil and 8000 to 10,000 cubic feet of 400 to 500 B.t.u. of gas is obtained. Ammonium ichthyol-sulfonate or ichthyol, used in medicinal compounds, is obtainable from this shale, and Johnson says that 35 pounds of ammonium sulfate per ton of shale can be obtained using the ammonia produced during retorting.

W.H.S.

APPENDIX

Register of localities

Block 1.--

LC-1 (Also LC-1A and -1B). Cut on Tennessee Highway 26, 0.5 mile SW of Sligo bridge over Center Hill Reservoir, DeKalb County. Road abandoned in 1948 and exposure now covered by debris from new highway above.

LC-2 Cut on long-abandoned highway on NW side of Short Creek, about 0.5 mile west of Sligo bridge, DeKalb County.

LC-4 On farm road about 0.75 mile NW of Tennessee Highway 26, about 3 miles west of DeKalb-White County line, DeKalb County.

LC-6 Waterfall on small stream a few hundred feet from Center Hill Reservoir, 4 airline miles south of Tennessee Highway 26 at county line, White County.

LC-8 Bed of south-flowing tributary of Sink Creek, at edge of Center Hill Reservoir, DeKalb County.

LC-10 Cut on north side of old Tennessee Highway 26, abandoned in 1948 but now used as a boat-landing road, 0.5 mile east of Sligo bridge, DeKalb County.

LC-11 South bank of Caney Fork River at northernmost point of Horseshoe Bend, 4 3/4 airline miles WNW of U. S. Highway 70S at Walling, White County. This exposure is now submerged by the Center Hill Reservoir.

LC-12 Small waterfall on Jake Poss farm, 900 feet downstream from main falls of Fall Creek on south side of gorge, 2 1/2 miles ESE of Smithville, DeKalb County.

LC-15 Cut on Holmes Creek road, 1.6 miles north of Smithville, DeKalb County.

LC-17 Cut on farm road, 1 mile north of Tennessee Highway 26 at Pomeroy Chapel and 3 1/2 airline miles east of Smithville, DeKalb County.

LC-30 Main waterfall on Pine Creek, DeKalb County.

LC-33 Bluffs on Sink Creek, 2 1/2 miles east of Keltonburg, DeKalb County.

LC-50 West-facing waterfall in branch of Short Creek, 2 1/4 airline miles south of Sligo bridge, 1 1/2 miles NE of Youngs Bend School, DeKalb County.

LC-51 Bluff at site of old Lunas Mill at junction of Cedar and Falling Water Creeks, White County.

LC-55 Cut on new Tennessee Highway 26, at east approach to new Sligo bridge, DeKalb County.

LC-56 Cut on new Tennessee Highway 26, at west approach to new Sligo bridge, DeKalb County.

LC-201 Adit, about 140 feet NW of LC-10.

Drill holes, Blocks 1 and 2.--

LC-100 East side of Tennessee Highway 56, 1.1 miles south of courthouse at Smithville, DeKalb County.

LC-101 Twenty feet south of LC-100.

LC-102 About 100 feet west and 30 feet above old Tennessee Highway 26, about 1,800 feet SE of Sligo bridge, in field road along ridge, DeKalb County.

LC-103 West side of Tennessee Highway 56, 725 feet south of road intersection at Shining Rock and 3.7 miles south of courthouse at Smithville, DeKalb County.

LC-104 Between Town Creek and Holmes Creek road, 300 feet west of bridge, in north edge of Smithville, DeKalb County.

LC-105 In road fork about 450 feet south of Cantrell Branch and 1 mile east of Tennessee Highway 56. About 2 1/2 airline miles SE of LC-103, DeKalb County.

LC-105A Twenty-five feet east of LC-105.

LC-108 West side of Caney Fork River, in bottom at Wrights Bend, DeKalb County. Four shallow holes at this locality, which is now covered by Center Hill Reservoir.

LC-113 Seventy feet east of Caney Fork River and 75 feet north of road at Dodsons store, southeastern part of White County.

LC-113A Twenty-five feet east of LC-113.

Block 4.--

13L-8 On Buffalo Valley road 0.1 mile south of U. S. Highway 70N and 2 1/2 airline miles SE of Chestnut Mound, Smith County.

13L-11 Road cut about 2 airline miles west of Silver Point, on road from Silver Point to Center Hill Dam, Putnam County.

13L-13 Road cut on west side of Dale Ridge, 4 airline miles NE of Dowelltown, DeKalb County.

13L-17 Road cut about 1 airline mile south of Gentry, 12 1/2 airline miles west of Cookeville, Putnam County.

13L-20 Cut on old Tennessee Highway 56 on south side of Caney Fork River, about 0.5 mile north of Buckner School, DeKalb County.

13L-22 Cut on U. S. Highway 70N, 0.3 mile west of Chestnut Mound corporation limit sign, Smith County.

13M-1 At Burgess Falls, about 0.1 mile upstream from old Cookeville power plant on Falling Water River, Putnam County.

13M-4 At Taylor Creek Falls, 9 airline miles NW of Sparta and near NW line of White County.

13M-5 Road cut 2 airline miles north of Laurel School and 6 1/2 airline miles east of Smithville, DeKalb County.

13M-7 At Gentrys Bluff on upper part of Mine Lick Creek, about 2 miles east of Boma and 2 1/4 miles south of Baxter, Putnam County.

13M-10 Road cut about 3 airline miles east of Silver Point on east side of Mine Lick Creek, Putnam County.

13M-19 In stream bed 1 1/2 airline miles NW of Boma, Putnam County.

13M-23 Road cut 1 1/2 airline miles NW of Bloomington Springs, 0.5 mile south of Goose Creek, Putnam County.

13M-24 Cut on county road about 0.5 mile north of U. S. Highway 70N, 0.25 mile east of Lafayette School, and 11 airline miles west of Cookeville, Putnam County.

Block 5.--

R-C1 Cut on Tennessee Highway 53, 2 1/2 miles south of Woodbury, Cannon County.

R-C2 Cut on county road 1.4 miles by road west of Tennessee Highway 53 at Sheboygan, Cannon County.

R-C3 Cut on west side of road, 2.9 miles south of Bradyville Church and 3.7 miles west of Hollow Springs crossroads, Cannon County.

R-C4 Small waterfall, south side of east-west road south of Short Mountain, 6.8 miles north of U. S. Highway 70S, along Short Mountain road, Cannon County.

R-C5 About 2 miles east of Gassaway on north side of gravel road to Pea Ridge, DeKalb County.

R-C6 West side of Auburntown road, about 3 miles north of its junction with U. S. Highway 70S on west edge of Woodbury, Cannon County.

R-C7 At English Falls near head of Dry Creek, 1.8 miles north of Cripps store and about 5 airline miles SE of Gassaway, DeKalb County, near Cannon County line.

R-C8 At Egypt Falls on tributary of Dry Creek, 5 1/2 airline miles SE of Dowelltown and 3 airline miles west of Smithville, DeKalb County.

LC-34 South side of Tennessee Highway 26, 3.1 miles east of Dowelltown, DeKalb County.

LC-60 Cuts on Tennessee Highway 53, 5.0 and 5.4 miles south of Gassaway, on north and south sides of ridge, Cannon County.

Block 6.--

10J-8 Road cut and exposure below dam, Ledsford Mill, 3.0 miles by county road NE of junction of Tennessee Highways 16 and 55, NE corner of Moore County.

10J-9 Hurricane Creek just below large dam at Cumberland Springs, Moore County.

10K-3 Road cut and small stream exposure on county road 0.9 mile east of Blanton, immediately west of Haggard Creek ford, Coffee County.

10K-4 Cut on county road leading to Crumpton Branch, 1.6 miles west of Mountview School, Coffee County.

10K-5 Cut on Cascade Branch road, 2.5 miles WNW of Ovoca and 0.6 airline mile SW of Bethany Church, Coffee County.

10K-6 On county road 0.3 mile south of church at Holland Hill, Coffee County. Only lower units sampled at this locality.

10K-10 In stream beside county road 1.2 airline miles east of Awalt, Franklin County.

10K-11 River bluff where road approaches Elk River most closely, 0.4 mile NE of Rock Creek bridge on county road, Franklin County.

11J-6 On county road 1.0 mile west of crossroads at Shiloh Cemetery, Bedford County. Only upper units sampled at this locality.

11K-1 Deep cut for U. S. Highway 41, 1 mile NW of Noah, Coffee County.

11K-2 Cut on McBride Branch road, 0.2 mile SW of Wilsons Chapel School at Hoodoo, Coffee County.

Block 7.--

14L-1 NW side of Tennessee Highway 80, 4.3 miles SW of Willette, and 0.5 mile NE of Smith County line, Macon County.

14L-5 East side of county road 2.2 miles ESE of Willette, and 0.4 mile south of Fairview School, Macon County.

14M-2 Cut on north side of Flynn Creek road, 1 mile NW of its junction with Tennessee Highway 56, Jackson County.

14M-6 East side of Tennessee Highway 85, 3.2 miles north of Rough Point, 5 airline miles NW of Gainesboro, Jackson County.

14M-7 Cut on SE side of Tennessee Highway 85, 0.6 mile east of Tennessee Highway 53 and about 3 miles NE of Gainesboro, Jackson County.

14M-8 Cut on west side of Tennessee Highway 56, 1.9 miles SE of Gainesboro, Jackson County.

14M-9 Cut on SE side of Roaring River road, 1.6 miles north of Sunny View School, and about 6 airline miles east of Gainesboro, Jackson County.

14M-10 Cut on west side of Tennessee Highway 53, 14 miles NE of Gainesboro and 1.8 miles NE of Clay-Jackson County line, Clay County.

14M-11 Cut on west side of Tennessee Highway 53, 7.6 miles SW of Gainesboro and 1.4 miles SW of junction of Highway 53 and Flynn Creek road, Jackson County.

14M-13 NW side of Keeling Branch road, 4.1 miles north of Whitleyville, Jackson County.

14M-14 Cut on north side of county road, 1.2 miles east of Freewill School, west side of Blackman Creek, Jackson County.

14M-15 North side of Shakerag Hollow road, 0.8 mile NW of New Salem School, and about 2 1/2 airline miles SSW of Gainesboro, Jackson County.

14M-16 East side of Sugar Creek road, 4.5 miles SE (up valley) of Highway 53, Jackson County.

14N-3 East side of Spring Creek at falls near Overton-Putnam County line, about 11 airline miles ESE of Gainesboro, Overton County.

14N-4 West side of dam on Mill Creek in Standingstone State Park, 2 miles SSW of Timothy, Overton County.

15N-12 Cut on north side of road about 250 yards west of Dale Hollow Dam, Clay County.

Table 5.--Distribution of routine samples of Chattanooga shale

| Block | No. of local- ities | Number of samples, by units | | | | | | | Total samples |
|---|---|---|---|---|---|---|---|---|---|
| | | Maury shale | Phos. beds | Top Black shale * | Upper Silt- stone | Middle Black shale | Middle Gray silt- stone | Lower Black shale | |
| 1 | 17 | 20 | 10 | 66 | 33 | 80 | 87 | 60 | 356 |
| 4 | 14 | 3 | 21 | 55 | 26 | 37 | 9 | 43 | 194 |
| 5 | 10 | 2 | 2 | 32 | 11 | 39 | 11 | 33 | 130 |
| 6 | 11 | - | - | 34 | 9 | 22 | 2 | 20 | 87 |
| 7 | 16 | - | 39 | 73 | 35 | 8 | - | 8 | 163 |
| cores | 5 | 3 | 1 | 15 | 6 | 15 | 19 | 11 | 70 |
| Total | 73 | 28 | 73 | 275 | 120 | 201 | 128 | 175 | 1,000 |

* Nonphosphatic part of the Top Black shale.

Table 7.--Summary of sample thicknesses and assays, Blocks 1 and 2 (thicknesses in feet and hundredths)

| Sample no. | LC-1 Thickness | LC-1 Uranium (percent) | LC-1A Thickness | LC-1A Uranium (percent) | LC-1B Thickness | LC-1B Uranium (percent) | LC-2 Thickness | LC-2 Uranium (percent) | LC-4 Thickness | LC-4 Uranium (percent) | LC-6 Thickness | LC-6 Uranium (percent) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Maury | | | | | | | | | | | | |
| 1 | 1.2 | 0.002 | 1.2 | 0.002 | | | 0.9 | 0.002 | 1.12 | 0.002 | 0.95 | 0.004 |
| 2 | 1.3 | .003 | 1.3 | .006 | | | 1.4 | .002 | 0.95 | .003 | | |
| Total & ave. | 2.5 | 0.0025 | 2.5 | 0.0040 | | | 2.3 | 0.002 | 2.07 | 0.0025 | 0.95 | 0.004 |
| Top Black | | | | | | | | | | | | |
| 11 | 1.5a | 0.009 | 1.5a | 0.009 | 1.5a | 0.008 | 0.26 | 0.006 | 0.3 | 0.004 | 0.37 | 0.005 |
| 12 | 1.5 | .008 | 1.5 | .003 | 1.5 | .008 | 1.63 | .007 | 1.22 | .010 | 1.85 | .006 |
| 13 | 1.5 | .007 | 1.5 | .009 | 1.5 | .008 | 2.00 | .007 | 2.00 | .008 | 1.90 | .007 |
| 14 | 1.95 | .006 | 1.95 | .007 | 1.95 | .007 | 1.49 | .008 | 1.04 | .008 | 1.15 | .005 |
| 15 | | | | | | | 1.57 | .006 | 2.00 | .008 | | |
| 16 | | | | | | | | | 1.43 | .007 | | |
| 17 | | | | | | | | | | | | |
| 18 | | | | | | | | | | | | |
| Total & ave. | 6.45 | 0.0073 | 6.45 | 0.007 | 6.45 | 0.0077 | 6.95 | 0.0069 | 7.99 | 0.0080 | 5.27 | 0.0061 |
| Upper silt | | | | | | | | | | | | |
| 21 | 1.45 | 0.004 | 1.45 | 0.007 | 1.45 | 0.006 | 1.65 | 0.005 | 2.00 | 0.006 | 1.94 | 0.005 |
| 22 | 1.0 | .002 | 1.0 | .005 | 1.0 | .004 | 0.84 | .004 | 0.87 | .004 | 0.90 | .006 |
| Total & ave. | 2.45 | 0.0032 | 2.45 | 0.0062 | 2.45 | 0.0052 | 2.49 | 0.0047 | 2.87 | 0.0054 | 2.84 | 0.0053 |
| Middle Black | | | | | | | | | | | | |
| 31 | 1.7 | 0.004 | 1.7 | 0.005 | 1.7 | 0.006 | 1.95 | 0.007 | 1.83 | 0.003 | 2.08 | 0.003 |
| 32 | 1.8 | .007 | 1.8 | .006 | 1.8 | .006 | 1.7 | .007 | 2.0 | .007 | 1.50 | .005 |
| 33 | 1.4 | .007 | 1.4 | .006 | 1.4 | .007 | 1.7 | .007 | 2.0 | .008 | 1.65 | .007 |
| 34 | 1.77 | .007 | 1.77 | .007 | 1.77 | .007 | 1.84 | .006 | 1.84 | .004 | 1.50 | .007 |
| 35 | 0.73 | .008 | 0.73 | .002 | 0.73 | .006 | | | | | 2.00 | .007 |
| Total & ave. | 7.40 | 0.0064 | 7.40 | 0.0056 | 7.40 | 0.0064 | 7.19 | 0.0067 | 7.67 | 0.0056 | 8.73 | 0.0057 |
| Three upper units Total & ave. | 16.3 | 0.0063 | 16.3 | 0.0062 | 16.3 | 0.0067 | 16.63 | 0.0065 | 18.53 | 0.0066 | 16.84 | 0.0058 |
| Middle Gray | | | | | | | | | | | | |
| 41 | 1.9 | 0.003 | 1.9 | 0.002 | 1.9 | 0.002 | 0.82 | 0.003 | 0.78 | 0.006 | 1.22 | 0.004 |
| 42 | 1.85 | .003 | 1.85 | .002 | 1.85 | .003 | 2.0 | .004 | 1.44 | .004 | 1.93 | .003 |
| 43 | 1.85 | .006 | 1.85 | .002 | 1.85 | .002 | 2.0 | .003 | 1.55 | .003 | 1.91 | .002 |
| 44 | 1.9 | .008 | 1.9 | .002 | 1.9 | .002 | 2.0 | .003 | 1.96 | .003 | 1.45 | .002 |
| 45 | 1.85 | .003 | 1.85 | .004 | 1.85 | .003 | 2.0 | .003 | 1.82 | .004 | 1.76 | .003 |
| 46 | | | | | | | 0.63 | .004 | 1.62 | .002 | 1.46 | .003 |
| 47 | | | | | | | | | 0.6 | .003 | 0.92 | .002 |
| Total & ave. | 9.35 | 0.0046 | 9.35 | 0.0024 | 9.35 | 0.0024 | 9.45 | 0.0033 | 9.77 | 0.0034 | 10.65 | 0.0027 |
| Lower Black | | | | | | | | | | | | |
| 51 | 1.8 | 0.006 | 1.8 | 0.004 | 1.8 | 0.004 | 2.0 | 0.004 | 2.0 | 0.004 | 1.64 | 0.003 |
| 52 | 1.95 | .005b | 1.95 | .005 | 1.95 | .007 | 2.0 | .003 | 1.83 | .005 | 2.00 | .007 |
| 53 | 1.8 | .003 | 1.8 | .004 | 1.8 | .005 | 1.19 | .005 | 1.31 | .005 | 1.30 | .005 |
| 54 | 0.8 | .003 | 0.8 | .003 | 0.8 | .003 | 2.0 | .005 | 1.63 | .003 | 1.78 | .004 |
| Total & ave. | 6.35 | 0.0045 | 6.35 | 0.0042 | 6.35 | 0.0051 | 12.24c | 0.0042 | 6.77 | 0.0042 | 6.72 | 0.0048 |

| Sample no. | LC-8 Thickness | LC-8 Uranium (percent) | LC-10 Thickness | LC-10 Uranium (percent) | LC-11 Thickness | LC-11 Uranium (percent) | LC-12 Thickness | LC-12 Uranium (percent) | LC-15 Thickness | LC-15 Uranium (percent) | LC-17 Thickness | LC-17 Uranium (percent) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Maury | | | | | | | | | | | | |
| 1 | | | 2.06 | 0.002 | 2.03 | 0.004 | 1.95 | | 1.32 | 0.003 | 1.97 | 0.002 |
| 2 | | | | | | | | | | | | |
| Total & ave. | 1.10 | * | 2.06 | 0.002 | 2.03 | 0.004 | 1.95 | | 1.32 | 0.003 | 1.97 | 0.002 |
| Top Black | | | | | | | | | | | | |
| 11 | | | 0.50 | 0.006 | | | 0.15 | | 0.50 | 0.005 | 0.10 | 0.007 |
| 12 | 0.83 | 0.008 | 1.60 | .011 | 2.00 | 0.007 | 2.00 | | 1.06 | .007 | 2.00 | .005 |
| 13 | 2.03 | .009 | 1.60 | .012 | 2.00 | .008 | 2.00 | | 2.00 | .007 | 2.00 | .005 |
| 14 | 2.00 | .008 | 1.50 | .011 | 1.38 | .005 | 1.90 | | 1.88 | .005 | 1.70 | .009 |
| 15 | 1.39 | .007 | 2.00 | .013 | 1.00 | .005 | 0.82 | | 2.00 | .005 | 1.30 | .008 |
| 16 | | | | | | | | | | | | |
| 17 | | | | | | | | | | | | |
| 18 | | | | | | | | | | | | |
| Total & ave. | 6.25 | 0.0081 | 7.2 | 0.0114 | 6.38 | 0.0065 | 6.87 | | 7.44 | 0.0058 | 7.10 | 0.0065 |
| Upper silt | | | | | | | | | | | | |
| 21 | 1.00 | 0.005 | 2.20 | 0.006 | 2.00 | 0.005 | 1.90 | 0.005 | 1.97 | 0.004 | 1.33 | 0.007 |
| 22 | 1.49 | .005 | 1.15 | .005 | 1.67 | .006 | 0.29 | .004 | | | 1.03 | .006 |
| Total & ave. | 2.49 | 0.005 | 3.35 | 0.0057 | 3.67 | 0.0055 | 2.19 | 0.0049 | 1.97 | 0.004 | 2.36 | 0.0066 |
| Middle Black | | | | | | | | | | | | |
| 31 | 2.00 | 0.005 | 0.70 | 0.006 | 2.00 | 0.006 | 1.88 | 0.007 | 2.25 | 0.005 | 2.00 | 0.006 |
| 32 | 2.00 | .007 | 1.80 | .009 | 1.37 | .006 | 1.47 | .007 | 1.93 | .006 | 2.00 | .005 |
| 33 | 2.00 | .008 | 1.40 | .009 | | | 1.90 | .006 | 2.00 | .007 | 2.00 | .005 |
| 34 | 1.52 | .008 | 2.00 | .008 | | | 2.06 | .007 | | | 1.55 | .008 |
| 35 | 1.18 | .009 | 2.00 | .009 | | | | | | | | |
| Total & ave. | 8.70 | 0.0072 | 7.9 | 0.0086 | 3.37 | 0.006 | 7.31 | 0.0067 | 6.18 | 0.0060 | 7.55 | 0.0059 |
| Three upper units Total & ave. | 17.44 | 0.0072 | 18.45 | 0.0091 | 13.42 | 0.0061 | 16.37 | | 15.59 | 0.0056 | 17.01 | 0.0062 |
| Middle Gray | | | | | | | | | | | | |
| 41 | | | 2.00 | 0.001 | 1.32 | 0.003 | 0.70 | 0.004 | 1.40 | 0.004 | 0.70 | 0.004 |
| 42 | | | 2.00 | .004 | 1.62 | .003 | 0.90 | .004b | 2.00 | .003 | 1.85 | .004 |
| 43 | | | 2.00 | .001 | 1.33 | .003 | 1.85 | .002 | 1.83 | .002 | 1.85 | .004 |
| 44 | | | 2.00 | .003 | 1.44 | .002 | 1.85 | .002 | 1.96 | .002 | 1.85 | .004 |
| 45 | | | 1.70 | .001 | | | 1.85 | .003 | 1.79 | .004 | 1.85 | .004 |
| 46 | | | | | | | 1.85 | .003 | | | 1.19 | .002 |
| 47 | | | | | | | | | | | | |
| Total & ave. | 11.68 | * | 9.70 | 0.0020 | 5.71 | 0.0027 | 9.00 | 0.0028 | 8.98 | 0.0029 | 9.29 | 0.0037 |
| Lower Black | | | | | | | | | | | | |
| 51 | | | 1.25 | 0.002 | 1.23 | 0.001 | 0.74 | 0.005 | 2.10 | 0.005 | 1.95 | 0.005 |
| 52 | | | 1.50 | .005 | 1.25 | .003 | 2.00 | | 2.00 | .005 | 2.00 | .008 |
| 53 | | | 1.15 | .004 | d | * | 2.00 | .004 | 2.00 | .005 | 2.00 | .008 |
| 54 | | | 0.90 | .003 | d | * | 2.00 | .004 | | | | |
| Total & ave. | 2.50 | * | 4.80 | 0.0036 | 10.38 | 0.0020 | 6.74 | | 6.10 | 0.005 | 5.95 | 0.0070 |

| Sample no. | LC-30 Thickness | LC-30 Uranium (percent) | LC-33 Thickness | LC-33 Uranium (percent) | LC-50 Thickness | LC-50 Uranium (percent) | LC-51 Thickness | LC-51 Uranium (percent) | LC-55 Thickness | LC-55 Uranium (percent) | LC-56 Thickness | LC-56 Uranium (percent) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Maury | | | | | | | | b | | | | e |
| 1 | 1.88 | 0.002 | 1.37 | 0.003b | 1.80 | 0.003 | 1.24 | | 1.80 | | | |
| 2 | | | | | | | | | | | | |
| Total & ave. | 1.88 | 0.002 | 1.37 | 0.003 | 1.80 | 0.003 | 1.24 | | 1.80 | | 2.50 | * |
| Top Black | | | | | | | | | | | | |
| 11 | | | | | | | | | 0.80 | | 2.00a | 0.011 |
| 12 | 1.33 | 0.009 | 1.61 | 0.007 | 1.82 | 0.011 | 1.75 | 0.009 | 1.30 | | 2.00 | .009 |
| 13 | 2.00 | .007 | 2.10 | .011 | 2.00 | .011 | 1.80 | .009 | 1.35 | | 2.25 | .009 |
| 14 | 1.63 | .005 | 1.41 | .009 | 1.85 | .011 | 1.98 | .009 | 1.75 | | | |
| 15 | | | | | | | | | 1.20 | | | |
| 16 | | | | | | | | | 1.20 | | | |
| 17 | | | | | | | | | | | | |
| 18 | | | | | | | | | | | | |
| Total & ave. | 4.96 | 0.0068 | 5.12 | 0.0091 | 5.67 | 0.011 | 5.53 | 0.009 | 7.60 | | 6.25 | 0.0096 |
| Upper silt | | | | | | | | | | | | |
| 21 | 1.19 | 0.005 | 1.58 | 0.007 | 1.35 | 0.009 | 1.58 | 0.008 | 2.10 | | 2.5 | 0.005 |
| 22 | 1.31 | .005 | 1.27 | .004 | 1.22 | .007 | 1.40 | .009 | | | | |
| Total & ave. | 2.50 | 0.005 | 2.85 | 0.0057 | 2.57 | 0.0081 | 2.98 | 0.0085 | 2.10 | | 2.5 | 0.005 |
| Middle Black | | | | | | | | | | | | |
| 31 | 2.06 | 0.005 | 1.97 | 0.006 | 2.01 | 0.009 | 1.82 | 0.007 | 1.90 | | 2.0 | 0.008 |
| 32 | 2.02 | .005 | 1.52 | .005 | 2.01 | .009 | 1.84 | .007 | 1.90 | | 2.0 | .007 |
| 33 | 2.00 | .006 | 1.92 | .007 | 2.01 | .009 | 1.71 | .008 | 2.00 | | 2.0 | .007 |
| 34 | 1.65 | .007 | 1.62 | .008 | 2.01 | .010 | 1.47 | .009 | 1.90 | | 1.65 | .007 |
| 35 | | | 1.50 | .007 | 2.01 | .011 | 1.60 | .007 | | | | |
| Total & ave. | 7.73 | 0.0057 | 8.53 | 0.0066 | 10.05 | 0.0096 | 8.44 | 0.0076 | 7.70 | | 7.65 | 0.0073 |
| Three upper units Total & ave. | 15.19 | 0.0060 | 16.50 | 0.0072 | 18.29 | 0.0100 | 16.95 | 0.0082 | 17.40 | | 16.40 | 0.0078 |
| Middle Gray | | | | | | | | | | | | |
| 41 | 1.70 | 0.004 | 1.26 | 0.004 | 0.87 | 0.003 | 1.92 | 0.004 | 0.50 | | | |
| 42 | 2.00 | .003 | 1.93 | .005 | 2.00 | .004 | 1.83 | .005 | 2.00 | | | |
| 43 | 2.00 | .003 | 1.37 | .003 | 2.00 | .002 | 1.58 | .003 | 2.00 | | | |
| 44 | 1.67 | .003 | 1.93 | .003 | 2.00 | .002 | 2.04 | .004 | 2.00 | | | |
| 45 | 1.90 | .003 | 1.76 | .003 | 2.00 | .004 | 1.38 | .003 | 2.00 | | | |
| 46 | | | 2.18 | .003 | 1.89 | .001 | 1.76 | .003 | | | | |
| 47 | | | | | | | | | | | | |
| Total & ave. | 9.27 | 0.0032 | 10.43 | 0.0035 | 10.76 | 0.0026 | 10.51 | 0.0037 | 8.50 | | 8.82 | * |
| Lower Black | | | | | | | | | | | | |
| 51 | 1.83 | 0.003 | 1.69 | 0.004 | 1.64 | 0.004 | 1.55 | 0.004 | 2.00 | | 2.09 | 0.004 |
| 52 | 1.68 | .006 | 1.50 | .006 | 1.81 | .006 | 1.70 | .007 | 1.90 | | 2.09 | .007 |
| 53 | | | 2.00 | .008 | 1.80 | .004 | 1.76 | .006 | 1.80 | | 2.10 | .005 |
| 54 | | | 1.28 | .004 | 1.80 | .003 | 1.69 | .005 | | | | |
| Total & ave. | 3.51 | 0.0044 | 6.47 | 0.0057 | 7.05 | 0.0043 | 6.70 | 0.0055 | 5.70 | | 6.28 | 0.0053 |

| Sample no. | LC-101 Thickness | LC-101 Uranium (percent) | LC-102 Thickness | LC-102 Uranium (percent) | LC-103 Thickness | LC-103 Uranium (percent) | LC-105A Thickness | LC-105A Uranium (percent) | | LC-113A Thickness | LC-113A Uranium (percent) | | Gruetli 10M-1 Sample no. | Gruetli 10M-1 Thickness | Gruetli 10M-1 Uranium (percent) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Maury | f | | | | | b | | | b | | | b | | | |
| 1 | | | 0.50 | 0.002 | 0.5 | 0.003 | 1.25 | 0.001 | 0.005 | | | | | | |
| 2 | | | | | | | | | | | | | | | |
| Total & ave. | | | 3.3g | | 1.6g | | 1.55g | | | | | | | | |
| Top Black | | | | | | | | | | | | | | | |
| 11 | | | 0.25 | 0.003 | | | | | | | | | | | |
| 12 | | | 1.95 | .007 | 2.5 | 0.010 | 1.60 | 0.007 | 0.009 | 2.1 | 0.005 | 0.009 | 1 | 2.0 | 0.012 |
| 13 | | | 2.00 | .009 | 2.0 | .009 | 1.15 | .007 | .010 | 1.1 | .004 | .008 | 2 | 1.5 | .009 |
| 14 | 4.0 | 0.009 | 1.90 | .007 | 1.7 | .007 | 1.20 | .007 | .010 | 2.5 | .002 | .006 | 3 | 1.0 | .011 |
| 15 | 1.5 | .006 | | | 0.4 | j | 1.05 | .004 | .007 | 1.0 | .005 | .008 | 4 | 1.5 | .010 |
| 16 | | | | | | | | | | 2.0m | .004 | .008 | 5 | 1.5 | .009 |
| 17 | | | | | | | | | | 1.0m | .005 | .008 | | | |
| 18 | | | | | | | | | | 1.8m | .002 | .007 | | | |
| Total & ave. | f | | 6.10 | 0.0074 | 6.6 | 0.0089 | 5.0 | 0.0065 | 0.0091 | 11.5 | 0.0036 | 0.0076 | | 7.5 | 0.0103 |
| Upper silt | | | | | | | | | | | | | | | |
| 21 | 2.0 | 0.005 | 1.3 | 0.006 | 1.1 | 0.005 | 1.35 | 0.003 | 0.006 | | | | | | |
| 22 | | | 1.2 | .005 | | | | | | | | | | | |
| Total & ave. | f | | 2.5 | 0.0055 | 1.1 | 0.005 | 1.35 | 0.003 | 0.006 | m | | | | | |
| Middle Black | | | | | | | | | | | | | | | |
| 31 | | | 1.8 | 0.007 | 1.9 | 0.006 | 2.10 | 0.004 | 0.014 | | | | 6 | 2.0 | 0.006 |
| 32 | | | 1.5 | .007 | 3.1k | .007 | 1.70 | .004 | .007 | | | | 7 | 1.5 | .007 |
| 33 | | | 1.8 | .007 | 2.0 | .008 | 1.30 | | .007 | | | | 8 | 2.0 | .006 |
| 34 | | | 2.0 | .008 | | | 1.60 | .004 | .008 | | | | 9 | 2.0 | .006 |
| 35 | | | | | | | 0.95 | | .009 | | | | | | |
| Total & ave. | | | 7.1 | 0.0073 | 7.0 | 0.0070 | 7.65 | | 0.0094 | m | | | | 7.5 | 0.0062 |
| Three upper units Total & ave. | f | | 15.7 | 0.0071 | 14.7 | 0.0077 | 14.0 | | 0.0089 | 11.5 | 0.0036 | 0.0076 | | 15.0 | 0.0082 |
| Middle Gray | | | | | | | | | | | | | | | |
| 41 | | | 2.0 | 0.002 | 1.9k | 0.004 | 2.05 | 0.002 | 0.004 | 1.3 | 0.001 | 0.004 | | | |
| 42 | | | 1.8 | .003 | 2.3 | .004 | 2.10 | .001 | .004 | 2.0 | .001 | .004 | | | |
| 43 | | | 2.0h | .003 | 2.3 | .002 | 2.00 | .001 | .004 | 1.5 | .001 | .004 | | | |
| 44 | | | 2.0 | .003 | 2.5 | .003 | 2.05 | .001 | .004 | 1.6 | .001 | .003 | | | |
| 45 | | | 1.8h | .003 | | | 1.40 | .001 | .004 | 2.0 | .001 | .003 | | | |
| 46 | | | | | | | | | | | | | | | |
| 47 | | | | | | | | | | | | | | | |
| Total & ave. | | | 10.35 | 0.0028 | 9.0 | 0.0032 | 9.60 | 0.0012 | 0.004 | 8.4 | 0.001 | 0.0036 | | | |
| Lower Black | | | | | | | | | | | | | | | |
| 51 | | | 1.25 | 0.004 | 1.9 | 0.005 | 1.95 | 0.002 | 0.005 | 2.0 | 0.002 | 0.005 | 10 | 2.5 | 0.003 |
| 52 | | | 1.9 | .004 | 2.0 | .006 | 2.00 | .003 | .007 | | | | 11 | 2.0 | .003 |
| 53 | | | 2.6 | .004 | 1.0 | .006 | 1.90 | .002 | .005 | | | | 12 | 2.0 | .003 |
| 54 | | | | | 1.5 | .005 | | | | | | | 13 | 1.5 | .002 |
| Total & ave. | | | 5.75 | 0.004 | 6.4 | 0.0055 | 5.85 | 0.0023 | 0.0057 | 2.0 | 0.002 | 0.005 | | 8.0 | 0.0028 |

* Interval not sampled; where thickness is not shown, interval is wholly or partially concealed. a Most of sample 11 at LC-1 and all at LC-56 is non-phosphatic black shale. b Radiometric assay. c 5.05 ft. concealed between samples 53 and 54 at LC-2. d Lowest 7.90 ft. at LC-11 under water at time of sampling. e LC-56 assays by Tracerlab method. f Core incomplete at LC-101.
g Maury incompletely cored at LC-102, -103, -105A. h No core recovered for 0.5 and 0.25 ft. respectively, below samples indicated at drill hole LC-102. j Lost core for 0.4 ft. at LC-103. k 0.9 and 0.5 ft. of core lost from intervals 32 and 41 at LC-103. m Upper silt missing at LC-113A, so Top Black and Middle Black could not be differentiated; samples 16-18 may be Middle Black.

Table 8.--Summary of sample thicknesses and assays, Block 4 (thicknesses in feet and hundredths)

| Sample no. | 13L-8 Thickness | 13L-8 Uranium (percent) | 13L-11 Thickness | 13L-11 Uranium (percent) | 13L-13 Thickness | 13L-13 Uranium (percent) | 13L-17 Thickness | 13L-17 Uranium (percent) | 13L-20 Thickness | 13L-20 Uranium (percent) | 13L-22 Thickness | 13L-22 Uranium (percent) | 13M-1 Thickness | 13M-1 Uranium (percent) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Maury | | | | | | | | | | | | | | |
| 1 | | | 1.57 | 0.001 | | | | | | | 2.15 | 0.001 | | |
| Total & ave. | 0.80 | * | 1.57 | 0.001 | 0.80 | * | | * | 2.37 | * | 2.15 | 0.001 | 1.00 | * |
| Top Black | | | | | | | | | | | | | | |
| 11 | 1.19 | | | | | | | | 1.65 | 0.004 | | | | |
| 11A | | | 1.17 | 0.002 | | | | | | | 1.04 | 0.002 | 0.72 | 0.003 |
| 11B | | | 1.71 | .003 | | | | | | | 1.80 | .003 | 1.98 | .003 |
| 11C | | | | | | | | | | | 1.79 | .004 | | |
| 12 | 1.95 | | 1.80 | .004 | 1.73 | 0.005 | | | 2.20 | .005 | 1.83 | .005 | 1.88 | .004 |
| 13 | 1.95 | | 1.90 | .003 | 1.70 | .005 | | | 2.20 | .006 | 1.89 | .005 | 2.00 | .006 |
| 14 | 1.95 | | 1.78 | .005 | 1.80 | .005 | | | 2.20 | .005 | 1.76 | .005 | 2.00 | .006 |
| 15 | 1.96 | | 1.63 | .005 | | | | | | | 1.76 | .004 | 2.00 | .006 |
| 16 | | | | | | | | | | | | | 1.80 | .006 |
| Total & ave. | 9.00 | | 9.99 | 0.0037 | 5.23 | 0.0050 | | * | 8.25 | 0.0050 | 11.87 | 0.0041 | 12.38 | 0.0050 |
| Upper silt | | | | | | | | | | | | | | |
| 21 | 1.50 | | 1.32 | 0.005 | 1.46 | 0.004 | 1.67 | 0.003 | 1.92 | 0.003 | 1.52 | 0.004 | 0.85 | 0.004 |
| 22 | 1.55 | | 1.31 | .002 | 1.50 | .003 | | | 1.30 | .003 | 1.50 | .002 | 1.99 | .005 |
| Total & ave. | 3.05 | | 2.63 | 0.0035 | 2.96 | 0.0035 | 1.67 | 0.0030 | 3.22 | 0.0030 | 3.02 | 0.0030 | 2.84 | 0.0045 |
| Middle Black | | | | | | | | | | | | | | |
| 31 | | | 1.55 | 0.004 | 1.45 | 0.004 | 1.50 | 0.004 | 2.04 | 0.004 | 2.00 | 0.005 | 1.94 | 0.004 |
| 32 | | | 1.55 | .004 | 1.50 | .005 | 1.50 | .004 | 2.04 | .004 | | | 1.69 | .005 |
| 33 | | | 1.55 | .004 | | | 1.34 | .003 | 2.04 | .004 | | | 1.69 | .005 |
| 34 | | | | | | | | | | | | | 1.69 | .005 |
| Total & ave. | | * | 4.65 | 0.0040 | 2.95 | 0.0045 | 4.34 | 0.0037 | 6.12 | 0.0040 | 2.00 | 0.0050 | 7.01 | 0.0047 |
| Three upper units Total & ave. | 12.05 | | 17.27 | 0.0038 | 11.15 | 0.0045 | | | 17.59 | 0.0043 | 16.89 | 0.0040 | 22.23 | 0.0049 |
| Middle Gray | | | | | | | | | | | | | | |
| 41 | | | | | | | | | | | 1.76 | 0.002 | | |
| 42 | | | | | | | | | | | 1.88 | .003 | | |
| 43 | | | | | | | | | | | 1.65 | .002 | | |
| 44 | | | | | | | | | | | | | | |
| 45 | | | | | | | | | | | | | | |
| 46 | | | | | | | | | | | | | | |
| Total & ave. | | * | 8.07 | * | 7.57 | * | 6.23 | * | 8.93 | * | 5.29 | 0.0024 | 8.03 | * |
| Lower Black | | | | | | | | | | | | | | |
| 51 | | | 2.02 | 0.002 | 1.80 | 0.003 | 1.33 | 0.002 | 1.53 | 0.003 | 2.01 | 0.003 | 2.07 | 0.003 |
| 52 | | | 2.01 | .002 | 1.80 | .003 | 1.50 | .003 | 1.60 | .004 | 2.01 | .002 | 1.76 | .003 |
| 53 | | | 2.02 | .002 | 1.80 | .002 | 1.50 | .002 | 1.70 | .004 | 2.02 | .002 | 1.76 | .003 |
| 54 | | | | | | | 1.78 | .001 | 1.70 | .003 | | | | |
| Total & ave. | | * | 6.05 | 0.0020 | 5.40 | 0.0027 | 6.11 | 0.0020 | 6.53 | 0.0035 | 6.04 | 0.0023 | 5.59 | 0.0030 |

| Sample no. | 13M-4 Thickness | 13M-4 Uranium (percent) | 13M-5 Thickness | 13M-5 Uranium (percent) | 13M-7 Thickness | 13M-7 Uranium (percent) | 13M-10 Thickness | 13M-10 Uranium (percent) | 13M-19 Thickness | 13M-19 Uranium (percent) | 13M-23 Thickness | 13M-23 Uranium (percent) | 13M-24 Thickness | 13M-24 Uranium (percent) | Average |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Maury | | | | | | | | | | | | | | | |
| 1 | | | | | | | 1.50 | 0.002 | | | | | | | |
| Total & ave. | 1.63 | * | 1.71 | * | 1.06 | * | 1.50 | 0.002 | 1.30 | * | 0.27 | * | 1.53 | * | 0.0013 |
| Top Black | | | | | | | | | | | | | | | |
| 11 | | | 1.55 | 0.003 | 2.10 | 0.005 | | | 2.12 | 0.003 | | | | | |
| 11A | 1.37 | 0.004 | | | | | 1.19 | 0.003 | | | 1.11 | 0.002 | 1.33 | 0.002 | |
| 11B | 1.19 | .004 | | | | | 1.42 | .004 | | | 1.58 | .003 | 1.32 | .003 | |
| 11C | | | | | | | 1.30 | .004 | | | | | | | |
| 12 | 1.85 | .006 | 1.53 | .004 | 1.80 | .005 | 1.94 | .007 | 1.85 | .004 | 1.77 | .005 | 1.72 | .004 | |
| 13 | 1.84 | .004 | 1.38 | .005 | 1.83 | .003 | 1.87 | .008 | 1.85 | .005 | 1.80 | .003 | 2.02 | .004 | |
| 14 | 1.85 | .005 | 1.25 | .005 | 1.84 | .005 | 1.97 | .008 | 1.85 | .006 | 1.80 | .005 | 2.02 | .003 | |
| 15 | 1.84 | .005 | 1.32 | .005 | 1.70 | .005 | 1.95 | .008 | 1.85 | .003 | 1.80 | .006 | 2.01 | .003 | |
| 16 | | | | | 1.70 | .004 | 1.84 | .004 | 1.85 | .003 | 1.40 | .003 | | | |
| Total & ave. | 9.94 | 0.0047 | 7.03 | 0.0043 | 10.97 | 0.0045 | 13.38 | 0.0060 | 11.37 | 0.0040 | 11.26 | 0.0040 | 10.42 | 0.0032 | 0.0045 |
| Upper silt | | | | | | | | | | | | | | | |
| 21 | 1.89 | 0.003 | 1.35 | 0.003 | 1.40 | 0.006 | 1.88 | 0.003 | 1.67 | 0.003 | 1.42 | 0.002 | 1.85 | 0.003 | |
| 22 | 1.17 | .004 | 1.34 | .002 | 1.47 | .003 | 1.12 | .002 | | | 1.40 | .002 | 1.85 | .002 | |
| Total & ave. | 3.06 | 0.0033 | 2.69 | 0.0025 | 2.87 | 0.0044 | 3.00 | 0.0026 | 1.67 | 0.0030 | 2.82 | 0.0020 | 3.70 | 0.0025 | 0.0031 |
| Middle Black | | | | | | | | | | | | | | | |
| 31 | 2.10 | 0.005 | 1.66 | 0.003 | 1.90 | 0.003 | 1.67 | 0.003 | 2.10 | 0.003 | 1.95 | 0.002 | 1.25 | 0.001 | |
| 32 | 2.11 | .006 | 1.67 | .003 | 1.90 | .004 | 1.88 | .004 | 2.11 | .004 | 1.90 | .003 | 1.26 | .002 | |
| 33 | 2.10 | .006 | 1.67 | .004 | 1.95 | .002 | 1.27 | .004 | | | | | | | |
| 34 | 2.11 | .006 | 1.67 | .004 | | | 1.26 | .004 | | | | | | | |
| Total & ave. | 8.42 | 0.0057 | 6.67 | 0.0035 | 5.75 | 0.0029 | 6.08 | 0.0037 | 4.21 | 0.0035 | 3.85 | 0.0025 | 2.51 | 0.0015 | 0.0038 |
| Three upper units Total & ave. | 21.42 | 0.0049 | 16.39 | 0.0037 | 19.59 | 0.0041 | 22.46 | 0.0050 | 17.25 | 0.0038 | 17.93 | 0.0034 | 16.63 | 0.0028 | 0.0041 |
| Middle Gray | | | | | | | | | | | | | | | |
| 41 | | | | | | | 1.72 | 0.002 | | | | | | | |
| 42 | | | | | | | 0.39 | .002 | | | | | | | |
| 43 | | | | | | | 0.76 | .002 | | | | | | | |
| 44 | | | | | | | 2.25 | .002 | | | | | | | |
| 45 | | | | | | | 1.48 | .002 | | | | | | | |
| 46 | | | | | | | 1.47 | .002 | | | | | | | |
| Total & ave. | 9.39 | * | 8.38 | * | 5.81 | * | 8.07 | 0.0020 | 6.04 | * | 5.01 | * | 4.38 | * | 0.0022 |
| Lower Black | | | | | | | | | | | | | | | |
| 51 | 1.58 | 0.004 | 1.63 | 0.002 | 1.65 | 0.003 | 1.50 | 0.002 | 1.50 | 0.002 | 1.57 | 0.003 | 2.12 | 0.002 | |
| 52 | 1.56 | .005 | 1.64 | .003 | 1.70 | .002 | 1.89 | .002 | 1.54 | .002 | 1.40 | .002 | 2.12 | .005 | |
| 53 | 1.85 | .005 | 1.64 | .003 | 1.80 | .001 | 1.87 | .002 | 1.68 | .002 | 1.60 | .002 | | | |
| 54 | 1.72 | .003 | 1.64 | .002 | | | 1.23 | .001 | | | | | | | |
| Total & ave. | 6.71 | 0.0042 | 6.55 | 0.0025 | 5.15 | 0.0019 | 6.49 | 0.0018 | 4.72 | 0.0020 | 4.57 | 0.0023 | 4.24 | 0.0035 | 0.0026 |

* Interval not sampled: where thickness is not shown, interval is wholly or partially concealed.

Table 9.--Summary of thicknesses and assays, Block 5 (thicknesses in feet and hundredths)

| | LC-34 | | LC-60 | | R-C1 | | R-C2 | | R-C3 | | R-C4 | | R-C5 | | R-C6 | | R-C7 | | R-C8 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample no. | Thickness | Uranium (percent) | Thickness | Uranium (percent) | Thickness | Uranium (percent) | Thickness | Uranium (percent) | Thickness | Uranium (percent) | Thickness | Uranium (percent) | Thickness | Uranium (percent) | Thickness | Uranium (percent) | Thickness | Uranium (percent) | Thickness | Uranium (percent) |
| Maury | | a | | a | | | | b | | | | | | | | | | | | |
| 1 | | | 2.52 | 0.002 | | | | | | | | | | | | | | | | |
| 2 | | | 1.69 | .003 | | | | | | | | | | | | | | | | |
| Total & ave. | 4.30 | * | 4.21 | 0.0024 | 4.00 | * | 3.10 | * | | * | 3.52 | * | 3.40 | * | | * | 3.20 | * | 2.16 | * |
| Top Black | | | | | | | | | | | | | | | | | | | | |
| 11 | 0.85 | * | | | | | | | | | | | 0.65 | 0.002 | | | | | 0.84 | |
| 12 | 1.34 | 0.006 | 1.56 | 0.008 | 1.50 | | 0.94 | 0.009 | 1.20 | | 1.36 | | 1.26 | .006 | 1.75 | | 1.06 | | 1.82 | |
| 13 | 1.84 | .007 | 2.00 | .008 | 1.50 | | 1.50 | .009 | 0.80 | | 1.80 | | 1.14 | .006 | 1.50 | | 1.35 | | 1.24 | |
| 14 | 1.88 | .008 | 2.00 | .009 | 1.50 | | 1.50 | .009 | | | 0.96 | | 1.61 | .004 | 1.50 | | 0.74 | | 1.10 | |
| 15 | 1.88 | .008 | | | | | | | | | | | | | 1.27 | | | | 1.17 | |
| Total & ave. | 7.79 | 0.0073 | 5.56 | 0.0084 | 4.50 | | 3.94 | 0.009 | 2.00 | | 4.12 | | 4.66 | 0.0048 | 6.02 | | 3.15 | | 6.17 | |
| Upper silt | | | | | | | | | | | | | | | | | | | | |
| 21 | 2.17 | 0.006 | 2.29 | 0.006 | 1.34 | | 1.22 | 0.006 | 1.24 | | 1.93 | | 1.50 | 0.004 | 1.22 | | 1.77 | | 1.85 | |
| Total & ave. | 2.17 | 0.006 | 2.29 | 0.006 | 1.34 | | 1.22 | 0.006 | 1.24 | | 1.93 | | 1.50 | 0.004 | 1.22 | | 1.77 | | 1.85 | |
| Middle Black | | | | | | | | | | | | | | | | | | | | |
| 31 | 2.02 | 0.005 | 1.77 | 0.007 | 1.90 | | 2.00 | 0.006 | 1.58 | | 1.35 | | 2.04 | 0.004 | 1.50 | | 1.20 | | 1.65 | |
| 32 | 0.70 | .007 | 2.10 | .007 | 2.00 | | 2.00 | .006 | 1.58 | | 1.50 | | 1.75 | .005 | 1.57 | | 1.79 | | 1.84 | |
| 33 | 1.50 | .008 | 2.30 | .007 | 2.00 | | 2.00 | .007 | 1.50 | | 1.50 | | 1.16 | .005 | 1.50 | | 1.67 | | 1.10 | |
| 34 | | | | | 2.00 | | 1.10 | .007 | 1.80 | | 1.65 | | 1.04 | .005 | 1.54 | | 1.50 | | 0.95 | |
| 35 | | | | | | | | | | | 2.00 | | | | | | | | | |
| Total & ave. | 4.22 | 0.0064 | 6.17 | 0.007 | 7.90 | | 7.10 | 0.0064 | 6.46 | | 8.00 | | 5.99 | 0.0046 | 6.11 | | 6.16 | | 5.54 | |
| Middle Gray | | | | | | | | | | | | | | | | | | | | |
| 41 | 1.60 | 0.004 | 1.90 | 0.005 | | | | | 0.51 | | | | | | | | | | | |
| 42 | 2.17 | .004 | 2.07 | .003 | | | | | 0.27 | | | | | | | | | | | |
| 43 | 2.01 | .005 | 2.28 | .005 | | | | | 1.97 | | | | | | | | | | | |
| 44 | 2.15 | .004 | 2.24 | .004 | | | | | 1.35 | | | | | | | | | | | |
| 45 | | | | | | | | | 0.97 | | | | | | | | | | | |
| 46 | | | | | | | | | 1.25 | | | | | | | | | | | |
| 47 | | | | | | | | | 1.08 | | | | | | | | | | | |
| Total & ave. | 7.93 | 0.0043 | 8.49 | 0.0042 | 9.00 | * | 9.45 | * | 7.40 | | 7.35 | * | 8.23 | * | 7.82 | * | 9.15 | * | 8.60 | * |
| Lower Black | | | | | | | | | | | | | | | | | | | | |
| 51 | 1.53 | 0.005 | 1.11 | 0.004 | | | 2.00 | 0.005 | 2.00 | | 1.30 | | 1.71 | 0.003 | 2.00 | | 1.94 | | 1.10 | |
| 52 | 1.76 | .005 | 1.87 | .005 | | | 2.00 | .005 | 1.94 | | 1.97 | | 1.50 | .004 | 2.00 | | 1.98 | | 2.00 | |
| 53 | 1.80 | .005 | 1.69 | .006 | | | 1.50 | .006 | 1.41 | | 1.50 | | 1.50 | .003 | 1.50 | | 1.98 | | 2.01 | |
| 54 | | | 1.73 | .005 | | | 0.98 | .005 | 2.00 | | | | | | 1.83 | | | | | |
| 55 | | | | | | | | | 1.54 | | | | | | | | | | | |
| Total & ave. | 5.09 | 0.005 | 6.40 | 0.0051 | | * | 6.48 | 0.0052 | 8.89 | | 4.77 | | 4.71 | 0.0033 | 7.33 | | 5.90 | | 5.11 | |

* Interval not sampled; where thickness is not shown, interval is wholly or partially concealed.
a Radiometric assays at LC-34 and -60.
b Assays at R-C2 by Tracerlab method; assay of interval 13 confirmed by assays on two special samples from that interval.

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Table 10.--Summary of sample thicknesses and assays, Block 6 (thicknesses in feet and hundredths)

| | 10J-8 | | 10J-9 | | 10K-3 | | 10K-4 | | 10K-5 | | 10K-6 | | 10K-10 | | 10K-11 | | 11J-6 | | 11K-1 | | 11K-2 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample no. | Thickness | Uranium (percent) | Thickness | Uranium (percent) | Thickness | Uranium (percent) | Thickness | Uranium (percent) | Thickness | Uranium (percent) | Thickness | Uranium (percent) | Thickness | Uranium (percent) | Thickness | Uranium (percent) | Thickness | Uranium (percent) | Thickness | Uranium (percent) | Thickness | Uranium (percent) |
| Top Black | | | | | | | | | | | | | | | | | | | | | | |
| 12 | 2.17 | | 2.04 | | 1.67 | | 1.59 | | 1.80 | | | | 4.27 | | 1.82 | | 1.88 | 0.005 | 2.11 | | 1.48 | |
| 13 | 2.15 | | 1.72 | | 1.64 | | 1.95 | | 1.83 | | | | | | 1.96 | | 2.02 | .004 | 2.11 | | 1.32 | |
| 14 | 2.15 | | 1.84 | | 1.64 | | 1.94 | | 1.74 | | | | | | 1.91 | | | | | | | |
| 15 | 2.15 | | 1.78 | | | | 1.95 | | 1.80 | | | | | | 1.82 | | | | | | | |
| 16 | | | 1.89 | | | | | | | | | | | | 1.89 | | | | | | | |
| 17 | | | 1.83 | | | | | | | | | | | | | | | | | | | |
| 18 | | | 1.90 | | | | | | | | | | | | | | | | | | | |
| Total & ave. | 8.62 | | 13.00 a | | 4.95 | | 7.43 | | 7.17 | | | * | 4.27 | | 9.40 | | 3.90 | 0.0045 | 4.22 | | 2.80 | |
| Upper silt | | | | | | | | | | | | | | | | | | | | | | |
| 21 | 0.73 | | | | 1.43 | | 0.86 | | 0.79 | | | | | | | | 1.48 | 0.003 | 1.00 | | 2.24 | |
| 22 | | | | | | | | | | | | | | | | | 1.54 | .004 | 1.75 | | | |
| Total & ave. | 0.73 | | a | | 1.43 | | 0.86 | | 0.79 | | | * | | | | | 3.02 | 0.0035 | 2.75 | | 2.24 | |
| Middle Black | | | | | | | | | | | | | | | | | | | | | | |
| 31 | 2.12 | | | | 2.07 | | 1.55 | | 1.68 | | 1.80 | 0.004 | | | | | | | 1.99 | | 1.58 | |
| 32 | 2.10 | | | | 2.08 | | 1.68 | | 2.00 | | 1.50 | .005 | | | | | | | 1.95 | | 1.31 | |
| 33 | 2.10 | | | | 2.08 | | 1.87 | | 2.00 | | 1.85 | .004 | | | | | | | 1.87 | | 1.53 | |
| 34 | | | | | | | 1.65 | | | | | | | | | | | | | | | |
| Total & ave. | 6.32 | | a | | 6.23 | | 6.75 | | 5.68 | | 5.15 | 0.0043 | | | | | | * | 5.81 | | 4.42 | |
| Middle Gray | | | | | | | | | | | | | | | | | | | | | | |
| 41 | 1.95 | | | | | | | | | | | | | | | | | | | | | |
| 42 | 2.03 | | | | | | | | | | | | | | | | | | | | | |
| Total & ave. | 3.98 | | 0.42 | * | 5.13 | * | 3.71 | * | 2.52 | * | 8.72 | * | | | | | | * | 10.48 | * | | * |
| Lower Black | | | | | | | | | | | | | | | | | | | | | | |
| 51 | 1.07 | | | | 1.80 | | 2.09 | | 2.09 | | 1.95 | 0.002 | | | | | | | 2.00 | | | |
| 52 | | | | | 1.84 | | 2.09 | | 1.47 | | 2.00 | .003 | | | | | | | 1.90 | | | |
| 53 | | | | | 2.00 | | 2.09 | | 1.77 | | 1.95 | .004 | | | | | | | 1.96 | | | |
| 54 | | | | | 1.59 | | | | 2.00 | | | | | | | | | | 1.95 | | | |
| 55 | | | | | 1.70 | | | | | | | | | | | | | | | | | |
| Total & ave. | 1.07 | | | | 8.93 | | 6.27 | | 7.33 | | 5.90 | 0.0030 | | | | | | * | 7.81 | | | * |

* Interval not sampled: where thickness is not shown, interval is wholly or partially concealed.

a Upper silt missing at 10J-9, so Top Black and Middle Black could not be differentiated; believed that samples 16-18 are Middle Black.

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Table 11.--Summary of sample thicknesses and assays, Block 7 (thicknesses in feet and hundredths)

| | 14L-1 | | 14L-5 | | 14M-2 | | 14M-6 | | 14M-7 | | 14M-8 | | 14M-9 | | 14M-10 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample no. | Thickness | Uranium (percent) | Thickness | Uranium (percent) | Thickness | Uranium (percent) | Thickness | Uranium (percent) | Thickness | Uranium (percent) | Thickness | Uranium (percent) | Thickness | Uranium (percent) | Thickness | Uranium (percent) |
| Top Black | | | | | | | | | a | | | | | | | |
| 11 | 1.83 | | | | | | 2.09 | | | | | | | | | |
| 11A | | | 2.00 | | 1.50 | | | | 2.10 | | 1.51 | | 1.96 | | 2.12 | |
| 11B | | | 2.00 | | 1.50 | | | | 2.10 | | 1.50 | | 1.95 | | 2.11 | |
| 11C | | | 2.00 | | | | | | 2.11 | | | | 1.95 | | 2.11 | |
| 11D | | | 1.50 | | | | | | 2.11 | | | | 1.95 | | | |
| 11E | | | 1.43 | | | | | | 2.11 | | | | | | | |
| 11F | | | | | | | | | | | | | | | | |
| 11G | | | | | | | | | | | | | | | | |
| 12 | 1.84 | | 2.15 | | 2.00 | | 2.09 | | 2.00 | | 1.90 | | 1.95 | | 1.80 | |
| 13 | 2.00 | | 2.15 | | 2.00 | | 2.09 | | | | 1.90 | | 1.95 | | 2.00 | |
| 14 | 2.00 | | | | 2.00 | | 2.09 | | | | 2.00 | | 1.95 | | 2.00 | |
| 15 | 2.00 | | | | 1.78 | | 2.09 | | | | 2.00 | | 1.95 | | | |
| 16 | 2.00 | | | | | | | | | | 2.00 | | | | | |
| 17 | 2.00 | | | | | | | | | | 1.97 | | | | | |
| 18 | 2.00 | | | | | | | | | | | | | | | |
| 19 | | | | | | | | | | | | | | | | |
| 20 | | | | | | | | | | | | | | | | |
| Total & ave. | 15.67 | | 13.23 | | 10.78 | | 10.45 | | 12.53 | | 14.78 | | 15.61 | | 12.14 | |
| Upper silt | | | | | | | | | | | | | | | | |
| 21 | | | 1.80 | | 2.31 | | 2.17 | | 1.95 | | 1.83 | | 1.66 | | 1.76 | |
| 22 | | | 1.80 | | 2.32 | | 2.17 | | 1.95 | | 1.83 | | 1.66 | | 1.76 | |
| 23 | | | 1.81 | | | | 2.17 | | 1.95 | | 1.84 | | 1.66 | | 1.76 | |
| 24 | | | | | | | | | 1.95 | | | | | | | |
| Total & ave. | | | 5.41 | | 4.63 | | 6.51 | | 7.80 | | 5.50 | | 4.98 | | 5.28 | |
| Middle Black | | | | | | | | | | | | | | | | |
| 31 | | | | | 1.93 | | | | | | | | | | | |
| 32 | | | | | | | | | | | | | | | | |
| 33 | | | | | | | | | | | | | | | | |
| Total & ave. | | | | | 1.93 | | | | | | | | | | | |
| Middle Gray Total | | | | | 3.29 | * | | | | | | | | | | |
| Lower Black | | | | | | | | | | | | | | | | |
| 51 | | | | | 1.65 | | | | | | | | | | | |
| 52 | | | | | 1.65 | | | | | | | | | | | |
| 53 | | | | | 1.64 | | | | | | | | | | | |
| Total & ave. | | | | | 4.94 | | | | | | | | | | | |

| | 14M-11 | | 14M-13 | | 14M-14 | | 14M-15 | | 14M-16 | | 14N-3 | | 14N-4 | | 15N-12 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample no. | Thickness | Uranium (percent) | Thickness | Uranium (percent) | Thickness | Uranium (percent) | Thickness | Uranium (percent) | Thickness | Uranium (percent) | Thickness | Uranium (percent) | Thickness | Uranium (percent) | Thickness | Uranium (percent) |
| Top Black | | | | c | | | | | | | | | | | a | |
| 11 | 2.05 | | 2.00 | | | | 1.57 | | | | 2.00 | | | | | |
| 11A | | | | | 2.24 | | | | 1.85 | | | | 1.70 | | 2.00 | |
| 11B | | | | | 2.24 | | | | 2.00 | | | | 1.70 | | 2.00 | |
| 11C | | | | | | | | | | | | | 1.70 | | 2.00 | |
| 11D | | | | | | | | | | | | | | | 2.00 | |
| 11E | | | | | | | | | | | | | | | 2.00 | |
| 11F | | | | | | | | | | | | | | | 1.50 | |
| 11G | | | | | | | | | | | | | | | 1.51 | |
| 12 | 2.05 | | 2.00 | | 2.23 | | 1.57 | | 2.00 | | 2.00 | | 1.76 | | 1.82 | |
| 13 | 2.06 | | 2.00 | | 2.00 | | 2.00 | | 2.00 | | 1.83 | | 1.76 | | 1.82 | |
| 14 | 2.06 | | 2.00 | 0.007 | 2.00 | | 2.00 | | 2.00 | | 2.00 | | 1.76 | | | |
| 15 | 2.06 | | 2.00 | .008 | 1.66 | | 2.00 | | 2.00 | | 2.00 | | 1.77 | | | |
| 16 | | | 2.00 | | 1.67 | | 2.00 | | 2.00 | | 2.00 | | 1.77 | | | |
| 17 | | | 1.00 | | 1.67 | | | | | | | | | | | |
| 18 | | | | | 1.66 | | | | | | | | | | | |
| 19 | | | | | 1.67 | | | | | | | | | | | |
| 20 | | | | | 1.67 | | | | | | | | | | | |
| Total & ave. | 10.28 | | 13.00 | | 20.71 | | 11.14 | | 13.85 | | 11.83 | | 13.92 | | 16.65 | |
| Upper silt | | | | | | | | | | | | | | | | |
| 21 | 2.18 | | 0.82 | | 1.55 | | 1.30 | | 1.97 | | 1.57 | | 2.27 | | 1.18 | |
| 22 | | | b | * | | | 1.30 | | 2.00 | | 1.57 | | 2.26 | | | |
| 23 | | | | | | | | | 2.00 | | | | | | | |
| 24 | | | | | | | | | 2.00 | | | | | | | |
| Total & ave. | 2.18 | | 5.00 b | | 1.55 | | 2.60 | | 7.97 | | 3.14 | | 4.53 | | 1.18 | |
| Middle Black | | | | | | | | | | | | | | | | |
| 31 | 2.09 | | | | 1.79 | | 2.24 | | | | 1.83 | | | | | |
| 32 | | | | | 1.79 | | | | | | 1.83 | | | | | |
| 33 | | | | | 1.79 | | | | | | | | | | | |
| Total & ave. | 2.09 | | | | 5.37 | | 2.24 | | | | 3.66 | | | | | |
| Middle Gray Total | 6.97 | * | | | | | 2.77 | * | | | 1.38 | * | | | | |
| Lower Black | | | | | | | | | | | | | | | | |
| 51 | | | | | | | 2.02 | | | | 1.64 | | | | | |
| 52 | | | | | | | 2.03 | | | | 1.63 | | | | | |
| 53 | | | | | | | | | | | 1.63 | | | | | |
| Total & ave. | | | | | | | 4.05 | | | | 4.90 | | | | | |

* Interval not sampled; where thickness is not shown, interval is wholly or partially concealed.
a Samples at 14M-7 and 15N-12 may be partially assigned to incorrect units, but definite reassignments cannot be made yet.
b Section in part of 14M-13 poorly exposed; thickness estimated where indicated.
c Radiometric assay.

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Table 6.--Special samples from Eastern Highland Rim

| Sample no. | Block | Thick-ness (feet) | Distance below top of Top Black shale (feet) | Equivalent routine sample c | Date (month and year) | Weight (lbs.) | Desti-nation d | Uranium (percent) e |
|---|---|---|---|---|---|---|---|---|
| S-100 a | 7 | 5.00 | 0 - 5.00 | 11-12 | 10-47 | 10,000 | BMI | 0.0061 |
| S-100 | 7 | 5.00 | 0 - 5.00 | 11-12 | 10-47 | 4,000 | Y-12 | 0.0042 |
| S-100 | 7 | 5.00 | 0 - 5.00 | 11-12 | 10-47 | 200 | USGS | |
| S-100(1-9) b | 7 | 9.00 | 0 - 9.00 | 11-14 | 2-48 | 450 | USGS | 0.0067 |
| R-C2-113B | 5 | 1.50 | 0.94- 2.44 | 13 | 7-48 | 200 | BMI | 0.0092 |
| 113L | 5 | 1.50 | 0.94- 2.44 | 13 | 7-48 | 200 | Y-12 | 0.0090 |
| 213 | 5 | 1.50 | 0.94- 2.44 | 13 | 1-49 | 10,000 | BMI | 0.0097 |
| 313 | 5 | 1.50 | 0.94- 2.44 | 13 | 1-49 | 250 | USGS | |
| 152 | 5 | 2.00 | 23.71-25.71 | 52 | 1-49 | 250 | USGS | |
| R-C4-113B | 5 | 1.80 | 1.36- 3.16 | 13 | 8-48 | 200 | BMI | 0.0083 |
| 113L | 5 | 1.80 | 1.36- 3.16 | 13 | 8-48 | 200 | Y-12 | |
| 113M | 5 | 1.80 | 1.36- 3.16 | 13 | 8-48 | 50 | USGS | |
| LC-6-B | 1 | 3.0 | 1.98- 4.98 | (13-14) | 3-48 | 200 | BMI | 0.007 |
| L | 1 | 3.0 | 1.98- 4.98 | (13-14) | 3-48 | 200 | Y-12 | 0.0065 |
| M | 1 | 3.0 | 1.98- 4.98 | (13-14) | 3-48 | 40 | USGS | 0.007 |
| LC-10-B | 1 | 2.0 | 3.44- 5.44 | 14, (13, 15) | 3-48 | 200 | BMI | 0.008 |
| L | 1 | 2.0 | 3.44- 5.44 | 14, (13, 15) | 3-48 | 200 | Y-12 | |
| M | 1 | 2.0 | 3.44- 5.44 | 14, (13, 15) | 3-48 | 40 | USGS | 0.008 |
| LC-11-B | 1 | 2.0 | 10.05-12.05 | 31 | 3-48 | 200 | BMI | 0.006 |
| L | 1 | 2.0 | 10.05-12.05 | 31 | 3-48 | 200 | Y-12 | 0.0057 |
| M | 1 | 2.0 | 10.05-12.05 | 31 | 3-48 | 40 | USGS | 0.006 |
| LC-11-102B | 1 | 2.0 | 2.0 - 4.0 | 13 | 3-48 | 200 | BMI | 0.0045 |
| L | 1 | 2.0 | 2.0 - 4.0 | 13 | 3-48 | 200 | Y-12 | 0.0038 |
| M | 1 | 2.0 | 2.0 - 4.0 | 13 | 3-48 | 50 | USGS | |
| LC-15-A | 1 | 2.0 | 3.68- 5.68 | (14, 15) | 1-48 | 40 | USGS | 0.008 |
| B | 1 | 2.0 | 3.68- 5.68 | (14, 15) | 1-48 | 200 | Y-12 | 0.008 |
| C | 1 | 2.0 | 3.68- 5.68 | (14, 15) | 1-48 | 200 | BMI | 0.0075 |
| LC-15(1-5) | 1 | 5.0 | 2.28- 7.28 | 13, 14,(12, 15) | 3-48 | 2,000 | Y-12 | |
| LC-15-101 | 1 | 5.0 | 2.28- 7.28 | 13, 14,(12, 15) | 8-48 | 2,000 | BMI | 0.0078 |
| LC-17-B | 1 | 2.0 | 3.53- 5.53 | (13, 14) | 3-48 | 200 | BMI | 0.0075 |
| L | 1 | 2.0 | 3.53- 5.53 | (13, 14) | 3-48 | 200 | Y-12 | |
| M | 1 | 2.0 | 3.53- 5.53 | (13, 14) | 3-48 | 40 | USGS | 0.008 |
| LC-33-101B | 1 | 2.1 | 1.61- 3.71 | 13 | 6-48 | 200 | BMI | 0.0087 |
| L | 1 | 2.1 | 1.61- 3.71 | 13 | 6-48 | 200 | Y-12 | |
| M | 1 | 2.1 | 1.61- 3.71 | 13 | 6-48 | 50 | USGS | |
| LC-55-101 | 1 | 17.4 | 0 -17.4 | 11-34 | 2-49 | 2,000 | Y-12 | 0.007 |
| LC-201-101 | 1 | 6.25 | 2.25- 8.5 | 12-15 f | 1-49 | 20 | Y-12 | 0.0085 |
| 102 | 1 | 6.25 | 2.25- 8.5 | 12-15 f | 1-49 | 20 | Y-12 | 0.0085 |
| 103B | 1 | 6.25 | 2.25- 8.5 | 12-15 g | 2-49 | 20 | BMI | 0.0079 |
| L | 1 | 6.25 | 2.25- 8.5 | 12-15 g | 2-49 | 20 | Y-12 | |
| M | 1 | 6.25 | 2.25- 8.5 | 12-15 g | 2-49 | 20 | USGS | |
| 104B | 1 | 6.25 | 2.25- 8.5 | 12-15 h | 2-49 | 20 | BMI | 0.0082 |
| L | 1 | 6.25 | 2.25- 8.5 | 12-15 h | 2-49 | 20 | Y-12 | |
| M | 1 | 6.25 | 2.25- 8.5 | 12-15 h | 2-49 | 20 | USGS | 0.005 |
| 105 | 1 | 6.25 | 2.25- 8.5 | 12-15 j | 2-49 | 20 | Y-12 | |
| 106 | 1 | 6.25 | 2.25- 8.5 | 12-15 j | 2-49 | 20 | Y-12 | |
| 111 k | 1 | 6.25 | 2.25- 8.5 | 12-15 | 1-49 | 30,000 | BMI | |
| 112 | 1 | 6.25 | 2.25- 8.5 | 12-15 | 2-49 | 25,000 | Y-12 | 0.0082 |
| 113 | 1 | 6.25 | 2.25- 8.5 | 12-15 | 2-49 | 20,000 | BMI | 0.0084 |
| 114 | 1 | 5.6 | 2.9 - 8.5 | 12-15 | 2-49 | 25,000 | m | |

a S-100 same as 14M-2.
b Nine samples, each 1-foot thick, numbered from top.
c Numbers in parentheses indicate sample intervals partially represented.
d BMI = Battelle Memorial Institute.
e Only chemical assays included.
f Grab sample from sample LC-201-111.
g Cut of sidewall sample at position of LC-201-111, right wall.
h Cut of sidewall sample at position of LC-201-112, left wall.
j Grab sample from LC-201-112.
k About 5-6 tons remain in bin outside adit.
m Stored in adit, in case it is ever wanted.

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Table 12.--Oil yield of Chattanooga shale; modified Fischer assay by U. S. Bureau of Mines

| Sample no. | Yield of products: Weight percent: Oil | Weight percent: Water | Weight percent: Spent shale | Weight percent: Gas loss | Gal. per ton: Oil | Gal. per ton: Water | Specific Gravity of oil at 60°/60°F | Properties of spent shale, % of original shale: Ign. loss | % of original shale: Ash | Tendency to coke |
|---|---|---|---|---|---|---|---|---|---|---|
| LC-55- 1 | 0.1 | 2.0 | 97.8 | 0.1 | 0.3* | 4.8 | | 6.4 | 91.4 | None |
| -11 | 1.6 | 2.0 | 95.2 | 1.2 | 4.2* | 4.8 | | 10.9 | 84.3 | None |
| -12 to -16 | 3.1 | 2.4 | 91.1 | 3.4 | 7.9* | 5.7 | | 13.7 | 77.4 | None |
| -21 | 1.4 | 1.8 | 95.7 | 1.1 | 3.6* | 4.3 | | 7.7 | 88.0 | None |
| -31 to -33 | 3.6 | 2.4 | 92.0 | 2.0 | 9.1 | 5.8 | 0.946 | 11.0 | 81.0 | None |
| -34 | 5.0 | 2.6 | 89.9 | 2.5 | 12.7 | 6.2 | .947 | 14.8 | 75.1 | None |
| -41 to -45 | .7 | 1.8 | 96.7 | .8 | 1.8* | 4.3 | | 6.3 | 90.4 | None |
| -51, -52 | 3.4 | 2.0 | 93.3 | 1.3 | 8.8 | 4.8 | .932 | 10.7 | 82.6 | None |
| -53 | 4.1 | 1.3 | 93.2 | 1.4 | 10.3 | 3.1 | .946 | 10.7 | 82.5 | None |
| LC-101-14 | 4.7 | 1.2 | 91.6 | 2.5 | 11.7 | 2.9 | 0.959 | 15.6 | 76.0 | None |
| -15 | 3.5 | 1.4 | 92.7 | 2.4 | 8.9 | 3.4 | .949 | 12.6 | 80.1 | None |
| -21 | 2.2 | 1.1 | 95.9 | .8 | 5.5* | 2.6 | | 7.9 | 88.0 | None |
| LC-102- 1 | None | 2.0 | 97.9 | .1 | None | 4.8 | | 4.8 | 93.1 | None |
| -11 | .9 | .5 | 98.1 | .5 | 2.2* | 1.2 | | 6.0 | 92.1 | None |
| -12 | 4.1 | 2.0 | 90.8 | 3.1 | 10.2 | 4.8 | .957 | 15.5 | 75.3 | None |
| -13 | 4.1 | 2.1 | 90.7 | 3.1 | 10.2 | 5.0 | .955 | 15.5 | 75.2 | None |
| -14 | 3.8 | 1.5 | 91.4 | 3.3 | 9.6 | 3.6 | .955 | 13.1 | 78.3 | None |
| -21 | 2.5 | 1.1 | 95.4 | 1.0 | 6.3 | 2.6 | .934 | 9.2 | 86.2 | None |
| -22 | 1.6 | 1.1 | 96.5 | .8 | 4.1* | 2.6 | | 7.1 | 89.4 | None |
| -31 | 4.6 | 1.0 | 92.1 | 2.3 | 11.6 | 2.4 | .943 | 11.9 | 80.2 | None |
| -32 | 3.9 | 1.2 | 92.8 | 2.1 | 9.9 | 2.9 | .945 | 11.0 | 81.8 | None |
| -33 | 4.5 | 1.5 | 91.3 | 2.7 | 11.5 | 3.6 | .940 | 13.0 | 78.3 | None |
| -34 | 3.9 | 2.8 | 90.7 | 2.6 | 9.9 | 6.7 | .947 | 14.2 | 76.5 | None |
| -41 | 1.2 | 1.4 | 96.4 | 1.0 | 3.0* | 3.4 | | 6.2 | 90.2 | None |
| -42 | .3 | 1.6 | 98.1 | .0 | .6* | 3.8 | | 5.3 | 92.8 | None |
| -43 | .5 | 1.7 | 97.8 | .0 | 1.2* | 4.1 | | 5.2 | 92.6 | None |
| -44 | 2.1 | 1.6 | 96.2 | .1 | 5.2* | 3.8 | | 6.9 | 89.3 | None |
| -45 | .7 | 1.5 | 97.7 | .1 | 1.7* | 3.6 | | 7.5 | 90.2 | None |
| -51 | 4.3 | 1.3 | 93.2 | 1.2 | 11.1 | 3.1 | .926 | 10.3 | 82.9 | None |
| -52 | 3.4 | 1.6 | 93.3 | 1.7 | 8.6 | 3.8 | .940 | 11.1 | 82.2 | None |
| -53 | 2.4 | 1.7 | 95.0 | .9 | 6.1* | 4.1 | | 8.8 | 86.2 | None |

* Estimated.

Table 13.--Oil yield of Chattanooga shale; modified Fischer assays by U. S. Geological Survey

| Sample no. | LC-11 | | LC-33 | | LC-102 | | LC-103 | | 13M-1 | | Unit average (gals./ ton) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Thickness (feet) | Oil (gals./ ton) | Thickness (feet) | Oil (gals./ ton) | Thickness (feet) | Oil (gals./ ton) | Thickness (feet) | Oil (gals./ ton) | Thickness (feet) | Oil (gals./ ton) | |
| Top Black | | | | | | | | | | | |
| 11A | | | | | | | | | 0.72 | 4.2* | |
| 11B | | | | | | | | | 1.98 | 13.4 | |
| 12 | 2.00 | 7.8 | 1.61 | 7.9 | 1.95 | 11.2 | 2.50 | 10.4 | 1.88 | 10.9 | |
| 13 | 2.00 | 5.6 | 2.10 | 11.2 | 2.00 | 11.7 | 2.00 | 10.1 | 2.00 | 11.6 | |
| 14 | 1.38 | 4.3* | 1.41 | 9.4 | 1.90 | 12.5 | 1.70 | 7.9 | 2.00 | 11.1 | |
| 15 | 1.00 | 7.6 | | | | | | | 2.00 | 11.9 | |
| 16 | | | | | | | | | 1.80 | 11.3 | |
| Total & ave. | 6.38 | 6.3 | 5.12 | 9.7 | 5.85 | 11.8 | 6.20 | 9.6 | 12.38 | 11.3 | 9.7 |
| Upper silt | | | | | | | | | | | |
| 21 | 2.00 | 13.8 | 1.58 | 5.6 | 1.30 | 6.7 | 1.1 | 7.9 | 0.85 | 5.8 | |
| 22 | 1.67 | 13.0 | 1.27 | 3.5* | 1.20 | 3.1* | | | 1.99 | 8.3 | |
| Total & ave. | 3.67 | 13.4 | 2.85 | 4.7 | 2.50 | 5.0 | 1.1 | 7.9 | 2.84 | 7.6 | 7.7 |
| Middle Black | | | | | | | | | | | |
| 31 | 2.00 | 11.2 | 1.97 | 8.9 | 1.80 | 4.2 | 1.90 | 12.0 | 1.94 | 11.9 | |
| 32 | 1.37 | 12.6 | 1.52 | 7.1 | 1.50 | 10.6 | 3.10 | 11.2 | 1.69 | 12.4 | |
| 33 | | | 1.92 | 10.3 | 1.80 | 12.4 | 2.00 | 14.9 | 1.69 | 12.9 | |
| 34 | | | 1.62 | 12.6 | 2.00 | 13.7 | | | 1.69 | 16.6 | |
| 35 | | | 1.50 | 3.6 | | | | | | | |
| Total & ave. | 3.37 | 11.8 | 8.53 | 8.7 | 7.10 | 10.3 | 7.00 | 12.5 | 7.01 | 13.4 | 11.3 |
| Lower Black | | | | | | | | | | | |
| 51 | 1.23 | 13.3 | 1.69 | 10.4 | 1.24 | 12.4 | 1.90 | 9.4 | 2.07 | 13.0 | |
| 52 | 1.25 | 11.4 | 1.50 | 10.1 | 1.90 | 10.5 | 2.00 | 11.9 | 1.76 | 12.4 | |
| 53 | | | 2.00 | 12.6 | 2.60 | 7.7 | 1.00 | 10.1 | 1.76 | 6.1 | |
| 54 | | | 1.28 | 3.6* | | | 1.50 | 8.6 | | | |
| Total & ave. | 2.48 | 12.3 | 6.47 | 9.7 | 5.74 | 9.6 | 6.40 | 10.1 | 5.59 | 10.6 | 10.5 |

* Estimated.

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