Geology and Mineralogy

This document consists of 98 pages.
Series A

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

RESULTS OF 1952-1953 SAMPLING OF CHATTANOOGA SHALE IN TENNESSEE AND ADJACENT STATES*

By

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June 1955

Trace Elements Investigations Report 366

*This report concerns work done on behalf of the Division of Raw Materials of the U. S. Atomic Energy Commission.

USGS - TEI-366

GEOLOGY AND MINERALOGY

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RESULTS OF 1952-1953 SAMPLING OF CHATTANOOGA SHALE IN TENNESSEE AND ADJACENT STATES

By Vernon E. Swanson and Thomas M. Kehn

ABSTRACT

Uranium analyses of 874 samples collected in 1952 and 1953 from 55 outcrops and 14 drill cores of Chattanooga shale in central Tennessee, southern Kentucky, northern Alabama, and northwest Georgia tend to support the conclusions on uranium distribution presented in previous reports. The 1952-1953 study supplied information on several areas where little data were previously known. Judging from available analyses, no area is believed to exist where the average uranium content of the Chattanooga shale is appreciably higher than reported here or in earlier studies.

The Gassaway member of the Chattanooga shale, 10 to 17 feet thick, along the Northern Rim of the Nashville Basin, has an average uranium content of about 0.005 percent. In south-central Tennessee, where the shale is generally 5 feet or less thick, the uranium content averages only 0.004 percent, being slightly higher on the Southern Rim of the Nashville Basin. Along the Sequatchie Valley in northeast Alabama, where the Chattanooga shale is about 20 feet thick, samples from four outcrops show 0.006 percent uranium and samples from 3 cores have about 0.005 percent uranium. Along the folded Appalachian belts farther east the shale is 25 to 40 feet thick but contains only about 0.003 or 0.004 percent uranium as indicated by analysis of outcrop samples.

The uranium determinations on 120 special samples collected from the Chattanooga shale and Maury formation suggest the following conclusions:

1. Two series of closely spaced samples indicate that in homogeneous black shale the uranium is uniformly disseminated, both laterally and vertically.

2. Weathering, as a factor in judging the reliability of outcrop samples, can usually be disregarded except where the shale samples are excessively weathered. Ample evidence exists, however, that excessive weathering leaches uranium from the shale.

3. Sandstones, and shales with high proportions of siltstone partings, generally have lower quantities of uranium than associated massive black shale.

4. Phosphate nodules and other phosphatic material generally have less uranium than the surrounding rock.

5. Some thin "bitumen" lenses and layers in the Chattanooga shale have as much as 0.025 percent uranium, but others of similar appearance contain about the same or less than the adjoining shale.

6. In many places black shale with abundant pyrite has a relatively high uranium content, but the pyrite itself is not believed to have induced uranium concentration.

7. Uranium is not uniformly distributed, either laterally or vertically, in the 2- to 3-foot thick Maury formation which overlies the Chattanooga shale. With a few exceptions, the Maury contains only 0.001-0.004 percent uranium.

8. Greater quantities of uranium can be expected in the Chattanooga shale as the organic content increases, the grain size and volume of clastic minerals decrease, and the length of time represented increases per unit thickness.

INTRODUCTION

Reconnaissance investigations on marine black shales during the last decade have shown that the Chattanooga shale of central Tennessee consistently contains more uranium than most shale. The Raw Materials Division of the Atomic Energy Commission has sponsored most of these studies because of the possibility that this shale may be a low-grade source from which large quantities of uranium may be extracted.

The present project was undertaken by the Geological Survey as one phase of an investigation begun in 1947, which aimed to: 1) determine the areas and beds of the Chattanooga shale in the east-central United States having the highest uranium content; 2) calculate probable reserves; and 3) learn as much as possible about the geology of the black shale.

Large areas had been systematically sampled before field work was curtailed in 1949, but the absence of information on several areas prevented formulation of conclusions on the general distribution of uranium. The outcrop sampling in the summer of 1952 was aimed primarily at eliminating those gaps, and the drilling in 1953 was intended to confirm the analytical and stratigraphic data obtained in 1952. The locations of the outcrops sampled in 1952 and during parts of 1947-1949 are shown on figure 1, and the location of holes drilled in 1953 are shown on figure 2. During the period 1947-1953, some 1,950 samples have been collected for uranium determinations from 148 localities in Tennessee, Kentucky, Alabama, and Georgia.

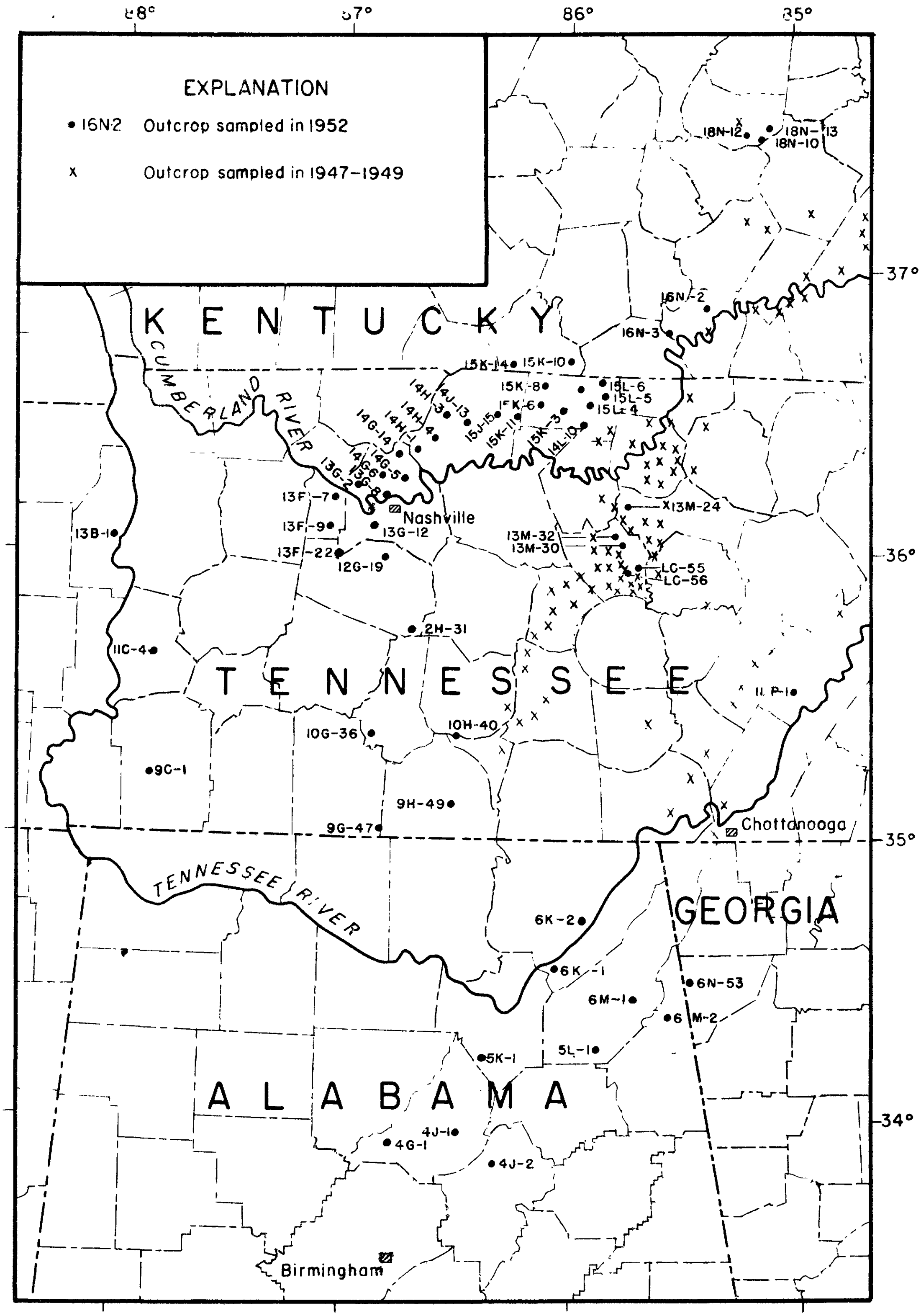


FIGURE 1.-OUTCROPS OF CHATTANOOGA SHALE IN TENNESSEE AND ADJACENT STATES SAMPLED IN 1952 AND 1947-1949

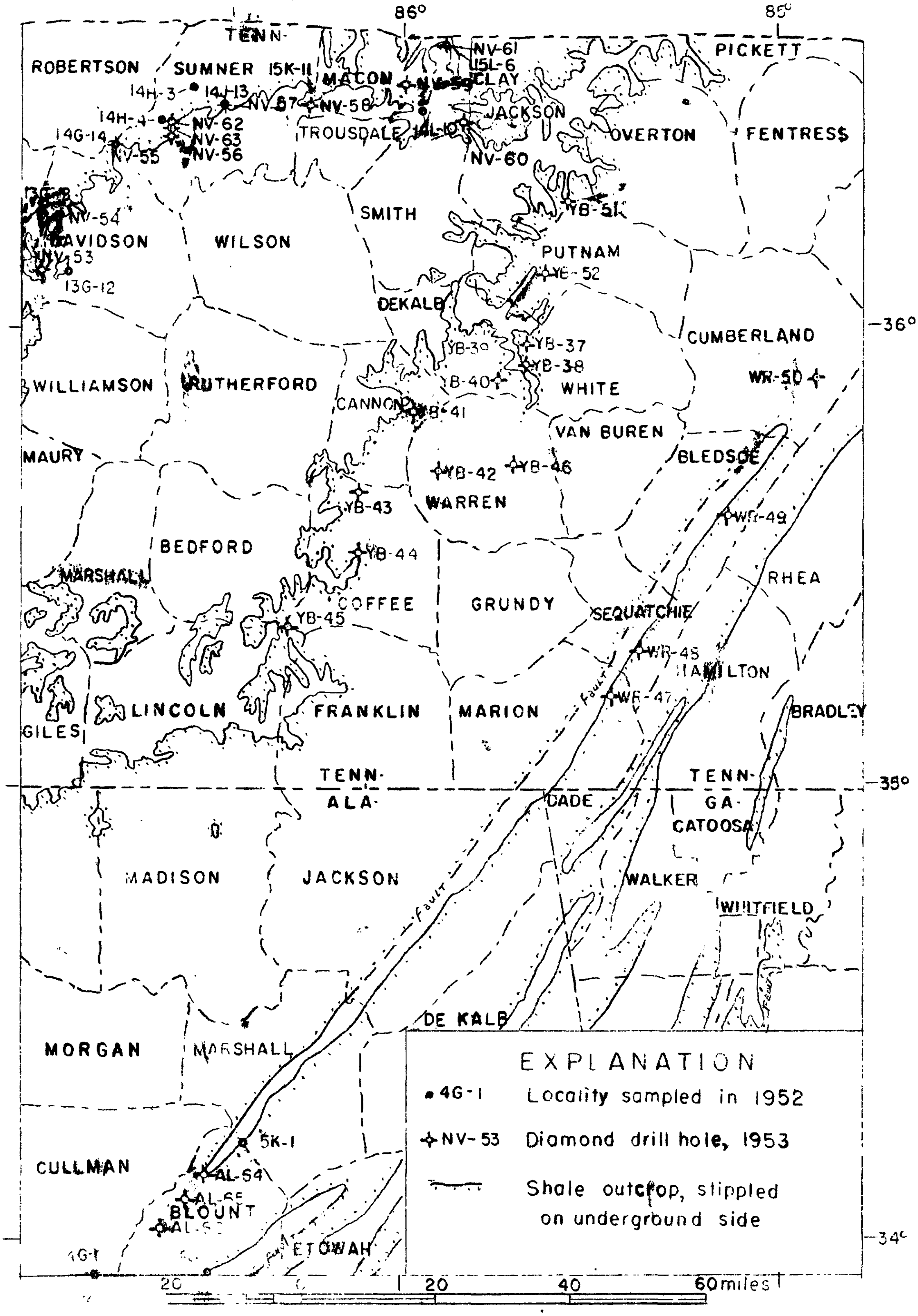


Figure 2. Location of holes drilled in Tennessee and Alabama in 1953. WR-YB-holes will be described in forthcoming reports.

During the 1952 field season (June 10-October 10, 1952) channel samples were collected from Chattanooga shale outcrops at about 5-mile intervals along the northern and northwestern edge of the Nashville Basin (fig. 3) in Tennessee and along the Cumberland River and several scattered inliers in southern Kentucky. More widely scattered outcrops were sampled in south-central Tennessee, in the Sequatchie or Browns Valley of northeast Alabama, and in the folded Appalachian area of northwest Georgia and northeast Alabama.

Numerous special samples were collected from the Chattanooga shale and overlying Maury formation to learn of any variations of uranium content within short distances, and in the hope of learning something about the association of uranium with specific minerals and types of sediments. The degree of weathering was recorded for all samples in order to ascertain the effect of weathering on the uranium content of outcrop samples--an unknown factor in judging the validity of samples.

The drilling program was carried on during August, September, and October of 1953 after completion of the closely-spaced drilling in the Youngs Bend area, DeKalb County, Tenn., (Kehn, manuscript in preparation). The holes were spaced at about 10-mile intervals along the Northern Rim of the Nashville Basin, with the exception of three closely-spaced holes north-northeast of Nashville, Tenn.; and three holes, about 5 miles apart, were drilled in Blount County, Ala. This drilling was done in order to obtain core samples of unweathered black shale behind the outcrop and to compare the uranium analyses of these core samples with those of samples from nearby outcrops. Two areas having shale of

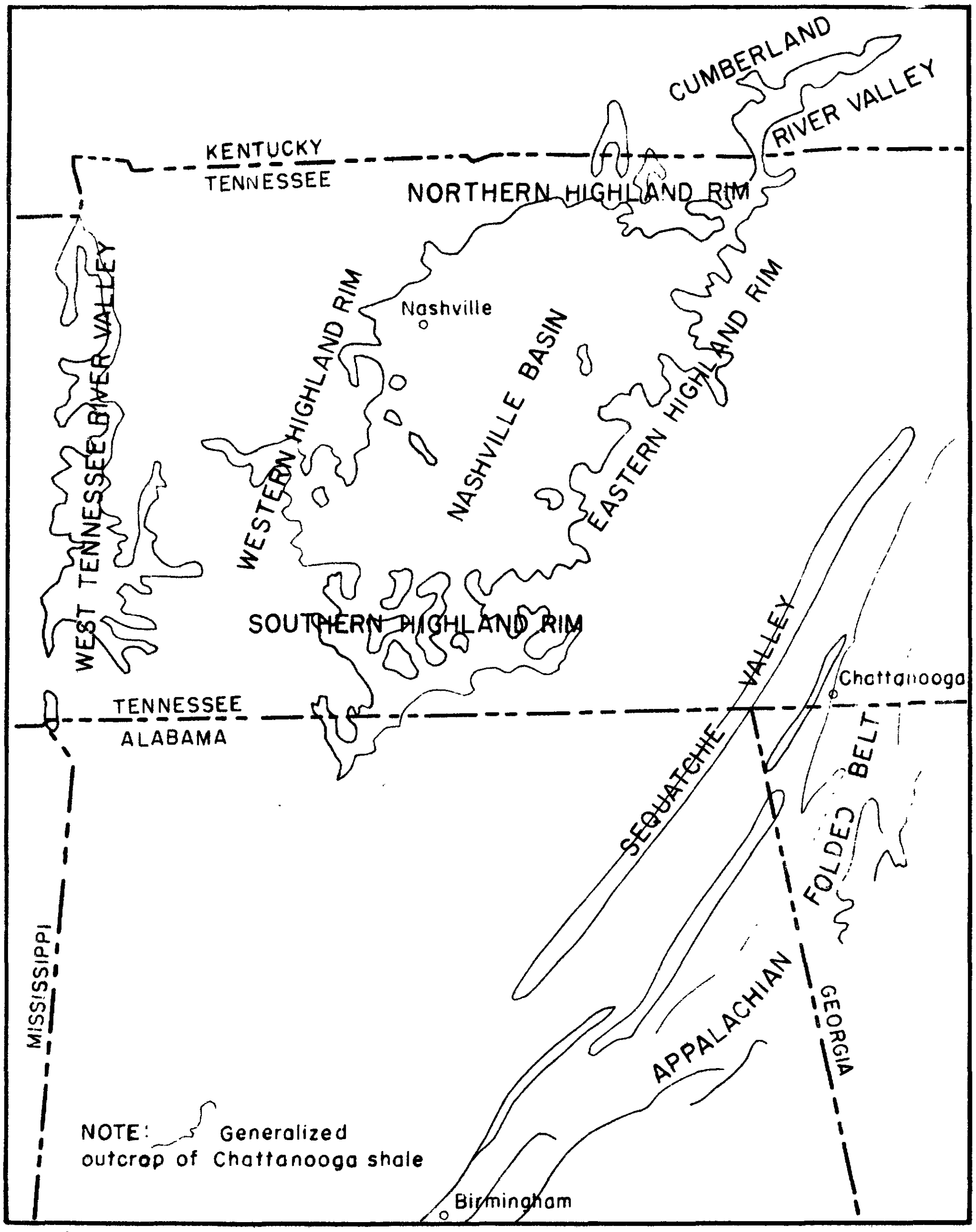


FIGURE 3—PHYSIOGRAPHIC DIVISIONS OF CENTRAL TENNESSEE AND PARTS OF ADJACENT STATES

anomalously high uranium content, as indicated by outcrop samples, were thus shown to have no more than the average amount of uranium.

A 1952 report (Conant and Swanson, 1952) assembled all uranium determinations on samples collected from the Chattanooga shale along the East Rim of the Nashville Basin of Tennessee and the Cumberland Valley area of southern Kentucky from 1947 to 1949, and set forth deductions concerning the distribution of uranium in the shale. The reader is referred to that report for more detailed information on the geology and geographic setting of the Chattanooga shale, and a review of the several earlier reports. Two other reports by members of the same Geological Survey party give analyses and related geologic information on the Chattanooga shale in the Sequatchie Valley area of Tennessee (Robeck and Brown, 1950) and in northern Kentucky (Robeck and Conant, 1951). A later report (Glover, 1954) presents data on the shale in the Sequatchie Valley of both Tennessee and Alabama.

ACKNOWLEDGMENTS

Louis C. Conant, who headed the Chattanooga shale field investigations from 1947 to 1954, coordinated much of the work and made numerous suggestions while this report was being prepared. During the 1952 field work, the authors were ably assisted in the geologic studies and the tedious collecting of samples by Chabot Kilburn and John L. Snider. Credit for the excellent core recovery is due the U. S. Bureau of Mines, and especially to Mr. Robert C. Hickman, Engineer-in-Charge of Drilling.

All samples were submitted to the Trace Elements Laboratory of the Geological Survey in Washington, D. C. for uranium determinations.

GEOLOGY

Chattanooga shale

The Chattanooga shale is part of a thin blanket of Upper Devonian and lower Mississippian black shales that once covered much of the eastern two-thirds of the United States. In central Tennessee and parts of neighboring states the shale is well exposed along the scarp at the edge of the Nashville Basin, and in many other areas outside the Basin where streams have incised their valleys through the Chattanooga. Except in the folded and faulted areas of the Sequatchie Valley and the folded Appalachian belt, the Chattanooga shale is essentially horizontal.

The Chattanooga shale is predominantly a massive and black siliceous pyritic shale. Beds and thin partings of gray claystone and siltstone are common in parts of the section in some areas, and thin sandstone beds are typically present at the base of the major units.

On the basis of lithology and fossil zonation (W. H. Hass, unpublished manuscript), the Chattanooga shale has been divided into two members, the Dowelltown (the "Lower Black shale" and "Middle Gray siltstone" of Conant and Swanson, 1952), which ranges in thickness from a feather edge to about 15 feet, and the Gassaway (the "Upper Black shale" of Conant and Swanson, 1952). These members can also be subdivided into smaller lithologic units which are traceable over large areas in some parts of Tennessee, but which are absent in most of the areas studied in 1952 and 1953. The more massive Gassaway member is of chief interest as it consistently contains the most uranium and is the most widespread of the two units; it was completely sampled at each selected outcrop and in each drill core. This member is commonly 10 to 17 feet thick.

The Chattanooga shale is of Late Devonian and early Mississippian age and is invariably overlain conformably by the Maury formation of early Mississippian age. The Maury formation is a greenish-gray claystone unit, typically 1 to 3 feet thick which is characterized by a basal concentration of large phosphate nodules. The Maury is overlain at most places by 50 to 200 feet of Fort Payne chert, a resistant hill- and ridge-capping formation, but at some other places the Maury is overlain by a succession of more or less calcareous shale that commonly has been termed the Ridgetop shale or the New Providence shale. The black shale rests with slight angular unconformity on any one of a number of Ordovician, Silurian, and Devonian formations; in most places it lies on medium-bedded limestone.

Four generalized stratigraphic sections representing the areas with which this report is concerned are shown in figure 4.

North-central Tennessee

Along the Northern Rim of the Nashville Basin, which extends roughly from where the Cumberland River enters Tennessee on the east to Nashville on the west (fig. 3), the Chattanooga shale is 15 to 30 feet

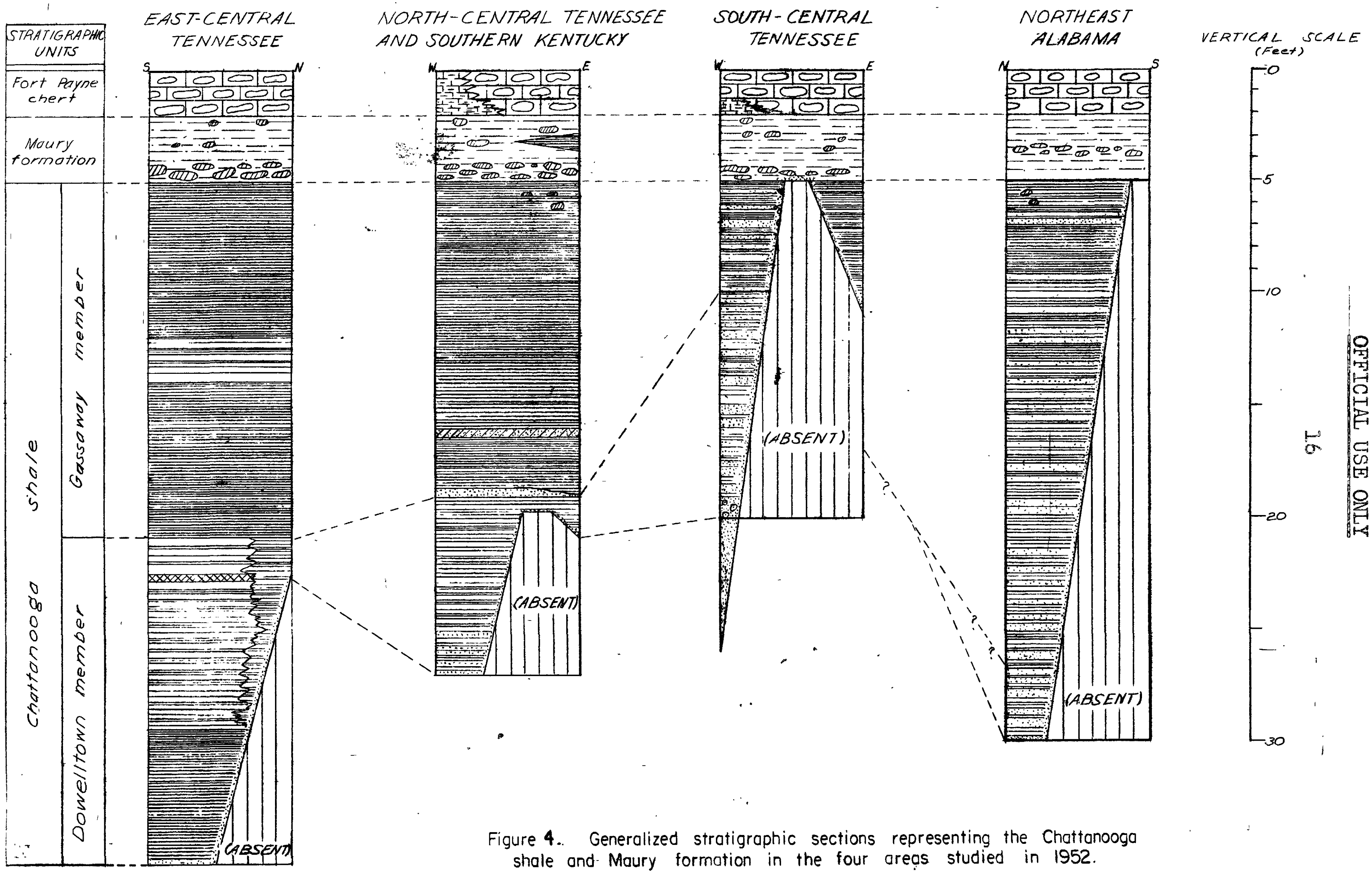


Figure 4. Generalized stratigraphic sections representing the Chattanooga shale and Maury formation in the four areas studied in 1952.

thick. The Gassaway member (the "Upper Black shale") is generally about 15 feet thick, thinning slightly in the direction of Nashville to about 10 feet. The more striking differences in thickness of the formation are due chiefly to thinning or thickening of the underlying Dowelltown member.

Throughout this area the base of the massive black shale of the Gassaway member is marked by a conspicuous quartz sandstone bed commonly 1 to 3 inches thick, which rests on less massive and locally slightly tilted gray shale beds of the Dowelltown member of the Chattanooga shale. Although the Gassaway cannot be subdivided into the three units characteristic of the Eastern Rim of the Basin, a thin but interesting and easily recognized lithologic unit, typically 2 to 5 feet above the base, in the lower third of the Gassaway can be traced along most of the Northern Rim. This layer, commonly 2 to 3 inches thick, consists of about 50 percent pyrite disseminated in a mass of phosphatic fossil fragments, bituminous debris, and quartz siltstone; because of the abundance of pyrite, the layer decomposes on the weathered surface to a distinctive punky black crust streaked with white and yellow iron sulphate minerals.

Three stratigraphic anomalies within this area should be mentioned. 1) Whereas the contact between the Chattanooga shale and the overlying greenish-gray claystone of the Maury formation is easily picked in other areas, in the eastern half of this area the Maury in places contains a layer of black pyritic shale as much as 2 feet thick, having about 0.005 percent uranium, and apparently identical in every other respect with that in the Chattanooga. However, the typical bed of large phosphate nodules elsewhere assigned to the Maury is present beneath the black shale layer and the formational contact is thus placed at the base of the nodule bed. Fossil evidence obtained by Hass also indicates that this black shale unit can best be assigned to the Maury. 2) In a relatively small and poorly defined area 12 to 15 miles west-northwest of Nashville (near the Davidson-Cheatham County line) the Chattanooga shale is absent. This is apparently only a very local feature as the formation is known to reach normal thickness within a few miles to the north, east, and south. 3) From east to west across the Northern Rim the tough massive Fort Payne chert grades laterally into a greenish calcareous siltstone that north of Nashville has been termed the New Providence shale (Wilson and Spain, 1936).

South-central Tennessee

The Chattanooga shale of the Southern and Southwestern Rim of the Nashville Basin is only about 5 feet thick, and only the Gassaway member is present. In an area of some 1,500 square miles, halfway between the Southwestern Rim and the west valley of the Tennessee River, the formation is entirely absent. Farther west, in the vicinity of the Tennessee River, the Chattanooga is as much as 30 feet thick but consists chiefly of numerous beds of ferruginous quartz sandstones and siltstones. Strikingly, the greenish-gray glauconitic sediments of the Maury formation, with the characteristic bed of phosphate nodules, persist over the entire area.

Comparable geologic conditions are known to prevail southward some 25 miles into adjacent parts of northern Alabama and northeastern Mississippi where the Chattanooga shale is overlain by 100 feet or more of younger sediments.

Northeastern Alabama

The Chattanooga shale, similar in most respects to the shale in central Tennessee, is exposed in northeastern Alabama along the limbs of several truncated folds. These folds extend roughly from the vicinity of Birmingham northeast into eastern Tennessee and, with the exception of the Sequatchie anticline, are in the folded Appalachian province. Except for these long narrow outcrop belts, the shale is overlain by 200 feet or more of Mississippian and Pennsylvanian rocks.

In the vicinity of Birmingham the Chattanooga shale is thin or absent, but the formation thickens irregularly toward the northeast, so that it is 30 to 40 feet thick in the northwestern corner of Georgia. Because of the numerous thin sandstone and siltstone beds scattered through most of the black shale, the Chattanooga in this area cannot be lithologically divided with certainty into its two members, but it is doubtful if sediments of Dowelltown age are present (Glover, 1954, p. 14). Outcrops suitable for stratigraphic study and sampling are difficult to find in this area, for at most outcrops the shale is badly folded and fractured.

SAMPLING

During the 1952 field season, 807 samples were taken for uranium analyses--776 from the Chattanooga shale and 31 from the overlying Maury formation. Of the 807 samples, 120 are special samples collected to obtain more detailed information on the distribution and mineralogic associations of the uranium within the Chattanooga shale. The remainder are channel samples mainly from the Gassaway member.

Table 1.--Summary of Chattanooga shale outcrops studied and sampled during 1952 field season

	Tennessee	Kentucky	Alabama	Georgia	Total
Number of outcrops visited and described	83	11	13	1	108
Number of outcrops sampled	38	7	9	1	55
Number of samples collected	579	123	100	5	807

For ease in comparing uranium analyses of samples from locality to locality, the samples were given numbers that indicate what part of the formation is represented. Samples numbered in the 1-10 series are from the Maury formation; samples of the 11-40 series are from the Gassaway member of the Chattanooga shale, the last digit of each sample number indicating the 1-foot interval from the top of the formation; samples in the 41-50 series are from the Dowelltown member; and samples in the 100 to 700 series are special samples.

In the early stages of the drilling program the cores were divided into 1-foot sample intervals using the same method of giving sample numbers as explained above. As a result of several tests, it was found that the uranium content of a composite sample of a stratigraphic unit would give essentially the same result as the weighted average content of the 1-foot samples (Kehn, manuscript in preparation).

Thus, the cores from the areas covered by this report were divided into 3- to 5-foot units for sample purposes and a total of 67 samples were taken for uranium analysis.

Localities (fig. 1) were assigned numbers following a grid system used in earlier studies (Conant and Swanson, 1952, plate 1). The cores taken from the Northern Rim have the prefix "NV" before each hole number and those from Alabama have "AL" before the number.

Outcrop samples of the Chattanooga shale were obtained by using pneumatic chisels and drills, powered from a compressor mounted on a jeep. These were used to get behind the weathered surface of the shale outcrop and to pry or knock out slabs or blocks of fresh shale; a small block of shale of approximately consistent top-surface dimensions was broken out of the larger mass with ordinary chisel-hammers to make up the channel sample. The average weight of the outcrop samples was about 4 pounds, each sample representing a 1-foot interval of black shale. Special samples commonly weighed 2 pounds or less.

The NX cores of shale obtained were approximately 2-1/8 inches in diameter. After preparing a stratigraphic log of a core, sample intervals were marked off and the core was sawed into longitudinal halves. One-half of the core was again halved and thus a quarter core was obtained and samples of one-quarter of the core were submitted for analysis. The Gassaway member was usually divided into 5.0-foot sample intervals with the last sample containing the unit of odd thickness; thus this member was divided into two or three samples. A sample representing a 5.0-foot interval of shale weighs approximately 4 pounds.

INTERPRETATION OF URANIUM ANALYSES OF OUTCROP AND CORE SAMPLES

Distribution of uranium by areas

As reported in earlier studies on the uranium within the Chattanooga shale and as substantiated by the study here reported, differences in uranium content from area to area, either in the formation as a whole or of any minor traceable unit, are a part of a fairly uniform regional trend. Granted that more closely spaced sampling would appreciably strengthen the reliability of any generalizations on uranium distribution, it is believed that adequate sampling within all outcrop areas in Tennessee, southern Kentucky, and northern Alabama has been done to indicate that no area exists where the average uranium content of the Chattanooga shale is appreciably higher than already reported.

All uranium determinations for the outcrop samples were reported by the laboratory in thousandths of a percent and were believed to be accurate within 0.001 percent. All figures in this report that show the fourth decimal place for the outcrop samples are merely arithmetical averages and should be considered as approximations. Insofar as errors in the determinations are random ones, such averaging is warranted; if systematic errors are involved, such averages can hardly be more accurate than the indicated 0.001 percent.

Uranium determinations for the core samples were reported by the laboratory in ten-thousandths of a percent and are believed to be accurate within $\pm$ 0.0005 percent.

The following summaries present the known and inferred uranium content of the Chattanooga shale in the areas sampled in 1952 and 1953 (fig. 1 and 2), with notations on significant variations. The analytical and sample data on which these summaries are based are presented in graphic form at the end of this report.

North-central Tennessee

The Gassaway member of the Chattanooga shale was systematically sampled at 26 outcrops spaced about 5 miles apart and 11 drill holes spaced about 10 miles apart along the Northern and Northwestern Rim of the Nashville Basin. The average thickness of the Gassaway member in this area is about 13 feet, and at most places the thickness of the overburden ranges from 50 to 250 feet. The weighted average of 340 uranium determinations of outcrop samples is 0.0055 percent, and of 23 determinations of core samples is 0.0053 percent.

Nine holes (NV-53, 54, 55, 56, 57, 58, 59, 60, 61) were located along the Northern Rim from a few hundred feet to 3 miles from sampled outcrops (fig. 2). These cores were intended to confirm the outcrop findings, to test the shale some distance behind the outcrop, and to obtain data from areas where outcrops were too weathered to sample.

The most important variation from the general average of the outcrop analyses is the higher uranium content of the Gassaway member at two localities about 10 miles apart and some 20 miles north of Nashville, 14G-14 (10.7 feet thick) and 14H-4 (10.0 feet thick), which average 0.0074 and 0.0070 percent uranium, respectively. These anomalously high areas were tested by holes NV-55, 56, 62, and 63 and analyses of the cores averaged 0.0056 percent uranium, which is only slightly above average for the Northern Rim.

Several outcrops in the vicinity of Nashville seemingly have anomalously low uranium contents, in particular 13F-9, 13G-12, and 14G-5. These outcrops were believed, on the basis of field evidence, to have shale that would have a relatively high uranium content. In view of the fact that the samples from these outcrops were submitted to the laboratory at a different time than samples from nearby outcrops, and as the analyses of samples from these nearby outcrops and drill cores (NV-53 and 54) are all similar, it is believed that the uranium analyses of shale at 13F-9, 13G-12, and 14G-5 are likely to be erroneously low.

At locality 15L-6 the analyses average 0.0062 percent uranium, but those from drill hole NV-61, about 1000 feet away from the outcrop, average 0.0052 percent. The explanation for this difference, though relatively minor, is not known, but the core analyses probably indicate the truer uranium content of the Gassaway member in this area.

The uranium content of the shale from the other drill holes differs very little from that of the shale at nearby outcrop localities.

South-central Tennessee

The Chattanooga shale was sampled at 9 outcrops scattered along the Southern and Southwestern Rim of the Nashville Basin and along the west valley of the Tennessee River. Throughout most of this area the formation averages only about 5 feet in thickness (the Dowelltown member is generally absent) and the thickness of the Maury-Fort Payne overburden ranges from 50 to 250 feet. The weighted average of 63 uranium analyses of outcrop samples is 0.0055 percent.

To set forth generalizations on the large area here included in south-central Tennessee is hazardous, not only because of the variation in uranium content of the Chattanooga shale over a large area, but also because of the varied geologic aspect of the shale. However, the geologic picture is rather well-known; and, as this controlled the spotting of outcrops to be sampled, an adequate basis is believed to exist to discuss the general uranium content of the shale, and to state that no part of the large area has shale of thickness and quality to be considered of economic interest.

As was expected, the sandstone facies of the Chattanooga shale, as at locality 9C-1, along the west Tennessee River, has very little uranium (estimated at 0.002 percent or less). The Hardin sandstone member, a basal quartzitic sandstone unit 5 to 15 feet thick confined to this part of Tennessee, contains less than 0.001 percent uranium. The amount of black shale in the formation increases to the north towards 13B-1, but has only about 0.004 percent uranium.

The results of a comprehensive study of the radioactivity of the Chattanooga shale in a large outcrop area, located between Nashville and locality 9C-1, have been reported by Brill and others (1945). More than 580 samples from 106 localities resulted in an estimate of an average uranium content of 0.004 percent for the Chattanooga shale.

Exclusive of its sandstone units, the Chattanooga shale is only about 5 feet thick or less over most of the area.

The Chattanooga is generally absent within the large area between localities 9C-1 and 10G-36, but reappears and gradually thickens eastward along the Southern Rim to about 9 feet, as at locality 10H-40. Interestingly, at localities 9G-47 and 9G-49 on the Southern Rim, the black shale is as uraniferous (0.007 to 0.008 percent) as any sampled, comparable to the stratigraphically equivalent upper 5 feet of shale sampled at LC-55 on the Eastern Rim. The shale is slightly less uraniferous and also thinner northward along the Western Rim towards the outcrops sampled south of Nashville.

Northeastern Alabama

The purpose of the sampling in northeast Alabama was to collect sufficient samples from several widely spaced outcrops to bring to light any areas that would warrant additional study. Parts or all of the Gassaway member, and in a few places the entire Chattanooga shale, were sampled at four outcrops spaced about 20 miles apart in the Sequatchie Valley (commonly called Browns Valley in Alabama), and at six similarly spaced outcrops in the folded Appalachian belt of Alabama and Georgia.

Butler and Chesterman (1945) first reported on the radioactivity of the Chattanooga shale in northern Alabama in 1944, but their wide reconnaissance provided insufficient data for detailed appraisal of the stratigraphic or regional distribution of uranium.

Judging from the 57 analyses here reported, the shale in the Sequatchie Valley of Alabama contains about 0.005 to 0.006 percent uranium. Additional study of the area surrounding locality 4G-1 was proposed considering the thickness of the shale and its relatively high average uranium content--36 feet thick averages about 0.006 percent uranium.

On the basis of these outcrop data obtained in 1952 and because the shale crops out only in small isolated areas on the southern part of the Sequatchie anticlinal structure, 3 holes were drilled in 1953 at about 10-mile intervals in what was considered to be the most promising areas. Analyses from these cores averaged from 0.0044 to 0.0057 percent uranium for about 12 to 34 feet of shale. The low uranium content of 0.0044 percent for 12 feet of shale in AL-64 may be due to the highly weathered condition of the shale. The shale in the two other cores contains much silt which might account for the lower analyses of these cores.

For the most part the relatively low quantities of uranium in the shale, coupled with both regional and local structural complications, do not encourage further interest in the folded Appalachian area. A few beds of black shale may have as much as 0.006 percent uranium, but the more abundant siltstone and sandstone beds have only about 0.002 to 0.004 percent uranium. A more detailed study of this area has been made by Glover (1954).

Miscellaneous localities in Tennessee

Localities 13M-24, 13M-30, and 13M-32 are on the Eastern Rim of the Nashville Basin where the 15 to 16 feet of the Gassaway member of the Chattanooga shale was sampled.

Locality 13M-24 had been sampled in 1948, but the low analyses reported on those samples made it desirable to resample the outcrop. The analyses of the new samples, shown in a later part of this report, are much higher than the old ones, and are now in line with the analyses of the same units at nearby outcrops. Thus, they should supersede analyses given for locality 13M-24 in an earlier report by Conant and Swanson (1952).

Laboratory reruns were made of a large number of samples collected in east-central Tennessee previous to 1952. The reruns have tended to reduce the previous abnormally high uranium analyses and raise the low analyses, so that the Gassaway member of the Chattanooga shale appears to contain about 0.006 percent on much of the Eastern Rim of the Nashville Basin.

Localities 13M-30 and 13M-32 are recently excavated highway cuts near Hurricane Bridge across Center Hill Reservoir, about 5 airline miles north of Sligo bridge. Here the Gassaway member averages 0.0064 percent uranium, which makes its average uranium content comparable to nearby localities sampled in 1948.

Locality 11P-1 is in the folded Appalachian belt of eastern Tennessee, and the uranium content is comparable with that in the Sequatchie Valley to the west (Robeck and Brown, 1950). The analyses of samples taken from the Gassaway member at this outcrop average 0.006 percent uranium.

Miscellaneous localities in Kentucky

The high uranium analysis of a Chattanooga shale sample (a single phosphate nodule from the upper 2 feet of the formation) from Marion County, Ky., submitted by a taxpayer, instigated the systematic sampling of several outcrops (18N-10, 18N-12, and 18N-13) in that area. Analyses of these 1952 samples confirm earlier conclusions that the average uranium content of the shale in central Kentucky is on the order of 0.003 percent.

The Gassaway member of the Chattanooga shale was sampled at two additional outcrops, 16N-2 (25.8 feet thick) and 16N-3 (21.8 feet thick), in the Cumberland River area of southern Kentucky in order to fill a minor gap in information already available on that area (Conant and Swanson, 1952). The averages of the uranium determinations from the two new localities, 16N-2 and 16N-3, are 0.0045 and 0.0052 percent uranium, respectively. These averages are slightly higher than those previously reported in this part of southern Kentucky but are still in accordance with the general decrease in uranium content of the Gassaway towards the north from Tennessee.

Summary

Any statement giving the average uranium content of the Chattanooga shale throughout the southeastern United States (approximately 0.0035 percent) should be immediately qualified by reference to numerous factors, such as formation thickness, variations in content with rock type, and the important differences in content in the different stratigraphic units. However, the general range in content from 0.001 to 0.012 percent uranium is valid, and regional trends and stratigraphic control in increasing or decreasing amounts of uranium within the Chattanooga shale have been generally established.

From analyses reported both here and in earlier reports, the Chattanooga shale contains the largest amounts of uranium in the Sequatchie Valley of Tennessee and on the Eastern Rim of the Nashville Basin. In these areas the Gassaway member of the Chattanooga shale, the stratigraphic unit of greatest uranium concentration and commonly about 15 feet thick, contains 0.006 to 0.007 percent uranium.

OBSERVATIONS ON THE DISTRIBUTION OF URANIUM

Variations within short distances

Two special sets of samples were collected at localities LC-55 and LC-56 along the approaches to Sligo bridge, DeKalb County, Tenn., in an attempt to ascertain any significant variations in uranium concentration in the black shale within short distances.

Fifty-three samples were collected from an essentially massive black shale unit 6.74 feet thick to determine any difference in uranium content of consecutive black shale beds in a vertical sequence. This set of samples is from the upper unit ("Top Black shale") of the

Gassaway member of the Chattanooga shale at LC-55, the excellent exposure along the east approach to Sligo bridge. The range in thickness of the beds sampled is three-eighths to 2½ inches, the average about 1¼ inches (fig. 5).

Probably the most conspicuous result of this small-scale sampling is the observation that throughout a thickness of almost 5.5 feet, extending from a few tenths of a foot from the top to about 1.1 feet from the base, the range in uranium content is 0.007 to 0.009 percent (five 0.007's, twenty-six 0.008's, and nine 0.009's). The consistency of uranium content from bed-to-bed within this unit is significant and tends to confirm the widely held suspicion that the uranium is evenly disseminated throughout the shale.

Investigations conducted at Pennsylvania State College under the supervision of Dr. T. F. Bates (Bates and others, 1952), also indicated a thorough dissemination of uranium within the shale. An autoradiograph study of the alpha tracks from thin sections of Chattanooga shale shows no real centers of uranium concentration, rather numerous scattered point sources are the rule.

In comparing the analyses with the detailed lithologic notes recorded when the samples were collected, a relationship is observed between the amount of uranium and the amount of quartz siltstone present in any one sample. The 6.74-foot Chattanooga shale unit appears as a single homogeneous black shale when observed several feet from the outcrop. When it is carefully studied inch-by-inch in hand specimens, however, differences in abundance and thickness of barely visible medium-gray

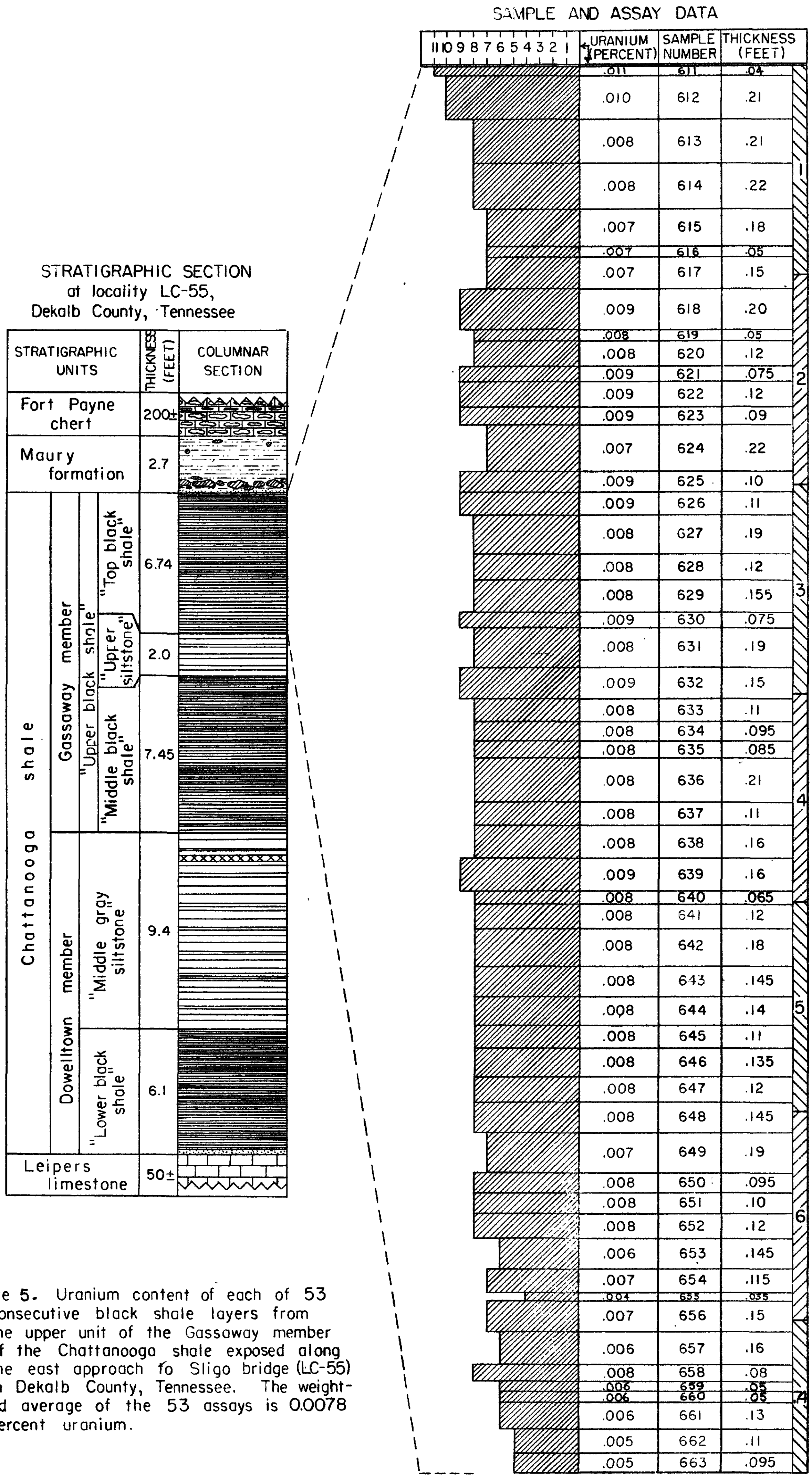


Figure 5. Uranium content of each of 53 consecutive black shale layers from the upper unit of the Gassaway member of the Chattanooga shale exposed along the east approach to Sligo bridge (LC-55) in Dekalb County, Tennessee. The weighted average of the 53 assays is 0.0078 percent uranium.

quartz siltstone partings are apparent. In any part of the 5.5-foot unit, which was cited in the preceding paragraph for its consistent uranium distribution, very few partings are present, and these are discontinuous and almost invisible to the naked eye. On the other hand, the lower foot of the 6.74-foot unit, though predominantly black shale, has thicker and more abundant siltstone beds than the overlying shale, and also has scattered minute pockets of siltstone. The average amount of uranium in the samples from the lower foot is about 0.002 percent less than in any other overlying foot.

The thin bed from which sample 655 was taken is a "varved bed," (the "Upper siltstone" on fig. 5; not to be confused with the basal bed of the middle unit of the Gassaway) with almost equal amounts of interbedded black shale and siltstone. This bed possesses the largest amount of siltstone of all of the 53 samples collected, and also had the least uranium (0.004 percent) of all 53 samples.

No megascopic mineral concentration was noted in any of the samples. Pyrite was seen only as scattered minute grains in the siltstone partings, but not as nodules or lenses. As all samples were of fresh shale from the same outcrop, the effect of weathering is believed negligible.

In order to learn if any significant short-distance lateral variation in uranium content exists, 47 samples were collected from a single bed of fresh black shale, about 0.1-foot thick, along the faces of the two Sligo bridge outcrops, LC-55 and LC-56. The bed sampled is 4.9 feet from the top of the Chattanooga shale, within the upper unit ("Top Black shale") of the Gassaway member (fig. 6).

Confidence in the exact correlation of the bed from LC-55 to LC-56, which are about 1 airline mile apart, is based on careful measurements from the bottom of the basal pyritic sandstone bed of the Maury formation; and from the top of the "varved bed", a laminated ferruginous sandstone and black shale bed in the middle unit ("Upper siltstone") of the Gassaway. Also, at both outcrops the sampled bed is separated from beds above and below by thin but distinctive siltstone partings that are visible as slight indentations on the exposed face of the shale.

As is the case of the analyses resulting from the vertical small-scale sampling at locality LC-55, the major deduction to be drawn from the analyses of samples collected at short intervals along a single bed is the consistency in uranium content. The range in uranium content of 47 samples is 0.008 to 0.011 percent (only one determination of 0.011 percent), the average is 0.009 percent, and most of the determinations are 0.009 percent (fig. 6). Remembering that the analyses are subject to an error of ± 0.001 percent, one would be hard pressed to support convincingly any theory of significant lateral trend in uranium concentration.

The most important conclusion resulting from this closely spaced sampling of the shale is the uniform distribution of uranium, both vertically and laterally, within a stratigraphic unit having lithologic homogeneity.

Effect of weathering

Most of the samples of Chattanooga shale that have been analyzed

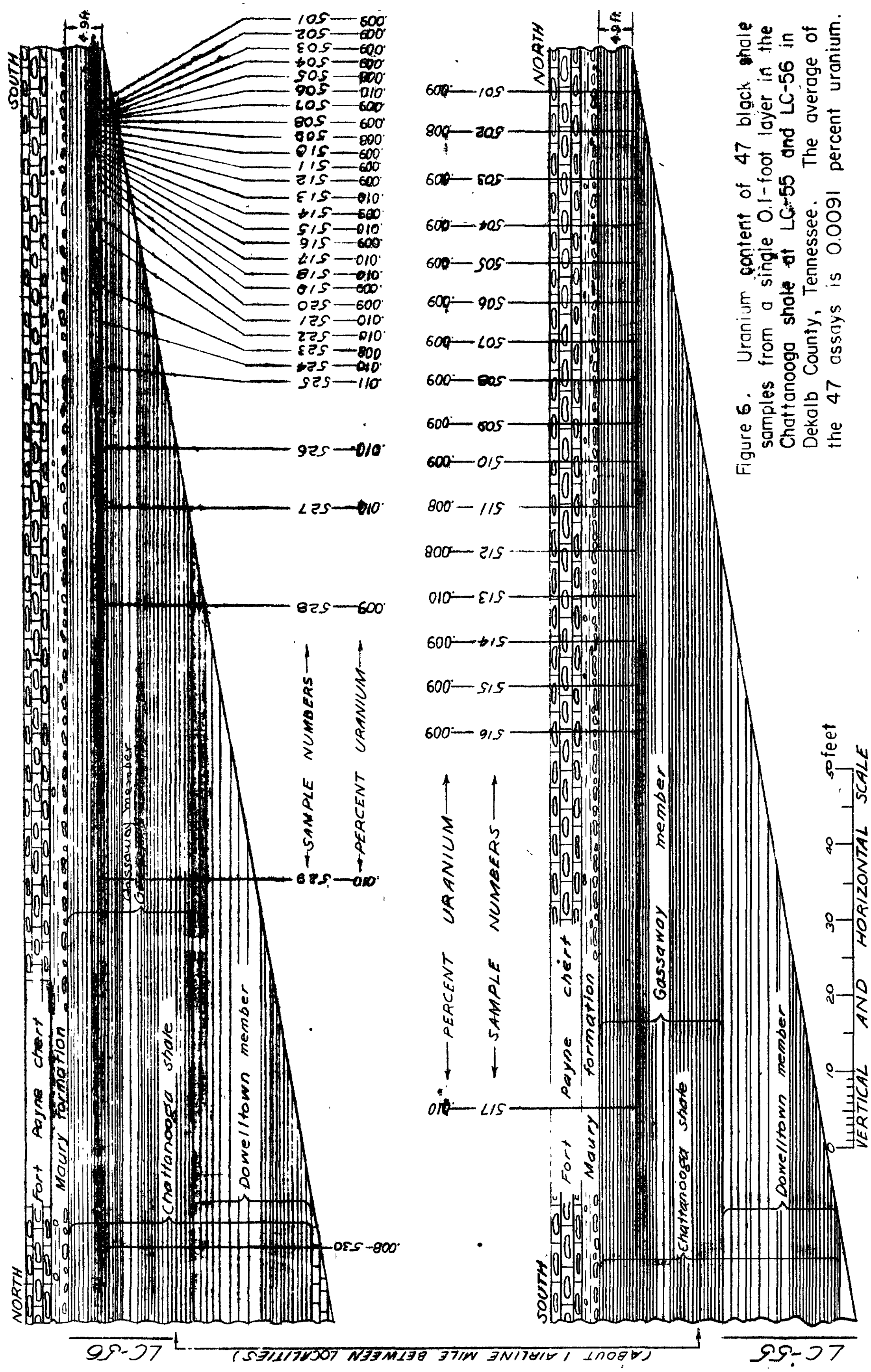


Figure 6. Uranium content of 47 black shale samples from a single 0.1-foot layer in the Chattanooga shale at LC-55 and LC-56 in Dekalb County, Tennessee. The average of the 47 assays is 0.0091 percent uranium.

in the past were collected from the faces of outcrops and the effect of weathering on the uranium content of the shale has existed as an unknown factor controlling the validity of the analyses. In 1952 a special effort was made to determine any systematic difference in uranium content of the shale due to varying degree of weathering, by recording whether a sample was of fresh shale or of slightly, moderately, or excessively weathered shale. The general conclusion, after careful comparison of analyses with sample information, is that the effect of weathering is negligible, as reflected in the analyses, except where the shale has undergone excessive decomposition and disintegration due to long exposure to the atmosphere.

The striking uniformity in uranium content of the single 0.1-foot bed at localities LC-55 and LC-56 has been described. The degree of weathering of each of the samples was recorded, the shale in the samples ranging from absolutely fresh black shale drilled out of the rock to shale that had disintegrated to wet fissile sheets, but the uranium contents of these samples are apparently completely independent of the four categories based on degree of weathering.

At many outcrops it was impossible to avoid taking one or more samples from intervals of shale which had weathered to a brownish clayey material; and at several places no alternative existed but to sample a hillslope outcrop of excessively weathered shale in order to approximate the geographical spacing desired. The analyses of this plastic brownish clayey material, which is the result of prolonged deep weathering of black shale, in several instances are judged to be 0.001 percent, or possibly 0.002 percent, lower than would be normally expected. This conclusion is also borne out by the slightly lower average of analyses at several outcrops, such as 15K-11, 14H-1, and 14H-3, where a large percentage of the sampled material was more weathered than usual. If weathering is assumed to be the sole reason for the lower uranium content of the Gassaway member at the localities mentioned, the estimated loss of uranium is only on the order of 0.001 percent. If an effort is made to sample the unweathered, harder, and more massive shale behind the clayey and fissile material on the surface of the outcrop, more dependable analyses can be made of the samples.

Although the general effect of weathering can be minimized when evaluating a number of analyses, ample evidence exists for the leaching of uranium out of the Chattanooga shale. Sulfuric acid, capable of readily assimilating uranium, is released upon weathering of the black shale, primarily because of the abundance (5 to 10 percent) of the widely disseminated and easily decomposed pyrite.

Secondary hydrous sulfate minerals are common as white and yellow encrustations and films even on relatively unweathered outcrop faces[1/]. The uranium content of samples of this friable material is as high, or higher, than the adjacent black shale from which the metal was undoubtedly derived. Two samples of these secondary salts are 13F-9-102, which

1/ Charles Milton of the U. S. Geological Survey, in his laboratory Report No. IWX-371 dated September 18, 1952, identified the yellow salt as copiapite, the white granular salt as coquimbite, and the finely fibrous white salt as halotrichite. The first two are hydrous ferric sulfates, the third, a hydrous ferrous aluminum sulfate.

contains 0.006 percent uranium and 14G-5-102, which contains 0.014 percent equivalent uranium (table 2).

Two water samples (Aberdeen and others, 1952) were collected by Robert A. Laurence inside of and near the entrance to the Sligo adit, which is approximately half a mile south of locality LC-55. These samples were the most uraniferous (one contained 690 parts per billion uranium) and most acid of 48 water samples reported. The water sample that contained the most uranium was taken near the inner end of the drift and is interpreted to be water that became uraniferous and acidic because of its contact with the black shale.

Table 2.--Analyses of special samples

PHOSPHATE

Sample no.	Uranium (percent)1/	Description
LC-55-602	0.005	Fragments of nodules in nodule bed, Maury formation.
6M-1-1	(0.002% eU)	Fragments of nodules, Maury formation.
12H-31-1	(0.002% eU)	Fragments of 10 nodules, Maury formation.
13L-11-101	0.004	Nodules from several layers in upper 1.6 feet of Chattanooga shale.
13L-22-101	0.002	Nodules from three layers in upper 1 foot of Chattanooga shale.
13L-22-102	0.004	Nodules from five layers 1.9 to 3.1 feet below top of Chattanooga shale.
13M-24-201	0.003	Nodules from three layers in upper 1 foot of Chattanooga shale.
13M-24-202	0.006	Nodules from three layers 1.1 to 2.0 feet below top of Chattanooga shale.
13M-24-203	0.004	Nodules from a layer 2.25 feet below top of Chattanooga shale.
13M-32-101	0.002	Fragments of nodules in nodule bed, Maury formation.

(Continued - next page)

1/ These determinations are by fluorimetric methods, except those in parentheses, which are by radiometric methods.

Table 2.--Analyses of special samples--Continued

	Sample no.	Uranium (percent) 1/	Description
PHOSPHATE	13M-32-102	0.003	Dark-gray claystone matrix of phosphate nodule bed, Maury formation.
	13M-32-103	0.002	Fragments of scattered nodules, upper part of Maury formation.
	15K-6-2	0.004	Fragments of nodules in nodule bed, Maury formation.
	HW 4054 (18N-13)	0.015	Nodule in upper 2 feet of Chattanooga shale.
BITUMEN	14G-5-103	0.025	Bitumen layer, 0.04 foot thick, 5.85 feet from top of Chattanooga shale.
	14G-14-101	0.003	Thin bitumen concentration, about 9 feet from top of Chattanooga shale.
	14G-14-103	0.006	Black shale, 0.3 foot thick, on which bitumen of 14G-14-101 rested.
	19N-7-102	0.002	Bitumen scraped from surface of black shale, lower part of Chattanooga shale.
	19N-7-103	0.002	Black shale, 0.03 foot thick, on which bitumen of 19N-7-102 rested.
SANDSTONE	9C-1-19	(<0.001% eU)	Fragments of light-gray fine-grained quartzitic sandstone, representing 8.3-foot Hardin sandstone member of Chattanooga shale.
	9G-47-15	(0.004% eU)	Dark-gray phosphatic quartz sandstone with scattered pyrite, 0.6-foot basal sandstone of Chattanooga shale.
	9H-49-16	(0.003% eU)	Dark-gray phosphatic quartz sandstone with scattered pyrite, 0.45-foot basal sandstone of Chattanooga shale.
	10G-36-101	0.005	Phosphatic, very fine-grained sandstone, abundant fossils, scattered pyrite, 0.05-foot thick, 3.4 feet from top of Chattanooga shale.
	10H-40-101	0.004	Quartz siltstone parting with abundant pyrite, 1.64-1.70 feet from top of Chattanooga shale.

(Continued - next page)

Table 2.--Analyses of special samples--Continued

Sample no.	Uranium (percent)[1]	Description
10H-40-18	0.005	Greenish-black fine-grained sandstone lens with flakes of black shale and abundant pyrite, 0.7 foot thick, 7 feet from top of Chattanooga shale.
11C-4-18	0.003	Dark-gray fossiliferous fine-grained quartz sandstone, 0.9 foot thick, 6.4 feet from top of Chattanooga shale.
13F-9-104	0.003	Medium-gray phosphatic poorly sorted quartz sandstone, 0.7 foot thick, 6.1 feet from top of Dowelltown member of Chattanooga shale.
14G-6-101	0.002	Pyritic siltstone bed, 0.2 foot thick and 12.0-12.2 feet from top of Chattanooga shale; about 50% pyrite, and abundant fossils, both phosphatic conodonts and bone fragments, and plant fragments and spores.
15K-10-101	0.003	Pyritic siltstone as in 14G-6-101; 0.15 foot thick and 11.2-11.35 feet from top of Chattanooga shale.
WEATHERED MATERIAL		
6K-2-101	0.001	Yellow plastic clay, a deeply weathered layer of black shale.
13F-9-102	0.006	Yellowish and whitish crust, mainly hydrous iron sulphate minerals, on outcrop face of black shale of Chattanooga.
14G-5-102	(0.014% eU)	Blackish crust streaked with yellowish and whitish minerals, weathered from pyritic bed.

Sandstone

Generally, of the several lithologic types present in the Chattanooga shale, sandstones have the smallest quantities of uranium.

In many parts of the areas studied and sampled in 1952 and 1953, sandstone beds are common in the Chattanooga shale and form distinctive units that can be used in stratigraphic correlation. In addition to the basal sandstone of the formation, which is 0.1 to 0.6 foot thick and invariably present in these areas, a basal sandstone of the Gassaway member, 0.1 to 0.3 foot thick, is typically present. A pyritic sandstone or siltstone, about 0.1 foot thick and 3 to 5 feet above the base of the Gassaway, is traceable over much of the outcrop area on the Northern Rim of the Nashville Basin, though it is difficult to detect in the cores. Sandstone and siltstone interbedded with black shale is the rule in most of southern Tennessee and northeast Alabama, and these coarser beds compose more than half of the formation near the southern part of the west Tennessee River area.

The presence and thickness of the sandstone beds in sampled intervals were recorded, and several samples made up wholly of sandstone were collected (table 2). The sandstones at the base of the formation and at the base of the Gassaway member, both very phosphatic and pyritic in many places, have an invariably low uranium content when compared to the immediately overlying black shale. Similarly, the pyritic siltstone bed has only about 0.002 percent uranium, whereas the confining black shale has about 0.006 percent. The observed relationship of decreasing uranium content with increase in number and thickness of siltstone partings in the 53 samples from locality LC-55 has already been described. In those areas where sandstone is a major component, the uranium content of the entire formation is only about 0.002 or 0.003 percent.

Phosphate

Phosphate, an important minor component of the Chattanooga shale and Maury formation, has been observed as scattered nodules up to 0.3 foot in greatest dimension within the upper few feet of the shale, in the form of abundant conodont and linguloid brachiopod fossils in all parts of the formation, as blue-black phosphatized shell fragments in the sandstones, and as microscopic particles disseminated in the black shale. Phosphate nodules, up to 2 feet in greatest dimension, are the most distinctive feature of the Maury formation, where they are commonly packed together to make up the "phosphate nodule bed" that can be traced over most of southern Kentucky, Tennessee, and northern Alabama.

In contrast to the intimate association of phosphate and uranium in other deposits, such as the pebble phosphates of Florida and the Phosphoria formation of Idaho, the phosphate in the Chattanooga and Maury formations generally has less uranium than the rock surrounding it.

In parts of the Eastern Rim of the Nashville Basin the upper 2 or 3 feet of Chattanooga shale is characterized by small phosphate nodules scattered through the black shale. Six special samples of these nodules, from localities 13L-11, 13L-22, and 13M-24 (table 2), contain only about 0.004 percent uranium, whereas the black shale in which they are embedded contains about 0.005 percent uranium. An exception to this, however, is the single phosphate nodule from the black shale in central Kentucky that was found to have 0.015 percent uranium (table 2, 18N-13).

Phosphate nodules in the Maury formation are believed to contain generally 0.002 to 0.004 percent uranium (table 2). In those localized areas where a black shale unit is present in the Maury, as at localities 15K-6 and 15K-10, the black shale has a higher uranium content than the underlying bed of phosphate nodules.

"Bitumen"

Vitreous asphalt-like material is commonly found in the Chattanooga shale, either in the form of discontinuous stringers, ranging from a thin film to almost an inch in thickness, or as the apparent remains of either fossil fish or plant fragments.

The highest analysis ever reported on a sample from the Chattanooga shale to date was that on fragments from a lens of "bitumen" collected at locality 14G-5--two chemical determinations of the same sample showed 0.026 and 0.024 percent uranium. A subsequent detailed study of this material from locality 14G-5 by I. A. Breger and J. M. Schopf (1955) showed the "bitumen" to be coalified wood (vitrain), which also contained unusually high percentages of germanium, vanadium, and nickel.

Two other special samples of "bitumen," however, from localities 14G-14 and 19N-7 (about 5 miles northwest of locality 18N-12 in Kentucky) analyzed about the same or less than the black shale in which they were found.

Pyrite

With the possible exception of phosphate, pyrite is the most conspicuous and abundant mineral concentration in the Chattanooga shale. In the form of small nodules, spherules, cubes, or lenses, its abundance varies among stratigraphic units and from area to area, but any thin section of any part of the shale shows the iron-sulfide mineral to be an important constituent, either as minute grains or coatings on organic particles.

The relative abundance of megascopic pyrite was noted as each sample was collected and a few special samples such as 14G-6-101 and 15K-10-101 (table 2) were submitted for analysis to determine if any relationship between the concentration of pyrite and the uranium could be demonstrated. Apparently no direct chemical tie exists, for samples collected because of their high percentage of pyrite contained considerably less uranium than the black shale adjacent to the pyritic samples; but generally there seems to be a greater concentration of pyrite in the black shale of higher carbonaceous content, which does have relatively higher uranium content. If any chemical association of uranium and pyrite does exist, it must be shown by detailed laboratory study.

The several observations and general conclusions noted on the relationship between certain minerals or rock types and uranium are by-products of a study primarily aimed at determining the regional and stratigraphic distribution of uranium for purposes of exploiting the black shale. Their validity and value are to be judged only in consideration of the limited chemical data that have been interpreted and supplemented by incorporating numerous field observations.

Maury formation

The Maury formation, with its distinctive bed of phosphate nodules, was sampled in all of the cores, and at several places within each area studied in 1952. The analyses of outcrop channel samples and of special samples of certain lithologic types in the Maury are given in table 3.

Analyses of samples that have been collected to date suggest that the uniform regional distribution of uranium, characteristic of the Chattanooga, will not be found in the Maury. Along the Eastern and Northern Rims of the Nashville Basin the 2 to 3 feet of sediments in the formation contain 0.003 percent uranium or less (an exception would be in those small areas where a bed of black shale is present in the Maury and the average for the formation would be on the order of 0.004 percent). From limited sample data, the content in the Maury elsewhere in Tennessee and Alabama is estimated to be 0.002 percent uranium or less (table 3).

The phosphate nodules in the Maury formation generally contain 0.002 to 0.004 percent uranium (table 2).

Table 3.--Analyses of samples from Maury formation

	Sample no.	Uranium (percent)1/	Description
NORTH-CENTRAL TENNESSEE	13F-9-1	0.006	Channel sample of entire Maury, 0.7 foot thick.
	15K-6-1	0.005	1.9 feet black shale unit in Maury, with phosphate nodules.

(continued - next page)

1/ These determinations are by fluorimetric methods, except those in parentheses, which are by radiometric methods.

Table 3.--Analyses of samples from Maury formation--Continued

Region	Sample no.	Uranium (percent)[1]	Description
NORTH-CENTRAL TENNESSEE	15K-6-2	0.004	0.4-foot phosphate nodule bed in dark-gray shale matrix.
	15K-8-1	0.004	2.4-feet black shale unit in Maury.
	15K-10-1	0.005	2.0-feet black shale unit in Maury, with phosphate nodules.
EAST-CENTRAL TENNESSEE	LC-55-601	0.004	Black shale matrix in phosphate nodule bed.
	LC-55-602	0.005	Fragments of phosphate nodules from nodule bed.
	LC-55-603	0.005	Channel sample of lower 0.45-foot bed of black shale with scattered phosphate nodules.
	LC-55-604	0.009	Pyritic sandstone bed 0.04 foot thick at base of formation.
	13M-32-101	0.002	Phosphate nodules from nodule bed.
	13M-32-102	0.003	Gray claystone matrix in phosphate nodule bed.
	13M-32-103	0.002	Scattered phosphate nodules from unit between nodule bed and base of Fort Payne.
SOUTH-CENTRAL TENNESSEE	9C-1-1	0.005	0.5-foot bed of glauconitic siltstone with phosphate nodules.
	10G-36-1	(0.002% eU)	Channel sample of upper 1.65 feet, light greenish-gray siltstone with few small phosphate nodules.
	10G-36-2	(0.003% eU)	Channel sample of middle 1.1 feet, interbedded medium-gray siltstone and dark-gray shale.
	10G-36-3	0.004 (0.006% eU)	Channel sample of lower 0.4 foot, light greenish-gray claystone.
	11C-4-1	(0.004% eU)	Channel sample of entire Maury, 0.9 foot thick.
	12H-31-1	(0.002% eU)	Fragments of scattered phosphate nodules.
	12H-31-2	(0.003% eU)	Channel sample of entire Maury, excluding phosphate nodules.

(Continued - next page)

Table 3.--Analyses of samples from Maury formation--Continued

	Sample no.	Uranium (percent)[1/]	Description
NORTHEAST ALABAMA	4G-1-106	(0.003% eU)	Channel sample of upper 3.0 feet, greenish silty claystone.
	6K-1-101	(0.002% eU)	Channel sample of 1 foot of light olive-gray claystone, beginning 1 foot above base of formation.
	6K-1-102	(0.002% eU)	Channel sample of lower 1 foot, light olive-gray claystone.
	6M-1-1	(0.002% eU)	Fragments of phosphate nodules from nodule bed 0.4 foot thick.
	6M-1-2	(0.003% eU)	Channel sample of upper 2.6 feet, light grayish-green claystone with few phosphate nodules.
	6M-1-3	(0.002% eU)	Channel sample of next 0.7 foot, abundant phosphate nodules in glauconitic siltstone matrix.
	6M-1-4	(0.003% eU)	Channel sample of next 1.0 foot, greenish-gray siltstone.
	6M-1-5	(0.003% eU)	Channel sample of next 1.0 foot, greenish-gray siltstone.
	6M-1-6	(0.003% eU)	Channel sample of next 0.3 foot, greenish-gray siltstone.
	6M-2-101	(0.004% eU)	1.7-feet black shale unit.
OTHER	11P-1-1	(0.003% eU)	Channel sample of entire Maury, 2.0 feet thick.
	11P-1-2	(0.002% eU)	0.4-foot phosphate nodule bed with glauconitic claystone matrix.

ORIGIN AND OCCURRENCE OF URANIUM IN THE CHATTANOOGA SHALE

Many problems are connected with formulating a reasonable interpretation of origin of the Chattanooga shale, but the combination of field and office study, and the availability of the results of certain laboratory studies warrants setting forth the authors' present concept on the origin and occurrence of uranium within the Chattanooga shale. If there be any value in this explanation, no part is claimed as original with this report (Beers, 1945; Breger and Deul, 1952; Burton and Sullivan, 1951; McKelvey and Nelson, 1950; Moore, 1954; Vine and Moore, 1952, and others); furthermore, the actual proof of the problem rests, not in the given explanation, but in highly rigorous experimentation in the laboratory.

It is generally accepted that the black muds that formed the Chattanooga shale were laid down at an extremely slow rate in unoxygenated waters. The supply of clastic mineral material was unusually limited, either because of the great distance from major source areas, or the inability of nearby land areas to contribute much sediment because of abnormally low relief and the predominance of calcareous rocks exposed to erosion; chemical precipitation of materials such as calcium carbonate or chert was incompatible with the environment of highly acidic waters. On the other hand, organic debris, for the greater part in a pulverized state, was available in relative abundance, probably originally in the form of land plants and floating sea algae, and accumulated on the sea floor and was preserved because of the particular chemical environment.

The water in the Chattanooga sea was abnormally rich in sulfuric acid, which, with the available iron in solution, formed a large amount of iron-sulfide on the sea bottom, mainly as minute particles disseminated throughout the bottom materials. Uranium, released from the chemically decomposing rocks of far off areas, was in solution in the sea water, possibly in somewhat abnormal amount because of its solvency in the presence of excess sulfuric acid. The rate of supply and the volume of uranium in the sea water are difficult to estimate, but the vast and uniquely uniform distribution of uranium in the black shale bespeaks an ample supply that was broadcast widely by water agitation. When the uraniferous water came into contact with the abundant carbonaceous debris on the sea bottom the metal was adsorbed, probably as an organo-uranium compound, thoroughly disseminated as submicroscopic specks or films attached to the individual shreds and fragments of the plant material.

The element of time is believed to be an all-important factor in understanding the concentration of uranium, and it is believed that the concentration of uranium is closely related to the rate of accumulation of clastic and plant debris.

In the past, several authors have stated that the amount of uranium is directly related to the amount of organic matter in the shale. More to the point, when considering the amount of uranium in a given volume of shale, is the ratio between mineral grains (clastic) and carbonaceous material, as the uranium is believed to be intimately and chemically tied, in greater or lesser amounts, to each particle of carbonaceous substance. Generally, then, the lower the ratio of clastic material to carbonaceous material, the greater the concentration of uranium.

The relationship between the abundance of syngenetic pyrite and the concentration of uranium seems also to be compatible with the above explanation though there is no indication that the uranium is chemically bound with pyrite. Pyrite, uranium, and organic material seem to be deposited and preserved in the same chemical environment.

Although any individual plant particle would accumulate only a very minor amount of uranium, probably because the chance of the plant particle coming into contact with the relatively scarce uranium in the water was small, the burial of that particle by either clastic or plant material would terminate its uranium-assimilating life.

Thus, the longer the exposure of each theoretical plane of organic material on the Chattanooga sea bottom, the greater would be the amount of uranium tied to that plane. But if a significant admixture of clastic mineral grains in that plane existed, the amount of uranium would be proportionately less; further, it follows that with the increased grain size of the "inert" clastic particles in that plane, the surface capable of taking uranium out of the water would also be smaller. Therefore, time, amount of organic material, and clastic mineral grain size and volume are believed to be most significant in controlling the amount of uranium in any given stratigraphic unit of black shale of the Chattanooga type. Greater quantities of uranium would be expected in these rocks as the organic matter increases, the grain size and volume of clastic minerals decreases, and the length of time represented increases. The quantitative influence of each of these factors can, at present, only be very roughly estimated.

GRAPHS OF ANALYSES

The remaining pages of this report present in graphic form the uranium content of all channel samples that were submitted for analyses in 1952. These graphs, when combined with those in TEI-224 (Conant and Swanson, 1952), present all analyses prior to 1953 pertinent to the distribution of uranium in the Chattanooga shale in central Tennessee, southern Kentucky, and northeast Alabama, representing a total of 1,772 analyses of samples taken from 134 outcrops.

The 14 cores taken on the Northern Rim of Tennessee and the southern part of the Sequatchie Valley of Alabama in 1953 are also presented. The analysis shown for each sample on these graphs are an arithmetic average of four to eight determinations of each sample, and the percentage of uranium shown below the graphs for the Gassaway or a part of the Gassaway is the weighted average of the analyses given in the graph for the given shale thickness.

Where applicable, a summary is given at the base of each column showing the sample numbers, the thickness, and the average of the uranium analyses of the Gassaway member ("Upper Black shale") of the Chattanooga shale. As previously explained, the fourth decimal place results from averaging of uranium determinations that were accurate only to the third decimal place, so these averages should not be accepted at full value and used for comparisons. However, the core analyses are considered to be accurate to ± 0.0005 percent.

Analyses of outcrop samples

The graphs on pages 52 through 82 present the analyses of the outcrop samples of Chattanooga shale collected in 1952, and the geographic location of each outcrop shown on figure 1.

4G-1 (Blount County, Alabama)

At Blount Springs, about 0.5 mile east of U. S. Highway 31 on country road; cut on south side of road.

Sample number	Thickness (feet)	Uranium content (percent)
11	1.0	0.005
12	1.0	.006
13	1.0	.007
14	1.0	.007
15	1.0	.008
16	1.0	.008
17	1.0	.008
18	1.0	.008
19	1.0	.008
20	1.0	.008
21	1.0	.006
22	1.0	.006
23	1.0	.005
24	1.0	.004
25	1.0	.006
26	1.0	.007
27	1.0	.007
28	1.0	.009
29	1.0	.008
30	1.0	.009
31	1.0	.007
32	1.0	.005
33	1.0	.004
34	1.0	.004
35	1.0	.004
36	1.0	.004
37	1.0	.002
101	3.0	
102	1.5	.006
103	1.5	.007
104	1.5	.005
105	1.5	.005
11-36	26.0	0.0065

4J-1 (Blount County, Alabama)
From the junction of Alabama Highways 25 and 38 at the northwestern edge of Oneonta, 0.2 mile northwest on Alabama Highway 38; cut on west side of road, incomplete section.

Sample number	Thickness (feet)	Uranium content (percent)
11	1.0	0.007
12	1.0	.006

4J-2 (St. Clair County, Alabama)
About 1 mile west of Whitney; about 0.1 mile west of intersection of U. S. Highway 11 and Alabama Highway 25; roadcut on north side of Highway 25.

Sample number	Thickness (feet)	Uranium content (percent)
101	3.0	0.006
102	3.0	.008

NOTE: Each sample believed to represent entire thickness of formation.

5K-1 (Marshall County, Alabama)
From courthouse at Guntersville, about 14 miles due southwest, then northeast 0.3 mile; outcrop in ditch, incomplete section.

Sample number	Thickness (feet)	Uranium content (percent)
11	1.0	0.008
12	1.0	.007
13	0.5	.008

5L-1 (DeKalb County, Alabama)
From intersection of U. S. Highway 11 and Alabama Highway 68 in Collinsville, west on Highway 68 for 0.1 mile; outcrop at base of west-facing bluff 100 feet north of highway, incomplete section.

Sample number	Thickness (feet)	Uranium content (percent)
11	1.0	0.006
12	1.0	.006
13	1.0	.005
14	1.0	.004
15	1.0	.005
11-15	5.0	0.0052

6K-1 (Jackson County, Alabama)
From road intersection just north of church at Langston, 0.55 mile due west-northwest on trailroad to top of hill; cut on north side of road.

Sample number	Thickness (feet)	Uranium content (percent)
11	1.0	0.004
12	1.0	*
13	1.0	*
14	1.0	.004
15	1.0	.005
16	1.0	.005
17	1.0	.005
18	1.0	*
19	1.0	*
20	1.0	*
121	3.5	*
122	4.5	*

* Probably 0.003% or less uranium

6K-2 (Jackson County, Alabama)
From railroad crossing at Hollywood, east 1.0 mile and across U. S. Highway 72, then east-southeast 2.6 miles; cut on north side of road at edge of reservoir, incomplete section.

Sample number	Thickness (feet)	Uranium content (percent)
15	1.0	*
16	1.0	0.005
17	1.0	.010
18	1.0	.010
19	1.0	.008
20	1.0	.007
21	1.0	.008
22	1.0	.007
23	1.0	.007
24	1.0	.005
25	2.5	.003

*Probably 0.003% or less uranium

6M-1 (DeKalb County, Alabama)
At Fort Payne, about 300 feet northwest of intersection of U. S. Highway 11 and Alabama Highway 35; cut on north side of road.

Sample number	Thickness (feet)	Uranium content (percent)	
11	1.0	*	
12	1.0	*	
13	1.0	*	
14	1.0	*	
15	1.0	*	
16	1.0	*	
17	1.0	*	
18	1.0	*	
19	1.0	*	
20	1.0	*	
21	1.0	*	
22	1.0	*	
23	1.0	*	
24	1.0	*	
25	1.0	*	
26	1.0	*	
27	0.8	*	

* Probably 0.003% or less uranium

6M-2 (Cherokee County, Alabama)
About one-half mile east of Blanche where new paved road curves northeast; cut on north side of road.

Sample number	Thickness (feet)	Uranium content (percent)
111	9.0	*
112	6.3	0.004
113	5.0	.005
114	8.5	*
115	11.3	.005

* Probably 0.003% or less uranium

6N-53 (Chattooga County, Georgia)
About $1\frac{1}{2}$ miles west of Menlo on Georgia Highway 48; cut on north side of highway.

Sample number	Thickness (feet)	Uranium content (percent)
101	1.7	*
102	6.	*
103	7.	*
104	20.	0.006
105	5.	.004

* Probably 0.003% or less uranium

9C-1 (Wayne County, Tennessee)
About 2.5 miles northwest of Three Churches, along Indian Creek; outcrop just above and to north of Indian Creek along road.

Sample number	Thickness (feet)	Uranium content (percent)
11	1.0	*
12	1.0	*
13	1.0	*
14	1.0	*
15	1.0	*
16	1.0	*
17	1.0	*
18	0.9	*

*Probably 0.003% or less uranium

9G-47 (Giles County, Tennessee)
From Tennessee-Alabama State line, north 1.6 miles on U. S. Highway 31; top of large roadcut on east side of highway.

Sample number	Thickness (feet)	Uranium content (percent)
11	1.0	0.010
12	1.0	.009
13	1.0	.008
14	0.6	.007
15	0.6	*
11-14	3.6	0.0087

* Estimate 0.003% uranium

9H-49 (Lincoln County, Tennessee)
From courthouse at Fayetteville, south 3.85 miles on U. S. Highway 241; roadcut on east side of highway.

Sample number	Thickness (feet)	Uranium content (percent)
11	1.0	0.008
12	1.0	.009
13	1.0	.008
14	1.0	.007
15	0.55	.005
16	0.45	*
11-15	4.55	0.0076

* Estimate 0.002% uranium

10G-36 (Marshall County, Tennessee)
From intersection of U. S. Highway 31A and Tennessee Highway 129 in Cornersville, west-northwest 0.9 mile on Highway 129; roadcut on south side of road.

Sample number	Thickness (feet)	Uranium content (percent)
11	1.0	0.009
12	1.0	.007
13	1.0	.006
14	1.0	.005
15	0.65	.005
11-15	4.65	0.0065

10H-40 (Bedford County, Tennessee)
From courthouse at Fayetteville, north 16.2 miles on U. S. Highway 241; roadcut on northeast side of highway.

Sample number	Thickness (feet)	Uranium content (percent)
11	1.0	0.008
12	1.0	.008
13	1.0	.008
14	1.0	.007
15	1.0	.007
16	1.0	.006
17	1.0	.005
18	0.7	.005
19	0.8	.005
11-19	8.5	0.0066

11C-4 (Perry County, Tennessee)

From courthouse at Linden, 0.2 mile northeast on Tennessee Highway 100; outcrop 100 feet north of city spring house.

Sample number	Thickness (feet)	Uranium content (percent)
11	0.35	0.006
12	1.0	.005
13	1.0	.005
14	1.0	.005
15	1.0	.005
16	1.0	.004
17	1.0	.004
18	0.9	.004
19	0.9	*
11-18	7.25	0.0046

* Probably 0.003% or less uranium

11P-1 (Rhea County, Tennessee)

From courthouse at Dayton, northeast about 1.8 miles on U. S. Highway 27, then northwest on county road about 1 mile to intersection; roadcut on northeast side of road.

Sample number	Thickness (feet)	Uranium content (percent)
11	1.0	0.007
12	1.0	.006
13	1.0	.005
14	1.0	.005
15	1.2	.005
21	1.0	.003
22	1.0	.004
23	0.7	.003
31	1.0	.008
32	1.0	.008
33	1.0	.009
34	1.0	.008
11-34	11.9	0.0060

12G-19 (Williamson County, Tennessee)
From courthouse at Franklin, northeast 4.1 mile on U. S. Highway 31, then north 1.0 mile on Holly Tree Gap road; outcrop 150 feet east of road behind barn.

Sample number	Thickness (feet)	Uranium content (percent)
11	1.0	*
12	1.0	*
13	1.0	*
14	1.0	0.006
15	1.0	.006
16	1.0	.006
17	1.0	.006
18	1.0	.007
19	0.85	*

* Probably 0.004% or less uranium

12H-31 (Williamson County, Tennessee)
In southeastern corner of county; about 3 miles east of intersection at Bethesda, and 1.15 miles east of Cross Key; in gully on southeast side of road.

Sample number	Thickness (feet)	Uranium content (percent)
11	1.0	0.003
12	1.0	.005
13	1.0	.006
14	1.0	.007
15	0.7	*
11-14	4.0	0.0053

* Probably 0.003% or less uranium

13B-1 (Benton County, Tennessee)
Roadcut on north side of U. S. Highway 70 (Tennessee Highway 1) 4.3 miles east of Camden; 0.1 mile west of Coleman's Service Station.

Sample number	Thickness (feet)	Uranium content (percent)
11	1.0	0.007
12	1.0	.006
13	0.6	.008
21	1.0	.007
22	1.0	.006
23	1.0	.004
40	1.0	.006
41	1.0	.005
42	1.0	.005
43	1.0	.004
44	1.0	.004
45	1.0	.003
46	1.0	.004
47	1.0	.003
48	1.0	.002
49	1.0	.002
50	1.0	.003
11-50	16.6	0.0046

13F-7 (Cheatham County, Tennessee)
From Ashland City southwest about 1 mile across the Cumberland River. At south end of bridge, turn east and proceed 4.7 miles along road paralleling the Cumberland River; outcrop on south side of road.

Sample number	Thickness (feet)	Uranium content (percent)
11	1.0	0.006
12	1.0	.006
13	1.0	.006
14	1.0	.005
15	1.0	.006
16	1.0	.005
17	1.0	.007
18	1.0	.005
19	1.0	.005
20	1.0	.006
21	1.0	.005
22	1.0	.005
23	1.0	.005
24	0.45	.005
11-24	13.45	0.0055

13F-9 (Cheatham County, Tennessee)
From general store at Pegram, west 2.2 miles on U. S. Highway 70; outcrop in vertical bluff on north side of road.

Sample number	Thickness (feet)	Uranium content (percent)
11	1.0	0.005
12	1.0	.004
13	1.0	.004
14	1.0	.006
15	1.0	.005
16	1.0	.005
17	1.0	.005
18	1.0	.005
19	1.0	.006
20	1.0	.004
21	1.0	.005
22	1.0	.006
23	1.0	.004
11-23	13.0	0.0049

13F-22 (Davidson County, Tennessee)
From intersection of South Harpeth Creek road and Tennessee Highway 100 at Linton, south on South Harpeth Creek road 0.7 mile; outcrop on north side of hill, 150 feet north of J. M. Groves farm.

Sample number	Thickness (feet)	Uranium content (percent)
11	1.0	0.005
12	1.0	.007
13	1.0	.007
14	1.0	.006
15	1.0	.005
16	1.0	.005
17	1.0	.007
18	1.0	.005
19	1.0	.006
20	1.0	.006
21	1.0	.006
22	0.65	.006
11-22	11.65	0.0059

13G-2 (Davidson County, Tennessee)
From post office in Ashland City, about 6.5 miles southeast on Tennessee Highway 12, then north-northeast along Bull Run road 4.3 miles; outcrop on southeast side of road just beyond curve.

Sample number	Thickness (feet)	Uranium content (percent)
11	1.0	0.005
12	1.0	.005
13	1.0	.006
14	1.0	.006
15	1.0	.005
16	1.0	.006
17	1.0	.006
18	1.0	.007
19	1.0	.006
20	1.0	.006
21	1.0	.006
22	1.1	.005
11-22	12.1	0.0057

13G-8 (Davidson County, Tennessee)
From intersection of U. S. Highway 41W and Tennessee Highway 12 at north edge of Bordeaux, north 5.8 miles on Highway 41W, then west 0.9 mile on Stenberg road; outcrop in gully 10 feet north of road.

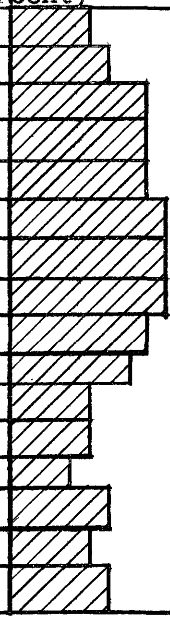
Sample number	Thickness (feet)	Uranium content (percent)
11	1.0	0.004
12	1.0	.005
13	1.0	.005
14	1.0	.006
15	1.0	.007
16	1.0	.006
17	1.0	.005
18	0.65	.008
11-18	7.65	0.0056

13G-12 (Davidson County, Tennessee)
About 5.8 miles southwest of Richland on U. S. Highway 70N; about 2.3 miles northeast of junction with U. S. Highway 70S; bluff on north side of highway.

Sample number	Thickness (feet)	Uranium content (percent)
11	1.0	0.001
12	1.0	.002
13	1.0	.006
14	1.0	.005
15	1.0	.003
16	1.0	.005
17	1.0	.004
18	1.0	.005
19	1.0	.003
20	1.0	.004
21	1.0	.005
22	1.0	.005
23	1.0	.004
24	1.0	.004
25	0.9	.004
11-25	14.9	0.0040

13M-24 (Putnam County, Tennessee)
About 12 airline miles west of courthouse at Cookeville; 0.25 mile east of Lafayette School; roadcut about 0.5 mile north of U. S. Highway 70N.

Sample number	Thickness (feet)	Uranium content (percent)
111	1.0	0.004
112	1.0	.005
113	1.0	.007
114	1.0	.007
115	1.0	.007
116	1.0	.008
117	1.0	.008
118	1.0	.008
119	1.0	.007
120	0.98	.006
121	1.0	.004
122	1.0	.004
123	0.7	.003
131	1.0	.005
132	1.0	.004
133	1.25	.005
111-133	15.93	0.0058



NOTE: Because of abnormally low assays (8, p. 74) of samples collected in 1948 from locality 13M-24, the outcrop was resampled. The new assays are comparable to previous assays of the Gassaway member of the Chattanooga shale at nearby outcrops.

13M-30 (DeKalb County, Tennessee)
From the east end of Hurricane Bridge over Center Hill Reservoir in northern DeKalb County, 1.2 miles east and south on Tennessee Highway 56; roadcut on northeast side of road.

Sample number	Thickness (feet)	Uranium content (percent)
11	1.0	0.009
12	1.0	.007
13	1.0	.008
14	1.0	.009
15	1.0	.008
16	1.1	.008
21	1.0	.007
22	1.0	.004
23	0.98	.003
31	1.0	.007
32	1.0	.005
33	1.0	.005
34	1.0	.005
35	1.0	.007
36	1.14	.007
11-36	15.22	0.0066

13M-32 (DeKalb County, Tennessee)
From the west end of Hurricane Bridge over Center Hill Reservoir in northern DeKalb County, 2.0 miles west and north on Tennessee Highway 56; roadcut on west side of road.

Sample number	Thickness (feet)	Uranium content (percent)
11	1.0	0.008
12	1.0	.008
13	1.0	.008
14	1.0	.008
15	1.0	.007
16	1.0	.007
~~17~~	~~0.28~~	~~.006~~
21	1.0	.004
22	1.0	.007
23	1.0	.003
24	1.0	.006
~~25~~	~~0.55~~	~~.006~~
31	1.0	.005
32	1.0	.005
33	1.0	.006
34	1.0	.006
~~35~~	~~0.4~~	~~.005~~
11-35	15.23	0.0061

14G-5 (Davidson County, Tennessee)

From intersection at stop light at Goodlettsville, south 2.5 miles on U. S. Highways 41 and 31W, then west 1.3 miles on paved county road; outcrop in road-cut on south side of road at top of hill.

Sample number	Thickness (feet)	Uranium content (percent)
11	1.0	0.004
12	1.0	.005
13	1.0	.005
14	1.0	.004
15	1.0	.006
16	1.0	.003
17	1.0	.005
18	1.0	.005
19	0.1	.003
41	1.0	*
42	1.0	.001
43	1.0	.001
44	1.0	.002
45	1.0	.001
46	1.0	.003
47	0.4	.002
11-19	8.1	0.0046

* Less than 0.001%

14G-6 (Davidson County, Tennessee)

From intersection at schoolhouse in Joelton, north on county road 0.2 mile, then east 2.0 miles on secondary road; outcrop on north side of road.

Sample number	Thickness (feet)	Uranium content (percent)
11	1.0	0.005
12	1.0	.005
13	1.0	.006
14	1.0	.005
15	1.0	.005
16	1.0	.005
17	1.0	.005
18	1.0	.005
19	1.0	.005
20	1.0	.005
21	1.0	.005
101	0.2	.002
22	1.0	.005
23	1.0	.005
24	1.0	.005
25	0.5	.005
11-25	14.7	0.0050

14G-14 (Bakers Station, Davidson County, Tennessee)
About 3.7 miles north-northwest of Goodlettsville on U. S. Highway 41E, then west 0.7 mile on Bakers Station road; cut on south side of road.

Sample number	Thickness (feet)	Uranium content (percent)
11	1.0	0.006
12	1.0	.007
13	1.0	.007
14	1.0	.007
15	1.0	.007
16	1.0	.008
17	1.0	.007
18	1.0	.009
19	1.0	.008
20	1.0	.008
21	0.7	.007
11-21	10.7	0.0074

14H-1 (Sumner County, Tennessee)
From schoolhouse at Whitehill, south 0.4 mile on U. S. Highway 31W, then east and south 0.7 mile on old abandoned highway; outcrop on hill slope 30 feet south of road, on I. D. Gorley farm.

Sample number	Thickness (feet)	Uranium content (percent)
11	1.0	0.005
12	1.0	.004
13	1.0	.004
14	1.0	.007
15	1.0	.006
16	1.0	.006
17	1.0	.006
18	1.0	.007
19	1.0	.005
20	0.7	.005
11-20	9.7	0.0055

14H-3 (Sumner County, Tennessee)
From schoolhouse at Cottontown, northwest 0.3 mile on Tennessee Highway 25, then northeast 2.4 miles on secondary road past County Poor Farm; outcrop on creek bank south of road.

Sample number	Thickness (feet)	Uranium content (percent)
11	1.0	0.007
12	1.0	.005
13	1.0	.005
14	1.0	.005
15	1.0	.005
16	1.0	.006
17	1.0	.005
18	1.0	.005
19	1.0	.005
20	1.0	.004
21	0.3	.004
11-21	10.3	0.0052

14H-4 (Sumner County, Tennessee)
From intersection about 0.1 mile east of schoolhouse at Shackle Island, north 3.0 miles on Drakes Creek road, then north-northeast 0.4 mile, then take west fork 0.2 mile; outcrop on east side of road.

Sample number	Thickness (feet)	Uranium content (percent)
11	1.0	0.007
12	1.0	.007
13	1.0	.005
14	1.0	.007
15	1.0	.007
16	1.0	.008
17	1.0	.008
18	1.0	.007
19	1.0	.007
20	1.0	.007
11-20	10.0	0.0070

14J-13 (Sumner County, Tennessee)

From courthouse at Gallatin, about 5 miles north-northwest on Tennessee Highway 109; outcrop on east side of road; locality 108 of K. Brille.

Sample number	Thickness (feet)	Uranium content (percent)
11	1.0	0.007
12	1.0	.008
13	1.0	.007
14	1.0	.007
15	1.0	.006
16	1.0	.005
17	1.0	.006
18	1.0	.006
19	1.0	.006
20	1.0	.003
21	1.0	.004
22	0.8	.004
11-22	11.8	0.0058

14L-10 (Macon County, Tennessee)

From courthouse at Lafayette, east for 4.5 miles on Tennessee Highway 52 to Webbtown, then south 0.8 mile, then southeast 2.0 miles, then south 1.1 miles; roadcut.

Sample number	Thickness (feet)	Uranium content (percent)
11	1.0	0.002
12	1.0	.003
13	1.0	.004
14	1.0	.005
15	1.0	.008
16	1.0	.006
17	1.0	.008
18	1.0	.006
19	1.0	.006
20	1.0	.007
21	1.0	.005
22	1.0	.003
23	1.0	.002
24	1.0	.001
25	0.75	.002
11-25	14.75	0.0046

15J-15 (Sumner County, Tennessee)

From schoolhouse at Bethpage, northeast 0.4 mile on U. S. Highway 31E, then northwest 1.9 miles on paved road, then west-northwest about 1.6 miles (through 5 gates); outcrop in creek bed.

Sample number	Thickness (feet)	Uranium content (percent)
11	1.0	0.004
12	1.0	.006
13	1.0	.007
14	1.0	.006
15	1.0	.005
16	1.0	.005
17	1.0	.005
18	1.0	.006
19	1.0	.006
20	1.0	.005
21	1.0	.006
23	1.0	.006
24	1.0	.005
25	1.0	.005
26	1.0	.005
27	0.3	.006
11-27	16.3	0.0055

(no sample no. 22)

15K-3 (Macon County, Tennessee)

From courthouse in Lafayette, southwest on Tennessee Highway 10 for 1.0 mile; outcrop on west side of highway.

Sample number	Thickness (feet)	Uranium content (percent)
11	1.0	0.005
12	1.0	.005
13	1.0	.006
14	1.0	.006
15	1.0	.006
16	1.0	.006
17	1.0	.007
18	1.0	.006
19	1.0	.006
20	1.0	.006
21	1.0	.006
22	1.0	.006
23	1.0	.005
24	0.3	.005
11-24	13.3	0.0058

15K-6 (Macon County, Tennessee)

From courthouse at Lafayette, 6.4 miles west on Tennessee Highway 52, then south 0.1 mile on secondary road; outcrop on west side of road.

Sample number	Thickness (feet)	Uranium content (percent)
11	1.0	0.005
12	1.0	.005
13	1.0	.006
14	1.0	.006
15	1.0	.006
16	1.0	.006
17	1.0	.006
18	1.0	.006
19	1.0	.006
20	1.0	.007
21	1.0	.006
22	1.0	.006
23	1.0	.006
24	0.9	.005
11-24	13.9	0.0059

15K-8 (Macon County, Tennessee)

From courthouse in Lafayette, north on Tennessee Highway 10 for 4.6 miles, then west about 3.5 miles; outcrop on north side of road along Clifty Creek.

Sample number	Thickness (feet)	Uranium content (percent)
11	1.0	0.006
12	1.0	.005
13	1.0	.007
14	1.0	.006
15	1.0	.006
16	1.0	.006
17	1.0	.005
18	1.0	.005
19	1.0	.004
20	1.0	.005
21	1.0	.005
22	1.0	.006
23	1.0	.005
24	1.0	.006
25	1.0	.004
26	0.6	.004
11-26	15.6	0.0053

15K-10 (Allen County, Kentucky)

From intersection of Kentucky Highways 100 and 99 in Holland, south on Highway 99 for 1.2 miles, then east on secondary road 1.4 miles; outcrop on south side of road.

Sample number	Thickness (feet)	Uranium content (percent)
11	1.0	0.005
12	1.0	.003
13	1.0	.004
14	1.0	.006
15	1.0	.006
16	1.0	.008
17	1.0	.006
18	0.9	.006
19	1.0	.006
20	1.0	.005
21	1.0	.006
22	1.0	.006
23	1.0	.006
24	1.0	.005
25	1.0	.005
26	1.0	.005
27	0.1	.004
11-27	16.0	0.0055

15K-11 (Sumner County, Tennessee)

About 4.7 airline miles south-southeast of railroad station in Westmoreland; outcrop on nose of hill 0.1 mile east of Pat Williams store; about 0.1 mile west of Macon-Sumner County line.

Sample number	Thickness (feet)	Uranium content (percent)
11	1.0	0.006
12	1.0	.006
13	1.0	.006
14	1.0	.006
15	1.0	.006
16	1.0	.004
17	1.0	.004
18	1.0	.005
19	1.0	.004
20	1.0	.005
21	1.0	.004
22	1.0	.005
23	0.8	.007
11-23	12.8	0.0052

15K-14 (Allen County, Kentucky)
From intersection of U. S. Highway 31E and Tennessee Highway 52 at Westmoreland, Tennessee, north 8.0 miles on U. S. Highway 31E (1.9 miles north of Kentucky-Tennessee State line); outcrop in pasture of James Fyke farm, 50 feet west of highway, incomplete section.

Sample number	Thickness (feet)	Uranium content (percent)
11	1.0	0.006
12	1.0	.005
13	1.0	.007
14	1.0	.005
15	1.0	.006
16	1.0	.007
17	1.0	.005
18	1.0	.006
19	1.0	.006
20	1.0	.005
21	1.0	.004
11-21	11.0	0.0056

15L-4 (Macon County, Tennessee)
From courthouse at Lafayette east for 6.9 miles on Tennessee Highway 52; outcrop on north side of highway, on east valley wall of Long Fork Creek.

Sample number	Thickness (feet)	Uranium content (percent)
11	1.0	0.006
12	1.0	.004
13	1.0	.005
14	1.0	.006
15	1.0	.008
16	1.0	.008
17	1.0	.007
18	1.0	.007
19	1.0	.007
20	1.0	.007
21	1.0	.008
22	1.0	.007
23	1.0	.006
24	1.0	.004
25	0.9	.002
11-25	14.9	0.0062

15L-5 (Macon County, Tennessee)
About 2.1 airline miles northwest of Red Boiling Springs. Outcrop in bluff 30 feet behind R. M. West farmhouse on west side of Long Hungry Creek.

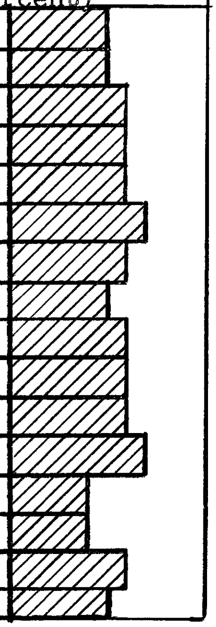
Sample number	Thickness (feet)	Uranium content (percent)
11	1.0	0.004
12	1.0	.004
13	1.0	.004
14	1.0	.006
15	1.0	.006
16	1.0	.006
17	1.0	.006
18	1.0	.004
19	1.0	.005
20	1.0	.005
21	1.0	.006
22	1.0	.006
23	1.0	.006
24	1.0	.005
25	0.7	.004
11-25	14.7	0.0052

15L-6 (Macon County, Tennessee)
About 5.9 airline miles north-northwest of Red Boiling Springs; about 2.6 miles northeast of Pumpkintown; roadcut about 200 yards east of Salt Lick Creek.

Sample number	Thickness (feet)	Uranium content (percent)
11	1.0	0.005
12	1.0	.004
13	1.0	.004
14	1.0	.006
15	1.0	.006
16	1.0	.007
17	1.0	.007
18	1.0	.006
19	1.0	.006
20	1.0	.006
21	1.0	.007
22	1.0	.008
23	1.0	.007
24	1.0	.007
25	1.0	.007
26	1.0	.007
27	0.5	.006
11-27	16.5	0.0062

15L-9 (Macon County, Tennessee)
About 4.7 airline miles northeast of courthouse at Lafayette; from schoolhouse at Galen, west 0.3 mile, then take north fork for 0.7 mile; roadcut.

Sample number	Thickness (feet)	Uranium content (percent)
11	1.0	0.005
12	1.0	.005
13	1.0	.006
14	1.0	.006
15	1.0	.006
16	1.0	.007
17	1.0	.006
18	1.0	.005
19	1.0	.006
20	1.0	.006
21	1.0	.006
22	1.0	.007
23	1.0	.004
24	1.0	.004
25	1.0	.006
26	0.7	.005
11-26	15.7	0.0056

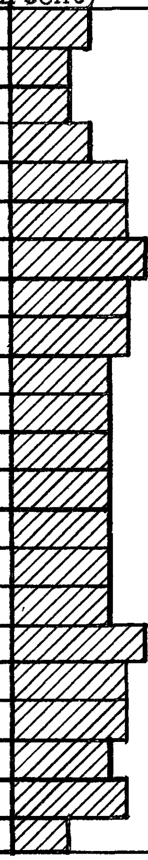


16N-2 (Cumberland County, Kentucky)
From courthouse at Burkesville, north on Kentucky Highway 61 for 6.1 miles, then 0.2 mile west to Beckham Parrish farm; outcrop in gully on hillside 100 yards north of house.

Sample number	Thickness (feet)	Uranium content (percent)
11	1.0	0.003
12	1.0	.003
13	1.0	.002
14	1.0	.002
15	1.0	.002
16	1.0	.004
17	1.0	.005
18	1.0	.005
19	1.0	.006
20	1.0	.005
21	1.0	.004
22	1.0	.004
23	1.0	.005
24	1.0	.004
25	1.0	.005
26	1.0	.005
27	1.0	.005
28	1.0	.004
29	1.0	.005
30	1.0	.004
31	1.0	.006
32	1.0	.006
33	1.0	.006
34	1.0	.006
35	1.0	.006
36	0.8	.006
11-36	25.8	0.0045

16N-3 (Cumberland County, Kentucky)
From courthouse at Burkesville, west on Kentucky Highway 90 for 6.5 miles, then southwest on Kentucky Highway 691 for 7.6 miles (1.2 miles west of town of Mud Camp); outcrop in roadcut.

Sample number	Thickness (feet)	Uranium content (percent)
11	1.0	0.004
12	1.0	.003
13	1.0	.003
14	1.0	.004
15	1.0	.006
16	1.0	.006
17	1.0	.007
18	1.0	.006
19	1.0	.006
20	1.0	.005
21	1.0	.005
22	1.0	.005
23	1.0	.005
24	1.0	.005
25	1.0	.005
26	1.0	.005
27	1.0	.007
28	1.0	.006
29	1.0	.006
30	1.0	.005
31	1.0	.006
32	0.8	.003
11-32	21.8	0.0052



18N-10 (Marion County, Kentucky)
About 2.5 airline miles southwest of post office at Bradfordsville, along Meador Creek road, approaching Staton Gap; outcrop in bed of logging road, incomplete section.

Sample number	Thickness (feet)	Uranium content (percent)
11	1.0	0.004
12	1.0	.003
13	1.0	.004

18N-13 (Marion County, Kentucky)
From post office at Bradfordsville, about 1.3 miles east-eastsouth on Kentucky Highway 49, then north about 0.4 mile; outcrop about 150 yards west of road and about 50 feet higher than road, incomplete section.

Sample number	Thickness (feet)	Uranium content (percent)
11	1.0	0.003
12	1.0	.002
13	1.0	.002
14	1.0	.002

18N-12 (Marion County, Kentucky)
From post office at Bradfordsville, 2.0 miles west on Kentucky Highway 49, then 3.1 miles west-westsouth on secondary road, then 2.5 miles south on Arbuckle Creek road; outcrop in creek bed and small quarry face.

Sample number	Thickness (feet)	Uranium content (percent)
11	1.0	0.004
12	1.0	.003
13	1.0	.003
14	1.0	.002
15	1.0	.003
16	1.0	*
17	1.0	.003
18	1.0	.004
19	1.0	.003
20	1.0	.005
21	1.0	.004
22	1.0	.004
23	1.0	.004
24	1.0	.004
25	1.0	.004
26	1.0	.003
27	1.0	.003
28	1.0	.003
29	1.0	.003
30	1.0	.003
31	1.0	.003
32	1.0	.003
33	1.0	.003
34	1.0	.002
35	1.0	.004
36	1.0	.003
37	1.0	.003
38	1.0	.003
39	1.0	.003
40	1.0	.005
41	1.0	.004
45	1.0	.001
46	1.0	.001
47 and 48	2.0	.001
49	1.0	.002
11-41	31.0	0.0033

* Not received

Analyses of core samples

The graphs on pages 83 through 96 present the analyses of core samples taken in 1953, and also the geographic location of each hole shown in figure 2.

NV-53 (Davidson County, Tennessee)
From Richland, 8.5 miles southwest on U. S. Highway 70N to junction of U. S. Highways 70N and 70S, then 0.3 mile west, and then 1.5 miles north on county road; hole about 300 feet west of road and 500 feet north of house.

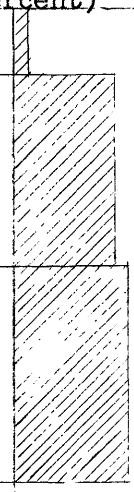
Sample number	Thickness (feet)	Uranium content (percent)
1	1.10	0.0030
12	4.00	0.0045
13	4.00	0.0054
14	5.36	0.0057
41	4.06	
12-14	13.36	0.0052

NV-54 (Davidson County, Tennessee)
From intersection of U. S. Highway 41W and Tennessee Highway 12 at north edge of Bordeaux, north 5.8 miles on Highway 41W, then west 1.2 miles on Stenberg road; hole about 500 feet west of house on north side of creek.

Sample number	Thickness (feet)	Uranium content (percent)
1	1.61	0.0013
12	5.00	0.0057
13	6.56	0.0058
41	5.00	
42	5.00	
43	3.49	
12-13	11.56	0.0058

NV-55 (Sumner County, Tennessee)
From intersection 3.7 miles north-northwest of Goodlettsville on U. S. Highway 41E, west 0.8 mile on Bakers Station road; hole on north side of road and about 100 feet west of house.

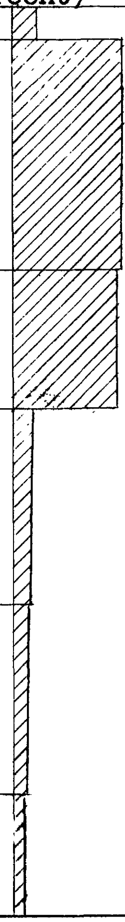
Sample number	Thickness (feet)	Uranium content (percent)
1	1.63	0.0006
12	5.00	0.0052
13	5.62	0.0059
41	6.57	
51	5.00	
52	4.35	
12-13	10.62	0.0056



NV-56 (Sumner County, Tennessee)

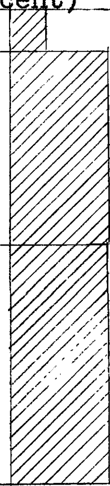
From courthouse at Gallatin, 8.0 miles west on Shackle Island road, then 1.0 mile north on Mount Olive road; hole on west side of road and on crest of ridge.

Sample number	Thickness (feet)	Uranium content (percent)
1	0.80	0.0013
12	6.00	0.0056
13	3.67	0.0054
41	5.00	0.0010
42	5.00	0.0008
43	3.15	0.0006
12-13	9.67	0.0055



NV-57 (Sumner County, Tennessee)
From courthouse at Gallatin, 5.5 miles north-northwest on Tennessee Highway 109, then 0.4 mile west on Camp Creek road; hole on south side of road and on north bank of creek.

Sample number	Thickness (feet)	Uranium content (percent)
1	1.00	0.0020
12	5.00	0.0053
13	6.23	0.0052
41	5.00	
42	5.69	
12-13	11.23	0.0052



NV-58 (Sumner County, Tennessee)
From Bransford, 3.3 miles south-southwest on Wolf Hill road, then, at crest of ridge, 0.2 mile west on new road; hole on south side of road.

Sample number	Thickness (feet)	Uranium content (percent)
1	0.30	0.0017
12	5.00	0.0047
13	5.00	0.0055
14	6.62	0.0033
41	4.00	
42	4.04	
43	4.34	
12-13	10.00	0.0051

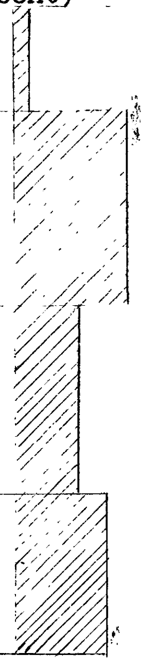
NV-59 (Macon County, Tennessee)
From courthouse at Lafayette, 2.2 miles east-southeast on Tennessee Highway 52, then 1.0 mile south on Dark Branch road; hole on west side of road.

Sample number	Thickness (feet)	Uranium content (percent)
1	0.33	0.0002
12	5.00	0.0037
13	5.00	0.0052
14*	5.67	0.0033
41	3.31	
12-13	10.00	0.0045

* Lower 2.20 feet of this sample is considered to be Dowelltown.

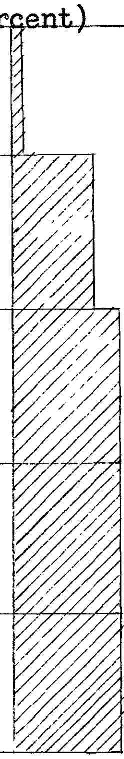
NV-60 (Macon County, Tennessee)
From Church at Willette, 1.[illegible] miles east-northeast on Tennessee Highway 56; hole on north side and above sharp bend in Highway.

Sample number	Thickness (feet)	Uranium content (percent)
1	2.75	0.0007
12	5.00	0.0060
13	5.00	0.0033
14	3.97	0.0048
41	3.67	
12-14	13.97	0.0047



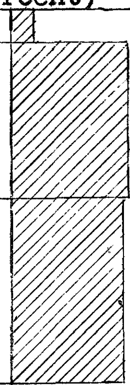
NV-61 (Macon County, Tennessee)
About 6 airline miles north-northwest of Red Boiling Springs; 2.8 miles northeast of Pumpkintown; hole is about 150 feet north of roadfork and 0.2 mile northeast of Salt Lick Creek.

Sample number	Thickness (feet)	Uranium content (percent)
1	3.27	0.0005
12	4.00	0.0042
13	4.00	0.0056
14	4.00	0.0056
15	3.57	0.0056
41	5.89	
12-15	15.57	0.0052



NV-62 (Sumner County, Tennessee)
From courthouse at Gallatin, 8.0 miles west on Shackle Island road, then 2.0 miles northeast on Mount Olive road; hole on east side of road and west of Mount Olive schoolhouse.

Sample number	Thickness (feet)	Uranium content (percent)
1	0.88	0.0022
12	4.00	0.0062
13	4.71	0.0058
41	4.00	
42	4.05	
12-13	8.71	0.0060



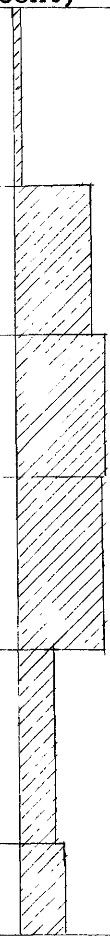
NV-63 (Sumner County, Tennessee)
From courthouse at Gallatin, 8.0 miles west on Shackle Island road, then 1.5 miles northeast on Mount Olive road; hole about 600 feet east of road on abandoned road.

Sample number	Thickness (feet)	Uranium content (percent)	
*			
12	5.00	0.0061	
13	5.00	0.0056	
14	4.1	0.009	
41	3.99		
12-13	10.00	0.0058	

* Core not recovered.

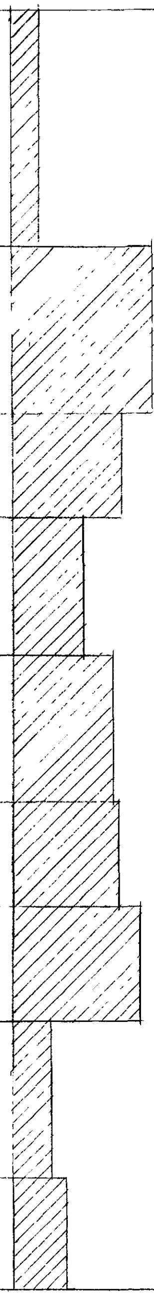
AL-64 (Blount County, Alabama)
From Brooksville 1.3 miles west on Alabama Highway 74 at intersection turn east-southeast on dirt road for 0.5 mile; hole on north side of road.

Sample number	Thickness (feet)	Uranium content (percent)
1	4.60	0.0004
12	3.75	0.0040
13	3.76	0.0046
14	4.44	0.0045
15	5.08	0.0017
16	2.32	0.0024
12-14	11.95	0.0044



AL-65 (Blount County, Alabama)
From Blountsville, about 2.3 miles northeast on Alabama Highway 38, then about 1.4 mile east-southeast on dirt road; hole about 500 feet north of road intersection.

1	6.10	0.0014
12	4.29	0.0074
13	2.71	0.0058
14	3.59	0.0037
15	3.84	0.0052
16	2.85	0.0056
17	2.84	0.0066
18	4.11	0.0020
19	2.96	0.0029
12-18	20.12	0.0057



AL-66 (Blount County, Alabama)

From Blountsville 3.1 miles west-southwest on Alabama Highway 38, then about 0.5 mile southeast on dirt road; hole on south side of road.

Sample number	Thickness (feet)	Uranium content (percent)
1	2.24	0.0025
12	4.60	0.0053
13	4.60	0.0043
14	4.60	0.0048
15	4.60	0.0060
16	4.63	0.0056
17	4.84	0.0050
18	5.73	0.0060
19	3.82	0.0023
20	5.13	0.0017

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