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RECONNAISSANCE SEARCH IN PARTS OF KENTUCKY, TENNESSEE, INDIANA, VIRGINIA, AND OHIO FOR AREAS WHERE URANIFEROUS BLACK SHALE MAY BE MINED BY STRIPPING

By

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RECONNAISSANCE SEARCH IN PARTS OF KENTUCKY, TENNESSEE, INDIANA, VIRGINIA, AND OHIO FOR AREAS WHERE URANIFEROUS BLACK SHALE MAY BE MINED BY STRIPPING

by Raymond C. Robeck and Louis C. Conant

ABSTRACT

The purposes of this investigation were (1) to find one or more areas where at least 200,000,000 tons of black shale could be obtained economically by stripping, and (2) to determine the uranium content of the shale in such areas.

Two types of areas were studied--those of horizontal and those of steeply dipping beds. Horizontal beds that might be stripped for the desired tonnage are present north of the Fort Payne chert region of Tennessee and west of the folded Appalachians. The folded regions do not appear to contain suitable areas mainly because of the complex geology and the consequent small available tonnages.

The areas that appear best suited for stripping are all in Kentucky: in Nelson and Bullitt Counties, near Boston; and in Montgomery and Powell Counties, near Levee and Clay City. In these areas something over 1,000,000,000 tons of black shale appear to be available by stripping, but this shale seems to contain only about 0.001 to 0.004 percent uranium. The shale would probably yield at least 15 gallons of oil per ton, and an

undetermined amount of gas. The overburden of the areas included in these tonnage calculations is locally as much as 100 feet thick, but in large areas averages only about 40 feet.

The uranium content of the shale in the areas suitable for stripping is so much lower than it is in the Eastern Highland Rim of Tennessee that further consideration of these areas as sources of uranium seems unwarranted, but if any further study were undertaken it should include some drilling in order to obtain samples of fresh rock and to learn the character and thickness of the overburden.

INTRODUCTION

The purposes of the investigation described in this report were (1) to find one or more areas where at least 200,000,000 tons of Chattanooga shale or its correlatives could be stripped economically, and (2) to determine the uranium content of the shale in such areas. A reconnaissance investigation based on these purposes was made by Robeck during August and September 1948 in eastern Tennessee, southwestern Virginia, Kentucky, southern Indiana, and southern Ohio. In December 1948 and April 1949 he collected samples from the three most promising areas in Kentucky and Indiana, and made additional studies of the extent of possible stripping localities. The results are presented in this report.

Consideration of the results of previous studies [1, 2, 6, 8] 1/, of concurrent studies of the Chattanooga shale, and of known geologic conditions in the area in and west of the Appalachian Mountains suggested that a combination of suitable uranium content and of economic stripping conditions might exist (1) in certain areas of horizontal beds west of the folded Appalachians, or (2) possibly in the folded Appalachians themselves.

Studies of the Chattanooga shale in east-central Tennessee have indicated that in general the uranium content of any unit of the shale is highest where the unit is blackest and is relatively thin. [4, pp. 52-54]

The thickness of the shale of Upper Devonian and early Mississippian age ranges from a fraction of a foot at Birmingham, Ala., to 1,000 feet in Virginia. Approximate average thicknesses of the shale in some of the regions are: central Tennessee, 30 feet; central Kentucky, 75 feet; eastern Ohio, 300 feet.

The Kentucky Geological Survey has estimated [5, p. 61] that the shale weighs about 130 pounds per cubic foot.

Simple calculations suggest that the proposed quantity of 200,000,000 tons in a single area might well be accessible in flat-lying beds a few tens of feet thick, but not in highly inclined beds. Thus a square mile of flat-lying shale 24 feet thick would contain about 43,000,000 tons, and 5 square miles would afford the stipulated tonnage. On the other hand, a

1/ Material in brackets relates to references at end of report.

vertical bed of like thickness, if mined to a depth of 100 feet, would yield only about 825,000 tons per linear mile, and about 250 miles of outcrop would be required to obtain 200,000,000 tons. In the area of folded rocks, however, the dips differ greatly within short distances, faulting is common, and mining conditions would vary so much that only a few million tons of shale could be obtained at any one locality.

The possibility of finding an area where repeated folding or other unusual geologic conditions might cause the shale to lie near the surface in greater thickness and over wider areas than normal was reviewed with R. A. Laurence, Regional Geologist, U. S. Geological Survey, who is familiar with the folded Appalachians. Laurence also spent some time with Robeck in the field looking for such an area, but none could be found, and it seems unlikely that any such area exists.

The areas of flat-lying rocks where the relatively higher grade shale would be amenable to stripping are described in the succeeding part of this report. Data on other areas where the flat-lying shale is of lower grade or less suitably situated for stripping or where the shale is folded are summarized in tabular form.

In areas of flat-lying rocks an overburden ratio of 2:1 was arbitrarily assumed to be permissible. Radiometric scanning in

the field indicated that the upper 40 feet of the shale in Kentucky is higher grade than the underlying beds, and that the lower beds are much too low grade to be of any interest. Accordingly, it was assumed that a maximum average overburden of about 80 feet could be tolerated. Reconnaissance work, therefore, was concentrated in areas where the maximum overburden is less than 100 feet.

During the reconnaissance, many outcrops were scanned with a Geiger-Mueller counter equipped for beta-gamma counting and connected to a cyclotron register. The counts obtained at these outcrops were compared with those previously obtained with the same instrument at many outcrops in Tennessee from which samples had been collected and chemically assayed for uranium. It was thought that such comparisons would provide satisfactory preliminary estimates of the uranium content to guide the field exploration. Subsequent chemical assays indicate, however, that the uranium content of the shale is appreciably lower than was suggested by the field scanning.

The locations of the outcrops investigated during the reconnaissance are shown on plate 1. Localities are numbered on a 15-minute quadrangle system extending north and east of 88°30' W. and 33°00' N. The 15-minute quadrangles are lettered alphabetically eastward (letters I and O are omitted) and are

numbered northward. These quadrangle symbols are shown on the borders of plate 1.

In addition to scanning the outcrops radiometrically, several 5-pound samples were taken from thin beds believed to be typical of much thicker sections. Later, the better outcrops in the areas most suited for stripping were sampled systematically and most of the samples were assayed chemically. Each of these later samples weighed about 10 pounds and represented about 2 feet of rock.

All the field work described in this report was done by Robeck. Part of the preparation of this report, especially the evaluation of the assays and the general conclusions based on them, was done by Conant. All laboratory assays given in this report were made by the Trace Elements Laboratory of the U. S. Geological Survey.

AREAS RELATIVELY SUITABLE FOR STRIPPING

General considerations

The Chattanooga shale in the area of unfolded rocks in central Tennessee is overlain by the tough Fort Payne chert which nearly everywhere forms steep slopes that rise 100 to 200 feet above outcrops of the shale. In Kentucky and northward, however, the Chattanooga shale and its correlatives are overlain by the much weaker New Providence shale which, in many places, forms a relatively thin overburden that probably could be removed, for the most part, by heavy earth-moving machinery. Several places were found in Kentucky where much more than 200,000,000 tons of shale could be obtained by stripping. The areas that appear relatively suitable for stripping are described below.

Boston district, Nelson and Bullitt Counties, Kentucky

Several large areas near the community of Boston, Nelson County, and in nearby parts of Bullitt County, are underlain by black shale, at shallow depths sufficiently above drainage level to afford good stripping possibilities (pl. 2). These areas are referred to, for convenience, as the Tewell Creek, Snake Run, and Wilson Creek areas. The shale, a correlative of the Chattanooga shale, is called the New Albany shale in this part of Kentucky.

In general, the upper 35 to 40 feet of New Albany shale is here a black shale, and the lower part, some 30 to 40 feet thick, has many gray beds in its upper part and black shale at its base. The upper black shale appears to have the highest uranium content.

The overburden in these areas, where it is 100 feet or less thick, consists chiefly of the weak New Providence shale, though at 25 to 40 feet above the black shale several layers of sandy or silty limestone crop out. Most of these layers are only a few inches thick, though one bed has a local maximum thickness of 4 feet (well exposed along U. S. Highway 62 about half a mile south of Boston). The continuity of this 4-foot bed is not known, and locally it may be thin or absent, but its continuity throughout the district should be assumed until its absence is proven.

Tewell Creek area

The Tewell Creek area is along the northwest edge of Nelson County just northeast of Boston, and is shown in the central part of plate 2. Its area is about 9 square miles. Nelson and Brill [6, p. 64, locality no. BR-171] reported field radiometric measurements at an outcrop in this area 1 mile from Boston (locality no. 20M-5 of this report) and these indicate an equivalent uranium content ranging between 0.003 and 0.007 percent for the upper 50 feet of the black shale. Field

measurements of radioactivity during the examination reported here suggested a maximum of 0.006 percent equivalent uranium, but chemical assays average only about 0.003 percent uranium. Table 1 shows the assays of a series of samples from the black shale in the upper 35 feet of the formation (locality no. 20M-5), and of 8 feet of black shale at the base of the formation where the uranium content is much lower (locality no. 20M-15).

The area is underlain by a 35-foot section of shale that should contain about 570,000,000 tons of rock. At an average uranium content of 0.003 percent, this amount of rock would contain about 17,000 tons of metallic uranium.

In very small parts of this area the top of the black shale has essentially no overburden; about 50 percent of the area has less than 50 feet of cover; about 35 percent of the area has 50 to 100 feet of cover; and the remainder has as much as 175 feet of cover in the form of small cone-shaped hills.

Most of the area supports second-growth forest whose trees have a maximum diameter of 18 inches, but some of the area is cleared and is poor crop land. U. S. Highway 62 traverses the south side of the area; Kentucky Highway 61 passes near the west end; and Kentucky Highway 245, a gravelled road, passes near the northeast side. A single-track line of the Louisville and Nashville Railroad passes through Boston.

Snake Run area

The Snake Run area is in Nelson County between Lick Creek and Rolling Fork River (south edge, pl. 2). The stratigraphy is essentially the same as at Tewell Creek, but a few more 100-foot knobs of New Providence shale are present. No systematic samples were collected for assay from this immediate area, but samples from locality nos. 20M-5 and 19M-6 (table 1) are from opposite sides of the area (pl. 2) and are probably not much different from any which might be taken from the Snake Run area.

In an area of about 7 square miles having an overburden ratio of 2:1 or less, the 35-foot shale bed would contain about 440,000,000 tons of rock whose uranium content is probably about 0.003 percent, as in the Tewell Creek area immediately to the north. This black shale would appear to contain about 13,000 tons of uranium.

Wilson Creek area

On the north side of Wilson Creek in the southeastern part of Bullitt County (northwest part of area in pl. 2) are 3 square miles in which the shale could be stripped about as easily as in the Tewell Creek area. In table 1 are assays of a series of samples from the upper part of the formation (locality no. 20M-13) and of three samples from the underlying gray beds of the formation (locality no. 20M-14). In this area a 30-foot shale bed probably

would yield about 160,000,000 tons of rock containing about 0.003 percent uranium, or some 4,800 tons of uranium.

Summary of the Boston district

The total amount of strippable shale in the Boston district is believed to be about 1,170,000,000 tons, but the uranium content is low. During this investigation the equivalent uranium content was estimated radiometrically at the outcrop to be about 0.004 percent, but chemical assays of samples that were collected indicate an average uranium content of only about 0.003 percent (table 1). This small indicated uranium content of the rock probably eliminates these areas from further serious consideration for stripping. The assays also indicate that no part of the shale has an appreciably higher uranium content.

The upper 30 to 35 feet of the black shale, to which the above figures relate, probably would yield from 15 to 20 gallons of oil per ton, as well as considerable gas. At 15 gallons per ton, the shale would yield about 17,500,000,000 gallons of oil.

Table 1.--Chemical assays of samples from the Boston district, Nelson and Pullitt Counties, Kentucky

Locality no.	20M-5 1/		20M-15 2/		19M-6 3/		20M-13 4/		20M-14 5/	
Sample number	Thickness (feet)	Uranium (percent)	Thickness (feet)	Uranium (percent)	Thickness (feet)	Uranium (percent)	Thickness (feet)	Uranium (percent)	Thickness (feet)	Uranium (percent)
					Top of New Albany shale					
1	2.00	0.003			2.00	0.003	2.00	0.001		
2	1.45	.003			2.00	.002	2.00	.006		
3	2.00	.002			2.00	.006	2.00	.005		
4	2.00	.002			2.00	.005	2.00	.005		
5	2.00	.004			2.00	.003	2.00	.002		
6	2.00	.002			2.00	.003	2.00	.002		
7	2.00	.002			2.00	.002	2.00	.003		
8	2.00	.003			2.00	.001	2.00	.003		
9	2.00	.005			2.00	.003	2.00	.002		
10	2.00	.003			2.00	.003	2.00	.002		
11	2.00	.003			2.00	.002	2.00	.002		
12	2.00	.003			2.00	.003	1.40	(concealed)		
13	2.00	.003			2.00	.003	2.00	.003		
14	2.00	.003			2.00	.002	2.00	.001		
15	2.00	.002			2.00	.003	2.00	.002		
16	2.00	.002			2.00	.002	1.80	.001		
17	2.00	.001			1.65	.002				
18	2.00	.002								
21									2.00	0.001
22									2.00	.001
23									2.00	.001
27			2.00	0.001						
28			2.00	.001						
29			2.00	.001						
30			2.00	.001						
Total thickness and average grade	35.45	0.003-	8.00	0.001	33.65	0.003-	29.80	0.003-	6.00	0.001

1/ Tewell Creek area. 2/ Tewell Creek area (lower 8 feet of formation). 3/ Rhodes Knob, south of Snake Run area. 4/ Wilson Creek area. 5/ Wilson Creek area (gray beds near middle of formation).

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Levee area, Montgomery County, Kentucky

The Levee area is some 90 miles east of the Boston district described above. It extends about 2 miles north and south and 4 miles east and west, and lies generally southeast of Levee, Montgomery County (pl. 3); it is essentially flat; and has only about 30 feet of New Providence shale above the black shale, though locally the cover is about 50 feet thick. For about a mile south of this area the New Providence thickens gradually to about 150 feet, then still farther south rises sharply several hundred feet into "mountainous" knobs. A small fault cuts across the northeast corner of the area causing the shale to be about 50 feet higher on the north side than on the south.

In the Levee area the black shale is split by the Bedford-Berea siltstone, generally some 1 to 2 feet thick. The overlying black shale, some 6 feet thick, is known as the Sunbury shale, and the underlying black shale, some 75 feet or more thick, is known as the Ohio shale. One bed of silty limestone about 1 foot thick and 2 feet above the Sunbury shale is the only resistant rock known to be present where the overburden does not exceed 50 feet.

On the basis of field measurements of radioactivity the upper 40 feet was estimated to contain not more than 0.005 percent uranium. Chemical assays indicate that the upper 35 to 40 feet contain only about 0.002 percent uranium, and that the lower beds

Table 2.--Chemical assays of samples from the Levee area, Montgomery County, Kentucky

Locality no.	20U-17 1/		20U-18 2/		20U-20 3/	
Sample number	Thickness (feet)	Uranium (percent)	Thickness (feet)	Uranium (percent)	Thickness (feet)	Uranium (percent)
			Sunbury shale			
1a			2.00	0.002		
1b			2.00	.004		
1c			2.75	.003		
			Bedford-Berea			
1d			6.00	.000		
	Sunbury shale		Ohio shale			
1	2.00	0.002				
2	2.00	.003	2.00	.001		
3	2.00	.003	2.00	.003		
4	2.00	.002	2.00	.002		
	Bedford-Berea					
5	2.00	.002	2.00	.001		
	Ohio shale					
6	2.00	.001	2.00	.000		
7	2.00	.001	2.00	.000		
8	2.00	.001	2.00	.000		
9	2.00	.001	2.00	.000		
10	2.00	.002	2.00	.001		
11	2.00	.002	2.00	.002		
12	2.00	.002	2.00	.001		
13	2.00	.001	2.00	.001		
14	2.00	.002	2.00	.001		
15	2.00	.002	2.00	.001		
16	2.00	.003				
17	2.00	.002				
18	2.00	.002				
					Lower Ohio shale	
30					2.00	0.001
31					2.00	.001
32					2.00	.001
33					2.00	.002
34					2.00	.001
35					2.00	.001
36					2.00	.001
37					1.30	.001
38					2.00	.000
39					2.00	.001
40					2.00	.000
41					3.00	.000
Total thickness and average grade	36.00	0.002	40.75	0.001+	24.30	0.001-

1/ Quarry 2.4 miles east of Levee. 2/ About 1 mile east of Jeffersonville and 0.5 mile south of U. S. Hy. 460. 3/ East edge of Levee; road cut and creek bank.

contain hardly 0.001 percent (table 2).

The strippable area is irregular in shape and is estimated to be about 6 square miles. A 35-foot section would yield about 380,000,000 tons of shale. The oil yield probably would be about 15 gallons per ton, or 5,700,000,000 gallons.

Clay City area, Powell County, Kentucky

The Clay City area, Powell County (pl. 3), is about 3 to 4 miles south of the Levee area. It consists chiefly of several southward-projecting ridges just north of Red River, and is between Brush Creek on the west and Morris Branch on the east. The thickness, stratigraphy, and uranium content of the black shale appear to be about the same as in the Levee area.

About 7 square miles are estimated to have 100 feet or less of shale overburden, and much of the area has less than 40 feet of overburden. The uranium content is so low, however, (table 3) that the area appears to warrant no further investigation.

Table 3.--Chemical assays of samples from the Clay City area, Powell County, Kentucky

Locality no.	20U-8 1/		20U-16 2/		20U-19 3/		
Sample number	Thickness (feet)	Uranium (percent)	Thickness (feet)	Uranium (percent)	Sample number	Thickness (feet)	Uranium (percent)
	Sunbury shale		Sunbury shale				
1	2.00		2.00	0.005			
2	2.00		2.00	.004			
	Bedford-Berea						
3	2.00		2.00	.003			
	Ohio shale		Bedford-Berea				
4	2.00	0.000	2.00	.001			
			Ohio shale				
5	2.00	.000	2.00	.001			
6	2.00	.000	2.00	.001			
7	2.00	.001	2.00	.001			
8	2.00	.001	2.00	.001			
9	2.00	.001	2.00	.002			
10	2.00	.001	2.00	.002			
11	2.00	.001	2.00	.000		Lower	Ohio shale
12	2.00	.001	2.00	.001	30	2.00	0.001
13	2.00	.001	2.00	.001	31	2.00	.001
14	2.00	.001	2.00	.001	32	2.00	.001
15	2.00	.001	2.00	.001	33	2.00	.001
16	2.00	.002	2.00	.002	34	2.00	.001
17	2.00	.003	2.00	.002	35	2.00	.001
18	2.00	.001	2.00	.002	36	2.00	.002
19	2.00	.001	2.00	.002	37	2.00	.002
20	2.00	.001			38	2.00	.002
21	2.00	.001			39	2.00	.001
22	2.00	.001			40	2.00	.001
23	2.00	.002			41	2.00	.002
24	2.00	.001			42	2.00	.001
25	1.45	.001			43	2.00	.001
					44	2.00	.001
Total thickness and average grade	49.45	0.001+	38.00	0.002-	45	2.00	.002
					46	2.00	.002
					47	2.00	.002
					48	2.00	.001
					49	2.00	.001
					50	2.00	.002
					51	2.00	.001
					52	2.00	.004
					53	2.00	.002
					54	2.75	.003
					55	1.90	.002
					Total thickness and average grade	52.65	0.002-

1/ Long cut along Kentucky Hy. 15, 1 to 2 miles west of Stanton. Lower part may overlap upper part of 20U-19.
2/ About 0.3 mile northeast of Clay City, on east-west road on north side of Red River.
3/ First cut east of West Bend, Kentucky Hy. 15.

Fort Knox area, Bullitt County, Kentucky

The eastern part of the Fort Knox Military Reservation, Bullitt County, is about 10 miles west of the Boston district. In the southeastern part of the Reservation the upper 30 feet of the New Albany shale is well exposed in the narrow gorge of Crooked Creek. The shale underlies large parts of the flood plain of Crooked Creek and the Rolling Fork River into which it drains, but in places an unknown portion of the upper part of the shale has been removed by erosion.

Exploitation of this area would be complicated by two facts: (1) it is presently in the impact area for practice artillery firing, and (2) it is subject to flooding by both the local streams and occasional backwater from high floods on the Ohio River.

Chemical assays of samples from the uppermost 24 feet of the New Albany shale average slightly less than 0.003 percent uranium (table 4). No further investigations of this area appear to be warranted.

New Albany area, Indiana

In southern Indiana the black shale underlies at moderate depths a north-south belt of low rolling good farm land. This belt extends from the Ohio River, between New Albany and Jeffersonville, northward some 20 miles to the vicinity of

Henryville. Throughout most of this distance U. S. Highways 31E and 31W and the Pennsylvania Railroad are on the shale. The southern part of the belt is shown on plate 4. Several areas along this belt could be stripped and would afford billions of tons of shale. North of Henryville a thick cover of glacial drift would make stripping impracticable.

Geiger-counter readings on the outcrops indicated that the shale in the New Albany area contains something less than 0.005 percent uranium. Chemical assays of samples from two localities (22L-2 and 23L-4, table 4) indicate that the upper part of the shale contains a little less than 0.004 percent uranium.

Noteworthy in the chemical assays is the much higher uranium content, 0.012 and 0.015 percent, of a thin bed near the top, only 0.15 and 0.2 foot thick. The bed that yields these unusually high assays consists largely of phosphate nodules, yet a similar phosphate-rich bed at the top of the black shale in central Tennessee contains less uranium than do the associated non-phosphatic beds of black shale. [4, p. 56]

This strikingly high uranium content of the thin phosphate bed at the top of the shale in the New Albany area raises the question of whether the bed locally may be sufficiently thick and extensive to merit consideration for exploitation. This is improbable because (1) a greater thickness was nowhere observed in this reconnaissance, (2) the bed is not known to have attracted attention as a possible source of phosphate, and

Table 4.--Chemical assays of samples from the Fort Knox area, Bullitt County, Kentucky, and the New Albany area, Clark and Floyd Counties, Indiana

Locality no.	20M-21 [1]		22L-2 [2]		23L-4 [3]	
Sample number	Thickness (feet)	Uranium (percent)	Thickness (feet)	Uranium (percent)	Thickness (feet)	Uranium (percent)
	Top of New Albany shale					
1	2.00	0.002	0.7	0.003	0.85	0.004
2	2.00	.003	0.2	.015*	0.15	.012*
3	2.00	.003	2.00	.003	0.95	.003
4	2.00	.003	2.00	.004	1.85	
5	2.00	.003	2.00	.004	2.00	.005
6	2.00	.001	2.00	.003	2.00	.002
7	2.00	.003	2.00	.002	2.00	.004
8	2.00	.003	6.00	.004	2.00	.003
9	2.00	.003	2.70	.002	2.00	.004
10	2.00	.003	2.00	.004		
11	2.00	.003	2.00	.003		
12	2.00	.003	2.00	.005		
13			2.00	.004		
Total thickness and average grade	24.00	0.003-	27.60	0.004-	13.80	0.004-
14			2.00	0.002		
15			2.00	.002		
16			2.00	.001		
17			2.00	.001		
18			2.00	.001		
19			2.00	.001		
20			2.00	.001		
21			2.00	.001		
22			2.00	.001		
23			2.00	.001		
Total thickness and average grade			20.00	0.001+		

* Phosphate nodule zone just below top of New Albany shale.

1/ Near abandoned bridge over Crooked Creek in Fort Knox Reservation, Bullitt County, Kentucky.

2/ Floyd County, Indiana. Silver Creek; samples taken from several places down stream from Blackiston Mill. Sample 1 is 10 to 20 feet below top of black shale, which was not accessible.

3/ Clark County, Indiana, north side of Indiana Hy. 39 just east of Henryville.

(3) Campbell [3, pp. 870-872] reports it to be only a few inches thick. Campbell traced the bed (termed by him the Falling Run member of the Sanderson formation) for about 175 miles along the outcrop in southern Indiana and northern Kentucky.

Summary of uranium content in areas relatively suited to stripping

In none of the known areas favorable for stripping is the uranium content of the shale comparable to that in central Tennessee. The average uranium content of shales favorable for stripping appears to be not more than 0.006 percent in any area, and to be considerably less in most of them. Under these circumstances it seems unlikely that the ease of stripping would compensate for the low uranium content, in spite of the large quantities of available shale.

In all the areas studied, the upper part of the black shale appears to have appreciably more uranium than the lower part. A middle or lower portion of the shale, which contains a notable number of gray beds, is very low in uranium.

Recommendations concerning further work

Because of the low uranium content of the black shale at all the places sampled during this investigation for possible stripping sites, further investigations of the shale in these areas do not appear warranted. If, however, any further investigations are

decided upon, drilling would be desirable in order to (1) obtain fresh samples of the shale, and (2) learn the character of the overburden that would have to be removed.

Such drilling, it is believed, would be most successful if done with diamond bits. Because of the fissile character of the shale, 3-inch cores would probably hold together much better than 2-inch ones. Two-inch cores, however, taken with good equipment and by a careful driller might be satisfactory. Smaller cores probably would be unsatisfactory.

LESS FAVORABLE AREAS OF FLAT-LYING ROCKS IN KENTUCKY AND OHIO

Several areas underlain by black shale in Kentucky and two areas underlain by black shale in Ohio have some features in common with the areas already described; but their smaller size, the absence of the richer upper part of the shale, a generally lower grade, or a combination of these factors, render them less favorable. In table 5 the areas are listed and the particular factors that render them less favorable are summarized. Small samples were collected and assayed from several of these localities, but at none of these localities was the entire shale section sampled. Geiger-counter readings on the outcrops indicated that no part of the shale that is thick enough to warrant exploiting has a uranium content significantly higher than that indicated by chemical analysis.

Table 5.--Less favorable areas of flat-lying rocks in Kentucky and Ohio

Locality		Location		Uranium (percent)		Shale (tons)	Remarks
No.	Name	State	County	equiv.*	chem.		
19M	Culver School	Ky.	Nelson	nd.	nd.		About 10 miles southeast of Boston, south of Culver School near U. S. Hy. 31E; several small areas without excessive overburden; tonnages small.
19N-7	SW. of Lebanon	Ky.	~~Marion~~ Bullitt or Hardin	0.004	0.001		Beside Kentucky Hy. 208, 3 miles southwest of Lebanon; 50 feet of shale exposed. Sample from gray-green shale in lower part of black shale. Rest of section not sampled. Excessive overburden in much of the area.
19N	New Market	Ky.	~~Marion~~ "	nd.	nd.		Shale underlies about 5 square miles of alluvial flats of Rolling Fork; presence of upper part of shale uncertain.
19P	Lebanon	Ky.	~~Marion~~ Bullitt	nd.	nd.	100,000,000	South and east of town. Thickness of overburden would exceed 150 feet.

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Table 5.--Less favorable areas of flat-lying rocks in Kentucky and Ohio (continued)

Locality		Location		Uranium (percent)		Shale (tons)	Remarks
No.	Name	State	County	equiv.*	chem.		
19S-9	Berea	Ky.	Madison	0.004	0.002		Small sample 0.5 foot below top of black shale in railroad cut 1 mile south of town. Small accessible tonnage.
19T	Rice Station	Ky.	Estill	nd.	nd.	150,000,000	About 3 to 4 miles west of Irvine. Top of shale eroded in many places; overburden mostly river-terrace deposits.
20L	Shepherdsville	Ky.	Bullitt	nd.	nd.		Shale underlies alluvial flats of Salt River; presence of upper part of shale uncertain.
20M	SE. of Shepherdsville	Ky.	Bullitt	nd.	nd.		Several small scattered areas between Shepherdsville and Boston without excessive overburden. Areas do not have stipulated tonnage, but are near Boston district.

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Table 5.--Less favorable areas of flat-lying rocks in Kentucky and Ohio (continued)

Locality		Location		Uranium (percent)		Shale (tons)	Remarks
No.	Name	State	County	equiv.*	chem.		
21V-10	Farmers	Ky.	Rowan	0.006	0.002		Sample 12 feet above base of Sunbury.
				0.003	0.001		Sample at top of Ohio shale. Overburden excessive; 15 feet of tough Bedford-Berea siltstone between Sunbury and Ohio shales.
25X-11	Idaho	Ohio	Pike	0.004	0.002		Sample 15 feet below top of outcrop, 0.4 mile east of Idaho on Ohio Hy. 772. Overburden generally excessive.
25X-12	Paint Creek, Copperas Mtn.	Ohio	Ross	0.004	0.002		Sample near base of section on road up Copperas Mtn. from Paint Creek. About 300 feet of Ohio shale exposed. Uranium content probably very low.

* Equivalent uranium figures are based on radiometric measurements at the outcrops.

nd. Not determined.

SMALL AREAS IN TENNESSEE

In the Eastern Highland Rim of Tennessee, where the most intensive work on the black shale has been done, considerable time was spent in search of areas suitable for large-scale stripping operations. Throughout most of that area the shale is overlain by the extremely tough Fort Payne chert, although north of Putnam County the Fort Payne is progressively more shaly and much less cherty. Where the Fort Payne chert is present any overburden ratio in excess of 1:1 probably could not be tolerated. The entire Chattanooga shale in the Eastern Highland Rim is only about 30 feet thick, and the more uraniferous part is only about 17 feet thick, so stripping would probably be restricted to areas having less than 20 feet of overburden. Such areas of thin overburden are exceptional and are limited essentially to small outliers, narrow and steep-sided ridges, and stream valleys just above the shale. No place in the Eastern Highland Rim is known where shale in excess of a few hundred thousand tons could be obtained through stripping on a 1:1 ratio. The usual overburden on any outlier or ridge that would produce 200,000,000 tons is 100 feet or more.

As a matter of record, the principal features of the known areas that come closest to meeting the tonnage requirement, as well as a few other smaller areas, are shown in table 6. More details on the uranium content and the thickness of the shale beds at some of those places has been presented in an earlier report. [4]

Table 6.--Small areas in Tennessee unsuited to large-scale stripping

Locality No.	Locality Name	Location (County)	Uranium (percent) chem.	Shale (tons)	Remarks
10K	Manchester	Coffee		100,000+	Falls of Duck River; small area.
10K	Powers Bridge	Coffee		100,000+	Flats of Duck River; upper part of shale may have been eroded.
12K	Gassaway	Cannon		small	Small outliers and ridges; tough chert overburden.
13K	Statesville	Wilson Bedford		small	Small outliers; shale overlain by 75 to 100 feet of tough chert.
13L-22	Chestnut Mound	Putnam	0.006	25,000,000	Possibly 1 or 2 square miles along ridge traversed by U. S. Hy. 70N; maximum of 75 feet of tough chert overburden.
14M-6	Cub Creek	Jackson		50,000,000	Irregular ridges and outliers west of Cumberland River; 10 to 100 feet of chert and shaly limestone overburden.
14M-7	Columbus School	Jackson			Conditions similar to 14M-6; tonnage probably less.

AREAS OF FOLDED ROCKS

It has been pointed out in the "Introduction" that a vertical bed 24 feet wide (a convenient figure close to the thickness of the more uraniferous part of the Chattanooga shale), if mined to a depth of 100 feet, would yield only about 825,000 tons per linear mile. The possibility of finding a complexly folded area where the thickness of the shale might be much greater was discussed with R. A. Laurence, Regional Geologist, U. S. Geological Survey, who has done much work in the areas of folded rock in Tennessee. He knows of no place where such conditions exist. His information, combined with study of geologic maps, made it possible to eliminate most of the region of folded rocks.

Prior reconnaissance and field measurements of radioactivity [6, 8] indicate that in general the shale in the folded areas is both structurally complex and low in radioactivity. This is especially true in northeastern Tennessee and southwestern Virginia where the shale is much thicker. The shale was tested again in the course of the field work described in this report at some of the places most likely to be suitable for stripping, and the weak radioactivity was corroborated. These observations have led to the conclusion that where equivalent units are present the uranium content of the shale is roughly inversely proportional to the thickness of the shale.

Although areas where large quantities of the shale could be stripped economically probably do not exist in the belt of folded rocks in Tennessee and adjacent states, the principal places investigated or considered, and comments pertinent to their evaluation, are listed in table 7.

One region of higher than average uranium content in the folded rocks is the area of Walden Ridge and the nearby Sequatchie Valley, in southeastern Tennessee. There the average uranium content is as high as in any area where the Chattanooga shale has been studied systematically. [7]

Table 7.--Areas of folded rocks, unsuited to large-scale stripping

Locality		Location		Uranium (percent)		Shale (tons)	Remarks
No.	Name	State	County	equiv.*	chem.		
10N	Sequatchie Valley	Tenn. and Ala.	several		0.007	small	Shale dips under high ridge; scattered small outliers having less than 75 feet of chert overburden might be stripped.
12Q-1	Roddy	Tenn.	Rhea		0.007	825,000	Tonnage estimated for a trench 100 feet deep, 24 feet wide, and 1 mile long. Beds vertical; no overburden; complexly folded and faulted; 0.9 mile west of U. S. Hy. 27 at Roddy.
12S	Oak Ridge	Tenn.	Anderson	nd.	nd.		Small outlier in complex structure; of interest only because it is within the Reservation where it might be sampled for experimentation. Area not visited.
14V	Poor Valley	Tenn.	Claiborne	0.004	nd.	small	Near Noe Chapel school. Rocks dip 25°; shale is thick, silty, sandy, and low-grade.

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Table 7.--Areas of folded rocks, unsuited to large-scale stripping (continued)

Locality		Location		Uranium (percent)		Shale (tons)	Remarks
No.	Name	State	County	equiv.*	chem.		
14W 15X	Howard Quarter School	Tenn.	Claiborne and Hancock	0.004	nd.	75,000,000	No overburden, shale is silty and sandy; in plunging syncline on ridge 0.5 mile north of school.
15V	Cumberland Gap	Tenn.	Claiborne	0.003	nd.		About 100 feet of shale exposed at railroad tunnel; no stripping possibilities.
15Y	Pattonsville	Va.	Scott	0.003	nd.		Shale thick; mostly sandy and silty; conditions similar to those at Howard Quarter school.
17EE	Burkes Garden	Va.	Bland	0.003	nd.		150 feet of nearly vertical beds exposed along Virginia Hy. 78, 6 miles east of Burkes Garden.
20MM	Millboro Springs	Va.	Bath	0.003	nd.		About 15 feet of shale near top of section; Virginia Hy. 39, 1.6 miles west of junction with Virginia Hy. 42.

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Table 7.--Areas of folded rocks, unsuited to large-scale stripping (continued)

Locality		Location		Uranium (percent)		Shale (tons)	Remarks
No.	Name	State	County	equiv.*	chem.		
	Cumberland Mountain Front	Tenn.					Shale present at most places on east-facing Cumberland Mountain Front, low on slopes east thereof. Dips gentle to vertical; much faulting. Heavy talus and overburden.
	Fort Payne	Ala.	DeKalb				Shale 10 to 20 feet thick. Thick overburden of tough Fort Payne chert.
	Ooltewah-Apison structure	Tenn. and Ga.	Hamilton and Catoosa				Large area of outcrop, but shale is involved in complex faulting and folding; underlies steep slopes of Fort Payne chert.

* Equivalent uranium figures are estimates based on radiometric measurements at the outcrops.

nd. Not determined.

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