Preliminary Report

RADIOACTIVITY OF PENNSYLVANIAN BLACK SHALES AND COALS IN KANSAS AND OKLAHOMA

By A. L. Slaughter

Trace Elements Investigations Report No. 18

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

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Series B

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ABSTRACT

The first field work for the purpose of determining the radioactivity of Pennsylvanian black shales in Oklahoma was done in October, 1944, in the vicinity of Tulsa. Small phosphatic nodules were found to have relatively high radioactivity, particularly those in the black shale overlying the Checkerboard limestone. In May and June, 1945, more work was done in order to determine with more assurance, the abundance and radioactivity of the nodules. The later work covered all known black shale horizons in the Pennsylvanian system that could be found. The work extended as far north as Kansas City.

A number of coals of Pennsylvanian age were tested. They are all much too low in radioactivity to be of further interest.

The black shale over the Checkerboard limestone is the best horizon from the standpoint of abundance and radioactivity of nodules. One sample of nodules from this shale contains 0.186 percent equivalent uranium, 0.095 percent uranium. However, the distribution and radioactivity of the nodules are widely variable. The average nodule content of the black shale is about two percent over a thickness of about 2.5 feet. The average equivalent uranium content of the nodules is about 0.035 percent and the average uranium content 0.015 to 0.020 percent. With a product of this grade in view, the large mining operation necessary to produce a relatively small amount of nodules does not seem justified.

Two black shale beds, each about two feet thick and neither of which contains any nodules, contain 0.024 and 0.017 percent equivalent uranium and 0.013 and 0.010 percent uranium respectively. Too little work was done to permit calculations of tonnage, but material of this grade does not merit more detailed work at this time.

INTRODUCTION

Russell/ called attention to the radioactivity of some Pennsylvanian

/ Russell, W. L., The total gamma ray activity of sedimentary rocks as indicated by Geiger Counter determinations: Geophysics, vol. 9, no. 2, pp. 180-216, April, 1944.

black shales in the vicinity of Tulsa, Okla. An examination was made and samples were collected from five shale horizons in this area by A. L. Slaughter and S. E. Clabaugh/ in October, 1944. The results of some of the work were

/ Slaughter, A. L. and Clabaugh, S. E., Reconnaissance in central and southwestern states, preliminary report: U. S. Geol. Survey Trace Elements Investigations rept. 9, unpublished, Mar., 1945.

favorable and, as there were known to be many black shales of Pennsylvanian age in northeastern Oklahoma and eastern Kansas, it was decided that more extensive work should be done in the area. A possible relation between helium, which is produced from wells in central Kansas, and Pennsylvanian black shales was suggested. The rocks from which helium is produced outcrop in eastern Kansas and northeastern Oklahoma.

The earlier work had shown that small nodules or concretions in the shales are the most highly radioactive. It was hoped that a locality might be found where the nodules were of sufficiently high radioactivity and present in sufficient quantity to make a nodule-concentrating operation feasible.

About one month during May and June, 1945 was spent in the Kansas-Oklahoma area by A. L. Slaughter, at first accompanied by J. O. Harder and later by C. W. Chesterman. Some of the more favorable horizons which are exposed near Tulsa were examined further, particularly the black shale bed above the Checkerboard limestone. All known black shales that could be found were tested. A number of coals of Pennsylvanian age were also tested.

Geological Considerations

Outcrops of Pennsylvanian rocks occur throughout the eastern one-fourth of Kansas and much of eastern Oklahoma. In the area covered by the index map (fig. 1) the strike of the rocks is north-northeast and they have a gentle dip to the west-northwest. The lowermost rocks of the system are exposed in northeastern Oklahoma and southeastern Kansas. The whole sequence can be covered by traveling west or north.

Outcropping rocks in Kansas have been described by Moore, Frye and Jewett.[1]

[1] Moore, R. C., Frye, J. C., and Jewett, J. M., Tabular description of outcropping rocks in Kansas: Kan. Geol. Survey, Bull. 52, part 4, 1944.

Figure 2 is a generalized columnar section with their average thicknesses and nomenclature of the rocks. The total thickness of Pennsylvanian rocks as shown by this section is about 2500 feet. Changes in stratigraphy along the strike make it advisable to illustrate the rocks with two columnar sections. The Bandera shale, for instance, is 20 to 50 feet thick in Kansas where it is a gray, yellow and maroon clay shale, but near Tulsa, Okla. it is represented by two to four feet of black fissile shale. Likewise, the Checkerboard limestone is overlain by several feet of black fissile shale in the Tulsa area, but this black shale is absent farther north. Figure 3 is a generalized columnar section of part of the Pennsylvanian rocks in the vicinity of Tulsa, following Gould.[1]

[1] Gould, C. N., Index to stratigraphy of Oklahoma: Okla. Geol. Survey Bull. 35, 1925.

Black shale beds occur throughout the Pennsylvanian sequence with the exception of the upper 400 feet or so of the Wabaunsee group (fig. 2) where none has been described. Many of them are units of cyclothems, representing a phase in a cycle of rhthmic sedimentation. The average thickness is about three feet; the observed range is from 0.2 feet for the Muncie Creek shale near Independence, Kan. (S174, fig. 1) to more than 12 feet for the black shale over the Checkerboard limestone in southern Washington County, Okla. (S187, fig. 1). The black fissile shale has in some places been partly weathered to dark clayey shale. Black shale beds are in some places in contact with limestone, both above and below. In many places they are separated from limestones by varying thicknesses of rather soft gray shales. They are commonly underlain by thin coal beds.

Many Pennsylvanian black shales are characterized by the presence of small, phosphatic concretions and concretionary masses. These concretions or nodules are of two general shapes; nearly round with a maximum diameter of two inches, usually less; and flat, irregularly shaped, and as much as three inches in their greatest dimension. They are fine-grained and hard, usually black, although some are brown. Some contain fine-grained pyrite or marcasite. When broken, many exhibit small fossil fragments at the center. In thin section, small, irregular particles of calcite are revealed. The nodules are quite highly phosphatic, containing as much as 31.4 percent P_2O_5 (see p. 8).

Nodules are very erratic in occurrence. Some black shale beds contain none, parts of others contain nearly five percent nodules by volume (fig. 4). At many localities the black shale contains only a few, less than one percent by volume; rarely do they compose more than 3 to 4 percent of the shale. They commonly occur in layers within the shale bed, other parts of the bed being devoid of them (figs. 4, 5, and 6). The same black shale bed varies from one outcrop to another in position and quantity of nodules.

Field methods

Methods of determining radioactivity in the field are similar to those used previously. General field procedure has been described by Stead.[1]

1/ Stead F. W., Field measurement of radioactivity, preliminary report: U. S. Geol. Survey Trace Elements investigations, rept. 13, May 1945, unpublished.

In addition to determining the radioactivity of the black shales and contained nodules, the percentage of nodules in the shales was an important consideration. This was determined at a number of places by making excavations to uniform dimensions across the shale bed (or part of the bed), separating all the nodules from the shale and measuring their volume by displacement in water. The percentage by volume of nodules in the shale was determined in this manner at S131. (figs 1 and 4). The volumes of the excavations varied from 557 cubic inches for sample 546 to 1920 cubic inches for sample 548.

Radioactivity

The radioactivity of the phosphatic nodules ranges from 0.016 to 0.095 percent equivalent uranium. There is no consistent physical difference between the nodules of high activity and those of low activity. However, at locality S136, a sample (S136-552) of flat irregular nodules with widths of two to three inches and a sample (S136-553) of larger round nodules with diameters of one to two inches each contain less equivalent uranium than a sample (S136-554) of smaller irregular shaped nodules.

The black shale is usually less radioactive than the nodules, although some of the better shales have about the same radioactivity as the lower grade nodules. The best sample (S179-562) of black fissile shale that is free of nodules contains 0.024 percent equivalent uranium and 0.013 percent uranium. Sample S178-561 is from a hard lens-like layer about one inch thick in the stark shale. This has neither the shape of what are termed nodules nor the phosphate content of the nodules but has a much higher radioactivity than any of the black shales, 0.044 percent equivalent uranium and 0.021 percent uranium.

Some gray shale and other light-colored clayey shales were tested where they are adjacent to black shales or coal. They are very low in radioactivity.

Narrow coal beds were tested at a number of horizons by outcrop counting and sampling or both. A sample (S167-532) of coal near the top of the Cherokee shale (Mulky coal) contains 0.004 percent equivalent uranium and a sample of the Mineral coal (S181-568) contains 0.002 percent. All others are essentially non-radioactive.

Ratio of uranium to total radioactivity

Total radioactivity is given as percent equivalent uranium. Uranium has been determined chemically in 32 samples and is responsible for about 55 percent of the total radioactivity of the average sample. In 23 of the samples the percent of total radioactivity due to uranium is between 45 and 65.

Thorium has been determined (spectrographically) in four samples which are listed below:

Sample No.	Description	Percent U (chem)	Percent ThO_2 (spectro)	Percent equiv. U calculated	Percent equiv. U lab. counting
S131-412	black shale	0.003	0.008	0.009	0.014
-412a	nodules from 412	0.062	0.02	0.076	0.123
-413a	Nodules	0.016	0.008	0.022	0.032
S136-418b	nodules	0.090	0.008	0.096	0.145

Equivalent uranium has been calculated by converting ThO_2 to equivalent uranium and adding this to uranium by chemical analysis. Calculated equivalent uranium is considerably lower than actual equivalent uranium as determined by gamma counting for all four samples. There is not enough thorium to account for the difference between percent uranium and percent equivalent uranium. If the data are correct, this indicates the presence of more of the highly radioactive disintegration products, such as radium, in the samples than is called for by equilibrium conditions.

Relation of phosphate to radioactivity and uranium.

Phosphate has been determined in seven shale samples and eleven nodule samples. These determinations and the ratios between phosphate and equivalent uranium and between phosphate and uranium are given on the following page. The highly phosphatic nodules contain more equivalent uranium and uranium, with one exception (S178-561), than do the low phosphate shales. However, neither in the shale group nor in the nodule group is there any close correlation between phosphate and equivalent uranium or between phosphate and uranium.

Ratio of phosphate to radioactivity and uranium

Sample No.	Type of material	% P_2O_5	% Equiv. U	% U	P_2O_5/equiv. U	P_2O_5/U
S131-412	shale	1.6	0.014	0.003	114	533
S136-418	"	0.5	0.010	0.004	50	125
S166-529	"	2.1	0.008(f)	0.005	262	420
S173-542	"	2.9	0.007	0.005	414	580
S178-559	"	0.6	0.016	0.008	38	75
-561	"	1.0	0.044	0.021	23	50
S179-562	"	1.9	0.024	0.013	80	145
S130-407	nodules	25.6	0.025	0.022	1000	1163
S131-412A	"	27.1	0.126	0.062	215	437
-413A	"	29.6	0.032	0.016	915	1850
-548	"	26.2	0.152	0.070	172	375
-549	"	26.7	0.108	0.050	248	530
S-136-418B	"	31.2	0.145	0.090	215	347
-552	"	23.1	0.055	0.029	420	795
-554	"	31.4	0.186	0.095	168	330
S166-530	"	28.8	0.028(f)	0.020	1030	1440
S173-541	"	25.1	0.035	0.017	717	1480
S179-564	"	21.7	0.062	0.032	350	680

(f) equivalent uranium determination by field gamma counting, all others by laboratory counting

Descriptions of horizons tested

Localities at which samples were taken are designated by locality numbers on the index map. (fig. 1). Places at which outcrop readings only were taken are shown by symbol.

The following descriptions list the tested horizons stratigraphically, beginning with the uppermost. The position of each horizon in the stratigraphic column is shown on one of two generalized columnar sections (figs. 2 and 3). The rocks at three localities (S131,S135,S179) are illustrated by individual sections (figs. 4, 5, and 6).

Much help in locating outcrops was obtained from the eleventh annual field conference guide book of the Kansas Geological Society. Two bulletins of the Kansas Geological Survey were also helpful. References are made to these three publications/ inthe following locality descriptions; stop numbers refer to the guide book, and bulletin numbers refer to the respective Kansas Geological Survey bulletins.

Determinations of equivalent uranium, by field gamma counting (f) and by laboratory gamma counting (l) are given, also determinations of uranium which are by chemical analysis. Where only outcrop readings have been taken, no sample numbers are given and the rock is listed as being low in equivalent uranium. In all cases this signifies less than 0.005 percent equivalent uranium and usually less than 0.003 percent.

/ R. C. Moore, et al., Eleventh annual field conference guide book, southeastern Kansas and northeastern Okla., Kan. Geol. Society, 1937.

/ R. C. Moore, Stratigraphic classification of the Pennsylvanian rocks of Kansas: Kan. Geol. Survey, Bull. 22, 1935.

/ Pierce, W. G. and Courtier, W. H., Geology and coal resources of the Southeastern Kansas coal field: Kan. Geol. Survey, Bull. 24, 1937.

Description	Samp. No.	thick. ft.	% equiv. U(f)	% equiv. U(l)	%U (chem)
Aarde shale member of Howard limestone (fig. 2)					
S194 - NE¼ NW¼ sec. 11, T34S, R9E, Chautauqua Co., Kan., stop 40 in 1937 Kan. guide book					
Howard limestone					
Church limestone, 3.2 ft. exposed					
Aarde shale					
Shale, brown-yellow, clayey............		1.1	low		
Shale, dark gray to black, fissile, no nodules............................	584	1.3	0.005	0.002	
Bachelor Creek limestone, 1.1 ft. exp.					
Holt shale member of Topeka limestone (fig. 2)					
S200 - SE¼ sec. 5, T11S, R16E, Shawnee Co., Kan., on bank of Indian Creek.					
Topeka limestone					
Coal Creek limestone					
Holt shale					
Shale, green, clayey					
Shale, dark gray to black, part fissile	591	1.8	0.006	0.004	
Dubois limestone					
Larsh-Burroak sh. member of Deer Creek limestone (fig. 2)					
S195 - Hwy. 60, 3 miles west of Pawhuska, Osage Co., Okla., stop 34					
Deer Creek limestone					
Ervine Creek limestone					
Larsh- Burroak shale, dark gray to blue Light- colored nodules, less than 1% of shale by volume.........................	585	3.4	0.022	0.021	
Rock Bluff limestone					

Description	Samp. No.	thick. ft.	% equiv. U(f)	% equiv. U(l)	%U (chem)
Queen Hill shale of Lecompton limestone (fig. 2)					
West edge of Lecompton, Douglas Co., Kan.					
Lecompton limestone					
Beil limestone					
Queen Hill shale, brown, blue, gray, yellow, one narrow, black, fissile, bed, mostly soft and clayey............		4.5	low		
Big Springs limestone					
Heebner shale of Oread limestone (fig. 2)					
S199 - Hwy. 40 just west of Lawrence, Douglas Co., Kan.					
Oread limestone					
Plattsmouth limestone					
Heebner shale					
Shale, dark gray, grading upward to light gray and yellow................		2.4			
Shale, black, fissile, one narrow horizon of small black nodules.......		3.1			
sample 590 is best 1 ft..............	590	1.0	0.008	0.009	
Leavenworth limestone					
S193 - Sec. 33, T33S, R11E, Chautauqua Co. Kan., stop 39					
Oread limestone					
Plattsmouth limestone					
Heebner shale					
Shale, soft,yellow....................		1.9	low		
Shale, dark gray to black, fissile...		4.0			
3 layers of dark irreg.-shaped nodules, less than 1% of shale bed......	583		0.018	0.019	
Leavenworth limestone, $1\frac{1}{2}$ ft. exp.					

Description	Samp. No.	thick. ft.	% equiv. U(f)	% equiv. U(l)	%U (chem)
Eudora shale member of Stanton limestone (fig. 2)					
S197 - Hwy 10, 2 miles west of Eudora, Douglas Co., Kan.					
Stanton limestone					
Stoner limestone, 8 ft. exposed					
Eudora shale					
Shale, yellow-gray, soft................		1.5	low		
Shale, dark gray to black, brown in part, fissile in part, soft and clayey in part..		4.8			
587 is 1.1 ft. sample of most black fissile part............................	587	1.1	0.001	0.006	
Captain Creek limestone					
Muncie Creek shale member of Iola limestone (fig. 2)					
S174 - $NW\frac{1}{4}$ sec. 29, T32S, R15 E, Montgomery Co., Kan. stop 11					
Iola limestone					
Rayton limestone					
Muncie Creek shale, black, fissile........	543	0.2	0.003		
Paola limestone					
S198 - Between Muncie and City Park, Kansas City, Kan.					
Iola limestone					
Rayton limestone					
Muncie Creek shale, dark gray to brown..		2.2			
2 narrow, black fissile layers, shale from upper 1.5'....................	589	1.5	<0.001		
dark brown nodules from upper 0.5'......	588	0.5	0.050	0.051	
Paola limestone					

Description	Samp. No.	thick. ft.	% equiv. U(f)	% equiv. U(l)	%U (chem)
NE¼ SE¼ sec. 8, T23N, R12E, Osage Co., Okla. stop 32					
Iola limestone					
Surface					
Muncie Creek shale					
Shale, black, fissile, brown stains... very few nodules		1.5	low		
Shale, dark gray, soft, 0.5' exp......			low		

Stark shale of Dennis limestone (fig. 2)

Description	Samp. No.	thick. ft.	% equiv. U(f)	% equiv. U(l)	%U (chem)
S178 - SE¼ sec. 14, T27S, R20E, Neosho Co. Kan. (p. 92, Bull. 22)					
Dennis limestone					
Winterset limestone					
Stark shale					
Shale, black, hard, fissile, red stains..	558	2.1	0.002		
small black nodules, less than 1% by volume..................................	560		0.016	0.019	
Shale, hard lens-like layer.............	561	0.1	0.042	0.044	0.021
Shale, black, hard, fissile, red stains..	559	2.2	0.011	0.016	0.008
Canville shale					

Hushpuckney shale member of Swope limestone (fig. 2)

Description	Samp. No.	thick. ft.	% equiv. U(f)	% equiv. U(l)	%U (chem)
S182 - Near junction of Kan. hwy. 35 and U. S. hwy. 69, northern Linne Co., Kan. (p. 85, Bull. 22)					
Swope limestone					
Bethany Falls limestone					
Hushpuckney shale					
Shale, green, soft......................		3.9			
Shale, black, fissile, no nodules.......	569	2.1	0.013	0.017	0.010
Middle Creek limestone					

Description	Samp. No.	thick. ft.	% equiv. U(f)	% equiv. U(l)	%U (chem)
Black shale at top of Bourbon shale (figs. 2&6)					
S179 - Sec. 16, T29S, R20E, Neosha Co., Kan., Kan. hwy. 57					
Hertha limestone					
Sniabar limestone					
Mound City shale, dark gray to black, fissile, darker near bottom..............		2.2	low		
Shale, dark gray, hackly, calcareous, with nodular limestone layer (Critzer ls)		1.0	low		
Bourbon shale					
Shale, black, fissile, platy in part, brown stained...........................		2.7			
Nodules from upper 1.7', not more than 1% of shale by volume..................	564	1.7	0.075	0.062	0.032
Shale, black, fissile..................	562	2.0	0.018	0.024	0.013
Shale, black, fissile nodules from bottom 1'.................	563	1.5	0.028	0.021	
Shale, gray, hackly, calcareous.........			low		
Black shale over Checkerboard limestone (fig. 3)					
S130 - SW¼ sec. 36, T19N, R12E, Tulsa Co., Okla., on Turkey Mountain					
Coffeyville formation					
Sandstone, brown, slabby					
Shale, black, fissile, yellow and brown stains on bedding, 5' exposed..................	406	5.0	0.004	0.003	
3 samples of nodules from shale bed: Flat nodules, brown interior, up to 3" dia., ½" thick..........................	407		0.017	0.025	0.022
Flat nodules, pitted exterior, white speckled, up to 2" dia., 1/2" thick.....	408		0.014	0.020	0.008
Round nodules, blue-gray interior average ½" dia..........................	409		0.016	0.029	0.018

Description	Samp. No.	thick. ft.	% equiv. U(f)	% equiv. U(l)	%U (chem)
S131 - NW$\frac{1}{4}$ sec. 13, T20N, R12 E, Tulsa Co., Okla. (fig. 4)					
Coffeyville formation					
Shale, blue to gray, soft					
Shale, black, fissile, reddish-brown stains, yellow coatings..................	413	1.7	0.003	0.008	
Nodules from 413.......................	413a		0.042	0.032	0.016
Shale, same............................	412	2.0	0.008	0.014	0.003
Nodules from 412.......................	412a		0.134	0.126	0.062
Shale, same............................	411	2.0	0.005	0.005	
Nodules from 411.......................	411a		0.024	0.028	0.014
Shale, dark bluish-gray, platy.........	410	0.6		0.002	
Checkerboard limestone					
(Nodules at this location were re-sampled, see fig. 4 for further details)					
Nodules, 4.5% of 0.6' of shale........	547	0.6	0.022	0.026	
Nodules, 4.8% of 0.6' of shale........	546	0.6	0.027	0.025	
Nodules, 2.9% of 0.7' of shale........	545	0.7	0.050	0.047	
Nodules, 3.3% of 0.4' of shale........	549	0.4	0.104	0.108	0.050
Nodules, 0.8% of 0.7' of shale........	548	0.7	0.157	0.152	0.070
Nodules, 2.3% of 0.5' of shale........	550	0.5	0.030	0.036	
S136 - SE$\frac{1}{4}$ sec. 36 T23N, R13E, Tulsa Co. Okla.					
Coffeyville formation					
Surface					
Shale, black, brown stains, yellow coatings, no nodules in sample, 2.5' exp..	418	2.5	0.007	0.010	0.004
Nodule samples gathered on surface 100' ± from where shale sample was taken.					
Nodules, dark gray, very hard, abund. Sulphides, up to 1' dia. 6" thick.....	418a		0.015	0.017	
Nodules, small, both round and flat...	418b		0.135	0.145	0.090
Nodules, flat, 2-3" across, $\frac{1}{2}$" thick..	552		0.050	0.055	0.029
Nodules, round, 1-2" dia...............	553		0.016	0.058	
Nodules, small, irreg. shaped..........	554		0.154	0.186	0.095

Description	Samp. No.	thick. ft.	% equiv. U(f)	% equiv. U(l)	%U (chem)
S175 - NE$\frac{1}{4}$ sec. 25, T28N, R15E, Nowata Co., Okla. stop 21					
Coffeyville formation					
Clay, 0.4' exposed					
Shale, black med. soft..................		0.5	low		
Shale, gray to brown, soft................		1.0	low		
Shale, black, hard, fissile...............		2.4	low		
1' of shale about in center has less than 5% round and flat nodules............	544	1.0	0.035	0.032	
Shale, dark gray to black, fissile........		0.6	low		
Shale, black, soft.......................		0.6	low		
Checkerboard limestone		0.5			
S187 - Sec. 5, T23N, R14E, Washington Co., Okla., Buck Creek					
Coffeyville formation					
Surface					
Shale, black to dark gray, bluish in part, contains hard, black, pyritic nodules, up to 2' dia. 6" thick at two horizons................................		10.8	low		
Nodules from lower 2' of shale, $\frac{1}{2}$-1$\frac{1}{2}$" dia., some flat and irreg., less than 2% of the 2' of shale by volume..........	575	2.0	0.038	0.039	
Shale, dark gray, fissile................		2.0	low		
Water level of Buck Creek, Checkerboard limestone probably 3-4' below					
S188 - SW$\frac{1}{4}$ sec. 13, T25N, R14E, Nowata Co., Okla.					
Coffeyville formation					
Shale, dark gray to gray, soft, platy					
Shale, black, platy, med. soft...........		2.7	low		
Nodules, $\frac{1}{4}$-1", 2.2% of shale............	576	2.7	0.037	0.048	0.027
Clay, yellow, sandy		0.3			
Checkerboard limestone					

Description	Samp. No.	thick. ft.	% equiv. U(f)	% equiv. U(1)	%U (chem)
S190 - NW¼ sec. 36, T21N, R12E, Tulsa Co., Okla., ditch beside road					
Coffeyville formation					
Surface					
Clay, brown, yellow, black..............		1.3			
Weathered nodules at bottom of clay....	579		0.016	0.019	
Shale, black, platy.....................		1.5	low		
Shale, dark gray, platy, soft..........		0.7	low		
Checkerboard limestone					
S191 - SE¼ sec. 34, T19N, R12E, Tulsa Co., Okla., U. S. hwy. 169					
Coffeyville formation					
Shale, gray, clayey					
Shale, black, fissile, lower 1' soft and clayey..............................		4.8	low		
Nodules from upper 1' of shale, gray, some are soft..........................	580	1.0	0.019	0.024	
Clay, red, sandy........................		0.3	low		
Clay, shale, gray, soft, 0.7' exposed...		0.7	low		
Checkerboard limestone probably about 1' below					
S192 - NW¼SW¼ sec. 11, T18N, R12E, Tulsa Co., Okla., U. S. hyw. 169					
Coffeyville formation					
Shale, gray, clayey....................			low		
Shale, dark gray to black..............		5.4	low		
Nodules, brown, from upper 1' of shale.	582	1.0	0.010	0.022	
Shale, dark gray, red in part, clayey..		1.0			
Shale, black, fissile..................		0.5	low		
Nodules from shale bed.................	581	0.5	0.025	0.031	
Shale, gray-black, hackly, 1.2' exposed		1.2	low		
distance to Checkerboard unknown					

Description	Samp. No.	thick.- ft.	% equiv. U(f)	% equiv. U(l)	%U (chem)
Black shale associated with Dawson coal (fig. 3)					
S132 - NE cor. sec. 28, T20N, R13E, Tulsa Co., Okla., Old Hickory mine					
Shale, black, fissile, yellow stains, sample picked from dump of old strip mine....................................	414		0.004	0.013	
Bandera shale (fig. 3)					
S133 - sec. 28, T20N, R14E, Tulsa Co., Okla., Garnett quarry					
Oologah limestone					
Altamount limestone					
Bandera shale					
Shale, gray, soft.......................		0.4			
Shale, black, fissile, yellow and brown stains...........................	415	2.3	0.003	0.003	
Nodules from 415........................	415a	2.3	0.020	0.022	0.016
Pawnee limestone					
S186 - $SE\frac{1}{4}$ $NE\frac{1}{4}$ sec. 17, T20N, R15E, Rogers Co., Okla., hwy. 66, bank Verdigris River					
Oologah limestone					
Altamount limestone					
Bandera shale, black, fissile............		3.4	low		
Nodules from upper 2.4', most are flat, up to 3" long, $\frac{1}{2}$" thick, between 1 and 2% of shale bed..........................	574	2.4	0.032	0.034	
Pawnee limestone					

Description	Samp. No.	thick. Ft.	% equiv. U(f)	% equiv. U(l)	%U (chem)
Anna shale member of Pawnee limestone (fig.2)					
S170 - SE$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 3, T33S, R20E, Labette Co., Kan. stop 8					
Pawnee limestone					
Myrick Station limestone					
Anna shale					
Shale, blue-black to gray...............		3.0	low		
Shale, black, hard, fissile.............		1.5	low		
Nodules from shale bed..................	537	1.5	0.042	0.039	0.018
Shale, blue to black, med. soft					
S196 - SE cor. sec. 29, T26N, R17E, Nowata Co., Okla. stop 22					
Pawnee limestone					
Myrick Station limestone					
Anna shale					
Shale, gray, soft........................		0.2			
Shale, dark gray to black, fissile......		3.3	low		
Nodules, hard, black, from lower 1$\frac{1}{2}$' of shale, less than 1% of entire bed....	586	1.5	0.042	0.038	0.018
Limestone					
Coal in Labette shale (fig. 2)					
In bank of Lightning Creek, W of Girard, Kan., Crawford Co.					
Labette shale					
Shale, gray to brown, sandy, platy limonitic crusts, 5' exposed					
Coal.................................		0.6	low		
Shale, blue-gray, narrow seams, coaly material................................			low		

Description	Samp. No.	thick.. ft.	% equiv. U(f)	% equiv. U(l)	%U (chem)
Black shale at base of Labette shale (fig. 3)					
S134 - NE$\frac{1}{4}$ sec. 34, T17N, R14E, Tulsa Co., Okla.					
Labette shale					
Sandstone, shaly, gray and tan					
Clay, red, sandy......................		0.3			
Shale, black, reddish-brown in part and soft due to weathering.............	416	1.3	0.004	0.007	
Nodules from shale bed................	416a	1.3	0.027	0.026	0.022
Shale, clayey, sandy, gray to tan......		0.6			
Fort Scott limestone					
Black shale in Fort Scott limestone (fig. 3)					
S135 - Center E line sec. 27, T18N, R14E, Tulsa Co., Okla. (fig. 5)					
Fort Scott limestone					
Limestone					
Shale, blue to black, clayey, very few nodules...........................		0.3			
Shale, black, fissile, brown stains...	417	2.5	0.005	0.004	
Nodules in upper 1.6', black, hard, round up to 1" dia., disc-shaped up to 3", 3.4% of 1.6' of shale by volume.	551	1.6	0.037	0.037	0.018
Earlier sample of nodules.............	417a		0.051	0.044	0.032
Limestone					
S169 - NE$\frac{1}{4}$ sec. 21, T33S, R21E, Labette Co., Kan., Railroad cut in Oswego, Kan.					
Fort Scott limestone					
Shale, black, fissile, not well exp....		3.4			
Nodules, rather scarce................	536		0.034	0.037	0.020
Shale, clayey, blue, gray, about 1' exp.					

Description	Samp. No.	thick. ft.	% equiv. U(f)	% equiv. U(l)	%U (chem)
S171 - SW$\frac{1}{4}$ SE$\frac{1}{4}$ sec. 10, T28S, R24E, Crawford Co., Kan.					
Fort Scott limestone					
Shale, black, fissile, a few black nodules, exposure is poor, only 0.5' sampled..................................	538	0.5	0.013		
S172 - NW edge of Fort Scott, Bourbon Co., Kan.					
Fort Scott limestone					
Limestone					
Shale, black, fissile, med. soft........		1.3	low		
Shale, black, fissile....................	539	0.7	0.013		
Nodules from 0.7' shale bed.............	540	0.7	0.030	0.035	
Clay, gray to tan.......................		0.4	low		
Shale, black, fissile, narrow coal seams		0.7	low		
Clay, gray to tan					
S173 - Old quarry E of Fort Scott, Bourbon Co., Kan.					
Fort Scott limestone					
Limestone					
Clay, shaly, brown to gray..............		0.8	low		
Shale, light to dark brown, soft, hackly.		0.7	low		
Shale, black, fissile....................	542	1.9	0.003	0.007	0.005
Nodules, from 542, not abundant..........	541	1.9	0.038	0.035	0.017
Clay, gray to tan........................		0.5	low		
Shale, black, thin coal seams............		0.6	low		
Shale, clayey, gray, yellow, brown.......		3.3	low		
Limestone					

Description	Samp. No.	thick. ft.	% equiv. U(f)	% equiv. U(l)	%U (chem)
S177 - Sec. 8, T30S, R23E, Crawford Co., Kan., 0.4 mile E of Lightning Creek on E-W center line of sec.					
Fort Scott limestone					
Limestone					
Shale, black, fissile....................	556	2.8	0.005		
Nodules from upper 1.5' of shale, less than 2% for 2.8' thickness..............	557	1.5	0.024	0.026	
Limestone					
S189 - sec. 11, T21N, R15E, Rogers Co., Okla., hwy, 20.					
Fort Scott limestone					
Limestone, about 10' exposed					
Shale, dark brown to dark gray..........		3.0	low		
Nodules from shale, weathered white on outside,brown to gray inside, most are flat, disc-like, not over 1% of shale bed.............................	577	3.0	0.016	0.018	
Shale, black, fissile, brittle, yellow and rust stains.........................		1.7	low		
Nodules, hard, pyritic, not over 2% of shale bed.............................	578	1.7	0.056	0.048	0.025
Shale, brown to black, clayey...........		0.3			
Limestone					

Description	Samp. No.	thick. ft.	% equiv. U(f)	% equiv. U(l)	%U (chem)
Black shale and coal at top of Cherokee shale (fig. 2)					
S165 - NW$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 1, T29S, R25E, Crawford Co., Kan.					
Fort Scott limestone, part of lower member exposed					
Cherokee shale					
Clay, blue to tan, soft..................		0.5			
Shale, black, fissile to hackly..........	526	2.5	0.005		
small oval-shaped nodules in lower 2' of shale..............................	528	2.0	0.013	0.016	
Shale, black, fissile to hackly..........	527	1.9	0.008		
Coal (Mulky coal)........................		0.5			
S167 - NW$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 5, T28S, R25E, Crawford Co., Kan., stop 3					
Fort Scott limestone, part of lower member exposed					
Cherokee shale					
Shale, black, fissile....................	531	2.9	0.005	0.005	
Small nodules in upper 1.5', 1-2% of whole shale bed........................	533	1.5	0.027	0.022	
Coal (Mulky).............................	532	0.6	0.001	0.004	
S168 - Center E line sec. 16, T33S, R21E, Labette Co., Kan., edge of Oswego					
Fort Scott limestone, part of lower member exposed					
Cherokee shale					
Shale, black, fissile....................		3.0	low		
Nodules estimated to be about 5% by volume of shale, 534 is small, round nodules................................	534		0.027	0.027	0.013
535 is flat irreg. nodules 2-3" long.....	535		0.018	0.019	
Clay, brown and gray					

Description	Samp. No.	thick. ft.	% equiv. U(f)	% equiv. U(l)	%U (chem)
S180 - Sec. 15, T31S, R23E, Crawford Co., Kan., hwy, 160, 3½ miles W of Cherokee					
Fort Scott limestone, part of lower member exposed					
Cherokee shale					
Shale, gray, clayey....................		0.3			
Shale, black, fissile................		3.7	low		
Nodules, small, black.................	565	3.7	0.034	0.027	
Nodules, black, soft, at lower contact of black, fissile shale, large, about 4"x6"x2"...........................	567		0.000		
Shale, gray, soft.....................			low		
Nodules, some round, some cigar-shaped, gray, hard, some pyrite, 2-3" dia.....	566		0.003		
Bevier coal (fig. 2)					
S184 - N edge sec. 4, T28S, R25E, Crawford Co., Kan.					
Cherokee shale					
Bevier coal, sample from dump at edge of pit...............................	572	?	0.000		
Black shale above Croweburg coal (fig. 2)					
S166 - NE¼ sec. 3, T29S, R25E, Crawford Co., Kan.					
Cherokee shale					
Shale, gray, clayey					
Shale, black, fissile................	529	3.7	0.008	0.004	0.005
horizon of large, nodules, up to 2' long by 1' thick, near top of shale..			low		
Nodules, small, black, confined to lower 1' of shale....................	530	1.0	0.028	0.022	0.020
Shale, gray, soft, thickness unknown.		?			
Croweburg coal, sample picked from waste pile at old strip pit..........	571	?	0.000		

Description	Samp. No.	thick. ft.	% equiv. U(f)	% equiv. U(l)	%U (chem)
Fleming coal (fig. 2)					
S185 - NW$\frac{1}{4}$ sec. 27, T30N, R24E, Crawford Co., Kan., hwy. 160					
Cherokee shale					
Shale, yellow-gray					
Shale, black, fissile....................		1.8	low		
Fleming coal..........................	573	0.2	0.000		
Mineral coal (fig. 2)					
S176 - 0.7 mile N of Frontenac, Crawford Co., Kan.					
Cherokee shale					
Mineral coal, sample from dump..........	555	?	0.000		
S181 - sec. 19, T31S, R23E, Crawford Co., Kan.					
Cherokee shale					
Mineral coal from operating pit..........	568	?	0.002		
Weir-Pittsburg coal (fig. 2)					
S183 - SE$\frac{1}{4}$ sec. 19, T31N, R33W, Barton Co. Mo., stop 1					
Cherokee shale					
Weir-Pittsburg coal, sample from shaft dump......................................	570	?	0.000		
Coals between Weir-Pittsburg and Columbus Coals (fig. 2)					
NE$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 10, T34S, R24E, Cherokee Co., Kan., (p. 26, Bull. 24)					
Cherokee shale					
Coal....................................		0.9	low		
Shale, gray, clayey in part, hard and micaceous in part, one narrow ls. bed (see section on p. 26, Bull. 24)..........		17.9	low		
Coal....................................		1.0	low		

Description	Samp. No.	thick. ft.	% equiv. U(f)	% equiv. U(1)	%U (chem)
Columbus and Rowe coals (fig. 2)					
Sec. 27, T30S, R25E, Crawford Co., Kan.					
Cherokee shale					
Shale, black, grading upward into gray shale...........................		1.5	low		
Rowe coal, Columbus and Rowe coals are nearly at same horizon and their exact stratigraphic relation is unknown......		1.5	low		
Shales, yellow-gray					
Black shale 75 ft. above base of Cherokee shale (fig. 2)					
NW$\frac{1}{4}$ sec. 18, T32S, R25E, Cherokee Co., Kan. hwy. 69					
Cherokee shale					
Surface					
Shale, dark gray to black, fissile......		6.0	low		
limestone, dark gray, concretionary.....		0.3			
Black shale and coal near base of Cherokee shale (fig. 2)					
NE$\frac{1}{4}$ sec. 9, T32S, R25E, Cherokee Co., Kan., sink hole, stop 6					
Cherokee shale					
Little Cabin sandstone, brownish, shaly and carbonaceous.........................			low		
Riverton coal...........................		1.0	low		
Shale, dark gray to black................		7.0	low		

Description	Samp. No.	thick. ft.	%- equiv. U(f)	% equiv. U(l)	%U (chem)
NW¼ NW¼ sec. 14, T33S, R25E, Cherokee Co., Kan., (p. 23, Bull. 24)					
Cherokee shale					
Little Cabin sandstone					
Shale, dark gray to black, fissile.........		1.8	low		
Riverton coal..............................		0.5	low		
Shale, gray, soft					

Results and Conclusions

The main interest in Pannsylvanian black shales in Kansas and Oklahoma has been in the radioactive nodules. However, two black shales, each about two feet thick and neither of which contains any nodules, the Hushpuckney shale (p. 13) and shale near the top of the Bourbon shale (p. 14 and fig. 6) contain 0.024 and 0.017 percent equivalent uranium and 0.013 and 0.010 percent uranium respectively. These compare favorably with the best samples from other black shales previously tested in the Trace Elements program. Too little work was done to permit calculations of tonnages. Material of this grade does not merit more detailed work at this time.

The black shale over the Checkerboard limestone was judged to be the most interesting on the basis of the earlier work by Slaughter and Clabaugh. The later work has not changed this opinion. Two of the earlier localities in this horizon, S131 and S136 were re-sampled and several new localities were examined, S175, S187, S188, S190, S191 and S192. It was previously stated that a five-foot thickness of this shale over a ten square mile-area and covered by not more than 25 feet of overburden might contain as much as five percent nodules containing about 0.060 percent equivalent uranium and about 0.030 percent uranium. The later work has proved that, at the best locality, S131 (fig. 4) a three-foot thickness of the shale contains 3.2 percent nodules containing 0.049 percent equivalent uranium and about 0.025 percent uranium. Nodules containing 0.095 percent uranium were found at S136 but nodules here are relatively scarce. At S188, 2.7 feet of shale contains 2.2 percent nodules which contain 0.048 percent equivalent uranium and 0.027 percent uranium. The possibility still exists that there may be ten square miles of shale with nodules about equal in abundance and uranium content to those at S131. Using three feet for average thickness and 3.2 percent nodule content, each square mile would contain about 6,000,000 tons of shale, about 200,000 tons of nodules containing 0.049 percent equivalent uranium and about 0.025 percent uranium. It is not likely, however, that such a deposit exists as no other locality was found where the nodules are as abundant and of as good grade as at S131. The average nodule content would probably be about two percent, the average thickness about 2.5 feet, and the nodules would probably contain 0.035 percent equivalent uranium and 0.015 to 0.020 percent uranium.

The black shale in the Fort Scott limestone at S135 (fig. 5) contains 3.4 percent nodules over a thickness of 1.6 feet and the nodules contain 0.037 percent equivalent uranium, 0.018 percent uranium. These figures are about average for this horizon from Tulsa, Okla. to Fort Scott, Kan., except that the average percentage of nodules is probably less than two. The massive limestone overlying this shale bed would make stripping difficult and costly.

Nodules in a 1.7-foot zone in the black shale at the top of the Bourbon shale (fig. 6) contain 0.062 percent uranium, 0.032 percent uranium, but the nodules make up less than one percent of the shale.

Nodules in the Muncie Creek shale near Kansas City, Kan. contain 0.051 percent equivalent uranium, probably about 0.025 percent uranium. They are relatively few and are contained in only 0.5 foot of shale.

A nodule product containing about 0.035 percent equivalent uranium and about 0.015 to 0.020 percent uranium could probably be produced from the shale over the Checkerboard limestone. The disadvantage is that a tremendous tonnage of shale would have to be mined to get a relatively small tonnage of nodules; a 50 to 1 concentration would be required. This does not seem to be economically feasible in view of the grade of the product.

All other horizons tested seem to offer less chance of being sources of uranium than those described above.