

DEPARTMENT OF THE INTERIOR

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**RECONNAISSANCE FOR URANIUM IN
THE INDIANA COAL FIELD**

**By
John L. Snider**

This report is preliminary and has not been edited or reviewed for conformity with U. S. Geological Survey standards and nomenclature.

August 1954

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CONTENTS

	Page
Abstract	1
Introduction	1
General geology	3
Coal geology	3
Previous work	4
Field methods	6
Radioactivity of samples	6
Radioactive deposits	20
Shale above Coal V	20
Shale above the Minshall coal	22
Origin of radioactivity of coal deposits	23
Deposition of radioactive material	25
Summary	25
Literature cited	26
Unpublished reports	26

ILLUSTRATION

Figure 1. Sample localities in Indiana coal field	2
---	---

TABLES

Table 1. Stratigraphic position and sample localities of some coal beds of Pennsylvanian age in Indiana	5
2. Location, lithology, and radioactivity of samples . . .	7
3. Relation of lithology of shale above Coal V to radio-activity	22

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ABSTRACT

A radioactivity of 0.001 or more percent equivalent uranium was found in five Indiana coal beds: the Upper Block, Minshall, Gentryville, Coal V, and Coal VII. The radioactive coal is local and the reserves are small. The radioactivity is in the top part of the bed in the thick coals. Most of the radioactive coal has a high percentage of ash. The black carbonaceous shale above Coal V and the Minshall coals contains about 0.006 and 0.003 percent equivalent uranium respectively, and the radioactivity appears to increase as the amount of organic matter increases in the shale. The black shale above Coal V is widespread in Indiana and adjacent states and the reserves of shale are large.

INTRODUCTION

A reconnaissance for radioactive coal beds and associated rocks in the Indiana coal field was made by the U. S. Geological Survey for the Division of Raw Materials of the U. S. Atomic Energy Commission. Preliminary field work was done by John W. Huddle and Marion J. Bergin in September and October, 1952. Field work was completed by John L. Snider in February and March, 1954.

The Indiana coal field is located in sixteen counties in the southwestern part of the state (fig. 1). It is part of the Eastern Interior coal province which also includes adjacent parts of Illinois and Kentucky.

The writer wishes to acknowledge the help of Charles E. Weir of the Indiana Geological Survey who supplied information concerning correlation of coal beds and localities where they could be sampled.

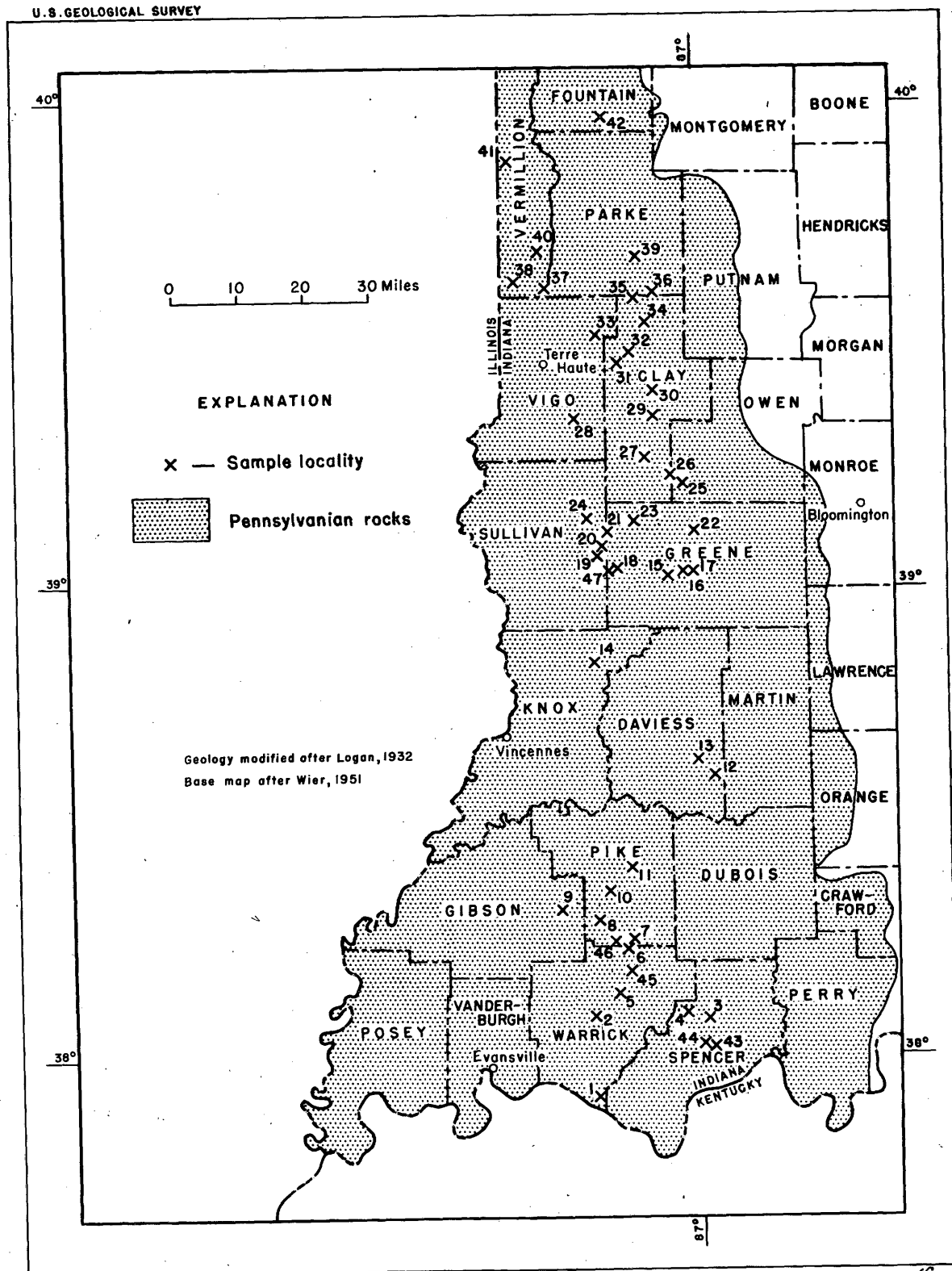


FIGURE 1.— SAMPLE LOCALITIES IN INDIANA COAL FIELD

GENERAL GEOLOGY

The area covered by this reconnaissance lies in the Tipton Till Plain and Wabash Lowland, parts of the Central Lowland physiographic province, and the Crawford Upland, a part of the Interior Low Plateaus province. The Tipton Till Plain covers a large part of northern Indiana and extends into the area under discussion in Vermillion, northern Parke, Fountain, Montgomery, northern Putnam, Hendricks, and Boone Counties, Ind. It is a glacial till plain with a low relief that exceeds 50 feet at few places. In this area the coal beds are exposed only along the major streams and in excavations, elsewhere they are covered with glacial drift ranging in thickness from a few feet to 60 feet. The Wabash Lowland is a generally low area following the Wabash River along the boundary between Indiana and Illinois. The lowland is characterized by wide, flat, aggraded valleys and steep bed rock hills that rise from 100 to 150 feet above the valley floor. It is within this area that most of the Indiana commercial coal-bearing rocks of Pennsylvanian age are located. The Crawford Upland, east of the Wabash Lowland and south of the Tipton Till Plain, is a belt of northward trending hills. The upland covers Perry and Crawford Counties and parts of Dubois, Martin, Greene, Owen, and Putnam Counties in Indiana. The upland is a maturely dissected area with a ragged eastern escarpment cut in the clastic rocks of Mississippian and lower Pennsylvanian age. The relief is moderate, about 350 feet, partly buried by glacial till in the northern part. The Crawford Upland has very small coal reserves, because the coals are thin and discontinuous (Spencer, 1953, fig. 5).

COAL GEOLOGY

The Pennsylvanian coal-bearing rocks of Indiana dip 20 to 24 feet per

mile to the west into the Eastern Interior Coal Basin (Spencer, 1953, p. 15). They lie unconformably on Mississippian or Devonian rocks and include, from bottom to top, rocks correlated with the Pottsville, Allegheny, and Cone-maugh series of the Appalachian region (Weir, 1951). Pennsylvanian rocks are overlain unconformably by unconsolidated material of Pleistocene or Recent age, principally glacial till and alluvial deposits. The lowest Pennsylvanian formation, the Mansfield sandstone, is predominantly a sandstone that is conglomeratic in the lower part. There are three coals in the Mansfield formation, but these are thin and discontinuous. (See table 1.) The overlying Brazil formation is less sandy and contains four commercial coals. Most of the commercial coals in Indiana are above the Brazil formation in the Staunton, Linton, and Dugger formations. The Shelburn formation at the top of the Indiana Pennsylvanian has thin discontinuous coal beds. The rocks of these formations include sandstone, siltstone, shale, limestone, and clay. Only the dark colored shales above some of the coals were found to be radioactive.

More than 25 coal beds in Indiana locally attain a thickness of two feet or more. Nine of these beds that are widely mined, as well as some of the less important beds, were sampled on this reconnaissance.

All coal beds in Indiana are classified as high volatile bituminous (Spencer, 1953, p. 3).

The stratigraphy is summarized in table 1, which shows the formations, coal beds, and localities where they were sampled.

PREVIOUS WORK

Nelson and Stratton made a reconnaissance for uranium in coal and shale in Indiana in October and November, 1946. Radioactivity measurements were made of Coal I, the Lower Block, Upper Block, Minshall coals,

Table 1.--Stratigraphic position and sample localities of some coal beds of Pennsylvanian age in Indiana.

Series	Formation	Coal bed	Sample locality
Conemaugh	Shelburn	Coal VIII	Not sampled
Allegheny	Dugger	Coal VII (Millersburg) Coal VI Coal Va	2, 9, 19, 38 14, 20, 21, 24 5, 10, 11
	Petersburg	Coal V	2, 5, 6, 8, 10, 11, 18, 28, 40, 45, 46, 47
	Linton	Coal IV Coal IIIa	7, 23
	Staunton	Coal III Gentryville Coal	27, 31, 32, 33, 41 4
Pottsville	Brazil	Coal II Minshall Upper Block Coal Lower Block Coal	12, 13, 39 3, 42 15, 16, 17, 22, 25, 29, 30, 34, 35, 36 26
	Mansfield	Fulda Coal Upper Cannelton Cannelton (Coal I)	Not sampled

Modified from Weir (Spencer, 1953, fig. 4)

and Coal III and associated shale beds. An unidentified coal near Gentryville in Spencer County was found to have 0.003 percent equivalent uranium (Nelson and Stratton, 1949, p. 6). This coal will be called the Gentryville coal in this report. A black shale above Coal IIIa in Clay County was reported by Nelson and Stratton to have 0.006 percent equivalent uranium. This report could not be checked by the author because exposures of the IIIa coal or the overlying shale could not be found at one reported locality.

FIELD METHODS

Coal beds and rocks above and below were measured and checked for radioactivity with a portable scintillation meter. Rocks other than coal were not sampled unless a reading above 0.005 milliroentgens per hour was observed. Coal beds were sampled even though no readings of coal beds were above background. Partings $3/8"$ or thicker were not included in the sample. Samples were collected arbitrarily in intervals of one foot to find out if uranium occurred in any part of the bed. All samples were collected in strip mines except the one of the Gentryville coal, which is exposed in a road cut.

The samples were crushed and checked with a portable scaler equipped with an assay cup. The radioactivity of the samples was estimated by comparing the readings with those of radioactivity standards. The radioactivity of the coal samples from Localities 3 and 4 were measured by the U. S. Geological Survey laboratory in Washington, D. C.

RADIOACTIVITY OF SAMPLES

Table 2 shows the localities where the samples were collected, name of the coal, position in the bed, and estimated radioactivity of the samples. Almost all coals were sampled in intervals of one foot, but

Table 2.--Location, lithology, and radioactivity of samples.

<u>Loc. No.</u>	<u>Location</u>	<u>Thickness (feet)</u>	<u>Lithology</u>	<u>Equivalent uranium (percent)</u> ^{1/}
1	Sterchen and Heim's mine 1.6 miles east of Yankeetown. SE $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 11, T. 7 S., R. 8 W., Newburg quadrangle, Warrick County.	3 ^{2/} 3.7 0.3	Shale Coal VII Shale	a ^{2/}
2	Sunlight Coal Co. mine 2.6 miles northwest of Boonville. SW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 15, T. 5 S., R. 8 W., Boonville quadrangle, Warrick County.	14 3.5	Siltstone Black shale 3-3.5 ft. above base 2-3 " " 1-2 " " 0-1 " "	0.005 .004 .008 .010 .003 a
3	Mulzer Mines - abandoned mine 3.7 miles southeast of Gentryville. SW $\frac{1}{2}$ NE $\frac{1}{2}$ sec. 16, T. 5 S., R. 5 W., St. Meinrad quadrangle, Spencer County.	0.6 7 0.1 2 1.7 3.7 0.3	Shale Coal V Underclay Limestone Shale 1-1.7 ft. above base 0-1 " " Minshall coal Underclay	.003 .003 .001 3/

^{1/} Equivalent uranium percent estimated from portable assay cup readings unless otherwise noted.

^{2/} a means less than 0.001 percent equivalent uranium.

^{3/} Radiation measurements by B. A. McCall, U. S. Geological Survey, Washington, D. C.

Table 2.--Location, lithology, and radioactivity of samples--Continued.

<u>Loc. No.</u>	<u>Location</u>	<u>Thickness (feet)</u>	<u>Lithology</u>	<u>Equivalent uranium (percent)</u>
6	Blackfoot Land and Coal Corp. mine 1.8 miles north of Scales- ville. Center of NW $\frac{1}{4}$ sec. 28, T. 3 S., R. 7 W., Degonia Springs quadrangle, Warrick County.	0.7 1 4.4 3	Shale, gray Shale, black Coal V Siltstone	0.004 .006 a
7	Blackfoot Land and Coal Corp. mine 7 miles southeast of Arthur. Center of SW $\frac{1}{4}$ sec. 15, T. 3 S., R. 7 W., Degonia Springs quad- rangle, Pike County.	15 - 2 0.1 -	Shale Coal IV Underclay	a
8	Enos Coal Mining Co. mine 3.8 miles southwest of Arthur. SW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 35, T. 2 S., R. 8 W., Petersburg quadrangle, Pike County.	1.7 2 2 5 0.1 -	Shale, black 1-1.7 ft. above base 0-1 " " Shale, gray 1-2 ft. above base 0-1 " " Siltstone Coal V Underclay	.003 .008 .004 .003 a

Table 2.--Location, lithology, and radioactivity of samples--Continued.

<u>Loc. No.</u>	<u>Location</u>	<u>Thickness (feet)</u>	<u>Lithology</u>	<u>Equivalent uranium (percent)</u>
9	Saxton Coal Co. mine 2 miles southwest of Oakland City. NE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 26, T. 2 S., R. 9 W., Petersburg quadrangle, Gibson County.	15 3.4 0.1	Siltstone Coal VII Underclay	a
10	Ayrshire Collieries Corp. mine 1 mile north of Arthur. SW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 12, T. 2 S., R. 8 W., Velpen quadrangle, Pike County.	1 1.7 3 1.3 1.7	Coal Va Underclay Shale Limestone Shale, black	a
			1-1.7 ft. above base 0-1 " "	0.005 .010
		1 6	Shale, gray Coal V	.003
		0.1 $\frac{1}{2}$	Underclay	a
11	Ayrshire Collieries Corp. mine 2 miles northeast of Winslow. SE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 21, T. 1 S., R. 7 W., Velpen quadrangle, Pike County.	0.6 0.5 12 3.7 0.7 2	Coal Va Siltstone Shale Limestone, massive Limestone, fragmental Shale, gray	a
			1-2 ft. above base 0-1 " "	.004 .003 $\frac{6}{16}$
		1 4 0.1 $\frac{1}{2}$	Shale, black Coal V Underclay	a

6/ 0.021 percent uranium in sample.

Table 2.--Location, lithology, and radioactivity of samples--Continued.

<u>Loc. No.</u>	<u>Location</u>	<u>Thickness (feet)</u>	<u>Lithology</u>	<u>Equivalent uranium (percent)</u>
12	Loggootee Block Coal Co. mine 2.5 miles southwest of Whitfield. SE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 15, T. 2 N., R. 5 W., Daviess County.	5 - 2.8 0.1 -	Siltstone Coal II Shale	a
13	Hicks Coal Co. mine 2.6 miles south of Cannelsburg. NW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 5, T. 2 N., R. 5 W., Daviess County.	5 - 3 0.1 -	Shale Coal II Underclay	a
14	Shasta Coal Corp. mine 2.6 miles northwest of Edwardsport. SW $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 27, T. 5 N., R. 8 W., Bicknell quadrangle, Knox County.	4.2 5.5 0.1 -	Siltstone Coal VI Underclay	a
15	Smock Coal Co. mine 1.5 miles southwest of Switz City. SE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 28, T. 7 N., R. 6 W., Switz City quadrangle, Greene County.	8 - 2 0.1 -	Shale Upper Block coal Underclay	a
16	Comet Collieries, Inc., mine 1.7 miles east of Switz City. SW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 24, T. 7 N., R. 6 W., Switz City quadrangle, Greene County.	10 - 0.6 12 2.4 0.1 -	Shale Upper Block coal Shale Upper Block coal Impure coal	a a

Table 2.--Location, lithology, and radioactivity of samples--Continued.

<u>Loc. No.</u>	<u>Location</u>	<u>Thickness (feet)</u>	<u>Lithology</u>	<u>Equivalent uranium (percent)</u>
17	Lambright Coal Co. mine 3.5 miles west of Bloomfield. SW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 19, T. 7 N., R. 5 W., Switz City quadrangle, Greene County.	1 - 3 1 -	Shale Upper Block coal Shale	a
18	A.B.C. Coal Co. mine 3 miles west of Linton. SW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 20, T. 7 N., R. 7 W., Linton quadrangle, Greene County.	3 1 3	Siltstone Shale, gray Shale, black 2-3 ft. above base 1-2 " " " 0-1 " " " .6x.6 ft. pyrite nodule 1 ft. above base Coal V	0.002 .003 .004 <u>7/</u> .008 <u>7/</u> .001 8/
		7.4	6.7-7.4 ft. above base 5.7-6.7 " " " 5.1-5.7 " " " (shale, not sampled) 5-5.4 ft. above base 1-5 " " " 3-4 " " " 2-3 " " " 1-2 " " " 0-1 " " " Underclay	.002 a a a a a a a a
		0.1 $\neq$		

7/ 0.008 percent uranium in sample.8/ 11.1 percent ash, 0.022 percent uranium in ash, 0.002 percent uranium in sample.

Table 2.--Location, lithology, and radioactivity of samples--Continued.

<u>Loc. No.</u>	<u>Location</u>	<u>Thickness (feet)</u>	<u>Lithology</u>	<u>Equivalent uranium (percent)</u>
19	Maumee Collieries Co. mine 1 mile southwest of Dugger. SE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 11, T. 7 N., R. 8 W., Dugger quadrangle, Sullivan County.	20 $\frac{1}{2}$ 3.7 0.1 $\frac{1}{2}$	Siltstone Coal VII Underclay	a
20	Tri-State Mining Corp. mine 1 mile northeast of Dugger. NW $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 1, T. 7 N., R. 8 W., Linton quadrangle, Sullivan County.	4 6 0.1 $\frac{1}{2}$	Shale Coal VI Impure coal	a
21	S. and A. Coal Corp. mine 2.5 miles northeast of Dugger. NW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 30, T. 8 N., R. 7 W., Linton quadrangle, Greene County.	1 2.3 0.1 $\frac{1}{2}$	Shale Coal VI Underclay	a
22	Al Lohr Coal Co. mine 1 mile southwest of Worthington. SW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 20, T. 8 N., R. 5 W., Bloomfield quadrangle, Greene County.	6 $\frac{1}{2}$ 2 0.1 -	Shale Upper Block coal Underclay	a
23	Maumee Collieries Co. mine 2.5 miles southeast of Jasonville. Center of NW $\frac{1}{4}$ sec. 11, T. 8 N., R. 7 W., Jasonville quadrangle, Greene County.	5 $\frac{1}{2}$ 3 0.1 $\frac{1}{2}$	Shale Coal IV Underclay	a

Table 2.---Location, lithology, and radioactivity of samples---Continued.

Loc. No.	Location	Thickness (feet)	Lithology	Equivalent uranium (percent)
24	Sherwood-Templeton Coal Co. mine 3.5 miles south of Hymera. NE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 16, T. 8 N., R. 8 W., Hymera quadrangle, Sullivan County.	5 6 0.1 $\nearrow$	Shale Coal VI Underclay	a
25	Maumee Collieries Co. mine 1.5 miles southeast of Coal City. SE $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 13, T. 9 N., R. 6 W., Coal City quadrangle, Owen County.	4 1.9 0.1 -	Shale Upper Block coal Impure coal	a
26	Mariah Collieries Corp. mine 1 mile west of Coal City. NW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 10, T. 9 N., R. 6 W., Coal City quad- rangle, Clay County.	1 - 1 16 8 3.4 0.1 -	Shale Upper Block coal Underclay Shale Lower Block coal Underclay	0.001 a
27	Gillespie Coal Co. mine 1 mile southwest of Clay City. NW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 31, T. 10 N., R. 6 W., Coal City quadrangle, Clay County.	1.5 2.8 0.5 4.0 $\nearrow$	Shale Coal III - top split Shale Coal III weathered (not sampled)	a
28	Maumee Collieries Co. mine 9 miles southeast of Terre Haute. SE $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 32, T. 11 N., R. 8 W., Lewis quadrangle, Vigo County.	1.4 1.6 3 1 - ---	Limestone Shale 1-1.6 ft. above base 0-1 " " Coal V Underclay Sample of shale from waste pile	.005 .010 a .010

Table 2.--Location, lithology, and radioactivity of samples--Continued.

<u>Loc. No.</u>	<u>Location</u>	<u>Thickness (feet)</u>	<u>Lithology</u>	<u>Equivalent uranium (percent)</u>
29	Brown Coal Co. mine 5.5 miles north of Clay City. SE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 32, T. 11 N., R. 6 W., Clay City quadrangle, Clay County.	6 - 3 1 $\frac{1}{4}$	Shale Upper Block coal Underclay	a
30	Big Bend Collieries, Inc., mine 8 miles south of Brazil. SE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 8, T. 11 N., R. 6 W., Clay City quadrangle, Clay County.	0.4 3 2 -	Impure coal Upper Block coal Underclay	a
31	Ayrshire Collieries Corp. mine 1.5 miles southwest of Staunton. SW $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 20, T. 12 N., R. 7 W., Clay City quadrangle, Clay County.	7.4 0.1 -	Coal III, top concealed in waste. Underclay	a
32	Big Bend Collieries, Inc., mine 1 mile east of Staunton. SE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 10, T. 12 N., R. 7 W., Clay City quadrangle, Clay County.	6 1 0.5 6 0.1	Sandstone Coal III - top split Sandstone Coal III Underclay	a a
33	Girton Coal Co. mine 2.5 miles north of Seelyville. SE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 35, T. 13 N., R. 8 W., Vigo County.	5 - 5.5 0.1 -	Siltstone Coal III Underclay	a
34	Love Bros. mine 2.3 miles north of Brazil. NE $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 19, T. 13 N., R. 6 W., Clay County.	1 - 3 3 -	Shale Upper Block coal Underclay	a

Table 2.--Location, lithology, and radioactivity of samples--Continued.

Loc. No.	Location	Thickness (feet)	Lithology	Equivalent uranium (percent)
39	Maple Grove Coal Co. 7 miles southeast of Rockville. SE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 2, T. 14 N., R. 7 W., Parke County.	1 - 2 0.1 -	Shale Coal II Underclay	a
40	Kanizer Brothers Coal Co. mine 3 miles northeast of Clinton. NW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 33, T. 15 N., R. 9 W., Vermillion County.	1 4 0.1 -	Shale 0-1 ft. above base Coal V Underclay	0.007 a
41	Harris Coal Co. mine 5.5 miles west of Newport. SW $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 35, T. 17 N., R. 10 W., Vermillion County.	0.3 4 0.1 -	Shale Coal III Underclay	a
42	Morgan Coal Co. mine 2.7 miles northeast of Kingman. SW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 20, T. 18 N., R. 7 W., Fountain County.	10 - 5 0.1 -	Shale Minshall coal Bone coal	a
43	Loran Day's mine 2 miles north of Newtonville. SW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 34, T. 5 S., R. 5 W., St. Meinrad quadrangle, Spencer County.	0.3 3 2.6 0.1 /	Limestone Shale 2-3 ft. above base 1-2 " " 0-1 " " Minshall coal 2-2.6 ft. above base 1-2 " " 0-1 " " Underclay	.002 .002 .002 .002 a a

Table 2.--Location, lithology, and radioactivity of samples--Continued.

<u>Loc. No.</u>	<u>Location</u>	<u>Thickness (feet)</u>	<u>Lithology</u>	<u>Equivalent uranium (percent)</u>
44	Mulzer Mines mine 4.3 miles north- east of Chrisney. SE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 33, T. 5 S., R. 5 W., St. Meinrad quadrangle, Spencer County.	0.5 5	Limestone Shale 4-5 ft. above base 3-4 " " " 2-3 " " " 1-2 " " " 0-1 " " " Minshall coal Underclay	0.002 .002 .002 .002 .001 a
45	Tecumseh Coal Corp. mine 2.5 miles southeast of Scalesville. NE $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 15, T. 4 S., R. 7 W., Degonia Springs quadrangle, Warrick County.	2 1.5 6.4 0.1	Limestone Shale 1-1.5 ft. above base 0-1 " " " Coal V 5.7-6.4 ft. above base 4.7-5.7 " " " 3-4.7 " " " (shale, not sampled) 2-3 ft. above base 1-2 " " " 0-1 " " " Underclay	.004 .008 .002 a a a a a

Table 2.--Location, lithology, and radioactivity of samples--Continued.

<u>Loc. No.</u>	<u>Location</u>	<u>Thickness (feet)</u>	<u>Lithology</u>	<u>Equivalent uranium (percent)</u>
46	Enos Coal Mining Co. mine 2.5 miles east of Spurgeon. $SE\frac{1}{4}SW\frac{1}{4}$ sec. 17, T. 3 S., R. 7 W., Degonia Springs quadrangle, Pike County.	0.8 1.5 4.9 0.1	Mudstone Shale 1-1.5 ft. above base 0-1 " " Coal V Underclay	0.004 .009 a
47	Maumee Collieries Co. mine 3.7 miles southwest of Linton. $SE\frac{1}{4}NW\frac{1}{4}$ sec. 30, T. 7 N., R. 7 W., Linton quadrangle, Greene County.	4.2 4.4 1 6 0.1	Limestone Shale, black 4-4.4 ft. above base 3-4 " " 2-3 " " 1-2 " " 0-1 " " Shale, gray Coal V Underclay	.003 .004 .008 .007 .007 .002 a

the radioactivity of the one-foot intervals is not listed unless one or more samples had 0.001 percent or more equivalent uranium.

RADIOACTIVE DEPOSITS

Locally the shale beds above the Number V and Minshall coals contain an average of about 0.006 percent equivalent uranium. The following are descriptions of these deposits.

Shale above Coal V

Sections were measured and samples collected of the shale above Coal V at Localities 2, 5, 6, 8, 10, 11, 18, 28, 40, 45, 46, and 47. The generalized section given below shows the association of the radioactive black shale to the adjacent rocks. Units 3, 4, and 5 are radioactive at many localities.

The beds numbered 1, 2, 3, 5, 6, and 7, in the section described below, are missing at many localities; units 3, 4 or 5 may lie directly on the coal, and the limestone may lie directly on unit 4 or 5 as at Localities 5, 6, 11, 28, 45, and 47. At Locality 6, unit 5 has abundant stem imprints which were observed for a distance of 300 feet along the highwall. This type shale contains pyritized brachiopod shells at Localities 8, 11, 18, and 47.

The black shale units 3, 4 and 5 range in thickness from 1 to 5.4 feet and averages 3.1 feet. The radioactivity ranges from 0.002 to 0.016 percent equivalent uranium and averages 0.006 percent. A sample of the shale from a dump at an abandoned mine at Locality 37 has 0.006 percent equivalent uranium.

Generalized section of beds above Coal V

		Thickness (feet)
	Alum Cave limestone	
9.	Limestone, dark gray, massive, hard, finely crystalline, spheroidal weathering, brachiopod shells and crinoid stems	0-5.9
8.	Limestone, light gray, massive, soft, fragments .01-.05 foot long, abundant crinoid stems and shell fragments	0-1.3
7.	Mudstone, dark gray, massive, .1 by .3 foot limestone nodules	0-.8
6.	Siltstone, dark gray, irregular fracture, pyritic, includes limestone lenses .1 foot thick containing brachiopod shells	0-14
5.	Shale, dark to medium dark gray, irregular fissility on weathered surface, blocky when fresh, dull luster, abundant pyritized invertebrate fossils or stem imprints, stringers of limestone (locally radioactive)	0-2
4.	Shale, grayish black to black, well developed fissility on weathered surface, massive with conchoidal fracture when fresh, satiny luster, .01 foot thick vitrain bands, pyritic nodules (locally radioactive)	1-4.4
3.	Shale, dark to medium dark gray, irregular fissility to blocky, dull luster, abundant pyritized invertebrate fossils and pyrite flakes (locally radioactive)	0-1.7
2.	Siltstone, medium gray, irregular fissility	0-10.8
1.	Shale, greenish black, plant imprints on base, pyrite nodules	0-.6
	Top of Coal V	

There appears to be a relationship between radioactivity and lithologic type of shale, which is shown in table 3, rather than to position in relation to the underlying coal or overlying limestone.

Table 3.--Relation of lithology of shale above Coal V to radioactivity.

Lithology	Radioactivity
Grayish black to black, hard, very fissile when weathered, conchoidal fracture when fresh, satiny luster, vitrain bands, few pyritic nodules. Typical of unit 4.	Ranges from 0.003 to 0.016 percent equivalent uranium, averages 0.006 percent.
Dark to medium dark gray, irregular shale fracture when weathered, blocky when fresh, dull luster, abundant pyritic flakes and either pyritized brachiopod shells or stem imprints. Typical of shale found in units 3 and 5.	Ranges from 0.002 to 0.004 percent equivalent uranium, averages, 0.003 percent.

Coal V crops out from the Kentucky-Indiana boundary to Vermillion County, Ind. It is correlated with Coal 5 of Illinois and Coal 9 of the western Kentucky coal field, both of which are widespread coals. The shale unit (beds 3, 4, and 5) is present at all the localities where Coal V was sampled on this reconnaissance, and is reported to overlie the coal at most places in Indiana although replaced by sandstone at a few localities (Cumings, 1922, p. 529).

The shale above the Kentucky No. 9 coal has 0.006 percent equivalent uranium in Hopkins County, Ky., where it is three feet thick (Nelson and Brill, 1948).

Shale above the Minshall coal

Samples of the shale above the Minshall coal were collected because of its lithologic similarity to the black shale above the Coal V, and

because field readings were above 0.005 mr/hr.

A generalized section of beds above the Minshall coal in Spencer County, Ind., is as follows:

	Thickness (feet)
Shale, grayish olive	20 /
Siltstone, medium dark gray, irregular fissility	1.5-5
Minshall limestone	
Limestone, medium gray, clastic, contains shell fragments	.2-.5
Limestone, medium dark gray, massive, finely crystalline, hard, forms ledge, contains <u>Dictyoclostus</u> , <u>Chonetes</u> sp., <u>Marginifera</u> sp., and crinoid stems	.7-2
Shale, black to dark gray, massive when fresh, well developed fissility when weathered, vitrain streaks, pyrite flakes	5-1.5
Top of Minshall coal	

The shale was not as radioactive as that above Coal V. The radioactivity of the shale ranged from 0.001 to 0.003 percent equivalent uranium and averaged 0.002 percent.

Origin of radioactivity of coal deposits

Results of chemical analyses of the Gentryville coal, the upper bench of Coal V and the shale above Coal V at Locality 5, the shale above Coal V at Locality 11, and the upper bench of Coal V and the shale above the coal at Locality 18 indicate that the radioactivity of these samples is due to uranium.

The uranium in coal may have been deposited contemporaneously with the coal, may have accumulated in the plants which formed the coal, or may have been deposited in the coal after it was formed. Conclusive

evidence concerning the time of accumulation of the uranium was not found in this study.

Four radioactive coal samples including Coal V at Localities 5, 18, and 45, and the Minshall coal at Locality 43 are of the top of the bed. The occurrence of the radioactivity at the top of these beds may indicate that the radioactive matter was deposited by ground water after the coal was formed. Ground water could have dissolved radioactive material from the shale beds above the coal, moved along joints and cracks in the shale or along the contact between the coal and shale, and deposited the material at the top of the coal bed. However, the coal is very well jointed and the shale is impermeable at many places. The radioactive sample of Coal VII was from the interval from 0.6 to 1.6 feet below the top of the bed. The radioactive matter could have been concentrated at the top of the coal by ground water, then leached down to this interval through cracks and joints in the coal. The uranium in the Gentryville coal could have been deposited by ground water moving down through the sandstone above the coal. The source of the uranium could have been beds above the sandstone or the sandstone itself.

The radioactivity at the top of Coal V probably is at least partly indigenous to the coal instead of derived from the shale above the coal. The radioactive shale was above the coal at all localities sampled, but the coal was radioactive only at Localities 5, 18, and 45. The coal has a high ash content at Localities 5 and 45, and uranium or other radioactive substances may be inherent in the fine grained detrital sediments, which were deposited contemporaneously with the coal, rather than in the organic matter.

Coal Va and the Upper Block coal at localities 5 and 36 are both dull and impure, and probably have a high ash content.

Deposition of radioactive material

The fact that the radioactive matter was deposited contemporaneously with the shale is indicated by the wide areal extent of the radioactivity in a stratigraphically limited shale unit. The source of the radioactivity could be uranium in sea water (McKelvey and Nelson, 1950, p. 44). The very dark gray shale containing abundant organic matter is more radioactive than the lighter colored shale containing less organic matter (table 3, p. 22). The vitrain stringers indicate that the organic matter is, in part, plant remains. The plant debris may have adsorbed radioactive elements from the sea water. This possibility was not tested by sampling the vitrain stringers.

Invertebrate fossils are abundant in the lighter colored members of shale unit (beds 3, 4, and 5), but were not observed in the darker colored, more radioactive members. The plant debris may have increased the acidity of the water so as to dissolve invertebrate shells, or made the water toxic to animals during the period of uranium accumulation.

SUMMARY

Most Indiana coal beds have less than 0.001 percent equivalent uranium. Radioactive zones do not persist over wide lateral areas, and in thick coals are limited to the top of the bed. Most of the radioactivity is associated with high ash coal. The origin and time of accumulation of radioactive matter was not determined. A carbonaceous shale above Coal V averaged 0.006 percent equivalent uranium. The radioactivity increases with the amount of organic matter in the shale. A dark shale above the Minshall coal is not unusually radioactive.

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