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RADIOACTIVITY OF COALS AND ASSOCIATED ROCKS IN BEAVER, CLEARFIELD, AND JEFFERSON COUNTIES, PENNSYLVANIA

By
John C. Ferm

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

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RADIOACTIVITY OF COALS AND ASSOCIATED ROCKS IN BEAVER, CLEARFIELD, AND JEFFERSON COUNTIES, PENNSYLVANIA

By John C. Ferm

ABSTRACT

Radioactivity of coal beds and associated rocks of the Pottsville, Allegheny, and Conemaugh formations was investigated in Beaver, Clearfield, and Jefferson counties, Pa., during the spring and summer of 1953. Measurements of radiation were obtained in the field with a portable scintillation counter, and 165 samples were checked in the office with calibrated counting equipment.

Of 56 localities visited, six have beds with radioactivity which is significantly greater than rocks in other localities. Samples from three localities in Beaver County (NC-SW-2-D and E, and NC-SW-3 on table 4 and figure 3) have maximum equivalent uranium of .007, .014, and .005 percent respectively; percent uranium in these samples is .007, .016, and .004. In three localities in Clearfield and Jefferson counties the maximum equivalent uranium values for coal are in the range of .003 and .004 and the uranium content is .002 percent.

In the stratigraphic interval studied, rocks associated with the Lower Freeport coal and, to a lesser degree, those associated with the Mercer coals at some places exhibit greater radioactivity than other parts of the stratigraphic sequence. Of the rock types, underclays generally show the greatest amount of radioactivity and coals the least.

Analysis of the data indicates that, except on a small scale, the occurrence of more radioactive beds is not related to structure. The data also suggest that moderate surficial weathering in this area has little effect on occurrences of radioactivity.

INTRODUCTION

A reconnaissance study of radioactivity of coal beds in eastern United States has been undertaken by the U. S. Geological Survey on behalf of the Division of Raw Materials of the U. S. Atomic Energy Commission. In connection with this program, radioactivity of coals and some of the associated rocks of the Pottsville, Allegheny, and Conemaugh formations was studied in Beaver, Clearfield, and Jefferson counties, Pa. (fig. 1). Data from this study not only provide a measure of radioactivity of rocks in these specific areas but also indicate the effect of general geologic background conditions on the occurrence of radioactivity in some coals and associated rocks.

Field work was done during the early spring and summer of 1953 by John L. Snider and John C. Ferm. Assistance with the statistical treatment of the data by Dr. D. G. Card of the University of Kentucky Agricultural Experiment Station is gratefully acknowledged.

PROCEDURES

Field

Field measurements of radioactivity were obtained with a portable meter of the scintillation type at exposures in highway and railroad cuts, and open pit and underground mines. Most measurements were obtained from coal beds and directly adjoining roof and floor rocks, although the radioactivity of other rock types was measured at a few localities.

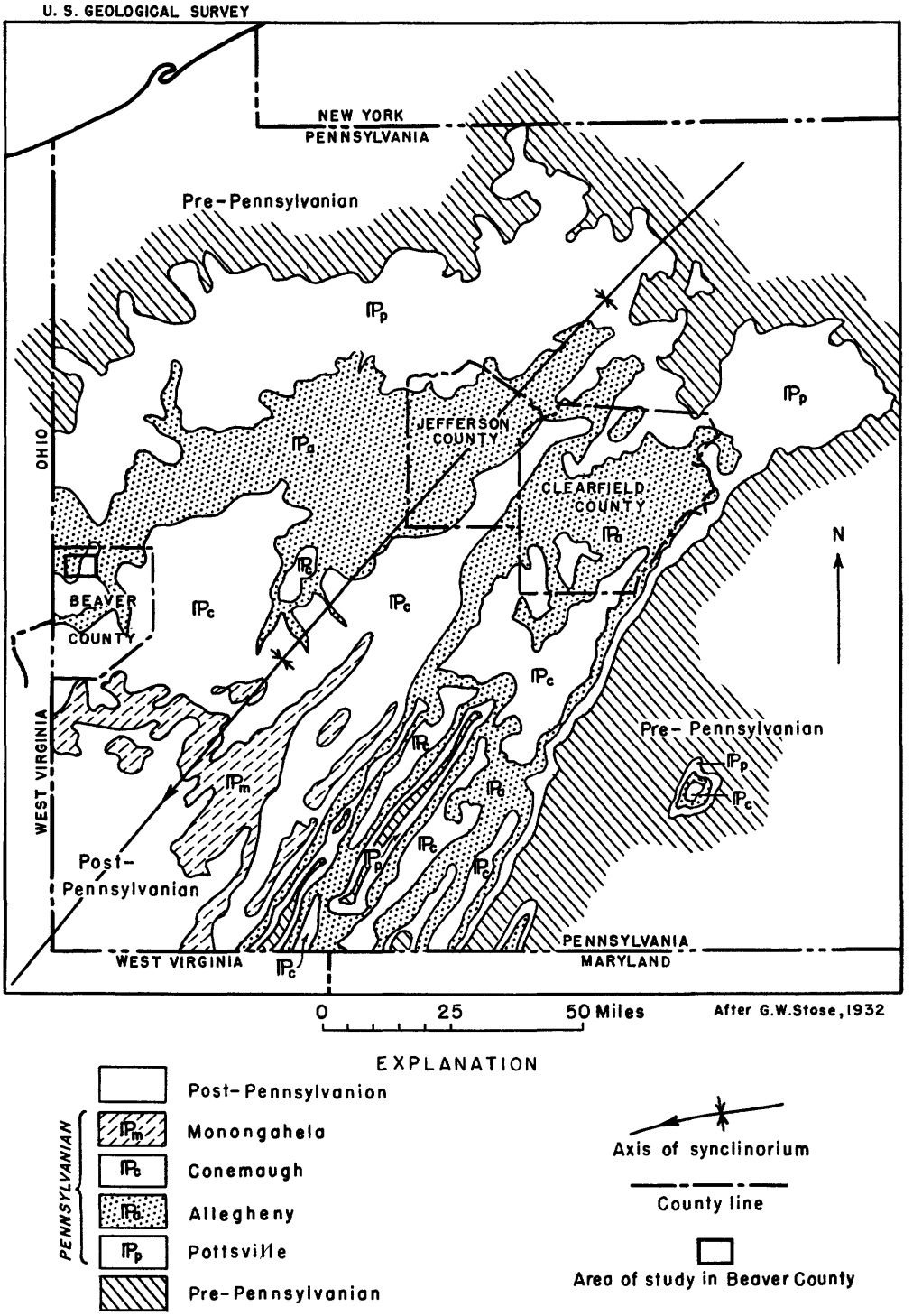


FIGURE 1. — PENNSYLVANIAN GEOLOGY OF WESTERN PENNSYLVANIA SHOWING THE LOCATION OF BEAVER, CLEARFIELD AND JEFFERSON COUNTIES.

Sampling procedures were determined by the amount of radioactivity considered significant for different rock types. Coal beds, in which very small concentrations of some radioactive minerals may be important when the coal is reduced to ash, were sampled at every locality investigated. Other rock types were sampled only at localities where the scintillation reading indicated radioactivity of 0.002 percent or more equivalent uranium.

Office

Field samples were prepared for radiation measurements by passing them through a jaw crusher to produce uniformity of size in the pieces in each sample. This was only partly accomplished because of different modes of fracture of different rock types. Coals, which are characterized by an equidimensional cleavage, were broken into pieces not exceeding one-half inch in diameter; whereas shales and "bony" coals with platy fracture tended to pass through the crusher in larger pieces.

Radiation measurements were made by placing the crushed samples in a portable assay cup-Geiger counter apparatus and recording the number of counts over a period of three minutes. This number was divided by three to obtain a counts per minute value. Conversion of these scaler values to uranium equivalents was made by comparing counts per minute values of a set of 60 samples with uranium equivalent percentages obtained by the U. S. Geological Survey laboratory in Washington on the same set of samples. The conversion scale (shown on table 1) was supplemented by comparing scaler measurements of standard samples of 0.020 and 0.015 percent equivalent uranium.

All samples were subsequently forwarded to the Washington laboratory for more precise radioactivity measurement and for chemical analysis of those samples with relatively high radioactivity.

Table 1.—Approximate conversion of assay cup-Geiger counter measurements to percent equivalent uranium.

Counts per minute (c/m)	Percent equivalent uranium (eU)
< 69	< .001
69-104	.001
105-139	.002
140-174	.003
175-209	.004
210-244	.005
245-279	.006
280-314	.007
315-349	.008
350-384	.009
385-419	.010
420-454	.011
455-489	.012
490-524	.013
525-559	.014
560-594	.015

DESCRIPTIVE GEOLOGY

General geology

Pennsylvanian rocks in the western half of Pennsylvania are divided into stratigraphic units characterized by the occurrence or absence of coal beds of economic importance. Lower Pennsylvanian rocks, designated the Pottsville series, are approximately 200± feet thick and lack important coals. The overlying Allegheny series, 300± feet thick, contains numerous beds of thick coal. The Conemaugh series, which includes 450± feet of strata overlying the Allegheny, is characterized by thin, non-persistent coals. The uppermost 300± feet of Pennsylvanian is called the Monongahela series and contains several coals of commercial importance.

The present study includes only rocks of the Pottsville, Allegheny, and part of the Conemaugh series.

The coal-bearing formations in western Pennsylvania occupy a synclinorium, the axis of which plunges toward the southwest corner of the state (fig. 1). North and northwest of the axis the formations dip gently south to southeast forming a slope with minor northeast trending flexures. East of the major axis, the folds are more pronounced and produce strong linearity in outcrop pattern parallel to major structural axis. Beaver County and part of Jefferson County lie north of the major synclinal axis and are characterized by gentle flexures; Clearfield County is part of the area of relatively stronger folds.

Local geology

The Beaver County area includes only a very small portion of the Allegheny and Conemaugh outcrop belts (fig. 1); the upper two-thirds of the Allegheny series is found in the valleys and lower portions of the hill slopes and only a very small part of the Conemaugh series caps the hill tops. A generalized description of this portion of the stratigraphic column is shown on table 2. These beds dip gently southward with very minor northeast-southwest trending flexures.

In the Clearfield-Jefferson county area, the outcrop distribution of Pottsville, Allegheny, and Conemaugh rocks is determined mainly by northeast-southwest trending folds that produce a well defined linearity of the outcrop belts and divide the area into four structural basins (fig. 2). Within these semi-isolated basins a dual system of stratigraphic nomenclature has developed. In the two western basins, designated Brookville and Punxsutawny, the coal beds are identified by names which are applied in the Beaver County area as well as other parts of the northern outcrop belt of the Allegheny

Table 2.—Composite section of parts of the Conemaugh and Allegheny series in the Beaver County area.[1]

	Thickness (feet)	Lithology
		Conemaugh series
		Upper part not exposed
	23	Sandstone and siltstone
	4	Shale, dark, limey, Brush Creek
	5	Siltstone
	1	Thin coal and underclay
	12	Siltstone
	15	Shale and sandstone
	½	Coal
	25	Shale and sandstone
	1	Coal
	3	Underclay
	7	Shale
	7	Flint clay, New Galilee
	1	Limestone
	25	Shale and sandstone
	2	Coal, East Palestine
	5	Underclay and limestone
	45	Sandstone and shale
	3	Shale
Total	184½	
		Allegheny series
	3	Coal, Upper Freeport
	8	Underclay and limestone
	40	Shale, siltstone, and sandstone
	2½	Coal, Lower Freeport
	3	Underclay and limestone
	50	Siltstone and sandstone
	0-12	Coal, Upper Kittanning
	25	Shale and sandstone
	2½	Coal, Middle Kittanning
	5	Underclay
	30	Shale and siltstone
	2	Coal, Lower Kittanning
	7	Underclay
		Lower part not exposed
Total	184	

1/ DeWolf, F. W. (1929), in part.

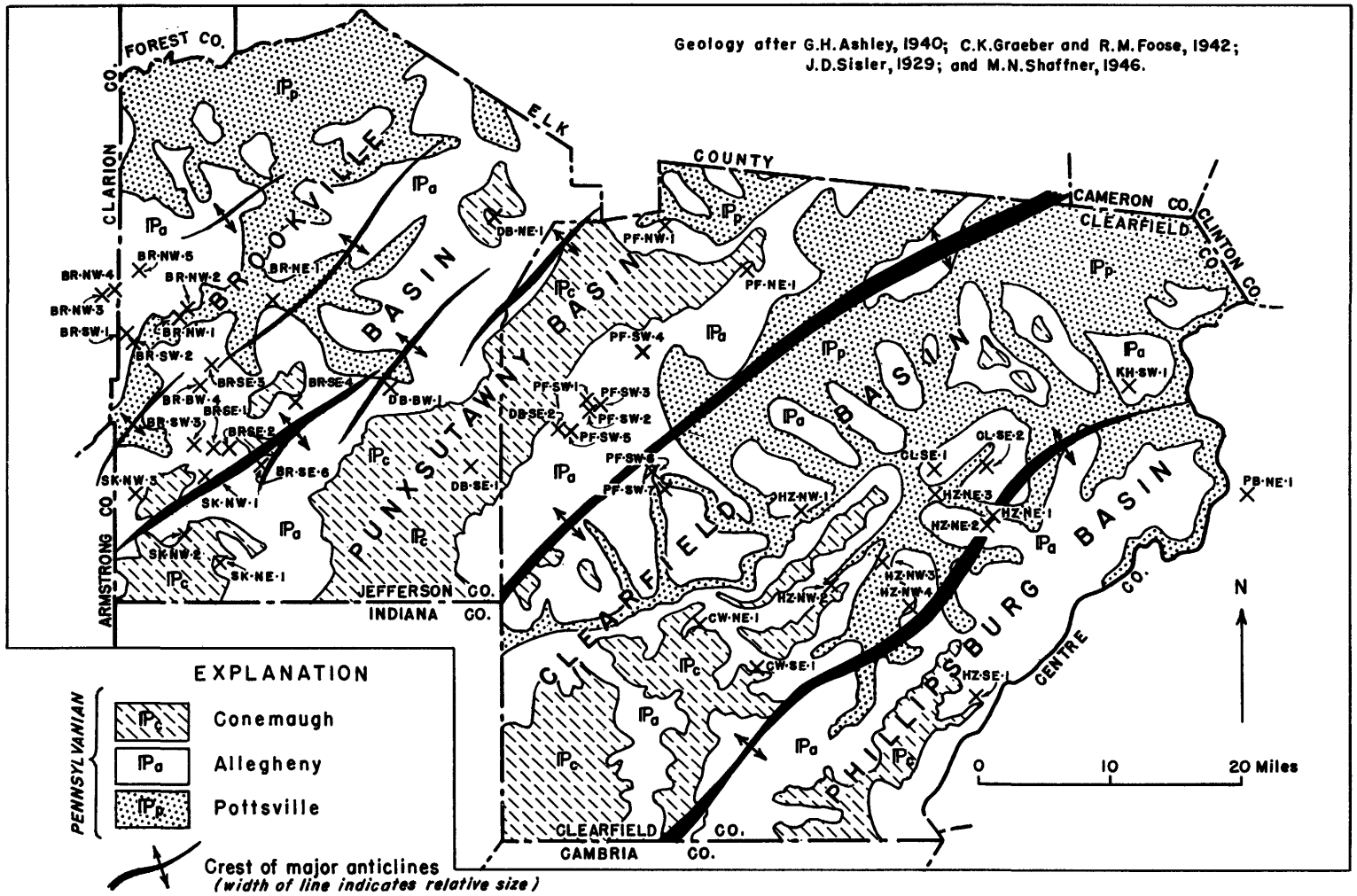


FIGURE 2.-AREAL GEOLOGY AND SAMPLE LOCALITIES IN THE CLEARFIELD AND JEFFERSON COUNTY AREA.

and Pottsville. In the two eastern basins (Clearfield and Phillipsburg) and their southern extensions, a letter system is more commonly used. A summary of stratigraphic nomenclature and the currently accepted correlations of the Allegheny and Pottsville coals is shown on table 3. Also shown is a generalized description of the Allegheny and Pottsville rocks in the Brookville basin and in the anticlinal area adjoining on the southeast.

RADIOACTIVITY DATA

General description

The location of sample sites is shown on figures 2 and 3 and radiation measurements obtained at each site are listed in tables 4 and 5. Sample localities in the Beaver County area are shown on figure 3 and the data pertaining to each locality are indicated on table 4. This table describes the geographic location and type of exposure at the locality as well as the stratigraphic and lithologic description of each sample collected there. Radioactivity measurements are also shown. These include scintillation meter reading, assay cup measurement, and equivalent uranium content calculated from the assay cup measurement, and equivalent uranium content measured by the U. S. Geological Survey laboratory in Washington, D. C. The results of chemical analysis, including percent uranium in sample, percent ash, and percent uranium in ash, are indicated for some samples with relatively high uranium equivalents. The location of Clearfield and Jefferson county sample sites is shown on figure 2; data obtained at these localities are shown on table 5 in a manner similar to the Beaver County data.

Table 3.—Composite section of the Allegheny and Pottsville series in the Clearfield and Jefferson county area.[1]

Approximate rock thickness and lithology in Brookville basin and anticlinal area adjoining on the southeast.		Nomenclature of Brookville and Punxsutawny basins.	Nomenclature of Clearfield and Phillipsburg basins.
Thickness (feet)	Lithology		
	Allegheny series		
4	Coal	Upper Freeport	E
10	Underclay, siltstone, and limestone		
20	Mostly siltstone		
3/4	Coal and underclay	Lower Freeport Rider	
20	Mostly siltstone		
3	Coal	Lower Freeport	D
10	Underclay, siltstone, and limestone		
20	Siltstone and/or sandstone		
1	Coal and underclay	Upper Kittanning	C'
5	Shale		
1/4	Coal and underclay		
30	Mostly siltstone		
2	Coal	Middle Kittanning	C
20	Underclay, coal, siltstone and/or sandstone		
40	Shale and siltstone		
3	Coal	Lower Kittanning	B
3	Underclay		
35	Mostly siltstone		
3	Limestone	Vanport	
25	Siltstone		
1	Coal and underclay	Upper Clarion	
20	Mostly siltstone		
2½	Coal	Lower Clarion	A'
3	Underclay		
35	Siltstone and/or sandstone		
2	Coal	Brookville	A
2	Underclay		
320½	Total		

1/ Compiled from Ashley, G. H., 1928, Graeber, C. K. and Foose, R. M., 1942, Shaffner, M. N., 1946, and Ferm, J. C., unpublished field notes.

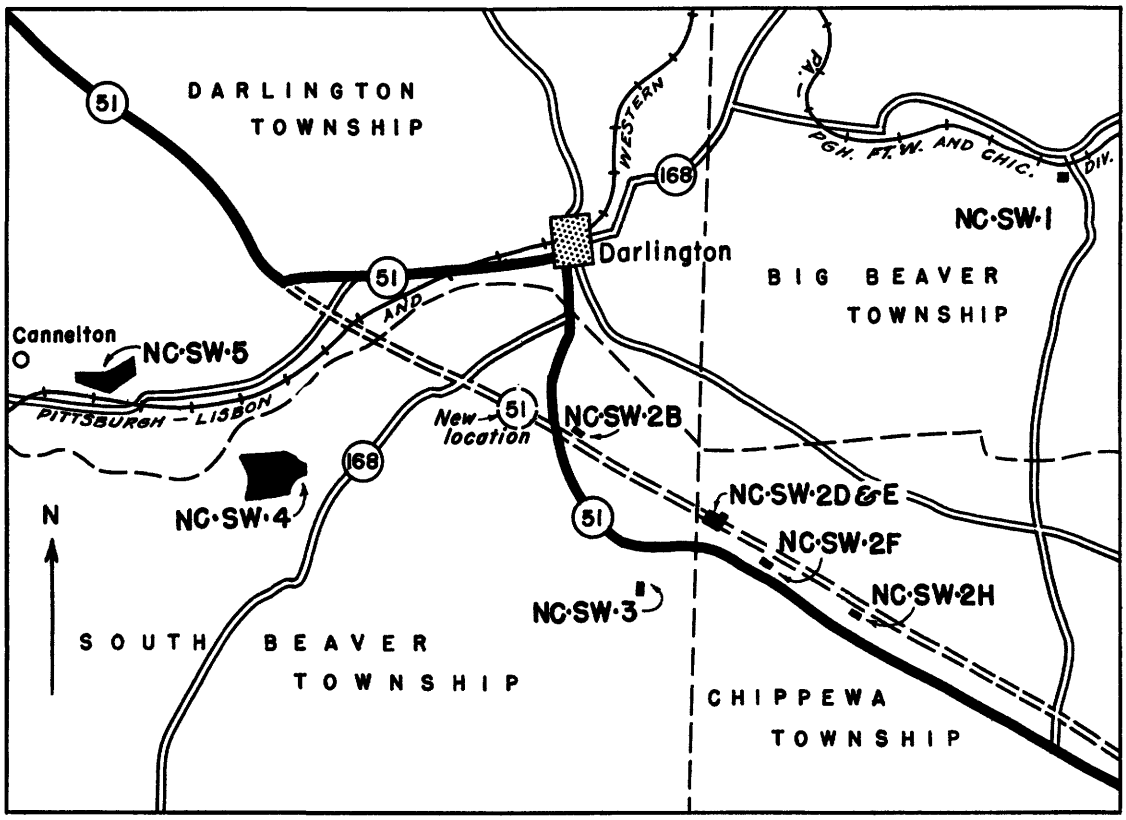
Table 3.—Composite section of the Allegheny and Pottsville series in the Clearfield and Jefferson county area-Continued.

Approximate rock thickness and lithology in Brookville basin and anticlinal area dajoining on the southeast.		Nomenclature of Brookville and Punxsutawny basins.	Nomenclature of Clearfield and Phillipsburg basins.
Thickness (feet)	Lithology		
		Pottsville series	
60	Siltstone and sandstone	Homewood	
30	Coal, underclay, and shale	Mercer	Flint Clay in Clearfield County
100	Siltstone and sandstone	Connoquenessing	
190	Total		

Some measure of radioactivity in Beaver, Clearfield, and Jefferson counties is indicated by the level of radioactivity found in 56 localities where samples were collected. In 29 localities samples contain less than 0.001 percent equivalent uranium. Twenty-one have at least one bed with 0.001 to 0.003 percent equivalent uranium and only six have beds with greater than 0.003 percent equivalent uranium.

Radioactivity great enough to be considered of possible importance was found at six of the 56 localities. At these places either the coal contained 0.003 percent or more equivalent uranium or other rock contained 0.005 percent or more equivalent uranium. These six localities have been selected for more detailed description.

(Text continued on page 36)



0 1 2 Miles

EXPLANATION

NC·SW·5 Sample locality; NC – New Castle 15" quad., SW – quarter of quad., 5 – locality within the quarter.

(for description of localities see Table 4.)

FIGURE 3. – MAP OF BEAVER COUNTY SAMPLE LOCALITIES

(LOCATION OF THIS AREA IN BEAVER COUNTY SHOWN ON FIGURE 1.)

Table 4.--Beaver County localities and radioactivity data listed alphabetically by 15-minute quadrangle.

Locality description[1]	Stratigraphic position	Lithology	Sample number	Mr/hr[2]	Counts per minute[3]	Equivalent uranium (percent)[4]	Equivalent uranium (percent)[5]
		BEAVER QUADRANGLE					
BV-NW-1[6] Old road cut on north side of Pennsylvania Highway 168 about 0.3 mile northwest of junction with Pennsylvania Highway 68 at Midland (not shown on fig. 3)	Brush Creek	Dark shale	161	.030	140	.003	None
		NEWCASTLE QUADRANGLE					
NC-SW-1 Old railroad cut on south side of Pennsylvania R.R. tracks about 2.5 miles due west from Homewood	Lower Freeport	Coal total 20"	52	.014	44	a[7]	a[7]

1/ Localities listed in this table are shown on figure 3.
2/ Field reading in milliroentgens per hour.
3/ Assay cup-Geiger counter measurements. (Background not subtracted.)
4/ Converted from assay cup-Geiger counter measurements (table 1). Chemical analyses, where shown, by Ivan Barlow, Joseph Budinsky, and Carmen Hoy, U. S. Geological Survey, Washington, D. C.
5/ Radioactivity measurements by Benjamin A. McCall, U. S. Geological Survey, Washington, D. C. None indicates no measurement.
6/ Locality code: BV=Beaver 15" quadrangle, NW=Northwest quarter of quadrangle, 1=locality within the quarter.
7/ a equals less than 0.001.

Table 4.--Beaver County localities and radioactivity data listed alphabetically by 15-minute quadrangle-Continued.

Locality description	Stratigraphic position	Lithology	Sample number	Mr/hr	Counts per minute	Equivalent uranium (percent)	Equivalent uranium (percent)
NC-SW-2B							
New road cut on north side of new Pennsylvania Highway 51 about 0.1 mile southeast of bridge on which new Pennsylvania Highway 51 crosses old Pennsylvania Highway 51. Crossing about 1 mile south of Darlington	Middle Kittanning	Coal total 18"	53	.010	43	a	a
NC-SW-2D							
New road cut on south side of new Pennsylvania Highway 51 about 0.95 mile southeast of bridge under NC-SW-2B	Lower Freeport	Coal bottom 3"	43	.048	284	.007 8/	.004, .005
	" "	Underclay top 2"	44	.060	307	.007 9/	.006, .008
	" "	" " 4½"	54	.060	235	.005 10/	.004, .005
	" "	" bottom 4½"	55	.040	195	.004	.004, .004

8/ Percent uranium in sample 0.007, percent ash 17.0, percent uranium in ash 0.041.
9/ " " " " 0.005, " " 87.5, " " " " 0.006.
10/ " " " " 0.004, " " 84.3, " " " " 0.004.

Table 4.--Beaver County localities and radioactivity data listed alphabetically by 15-minute quadrangle--Continued.

Locality description	Stratigraphic position	Lithology	Sample number	Mr/hr	Counts per minute	Equivalent uranium (percent)	Equivalent uranium (percent)
NC-SW-2E							
Prospect pit in new cut	Lower Freeport	Coal top 12"	48	.012	33	a	a
on north side of new Penn-	" "	" middle 6"	47	.032	38	a	a
sylvania Highway 51 about	" "	" bottom 6"	46	.080	313	.007[11]	.007, .010
0.95 mile southeast of bridge	" "	" bottom 3"	165	.100	450	.011	None
described under NC-SW-2B	" "	Underclay top 3"	45	.115	549	.014[12]	.011, .011
	" "	" top 1½"	163	.080	360	.009	None
	" "	" 5" below top	164	.060	198	.004	None
NC-SW-2F							
Old strip pit on south	Upper Freeport	Coal top 28"	51	.014	37	a	a
side of New Pennsylvania	" "	" middle 28"	50	.014	36	a	a
Highway 51 about 1.2	" "	" bottom 14"	49	.018	55	a	a
miles southeast of bridge described under NC-SW-2B							
NC-SW-2H							
New road cut on south side of new Pennsylvania Highway 51 about 1.8 miles southeast of bridge described under NC-SW-2B	Brush Creek	Dark shale	56	.030	150	.003	.004, .003

11/ Percent uranium in sample 0.010, percent ash 16.9, percent uranium in ash 0.060.
12/ " " " " 0.016, " " 60.7, " " " " 0.026.

Table 4.--Beaver County localities and radioactivity data listed alphabetically by 15-minute quadrangle-Continued.

Locality description	Stratigraphic position	Lithology	Sample number	Mr/hr	Counts per minute	Equivalent uranium (percent)	Equivalent uranium (percent)
NC-SW-3							
Active strip pit about 0.2 mile south of old Pennsylvania Highway 51 at a point 1.7 miles south of Darlington	Lower Freeport	Coal top 11"	63	None[13]	41	a	a
	" "	" bottom 9"	62	"	57	a	a
	" "	Underclay top 3"	61	"	228[14]	.005[15]	.004, .004
	" "	" " 3"	64	"	175[14]	.004[16]	.003, .003
	" "	" " 3"	65	"	222[14]	.005	.004, .004
	" "	" " 3"	66	"	179[14]	.004	.004, .004
NC-SW-4							
Diamond drill cores about 1.8 miles southwest of Darlington	Lower Kittanning	Coal total 3'3"	57	None	34	a	a
	" "	" " 2'2"	58	"	33	a	a
	" "	" " 2'4"	59	"	52	a	a
	" "	" " 2'	60	"	36	a	a
	" "	" " 2'3"	67	"	29	a	a
	" "	" " 2'5"	149	"	29	a	a
	" "	" " 2'	150	"	34	a	a
	" "	" " 2'1"	151	"	35	a	a
	" "	" " 2'1"	152	"	37	a	a
	" "	" " 2'5"	153	"	47	a	a
	" "	" " 2'6"	154	"	34	a	a
	" "	" " 2'8"	155	"	37	a	a
	" "	" " 2'6"	156	"	34	a	a
	" "	" " 2'2"	157	"	41	a	a
	" "	" " 2'2"	158	"	41	a	a

13/ None indicates no scintillometer reading.
14/ Average of four sub-samples.
15/ Percent uranium in sample 0.004, percent ash 57.1, percent uranium in ash 0.005.
16/ " " " " 0.004, " " 55.7, " " " " 0.004.

Table 4.--Beaver County localities and radioactivity data listed alphabetically by 15-minute quadrangle--Continued.

Locality Description	Stratigraphic position	Lithology	Sample number	Mr/hr	Counts per minute	Equivalent uranium (percent)	Equivalent uranium (percent)
NC-SW-5							
Diamond drill cores on north side of Pittsburgh, Lisbon, and Western Railroad about 0.4 mile east of Cannelton	Lower Kittanning	Coal total 2'1"	159	None	42	a	a
	" "	" " 2'5"	160	"	41	a	a

Table 5.—Clearfield-Jefferson county localities and radioactivity data listed alphabetically by 15-minute quadrangle.

Locality description 1/	Structural position	Stratigraphic position	Lithology	Sample number	Mr/hr 2/	Counts per minute 3/	Averaged c/m per coal bed 4/	Equivalent uranium (percent) 5/	Equivalent uranium (percent) 6/
			BROOKVILLE QUADRANGLE						
BR-NE-1									
Old strip pit on west side of Pennsylvania Highway 236, 0.7 mile from junction of Pennsylvania Highway 236 and U. S. Highway 322 near Brookville	Syncline	Mer. 7/	Coal top 18"	16	None	46)		a 8/	a 8/
		"	" bottom 8"	17	"	72)	54	.001	a
BR-NW-1									
Old road cut on north side of Pennsylvania Highway 28 about 0.6 mile east of Summerville	Syncline	Mer.	Coal total 14"	15	.023	80		.001	.001, .001

1/ Localities listed in this table are shown in figure 2.
2/ Field reading in milliroentgens per hour.
3/ Assay cup-Geiger counter measurement. (Background not subtracted.)
4/ Weighted average counts per minute for coal beds sampled in benches.
5/ Converted from assay cup-Geiger counter measurements. (table 1.) Chemical analyses, where shown, by Ivan Barlow, Joseph Budinsky, and Carmen Hoy, U. S. Geological Survey, Washington, D. C.
6/ Radioactivity measurements by Benjamin A. McCall, U. S. Geological Survey, Washington, D. C.
7/ L = Lower, M = Middle, U = Upper, Rid. = rider, Mer. = Mercer, Bkv. = Brookville, Cl. = Clarion, Kit. = Kittanning, Free. = Freeport, and Vpt. = Vanport.
8/ a equals less than 0.001.

Table 5.--Clearfield-Jefferson county localities and radioactivity data listed alphabetically by 15-minute quadrangle-Continued.

Locality description	Structural position	Strati-graphic position	Lithology	Sample number	Mr/hr	Counts per minute	Averaged c/m per coal bed	Equivalent uranium (percent)	Equivalent uranium (percent)
BR-NW-2									
Cut to old mine portal on north side of Pennsylvania Highway 28 about 0.9 mile east of Summerville	Syncline	Bkv.	Coal top 11"	14	.014	43)		a	a
		"	Coal bottom 22"	13	.014	36)	38	a	a
BR-NW-3									
Old railroad cut on south side of New York Central Railroad about 0.5 mile west of Sutton Station	Anticline	Vpt.	Limestone 1'7"	37	.015	53		a	a
		U.Cl.	Coal top 7"	38	.015	46)		a	a
		U.Cl.	Coal bottom 3"	39	.024	55)	49	a	a
BR-NW-4									
Old railroad cut on north side of New York Central Railroad about 0.2 mile east of Sutton Station	Anticline	L.Cl.	Coal top 15"	40	.012	44)		a	a
		L.Cl.	Coal bottom 13"	41	.012	41)	43	a	a
		L.Cl.	Underclay top 1'	42	.033	170		.003	.003, .003
BR-NW-5									
Old strip pit on east side of paved road, about 1 mile due south of Corsica	Anticline	U.Cl.	Coal total 17"	5	.016	57		a	a
		L.Cl.	Coal top 14"	4	.010	32)		a	a
		L.Cl.	Coal bottom 21"	3	.012	38)	36	a	a

Table 5.--Clearfield-Jefferson county localities and radioactivity data listed alphabetically by 15-minute quadrangle-Continued.

Locality description	Structural position	Strati-graphic position	Lithology	Sample number	Mr/hr	Counts per minute	Averaged c/m per coal bed	Equivalent uranium (percent)	Equivalent uranium (percent)
BR-SE-1									
Old strip pit about 1.1 miles due east of Worthville	Syncline	U.Kit.	Coal top 26"	20	.010	39)		a	a
		U.Kit.	Coal middle 26"	19	.010	36)	37	a	a
		U.Kit.	Coal bottom 7"	18	.012	33)		a	a
		U.Kit.	Fusain lens 2' from base	21	.012	61		a	a
BR-SE-2									
Old strip pit about 1.9 miles due north of Sprankle Mills	Syncline	L.Free.	Coal total 28"	22	.012	40		a	a
		L.Free.	Coal bottom 4"	23	.018	40		a	a
BR-SE-3									
Old strip pit on west side of earth road, about 0.7 mile northwest of Stanton	Anticline	L.Kit.	Dk. shale 15' over L. Kit. coal	72	.032	128		.002	a
		L.Kit.	Dk. shale 3' over L. Kit. coal	71	.032	144		.003	a
BR-SE-4									
Old railroad cut on east side of Pittsburgh & Shawmut Railroad about 0.9 mile south of Knoxdale	Anticline	L. Kit.	Dk. shale about 18' over L. Kit. coal	73	.030	122		.002	a

Table 5.—Clearfield-Jefferson county localities and radioactivity data listed alphabetically by 15-minute quadrangle -Continued.

Locality description	Structural position	Strati-graphic position	Lithology	Sample number	Mr/hr	Counts per minute	Averaged c/m per coal bed	Equivalent uranium (percent)	Equivalent uranium (percent)
BR-SW-1A[9]									
Old road cut on south side of Pennsylvania Highway 28 about 0.8 mile west of Summerville	Syn-cline	L.Free.	Dk. shale 6" at top of L.Free. coal	70	.032	183		.004	a
		L.Free.	Coal total 8"	1	.022	66		a	a
		L.Free.	Coal bottom 4"	69	.028	67		a	a
		L.Free.	Underclay top 6"	68	.031	116		.002	a
BR-SW-1B[9]									
Old road cut on north side of Pennsylvania Highway 28 about 0.5 mile west of Summerville	Syn-cline	M.Kit.	Coal total 9"	2	.022	41		a	a
BR-SW-2									
Stream cut about 0.9 mile southwest of the Pennsylvania Railroad depot at Summerville	Syn-cline	U.Cl.	Coal total 6"	8	None	59		a	a
		L.Cl.	Coal top 17"	7	.012	30)		a	a
		L.Cl.	Coal bottom 21"	6	.015	33)	32	a	a

9/ These localities shown as BR-SW-1 on figure 2.

Table 5.--Clearfield-Jefferson county localities and radioactivity data listed alphabetically by 15-minute quadrangle-Continued.

Locality description	Structural position	Strati-graphic position	Lithology	Sample number	Mr/hr	Counts per minute	Averaged c/m per coal bed	Equivalent uranium (percent)	Equivalent uranium (percent)
BR-SW-3									
Old road cut at Worthville, on north side of road to Cool Spring	Syncline	L.Kit.	Coal top 16"	10	.015	41)		a	a
		L.Kit.	Coal bottom 16"	11	.015	94)	68	.001	a
BR-SW-4									
Old strip pit on south side of Pittsburgh & Shawmut Railroad about 1 mile southeast of Conifer	Anticline	M.Kit.	Shale, 6", on top M.Kit. coal	162	.022	136		.002	None
		M.Kit.	Coal total 27"	9	.018	51		a	a
CLEARFIELD QUADRANGLE									
CL-SE-1									
Old strip pit on east side of unpaved road 0.3 mile south of Bishtown	Syncline	C'	Cannel coal top 10"	114	.021	57)		a	a
		C'	Cannel coal middle 28"	113	.015	50)		a	a
		C'	Coal middle 3"	112	.014	35)		a	a
		C'	Coal bottom 8"	111	None	40)	49	a	a
CL-SE-2									
High wall of active strip pit on south side of paved road, 1.7 miles southwest of Shiloh	Anticline	C	Coal total 15"	117	.018	58		a	a

Table 5.—Clearfield-Jefferson county localities and radioactivity data listed alphabetically by 15-minute quadrangle—Continued.

Locality description	Structural position	Strati-graphic position	Lithology	Sample number	Mr/hr	Counts per minute	Averaged c/m per coal bed	Equivalent uranium (percent)	Equivalent uranium (percent)
CL-SE-2									
Active strip pit 1.7 miles southwest of Shiloh	Anti-cline	B	Coal top 25"	116	.014	38)		a	a
		B	Coal bottom 9"	115	.022	58)	43	a	a
			CURWENSVILLE QUADRANGLE						
CW-NE-1									
Active strip pit on south side of Watt's Creek 0.8 mile northwest of Kerrmoor	Syn-cline	E	Coal total 23"	134	.017	46		a	a
CW-SE-1									
Active strip pit on north side of paved road, 0.8 mile northeast of Anson-ville	Syn-cline	D	Coal total 32"	135	.012	36		a	a
			DUBOIS QUADRANGLE						
DB-NE-1									
Mine near portal on north side of paved road, 0.2 mile due east of Westville	Syn-cline	Free.	Coal total 33"	148	.018	43		a	a
DB-SE-1									
Cramer Mine, near face, Stump Creek	Syn-cline	L.Free.	Coal top 16"	93	.022	35)		a	a
		L.Free.	Coal bottom 14"	92	.026	40)	37	a	a
		L.Free.	Underclay top 3"	94	.031	129		.002	a

Table 5.—Clearfield-Jefferson county localities and radioactivity data listed alphabetically by 15-minute quadrangle-Continued.

Locality description	Structural position	Strati-graphic position	Lithology	Sample number	Mr/hr	Counts per minute	Averaged c/m per coal bed	Equivalent uranium (percent)	Equivalent uranium (percent)
DB-SE-2									
Old strip pit on north side of paved road, 0.9 mile due east of Helvetia	Syn-cline	U.Free.							
		Rid.	Coal total 6"	81	.022	55		a	a
		U.Free.	Coal top 26"	80	.010	45)		a	a
		U.Free.	Coal middle 22"	79	.010	35)	41	a	a
		U.Free.	Coal bottom 22"	78	.010	42)		a	a
DB-SW-1									
High wall of active strip mine about 2.6 miles southwest of Reynoldsville	Anti-cline	U.Kit.	Coal total 14"	12	None	77		.001	a
			HOUTZDALE QUADRANGLE						
HZ-NE-1									
Old strip pit on west side of U. S. Highway 322, 0.15 mile south of junction with Pennsylvania Highway 153	Anti-cline	A'	Coal total 15"	119	.014	32		a	a
		A'	Underclay 10' below A' coal	118	.031	135		.002	.002
HZ-NE-2									
Active strip pit about 0.5 mile due south of New York Central Railroad Depot, Bigler	Anti-cline	A'	Coal total 48"	136	.015	31		a	a
		A'	Underclay 4' below A' coal	137	.030	138		.002	.002

Table 5.--Clearfield-Jefferson county localities and radioactivity data listed alphabetically by 15-minute quadrangle-Continued.

Locality description	Structural position	Strati-graphic position	Lithology	Sample number	Mr/hr	Counts per minute	Averaged c/m per coal bed	Equivalent uranium (percent)	Equivalent uranium (percent)
HZ-NE-3									
Mine near portal on south side of U. S. Highway 322, 1.25 miles west of junction with Pennsylvania Highway 970	Syn-cline	Mer.	Coal total 6"	143	.028	45		a	a
		Mer.	Flint clay 9" below coal	144	.036	140		.003	.002
HZ-NW-1									
Old railroad cut on north side of Pennsylvania Rail-road located on south side of U. S. Highway 322, 2.5 miles south of Hyde	Syn-cline	A'	Coal total 12"	120	.016	37		a	a
HZ-NW-2									
Mine near portal on south side of paved road be-tween Oshanter and Faunce, about 1 mile from Oshanter	Syn-cline	E	Coal total 29"	121	.017	39		a	a
Old strip pit. Same locality	Syn-cline	D	Coal (cannel) top 15"	123	.021	67)		a	a
		D	Coal bottom 24"	122	.018	39)	50	a	a

Table 5.—Clearfield-Jefferson county localities and radioactivity data listed alphabetically by 15-minute quadrangle-Continued.

Locality description	Structural position	Strati-graphic position	Lithology	Sample number	Mr/hr	Counts per minute	Averaged c/m per coal bed	Equivalent uranium (percent)	Equivalent uranium (percent)
HZ-NW-3									
High wall of old strip pit on west side of Clearfield Creek about 2.3 miles northeast of Faunce	Syn-cline	Mer.	Coal total 42"	128	.015	54		a	a
Old strip pit. Same locality	Syn-cline	Mer.	Coal top 15"	127	.014	44)		a	a
		Mer.	Coal bottom 15"	126	.018	41)	43	a	a
		Mer.	Coal top 9"	125	.029	58)		a	a
		Mer.	Coal (bony) bottom 4"	124	.042	159)	89	.003 10/	.003
HZ-NW-4									
Mine near portal on west side of paved road about 3 miles north of Henderson	Anti-cline	Mer.	Flint clay 2' fm. top	129	.041	198		.004 11/	.002, .002
		Mer.	Flint clay 5' " "	130	.049	131		.002	.003, .003
		Mer.	Flint clay 6' " "	131	.045	147		.003 12/	.003, .003
HZ-SE-1									
Old strip pit on south side of Pennsylvania Highway 53, 2.3 miles northeast of junction with Pennsylvania Highway 353 in Houtzdale	Syn-cline	D	Coal top 33"	133	.015	47)		a	a
			Coal bottom 33"	132	.015	43)	45	a	a

10/ Percent uranium in sample 0.002, percent ash 74.8, percent uranium in ash 0.003.
11/ " " " " 0.001, " " 86.7, " " " " 0.001.
12/ " " " " 0.0007, " " 15.8, " " " " 0.004

Table 5.--Clearfield-Jefferson county localities and radioactivity data listed alphabetically by 15-minute quadrangle-Continued.

Locality description	Structural position	Strati-graphic position	Lithology	Sample number	Mr/hr	Counts per minute	Averaged c/m per coal bed	Equivalent uranium (percent)	Equivalent uranium (percent)
			KARTHUS QUADRANGLE						
KH-SW-1 Active strip pit about 1.8 miles south of Keewaydin	Flank	C'	Coal total 24"	142	.010	38		a	a
		C	Coal top 9"	141	.022	60)		a13/	.001
		C	Coal bottom 23"	140	.015	40)	46	a	a
			PENFIELD QUADRANGLE						
PF-NE-1 Mine near portal on east side of Pennsylvania Highway 153, 3.7 miles southeast of Penfield	Syncline	?	Coal total 30"	145	.014	42		a	a
PF-NW-1 Mine near portal on east side of unpaved road, 3.4 miles due north of Sabula	Syncline	L.Kit.	Dk. shale 1' above L. Kit. coal	147	.038	164		.003	.003
		L.Kit.	Coal total 30"	146	.018	36		a	a
PF-SW-1 Fresh prospect pit about 0.1 mile northwest of Baltimore & Ohio Railroad (Buffalo, Rochester, & Pittsburgh) tracks at Luthersburg Station	Flank	Cl.	Coal top 16"	91	.012	39)		a	a
		Cl.	Coal bottom 9"	90	.016	42)	40	a	a

13/ Percent uranium in sample 0.0004, percent ash 62.3, percent uranium in ash 0.0006.

Table 5.--Clearfield-Jefferson county localities and radioactivity data listed alphabetically by 15-minute quadrangle-Continued.

Locality description	Structural position	Strati-graphic position	Lithology	Sample number	Mr/hr	Counts per minute	Averaged c/m per bed	Equivalent uranium (percent)	Equivalent uranium (percent)
PF-SW-2									
Old strip pit on south side of unpaved road about 0.2 mile southwest of Luthersburg Station	Flank	M.Kit.	Coal top 19"	88	.022	50)		a	a
		M. Kit.	Coal bottom 12"	87	.022	43)	47	a	a
PF-SW-3									
Highwall active strip pit on north side of unpaved road about 0.4 mile northeast of Luthersburg Station	Flank	U.Kit.	Coal total 14"	89	.024	38		a	a
Active strip pit at same locality	Flank	L.Kit.	Coal top 11"	86	.022	36)		a	a
		L.Kit.	Coal bottom 20"	85	.022	55)	48	a	a
PF-SW-4									
Active strip pit on south side of paved road, 1.4 miles southwest of Homecamp	Syn-cline	L.Kit.	Dk. shale 20" over L. Kit. coal	76	.032	146		.003	a
		L.Kit.	Coal top 8"	75	.018	38)		a	a
		L.Kit.	Coal bottom 21"	74	.018	40)	39	a	a
PF-SW-5									
Old strip pit on north side of Pennsylvania Highway 951, 1.4 miles west of Luthersburg	Flank	L.Free.	Coal top 7"	84	.025	44)		a	a
		L.Free.	Coal bottom 14"	83	.026	39)	41	a	a
		L.Free.	Underclay top 2½"	82	.030	137		.002	a

Table 5.—Clearfield-Jefferson county localities and radioactivity data listed alphabetically by 15-minute quadrangle-Continued.

Locality description	Structural position	Strati-graphic position	Lithology	Sample number	Mr/hr	Counts per minute	Averaged c/m per coal bed	Equivalent uranium (percent)	Equivalent uranium (percent)
PF-SW-6									
Old strip pit about 0.7 mile south of Chestnut Grove	Anti-cline	Mer.	Coal top 4"	110	.018	70)		.001[14]	.001
		Mer.	Coal bottom 23"	109	.015	53)	56	a	a
		Mer.	Coal top 4"	108	.024	56)		a	a
		Mer.	Coal (bony) middle 6"	107	.024	106)		.002[15]	.002
		Mer.	Coal bottom 7"	106	.030	117)	99	.002[16]	.002
		Mer.	Coal total 6"	105	.028	50		a	a
Mine near portal at same locality		Mer.	Flint clay, under coal	97	.043	93		.001	a
		Mer.	Flint clay 3½' below coal	96	.040	132		.002	a
		Mer.	Flint clay 6' below coal	95	.029	89		.001	a
Mine at face at same locality		Mer.	Flint clay, under coal	99	.033	146		.003	.002.
		Mer.	" "1½' below "	100	.042	140		.003	.002
		Mer.	" " 3' " "	101	.038	96		.001	.001
		Mer.	" "4½' " "	102	.036	97		.001	.001
		Mer.	" " 6' " "	103	.034	105		.002	.001
Mine at another face at same locality		Mer.	" " under coal	104	.044	125		.002	.002

14/ Percent uranium in sample 0.0007, percent ash 67.3, percent uranium in ash 0.001.
15/ " " " " 0.0006, " " 31.9, " " " " 0.002.
16/ " " " " 0.0006, " " 25.1, " " " " 0.002.

Table 5.--Clearfield-Jefferson county localities and radioactivity data listed alphabetically by 15-minute quadrangle-Continued.

Locality description	Structural position	Strati-graphic position	Lithology	Sample number	Mr/hr	Counts per minute	Averaged c/m per coal bed	Equivalent uranium (percent)	Equivalent uranium (percent)
PF-SW-7									
Active strip pit on south side of U. S. Highway 322, 1.8 miles southeast of Chestnut Grove	Anti-cline	A'	Coal total 30"	98	.013	46		a	a
			PHILLIPSBURG QUADRANGLE						
PB-NE-1									
Active strip pit about 0.2 mile north of the New York Central Railroad at Gorton	Syn-cline	A	Coal total 27"	138	.016	43		a	a
		A	Underclay top 3"	139	.030	145		.003	.003
			SMICKSBURG QUADRANGLE						
SK-NE-1									
High wall of old strip pit about 2.3 miles northwest of Hamilton	Flank	L.Free. Rid.	Coal total 5"	29	.030	142		.003 17/	.003, .003
		"	Underclay top 5"	30	.028	115		.002	.002, .003
Old strip pit at same locality		L.Free. U.split	Coal top 6"	28	.022	105)		.002	.001
		" "	Coal middle 9"	27	.013	48)		a	a
		" "	Coal bottom 8"	26	.013	37)	52	a	a
		L.split	Coal bottom 24"	31	.009	28		a	a

17/ Percent uranium in sample 0.002, percent ash 84.1, percent uranium in ash 0.002.

Table 5.--Clearfield-Jefferson county localities and radioactivity data listed alphabetically by 15-minute quadrangle-Continued.

Locality description	Structural position	Strati-graphic position	Lithology	Sample number	Mr/hr	Counts per minute	Averaged c/m per coal bed	Equivalent uranium (percent)	Equivalent uranium (percent)
SK-NW-1									
High wall of active strip pit about 1.2 miles southwest of Sprankle Mills	Anti-cline	M. Kit	Coal total 10"	25	.018	41		a	a
Active strip pit at same locality		L. Kit.	Coal total 35"	24	.015	28		a	a
SK-NW-2									
Old strip pit about 1.1 miles southeast of Dora	Anti-cline	U.Free.	Coal total 20"	35	.012	36		a	a
High wall of active strip pit at same locality		L.Free.	Shale 2" overlying coal	34	.029	57		a	.003, .003
		Rid.	Coal total 3"	33	.026	179		.004[18]	.004, .006
		"	Underclay top 2"	32	.024	130		.002	.002, .002
SK-NW-3									
Old strip pit about 1.3 miles due north of Timblin	Syn-cline	U.Kit.	Coal top 19"	36	.010	29		a	a

18/ Percent uranium in sample 0.002, percent ash 81.3, percent uranium in ash 0.003.

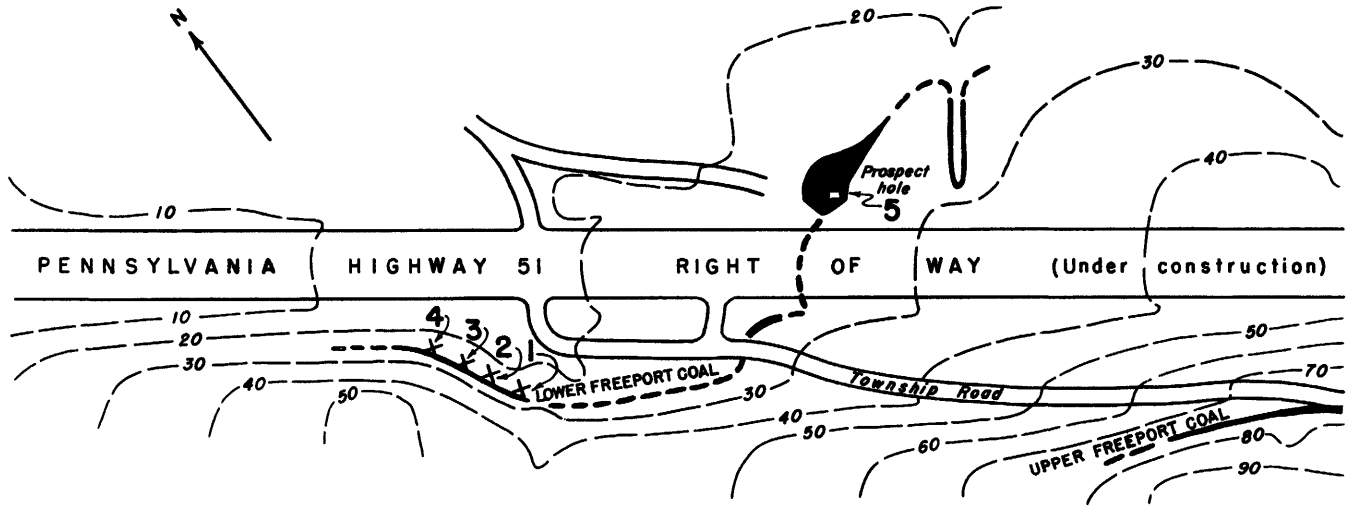
Localities with relatively high radioactivity

Beaver County

The greatest radioactivity detected in the investigation is at three localities in Beaver County. (NC-SW-2D and E and NC-SW-3 on figure 3 and table 4.)

At localities NC-SW-2D and E, equivalent uranium contents as much as 0.014 percent were obtained from the upper 6± inches of Lower Freeport underclay and the lower 6± inches of overlying coal. This zone was studied in new road cuts along relocated Pennsylvania Highway 51. Figure 4 is a detailed map of the cut, showing the sites where abnormally high radioactivity was measured. On the southwest side of the highway, the Lower Freeport coal and underclay is exposed for a distance of 100 feet about seven feet above the base of the cut. In this outcrop samples of the upper nine inches of the underclay and lower three inches of the coal contain 0.004 to 0.007 percent equivalent uranium (sites 1-4, fig. 4). From this cut, the coal can be traced to the northeast side of the road where the ground has been leveled to approximately highway grade. At this place (site 5, fig. 4), a prospect hole was dug through the coal and into the top 6 inches of underclay. Samples of the top 6 inches of underclay in this prospect contain 0.004 to 0.014 percent equivalent uranium, and a sample of the lower 6 inches of coal contains 0.007 percent equivalent uranium. The remaining upper 18 inches of coal has less than 0.001 percent equivalent uranium.

About half a mile southwest of the above sites at Locality NC-SW-3 (fig. 3), equivalent uranium contents of 0.004 and 0.005 percent were measured from four samples of the upper three inches of the Lower Freeport underclay. At this place the underclay and overlying coal are exposed for



SITE ON MAP	ROCK TYPE	FIELD RADIOACTIVITY mr/hr	SAMPLE NO.	EQUIVALENT URANIUM PERCENT	PERCENT ASH	PERCENT URANIUM IN ASH	PERCENT URANIUM IN SAMPLE
1.	Lower 3" coal	.048	43	.007	17.0	.041	.007
	Upper 2" clay	.060	44	.007	87.5	.006	.005
2.	Upper 3" underclay	.060					
3.	Upper 3" underclay	.038					
4.	Top 16" coal	.010					
	Mid 12" coal	.020					
	1½" shale parting	.023					
	Bottom 4" coal	.036					
	Top 4½" clay	.060	54	.005	84.3	.006	.004
	Bottom 4½" clay	.040	55	.004			
5.	Top 12" coal	.012	48	<.001			
	Mid 6" coal	.032	47	<.001			
	Bottom 6" coal	.080	46	.007	16.9	.060	.010
	Bottom 3" coal	.100	165	.011			
	Top 1½" clay	.080	163	.009			
	Top 3" clay	.115	45	.014	60.7	.026	.016
	1½" clay 5" below top	.060	164	.004			

0 100 200 Feet

EXPLANATION

Coal outcrop

20

Approximate topographic contours *(assumed datum)*

×2

Site of samples

FIGURE 4.— MAP OF HIGHWAY CUT AND RADIOACTIVITY DATA NEAR DARLINGTON, BEAVER COUNTY, PA.
(LOCALITIES NC·SW·2D & E)

75194

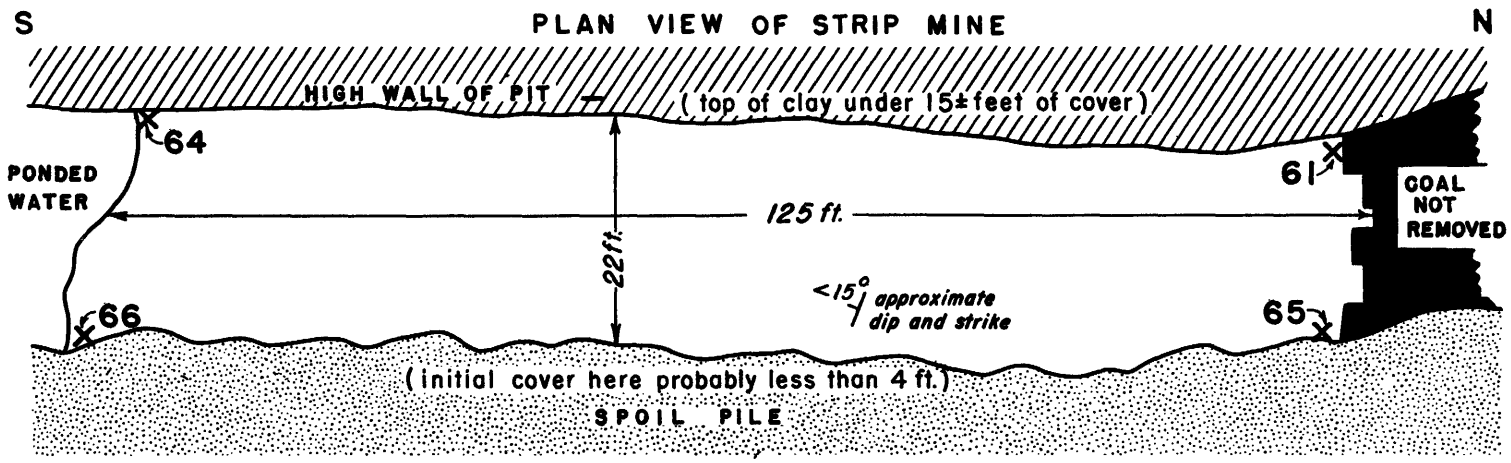
about 125 feet in the floor of an active strip mine cut (fig. 5). At the north end of the cut, the underclay-coal contact was concealed by coal not yet removed; at the south end, this underclay-coal contact dips gently below the level of ponded water. On the west side of the cut, the coal was exposed beneath about 15 feet of overburden and appeared unweathered; on the east side, about 20 feet away, the original cover was probably less than four feet and the coal was too weathered for commercial operation.

The presence of variable degrees of weathering and of structural position at this place seemed to provide an opportunity for testing the possible effects of these geological factors on the intensity of radioactivity. For this test, two sets of samples of the upper three inches of underclay were collected, one set representing the up dip and down dip sites of unweathered clay under 15 feet of cover, the other consisting of comparable up and down dip situations under conditions of greater weathering. Each sample was split into four sub-samples in an ASTM splitter and assay cup measurements of each set of four sub-samples were averaged. The location of the samples in the pit and results of radioactivity measurements are shown on figure 5. Statistical analysis of the data is shown on table 10 in the appendix.

One other outcrop of the Lower Freeport zone was studied in this area at NC-SW-1 (fig. 3) about three miles northeast of the two localities described above. At this place the equivalent uranium content is less than 0.001 percent.

Clearfield and Jefferson counties

At two Jefferson County localities a thin "rider" coal between the Lower and Upper Freeport beds has an equivalent uranium content that ranges



Sample number	64	66	61	65
Assay cup values of sub-samples *(in counts per minute)*	172 174 182 170	178 175 178 185	230 227 229 226	231 208 225 223
Average for sub-samples	175	179	228	222
eU *(from averaged sub-samples)*	.004	.004	.005	.005

FIGURE 5. — PLAN VIEW AND RADIOACTIVITY DATA AT A STRIP MINE IN THE LOWER FREEPORT COAL NEAR DARLINGTON, BEAVER COUNTY, PENNSYLVANIA (LOCALITY NC·SW·3)

from 0.003 to 0.004 percent. At SK-NE-1 (fig. 2) this bed was sampled in a deeply weathered zone near the top of a cut in an abandoned open pit mine on the Lower Freeport coal. At this locality the "rider" coal is five inches thick and contains 0.003 percent equivalent uranium; a sample of the underlying clay has 0.002 percent equivalent uranium. About two miles to the northwest (locality SK-NW-2, fig. 2), the equivalent stratigraphic zone was sampled in another weathered exposure near the top of an operating strip pit on the Lower Freeport. Here the coal is three inches thick and contains 0.004 percent equivalent uranium. A sample of the clay directly underlying the coal has an equivalent uranium content of 0.002 percent. This "rider" zone was not studied at other localities.

At Clearfield County locality HZ-NW-3, a sample of "bony" coal from a coal bed in the Mercer group contains 0.003 percent equivalent uranium. This sample represents the bottom four inches of a 13-inch bed exposed at the bottom of an abandoned coal and clay strip pit. Samples of other beds at this locality contain less than 0.001 percent equivalent uranium. Rocks at this approximate stratigraphic position were studied at several places in the Clearfield-Jefferson county area; at these localities the equivalent uranium content of coal samples ranges from less than 0.001 to 0.002 percent and similar contents of associated flint clays and underclays range from less than 0.001 to 0.004 percent.

FACTORS AFFECTING THE OCCURRENCE OF RADIOACTIVITY

In addition to providing information on radioactivity in specific areas, the data were examined to determine possible effects of several general geological background conditions on the occurrence of radioactive materials. These background factors included weathering, stratigraphic position, rock type, and structural position.

Weathering

The ability of weathering processes to remove, alter, or concentrate many economic minerals has long been recognized, and this knowledge constitutes an important aid in many types of prospecting. Radioactive minerals in many sedimentary rocks are believed to be much affected by weathering processes; these minerals may possibly be removed to such a degree that rocks with moderate or low radioactivity could not be detected in weathered exposures. Inasmuch as both weathered and unweathered exposures were sampled in this study, it was possible to test for an association between degrees of weathering at sample sites and the amount of radioactivity found there.

For this test the data from tables 4 and 5 were arranged on table 6 to show the number of weathered and unweathered sample sites in which relatively high and low radioactivity was found. Weathered sample sites include old highway, railroad, and strip mine cuts, natural exposures, and weathered zones near the top of open cut pits. Currently operating strip mines, underground workings, and fresh highway cuts constitute types of unweathered exposures. High and low radioactivity is indicated by the highest equivalent uranium value obtained from the sample or samples at any given site. These maximum equivalent uranium measurements presumably represent the highest radioactivity that can be found at either a weathered or unweathered site, and should no significant difference be found between the number of weathered sites with "high" and "low" radioactivity, we must conclude that further prospecting for radioactivity in similar geologic situations need not be restricted to unweathered exposures. In table 6 two categories of relatively high and low radioactivity are shown. In the left half equivalent uranium greater than 0.001 percent is considered

Table 6.--Relation of radioactivity to weathered and unweathered exposures.

	Number of sample sites with 0.001 percent or less equivalent uranium	Number of sample sites with greater than 0.001 percent equivalent uranium	Total	Number of sample sites with 0.002 percent or less equivalent uranium	Number of sample sites with greater than 0.002 percent equivalent uranium	Total
Number of weathered sample sites	23	13	36	29	7	36
Number of unweathered sample sites	12	12	24	15	9	24
Total	35	25	60	44	16	60

high; 0.001 percent or less equivalent uranium is low. On the right half greater than 0.002 percent equivalent uranium is high; 0.002 percent or less is low.

To test for the possible association between weathered and unweathered sample sites with high and low radioactivity, the two halves of table 6 can be treated as contingency tables and chi square calculated as a test of independence. These calculations (table 9 in the appendix) indicate that the differences on table 6 are not significantly greater than would be expected from variations due entirely to chance, and consequently, that the occurrence of radioactivity at the level of 0.002 percent or less equivalent uranium is not well associated with weathered or unweathered exposures of coal and associated rocks, and that further prospecting in areas of this type need not exclude weathered exposures.

A second test of the effects of weathering was made at Beaver County locality NC-SW-3, a strip mine pit near Darlington (figs. 3 and 5). The analysis of variance technique applied to these data (table 10 in the appendix) indicates that, at this locality, the differences in radioactivity in weathered and unweathered portions of the cut are not significant.

Stratigraphic position and rock type

Preferential occurrence of radioactive materials in certain stratigraphic positions and rock types is indicated on table 7, on which all samples containing 0.003 percent or more equivalent uranium are grouped according to stratigraphic zones. Also shown is the rock type of each sample.

The stratigraphic zone showing the greatest amount of radioactivity

Table 7.—Samples with 0.003 percent or more equivalent uranium arranged in stratigraphic zones and by counties.

Rock type and thickness	Equivalent uranium	Sample number[1/]	County	Locality number
		Lower Freeport		
Coal, bottom 6"	.007	46	Beaver	NC-SW-2-E
Coal, bottom 3"	.011	165	"	NC-SW-2-E
Underclay, top 1½"	.009	163	"	NC-SW-2-E
Underclay, top 3"	.014	45	"	NC-SW-2-E
Underclay, 5" from top	.004	164	"	NC-SW-2-E
Coal, bottom 3"	.007	43	"	NC-SW-2-D
Underclay, top 2"	.007	44	"	NC-SW-2-D
Underclay, top 4½"	.005	54	"	NC-SW-2-D
Underclay, bottom 4½"	.004	55	"	NC-SW-2-D
Underclay, top 3"	.005	61	"	NC-SW-3
Underclay, top 3"	.004	64	"	NC-SW-3
Underclay, top 3"	.005	65	"	NC-SW-3
Underclay, top 3"	.004	66	"	NC-SW-3
Rider coal, total 5"	.003	29	Jefferson	SK-NE-1
Rider coal, total 3"	.004	33	"	SK-NW-2
Dark shale overlying coal	.004	70	"	BR-SW-1-A
		Mercer		
Coal, bottom 4", bony	.003	124	Clearfield	HZ-NW-3
Flint clay, 9" below coal	.003	144	"	HZ-NE-3
Underclay, 6" below coal	.003	131	"	HZ-NW-4
Underclay, 2" below coal	.004	129	"	HZ-NW-4
Flint clay, 3" below coal	.003	99	"	PF-SW-6
Flint clay, 1½" below coal	.003	100	"	PF-SW-6
		Other		
Dark shale, Brush Creek	.003	56	Beaver	NC-SW-2-H
Dark shale, Brush Creek	.003	161	"	BV-NW-1
Dark shale, 1' over Lower Kittanning coal	.003	147	Clearfield	PF-NW-1
Dark shale, 20" over Lower Kittanning coal	.003	76	"	PF-SW-4
Dark shale, 3' over Lower Kittanning coal	.003	71	Jefferson	BR-SE-3
Underclay, 6" below Lower Clarion coal	.003	42	Clarion[2/]	BR-NW-4-B
Underclay, 3" below Brookville (A) coal	.003	139	Centre[3/]	PB-NE-1

1/ Calculated from assay cup measurements.
2/ This locality closely adjoins Jefferson County.
3/ This locality closely adjoins Clearfield County.

is the Lower Freeport coal and associated rocks. In the Beaver County area, the beds of greatest radioactivity include the lower 3± inches of the Lower Freeport coal and the uppermost 12 inches of underclay. Of the samples collected in this area the highest equivalent uranium content, 0.014 percent, is found in the underclay. The greatest content in coal is 0.011 percent equivalent uranium. In three Jefferson County localities rocks with maximum equivalent uranium of 0.003 and 0.004 percent are associated with the Lower Freeport coal. At two localities (SK-NE-1 and SK-NW-2) a thin "rider" coal occurring about 25 to 30 feet above the Lower Freeport contains 0.003 and 0.004 percent equivalent uranium. At another locality (BR-SW-1-A), a sample of dark shale overlying the Lower Freeport coal contains 0.004 percent equivalent uranium.

Samples of the Mercer coal group in a few Clearfield County localities contain 0.003 to 0.004 percent equivalent uranium (localities HZ-NE-3, HZ-NW-4, and PF-SW-6 on table 5). Most of these samples were collected from the economically important refractory clay zone which includes flint, semi-flint, and plastic varieties of clay. At one locality (HZ-NW-3), a sample representing the bottom four inches of a 13-inch Mercer coal bed contains 0.003 percent equivalent uranium.

Samples of dark shales of probable marine or brackish water origin and underclays at a few other stratigraphic positions have equivalent uranium contents of 0.003 percent. These include the dark shale associated with the Brush Creek limestone, dark shale overlying the Lower Kittanning coal, and the underclays of the Brookville and Lower Clarion coals. These samples probably illustrate an association of radioactivity with the dark shale and underclay rock types rather than with a certain stratigraphic position.

Structure

Possible influence of structural attitude on the occurrence of radioactivity was tested, using the data of the present investigation. In the first test, samples from the large anticlines and synclines in the Clearfield-Jefferson county area were compared for differences in radioactivity. In the second, Beaver County data were used to evaluate the effect of local structure.

Comparative data for the Clearfield-Jefferson county area are shown in table 8. For this comparison only coal beds are used inasmuch as these beds were sampled irrespective of radioactivity and thus constitute a reasonably representative sample of a single rock type. Furthermore, only beds sampled either near the crests of anticlines or in the deeper parts of synclines are included. As a measure of radioactivity in each bed, counts per minute values obtained from the assay cup-Geiger counter technique are listed; where thicker coals were sampled in benches, weighted average counts per minute values are used to represent the bed. To reduce bias from stratigraphic zones, the beds were assembled into stratigraphic groups containing nearly an equal number of localities and an average counts per minute value was established for each group. The average for groups on anticlines and synclines constitute a measure of radioactivity on structurally extreme positions. Comparison of these two averages (table 8) indicates slightly greater radioactivity on anticlines, but the difference is probably too small to be significant.

The effect of structure on a local scale was tested at Beaver County locality NC-SW-3 (fig. 5), and analysis of these data (table 10) shows a significantly greater amount of radioactivity in samples from the up-dip part of the exposure. This may indicate either (1) a primary concentration

Table 8.—Relation of structural position to radioactivity of coals.

Stratigraphic position	Anticlines		Synclines	
	Location	Counts per minute assay cup measurements	Location	Counts per minute assay cup measurements
Upper Freeport	SK-NW-2	36	CW-NE-1	46
			DB-SE-2	41
			DB-SE-2 (rider coal)	55
			HZ-NW-2	39
Freeport (Upper? - Lower?)			DB-NE-1	43
Lower Freeport	SK-NW-2 (Rider coal)	179	BR-SW-1	66
			BR-SE-2	40
			CW-SE-1	36
			DB-SE-1	37
			HZ-NW-2	50
			HZ-SE-1	45
Average all Freeport		108		45
Kittanning other then Lower Kittanning	BR-SW-4	51	BR-SW-1	41
	CF-SE-2	58	BR-SE-1	37
	DB-SW-1	77	CF-SE-1	49
	SK-NW-1	41		
Lower Kittanning	CF-SE-2	43	BR-SW-3	68
	SK-NW-1	28	PF-NW-1	36
			PF-SW-1	39
Average all Kittanning		50		45
Upper Clarion	BR-NW-3	49	BR-SW-2	59
	BR-NW-5	57		
Lower Clarion	BR-NW-4	43	BR-SW-2	32
	BR-NW-5	36	HZ-NW-1	37
	HZ-NE-1	32		
	HZ-NE-2	31		
	PF-SW-7	46		
Average all Clarion		42		43
Brookville			BR-NW-2	38
			PB-NE-1	43
Mercer	PF-SW-6	50	BR-NE-1	54
	PF-SW-6	99	BR-NW-1	80
	PF-SW-6	56	HZ-NW-3	89
			HZ-NW-3	54
			HZ-NW-3	43
			HZ-NE-3	45
Average Brookville-Mercer		68		56
Average all stratigraphic groups		67		47

of radioactive minerals on structural highs or (2) a relative reduction in radioactive materials by ground water migrating along the structurally lowest portion of the impervious clay zone.

SUMMARY

Of the 56 localities studied in Beaver, Jefferson, and Clearfield counties, six have rocks with relatively high radioactivity. Localities with greatest radioactivity are located in Beaver County where the basal six inches of the Lower Freeport coal and the upper foot of the underlying clay contain as much as 0.014 percent equivalent uranium. In Jefferson County, samples of a thin "rider" coal 20 to 30 feet above the Lower Freeport coal contain 0.003 to 0.004 percent equivalent uranium. Plastic and semi-flint clays associated with the Mercer coals of Clearfield County contain 0.003 to 0.004 percent equivalent uranium.

As a rock group, the underclays show the greatest radioactivity; usually the uppermost part of each underclay has the greatest radioactivity. Coal beds as a rule exhibit the least radioactivity, although some exceptions are found where the underlying clay is radioactive.

On the basis of results of the present study, structural attitude, excepting some small scale flexures, apparently has little effect on the occurrence of radioactivity. In one local area the amount of radioactivity from samples of an up-dip site is significantly greater than from that in a down-dip position. On a regional scale, average radioactivity of coal beds on or near the crest of major anticlines is slightly greater than those in the synclines, but the difference is probably not significant.

Weathering appears to have little effect on the occurrence of radioactivity in the exposures examined. Of all sites where samples were collected, the number of old highway, railroad, and strip mine cuts with

beds having more than 0.002 percent equivalent uranium does not differ significantly from the number of less weathered exposures with beds of similar equivalent uranium content. Similar results were obtained from samples collected in weathered and unweathered portions of a strip mine.

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APPENDIX

Statistical analyses

Table 9.—Calculation of Chi Square; test of independence of weathering and radioactivity.

	>0.001 equivalent uranium		0.001 or < 0.001 equivalent uranium		Observed totals
	Observed	Expected	Observed	Expected	
Weathered	13	15	23	21	36
Unweathered	12	10	12	14	24
Observed totals	25		35		60

	>0.002 equivalent uranium		0.002 or < 0.002 equivalent uranium		Observed totals
	Observed	Expected	Observed	Expected	
Weathered	7	9.6	29	26.4	36
Unweathered	9	6.4	15	17.6	24
Observed totals	16		44		60

At a level of 0.001 equivalent uranium

$$\chi^2 = \frac{[(O-E) - .5^*]^2}{E} = .15 + .11 + .23 + .16 = .65$$

$$DF = 1 : P = .50, \chi^2 = .455^{**} : P = .30, \chi^2 = 1.074^{**}$$

At a level of 0.002 equivalent uranium

$$\chi^2 = \frac{[(O-E) - .5^*]^2}{E} = .46 + .17 + .69 + .25 = 1.57$$

$$DF = 1 : P = .30, \chi^2 = 1.074^{**} : P = .20, \chi^2 = 1.642^{**}$$

* Yates' correction applied by subtracting 0.5 regardless of sign of (O-E).

** Snedecor, G. W., Statistical methods, 1950, table 9.2.

Table 10.—Analysis of variance of radioactivity at Beaver County locality NC-SW-3, a strip mine near Darlington. (Figs. 3 and 5.)

	Down-dip		Up-dip		Row totals
High cover (relatively un-weathered)	Sample 64	12*	Sample 61	70*	
		14		67	
		22		69	
		10		66	$\Sigma X_{r1} = 330$
	$\Sigma X_{64} = 58$		$\Sigma X_{61} = 272$		$\Sigma X^2_{r1} = 19{,}430$
Low cover (relatively weathered)	Sample 66	18*	Sample 65	71*	
		15		48	
		18		65	$\Sigma X_{r2} = 323$
		25		63	$\Sigma X^2_{r2} = 17{,}037$
	$\Sigma X_{66} = 76$		$\Sigma X_{65} = 247$		
Column totals	$\Sigma X_{c1} = 134$		$\Sigma X_{c2} = 519$		$\Sigma X_t = 653$
	$\Sigma X^2_{c1} = 2{,}422$		$\Sigma X^2_{c2} = 34{,}045$		$\Sigma X^2_t = 36{,}467$

1. $C.T. = \frac{(\Sigma X_t)^2}{N} = \frac{426{,}409}{16} = 26{,}651$

2. Total S.S. $= \Sigma X^2 - C.T. = 36{,}467 - 26{,}650 = 9{,}816$

3. Rows S.S. $= \frac{(\Sigma X_{r1})^2 + (\Sigma X_{r2})^2}{8} - C.T. = \frac{213{,}229}{8} - 26{,}650 = 3$

4. Columns S.S. $= \frac{(\Sigma X_{c1})^2 \quad (\Sigma X_{c2})^2}{8} - C.T. = \frac{287{,}317}{8} - 26{,}650 = 9{,}262$

5. Sample S.S. $= \frac{(\Sigma X_{64})^2 + (\Sigma X_{61})^2 + (\Sigma X_{66})^2 + (\Sigma X_{65})^2}{4} - C.T. =$

$\frac{144{,}133}{4} - 26{,}650 = 9{,}382$

6. Interaction S.S. = S.S. samples − (SS rows + SS columns) = 117

7. Error S.S. = S.S. total − S.S. samples = 434

*Assay cup values coded by subtracting 160

Table 10.— Analysis of variance of radioactivity at Beaver County locality NC-SW-3, a strip mine near Darlington- Continued.

Analysis of variance table

Source of variation	D. F.	S. S.	Mean square
Rows (High & low cover)	1	3	3
Columns (up & down dip)	1	9,262	9,262
Interaction	1	117	117
Experimental error	12	434	36
Total	15	9,816	
Pooled interaction & error	13	551	42

F test for significance of interaction:

$F = \frac{117}{36} = 3.25$ $\quad$ $^{**}F_{.95}(1,12) = 4.75$

F test for significance of rows using pooled experimental error:

$F = \frac{3}{42} = .071$ $\quad$ $^{**}F_{.95}(1,13) = 4.67$

F test for significance of columns using pooled experimental error:

$F = \frac{9,262}{42} = 220.52$ $\quad$ $^{**}F_{.95}(1,13) = 4.67$

** Dixon, W. J., and Massey, F. J., Jr., 1951, table 7a.
F ratios from table 7a which are larger than calculated F ratios indicate that calculated F is not significant at level of .95. Where calculated F is larger than F in table 7a the reverse is true.

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