[redacted]

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

EASTERN BLACK SHALE RECONNAISSANCE

PRELIMINARY REPORT

By

A. L. Slaughter
S. E. Clabaugh

August 1944

Trace Elements Investigations Report 1

[redacted]

[redacted]

USGS — TEI-1

Distribution (Series B)	No. of Copies
N. M. Denson (Fuels), Denver	1
Jane Titcomb (GSP), Washington	1
S. C. Creasey (MD), Washington	1
H. A. Tourtelot (Fuels), Washington	1
R. P. Fischer (MD), Grand Junction	1
R. W. Swanson (MD), Spokane	1
C. E. Dutton (MD), Madison	1
R. A. Laurence (MD), Knoxville	1
A. H. Koschmann (MD), Denver	1
Frank Stead (Geophysics), Washington	1
	10

[redacted]

Trace Elements Program

Eastern Black Shale Reconnaissance

Preliminary Report

U. S. Geological Survey

A. L. Slaughter
S. E. Clabaugh

August 25, 1944

A reconnaissance of the black shales of the Eastern United States for the purpose of determining their radioactivity was undertaken during the summer of 1944. The work was a part of the "Trace Elements" program which is under the direction of W. W. Rubey. The principal interest is in uranium and to a lesser extent in thorium. It is hoped that an area might be found where the shale can be exploited for these elements.

The party consisted of A. L. Slaughter, S. E. Clabaugh, and W. H. Hass. Mr. Hass began the work in Washington, D. C., by assembling literature and maps which were used as a guide during the reconnaissance. The work was greatly facilitated by his familiarity with a number of the black shale sections visited. In the course of the field work he made extensive collections of conodont fauna which will be used in age and correlation studies of the shales.

The party gathered in Centerville, Tenn., and began the trip on June 17. The last sections visited were in West Virginia and the party arrived in

Washington on August 21. Slaughter and Clabaugh spent July 2-11 on side trip to the North Carolina pegmatite areas while Hass returned to Washington for other work. Results of the brief investigation of radioactive elements in several North Carolina pegmatites are presented in a separate report now in preparation.

Field Methods

A Geiger-Muller counter, which measures gamma ray emission of radioactive substances, was used in the field for testing the radioactivity of the shales. The measurement of radioactivity is made by listening to "clicks" in headphones when the counter tube is placed on the rock to be tested or is surrounded by the crushed sample. The frequency of the clicks is a measure of the radioactivity. However, some of the clicks are attributable to a so-called "background" of cosmic ray effects and this background must be determined with the counter tube removed from the influence of the material being tested.

The counter was used in two ways. After the outcrop was marked out for sampling, usually in intervals of five feet or less, a reading was taken at the center of each interval over a five minute period. Samples from intervals which gave higher counts were selected for further testing and, if the outcrop count seemed to justify it, the interval was split into smaller units for sampling. These selected samples were ground to about four-mesh in an iron mortar. Counts were then made on about 500 grams of the crushed sample. The time spent in counting a crushed sample was usually 25 minutes, consisting of three five-minute background counts and two five-minute sample counts taken alternately. On each consecutively tested sample after the first, a saving of five minutes background counting is effected. The instrument is calibrated by making a number of counts on a carnotite-bearing sand of known

uranium content. The true count (difference between average sample count and average background count) can then be expressed as equivalent uranium (the amount of uranium in equilibrium with its disintegration products that would yield the same gamma ray activity). Actually, a portion of the activity of some of the samples is probably attributable to thorium and its disintegration products and to radioactive potassium, with the result that the amount of uranium in a sample may be considerably less than is indicated by the "equivalent uranium". On the other hand, the assumption of radioactive equilibrium probably tends to underestimate the amount of uranium in some of the samples, because more soluble radioactive products may have been removed from the rocks by circulating ground waters and because some radon gas may escape from the samples when they are crushed for testing.

The following are given as examples of field determinations:

Sample No.	Bg. count	Samp. count	Bg. count	Samp. count	Bg. count	Avg. Bg.	Avg. Samp.	True count	Equivalent uranium(%)
S101-24	10	18	4	12	5	6.3	15.0	8.7	.0087
S101-25	10	20	6	20	8	8.0	20.0	12.0	.012
S112-213a	7	13	12	18	11	10.0	15.5	5.5	.0055

Counting interval is five minutes.
The factor for converting true five-minute count to percent equivalent uranium was found to be approximately .001.

Several counts of the background and the sample are required in order to reduce the effect of the purely accidental variation in activity of the cosmic rays and of the gamma rays from radioactive materials. The true counts, or the differences between the background counts and the sample counts, vary according to statistical laws, and the reliability of the average difference between these counts can thus be stated in terms of the probable error.

$$\text{Probable error} = 0.6745 \sqrt{\frac{X_1^2 + X_2^2 + \ldots\ldots X_n^2}{n(n-1)}}$$

where X_1, X_2, and X_n are the differences between individual determinations and the average of a group of n determinations. For the three samples given on the preceding page, the probable errors are as follows:

Sample No.	True count	Probable error	Percentage probable error
S101-24	8.7	±1.2	14
S101-25	12.0	±0.5	4
S112-213a	5.5	±1.0	18

Note that the proportionate error or percentage probable error is considerably greater for the least radioactive sample than it is for the most radioactive one. The probable error in the true count of any sample could be decreased by increasing the total time of counting. However, the procedure adopted for the present field work is considered to be sufficiently accurate for the purpose of preliminary reconnaissance and selection of the more promising localities.

Geiger counts at outcrops gave only relative values for radioactivity of the shales, but the ratio of the outcrop count to the true count was usually found to be about 10 to 1. Results obtained by various methods are shown graphically on the columnar sections (see for example, S101, S102, S112). Comparison of results shows that outcrop counting serves as a rapid method of selecting the better parts of the shales and eliminates much that is of no further interest from the standpoint of radioactivity. In some places the shales were tested only by making outcrop counts and were not sampled. A list of formations thus tested is given at the end of Appendix II.

All samples were sent to Washington where those selected by field counts are now being analyzed for uranium and thorium. Uranium analyses have been completed on some samples and are incorporated in this report. Methods and accuracy of the uranium determinations are discussed in a report now being prepared in the Section of Chemistry and Physics of the Geological Survey.

Samples will later be analyzed spectrographically for other minor constituents.

Chemical analyses of 35 black shale samples show that they contain on the average slightly less uranium than was indicated by field counts (see appendix I). Half of the analyzed samples contain between 67 and 115 percent of the field estimate, and a few analyses show uranium content greatly different from that indicated by field counts. These discrepancies may be due largely to the presence of other radioactive elements in the samples, but they are probably to be accounted for in part by inaccuracies in field counts and by possible departures from radioactive equilibrium.

The sampling was done by chipping small channels across the shale. Samples cut across a five foot thickness of shale had an average weight of about four pounds.

Areas covered

Sample localities are shown on the index map (fig. 1). Detailed descriptions of these localities are given in Appendix II.

Stratigraphy of the black shales

The stratigraphy of the black shales is shown on the columnar sections and some details are given in Appendix II. The formations sampled and the states in which they were sampled are listed below.

Chattanooga shale, central and north-central Tennessee and southern Kentucky.

Chattanooga shale of Swarts, 1/ 1927 (Big stone Gap shale of Stose 2/, 1923), southwestern Virginia.

Genesee shale, southwestern Virginia.

Portage shale, southwestern Virginia.

Ohio shale, central and southern Ohio.

Sunbury shale, central Ohio.

New Albany shale, southeastern Indiana.

Antrim shale, northern Michigan.

Huron shale, northern Ohio.

Cleveland shale, northern Ohio.

West River shale, western New York.

Middlesex shale, western New York.

Rhinestreet shale, western New York.

Dunkirk shale, western New York.

Genesee shale, western New York.

Harrell black shale of Woodward3/, 1943 (part of Jennings formation of Darton 4/, 1893), eastern West Virginia.

Marcellus black shale of Woodward3/, 1943 (part of Romney shale of Darton4/, 1892) eastern West Virginia.

1/ Swartz, J. H., The Chattanoogan age of the Big Stone Gap shale: Am. Jour. Sci., 5th ser., vol. 14, pp. 485-499, 1927.

2/ Stose, G. W., Geology of pre-Pennsylvanian rocks, in Eby, J. B., The geology and mineral resources of Wise County and the coal-bearing portion of Scott County, Virginia. Virginia Geol. Survey Bull., no. 24, 1923.

3/ Woodward, H. P., Devonian system of West Virginia: West Virginia Geol. Survey Bull., vol. 15, 1943.

4/ Darton, N. H., Notes on the stratigraphy of a portion of central Appalachian Virginia: Am. Geologist, vol. 10, pp. 13-18, 1892.

Results and conclusions

Results of field tests are shown on the columnar sections (see, for example, S102). The outcrop counts are expressed in counts per minute. Geiger count determinations on crushed samples are expressed as 10^{-5} grams of equivalent uranium per gram (1×10^{-5} grams per gram is equal to .001 percent). Results of chemical analyses for uranium are also shown on the columnar sections, expressed as 10^{-5} grams of uranium (not equivalent uranium) per gram so as to be directly comparable with results by the other methods. Samples which have been analyzed chemically or checked by laboratory Geiger counts are listed in Appendix I. Not until chemical analyses for thorium

are completed will it be possible to test the assumption of radioactive equilibrium on which is based the estimation of equivalent uranium from Geiger counts.

The most highly radioactive shales were found at the localities listed below (see index map, fig. 1. and columnar sections):

Sample	Formation	Location	Thickness and uranium content by chemical analyses of best part of section	
			Thickness in feet	Percent
S100	Chattanooga shale	North-central Tenn.	7.5	.008
S101	Chattanooga shale	Central Tenn.	13.5	.008
S102	Chattanooga shale	North-central Tenn.	11.0	.007
S111	Albany shale	Southeastern Ind.	15.0	.005
S112	Chattanooga shale	Southern Ky.	10.0	.006

At locality S101 a thickness of 5 feet of shale and at locality S100, 30 miles to the north, a thickness of 2½ feet contains 0.01 percent uranium. The present investigation seems to have demonstrated lateral continuity of such amounts of uranium in the black shales, and if Sections S100 and S101 are representative, the area between and adjacent to them contains not less than several hundred million tons of shale with the same uranium content. Data given in the table above indicate that billions of tons of black shale in the Tennessee-Kentucky area contain more than .007 percent uranium. Whether or not the region containing these sample localities warrants further investigation depends upon results of continuing investigations in other parts of the country.

An important result of the work is the elimination of large areas of black shales from possible further consideration.

The highest values for radioactivity have been obtained where the black shale formations are relatively thin, as in the Chattanooga shale in central and north-central Tennessee and southern Kentucky where the thickness ranges from 25 to 46 feet. In southwestern Virginia it is nearly 200 feet thick, contains abundant fine clastics, and is less radioactive. It appears that the radioactive material is somewhat more concentrated where the formation is thin or where the same time interval is represented by less deposited material than elsewhere.

Of the formations tested, those containing the more highly radioactive shales are at or near the Devonian-Mississippian boundary. This suggests that the black shales deposited at that time afforded for some unknown reason a particularly favorable environment for the concentration of radioactive material. Shales from lower in the Devonian (Hamilton, Genesee, and Portage) in New York and West Virginia which closely resemble those near the Devonian-Mississippian contact are nevertheless the lowest in radioactivity of any of the shales tested.

Additional chemical determinations and gamma ray counts will be made in the Washington laboratories, but it seems unlikely that they will alter the present conclusions.

Appendix I

List of samples analyzed for uranium

Sample No.	Percent uranium determined by chemical analysis	Equivalent uranium (in percent) determined by gamma ray counts of crushed sample	
		Laboratory counts	Field counts
S100 - 9	.006	.010	———
-10	.010	.012	.018
-11	.008	.012	.003
S101 -24	.007	.009	.009
-25	.010	.010	.012
-26	.010	.010	.008
-27	.007	.011	.009
-28	.008	.009	.010
-29	.008	.013	.006
S102 -31	.004	.008	.009
-32	.008	.009	.006
-33	.008	.007	.009
-34	.008	.009	.013
-35	.005	.013	.006
-36	.006	.011	.009
-37	.007	.017	.009
-38	.008	.022	.008
-39	.002	.007	.002
-40	.004	.010	.004
S103 -45	.002	.006	.004
-49	.002	.007	.005
S109 -157a	.003	.006	.004
-162	.004	.005	.004
-168	.004	.007	.005
S110 -189	.004	.004	———
S111 -195	.007	.010	.004
-196	.007	.010	.004
-197	.007	.010	.006
-201	.008	.011	.012
-210	.008	.010	.006
-211	.008	.011	.006
S112 -214a	.006	.010	.011
-214b	.005	.011	.009
-215a	.006	.013	.011
-215b	.006	.008	.008

Appendix II

Details of Sample Locations

S100------ Chattanooga shale, 30.8 feet sampled, which is total thickness. Go west from Cookeville, Tenn. on highway 70N, 5.6 miles to highway 56, north on 56 about one mile to dirt road marked to Flynn's Lick, one mile along this road to outcrop in road bank; near Jackson County line. in Jackson County.

S101------ Chattanooga shale, 31 feet sampled, which is total thickness; White County, Tenn., along bank of Caney Fork about 4.5 miles below Great Falls Dam. Go 0.1 mile past Walling railway station, turn left on Webb Camp road, then 6 miles to river.

S102------ Chattanooga shale, 16.7 feet sampled, 25 feet tested, which is total thickness, Jackson County, Tenn.; road cut on Flynn's Lick road. Go 12.1 miles from highway 70N on highway 56, follow Flynn's Lick road for 3.8 miles.

S103------ Chattanooga shale of Swartz[5], 1927, 189.5 feet sampled, which is total thickness; in Va. on U. S. highway 25E between Middlesboro, Ky. and Cumberland Gap, Tenn. at junction with U. S. highway 58.

S104------ Chattanooga shale of Swartz[6], 1937, total thickness of 204 feet sampled, also Portage shale, 62 feet sampled from total thickness estimated to be 400 feet by Stose[2], in bank of Powell River at edge of town of Big Stone Gap, Va.

S105------ Basal portion of Genesee shale in contact with the Helderberg limestone, 18.7 feet sampled, thickness near Big Stone Gap reported as 200 feet by Stose[7]; road bank 3.2 miles south of the Big Stone Gap P. O. on highway 23.

S108------ Sunbury shale, 13.1 feet sampled, thickness reported to be 30 feet, exposed in bank of Duncan Run, 2½ miles from Walnut Creek, Delware County. Ohio, Westerville quadrangle.

S109------ Lower part of Ohio shale, 108 feet sampled; exposed in the narrows at northeastern edge of the town of Worthington, Ohio; Dublin quadrangle.

S110------ Upper part of Ohio shale, 83 feet sampled, Ohio shale reported to be about 400 feet thick near Chillicothe[8] ; in gully tributary to Paint Creek, 4½ miles from Chillicothe, Ohio; Rozabel quadrangle.

S111------ New Albany shale, 5.7 feet of basal portion sampled in bank between highway 31 and railroad, 1½ miles north of Speed, Ind.; 38 feet sampled (top exposed) 3 miles east of Henryville, Ind. on highway 39; 49 feet of the central portion sampled in bank of Silver Creek about two miles from the Ohio River at New Albany, Ind. The New Albany is about 100 thick in this area [9].

S112------ Chattanooga shale, 46.1 feet sampled, which is full thickness; Pulaski County, Ky.; where the Liberty road crosses Big Clifty Creek about 5½ miles from Somerset, Ky.

S113------ Antrim shale, 29.3 feet sampled at the quarry of the Huron Portland Cement Co., 9 miles west of Alpena, Mich., on state highway 32; 3.2 feet sampled near base along highway 23, 5 miles south of Alpena.

S114------ Antrim shale, 5.5 feet sampled at north shore of Lake Charlevoix, 9½ miles from Boyne City, Mich.; 34 feet sampled on north side of Lake Charlevoix, in gully 10 miles from Boyne City.

S115------ Antrim shale, 22.6 feet sampled at shore of Lake Michigan, ½ mile south of Norwood, Mich. The Antrim is probably between 100 and 150 feet thick.

S116------ Huron shale, 8.2 feet sampled at edge of Huron River one mile above Milan, Ohio; 15 feet sampled and an additional 25 feet tested with the counter in road bank in Huron County, 3/4 mile south of county line at Seymour Creek; 9.3 feet sampled in bank of the West Branch of Huron River eight miles south of Monroeville, Ohio.

S117------ Cleveland shale, 87 feet sampled, total thickness unknown at this point but the formation thins to 50 feet and less east of Cleveland; at junction of East Branch and West Branch of Rocky River near Olmstead, Ohio.

S118------ West River shale, full thickness of 8.7 feet sampled, Middlesex shale, full thickness of 6.2 feet sampled, Rhinestreet shale, full thickness of 173.2 feet sampled, all in bank of Eighteen Mile Creek from just below railroad bridges near Lake Erie to Hamburg, New York.---Dunkirk shale, 37.9 feet sampled; reported to be 55 feet thick, South Branch of Eighteen Mile Creek at Clarksburg, New York.

S119------ Genesee shale, 45 feet sampled which is full thickness; in steep gully on east shore of Lake Canandaigua, 9 miles south of Canandaigua, New York/

S120------ Marrell shale of Woodward[10], 1943, 95 feet sampled; reported to be 300 feet thick; exposed in road bank on highway 50, 0.3 mile west of Burlington, West Va. Marcellus shale of Woodward[11], 1943, 14 feet sampled in road cut on W. Va. Highway 98 about 3 miles from Romney, W. Va.; 65 feet sampled along old side road at highway 50 at Mineral-Hampshire County line. Total thickness of Marcellus may reach 500 feet in Hampshire County.

Formations tested with the Geiger counter but not sampled

Price and Macrady formations----about 250 feet thick, all tested, at upper end of section S103 near Cumberland Gap, Tenn., activity low, average 4.1 counts per minute; also at upper end of section S104, Big Stone Gap, Va.,60 feet tested average activity 5.4 counts per minute.

Portage formation----upper 50 feet tested, total thickness about 250 feet, not well exposed; at lower end of section S103, Cumberland Gap, Tenn.; activity low, average 5.9 counts per minute.

Antrim shale----6 feet exposed in road cut south side of Lake Charlevoix Mich. across lake from section S114; activity 8 counts per minute.

Cleveland shale----city park at Euclid, Ohio, full thickness of 57 feet tested; activity low, average 5 counts per minute.

Rhinestreet shale----30 feet tested, exposed on west side of Conesus Lake near south end, just above lake road to Geneseo, New York; activity low, average 5 counts per minute.

West River shale----14 feet, at upper end of section S119, Canandaigua, New York; activity 5.3 counts per minute.

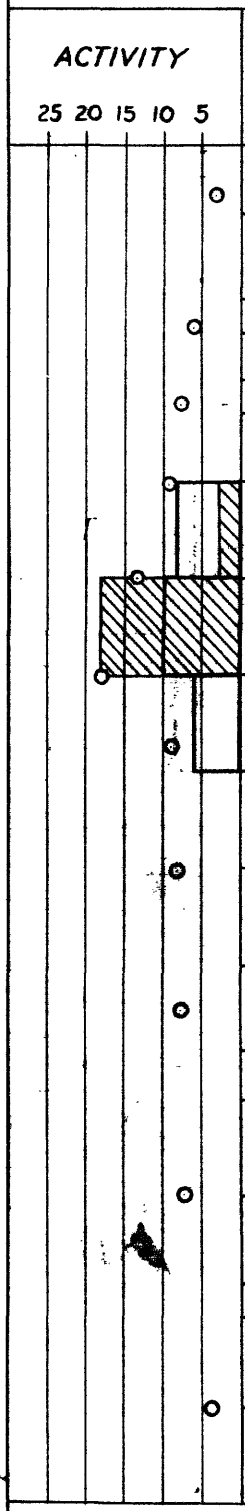
Middlesex shale and probably part of Cashaqua shale----31 feet tested, upper part of section S119, Canandaigua, New York; activity 5 counts per minute.

Dunkirk shale----56 feet tested in road bank 1½ miles north of Garwoods, New York; activity 5 counts per minute.

5/ Swartz, J. H., op. cit.
6/ Idem.
7/ Stose, G. W., op. cit.
8/ Hyde, J. E., Geology of Camp Sherman Quadrangle: Ohio Geol. Survey 4th ser., Bull., no. 23, p. 147, 1921.
9/ Savage, T. E., The Devonian rocks of Kentucky: Kentucky Geol. Survey ser. 6, vol. 33, p. 89, 1930
10/ Woodward, H. P., op. cit.
11/ Idem.

CONFIDENTIAL

Section S100, Jackson County, Tenn.



Thickness in feet	Columnar Section	Sample No.	DESCRIPTION	Formation
			Shale, blue-gray, calcareous	RIDGETOP
2.5		16	Shale, gray, soft, thin-bedded	
0.4		15	Clay, green, sandy, glauconitic; Maury member ?	
1.6		14	Shale, gray-brown, clayey, abundant brown nodules	CHATTANOOGA
0.4		13	Shale, black, clayey, nodules at top	
2.0		12	Shale, black, fissile, tough	
2.5		11		
2.5		10	Shale, black, hard, hackly, petroliferous odor	
2.5		9	Shale, black, tough, petroliferous odor, clay layers	
2.5		8		
2.5		7	Shale, black, fissile, tough, harder layer at base	
2.2		6	Shale, brown, with softer gray beds	
1.3		5	Shale, black, fissile, grayish-yellow stains	
2.5		4	Shale, black, fissile, in part tough, hackly	
2.5		3	Shale, black, fissile	
0.4		2	Sandstone, brown, lower part clayey; Hardin mbr ?	
2.5		1	Limestone, brown to gray, sandy	
			Limestone, blue-gray, sandy	

Scale
5 0 5 10 feet

ACTIVITY:
o Count per minute at outcrop

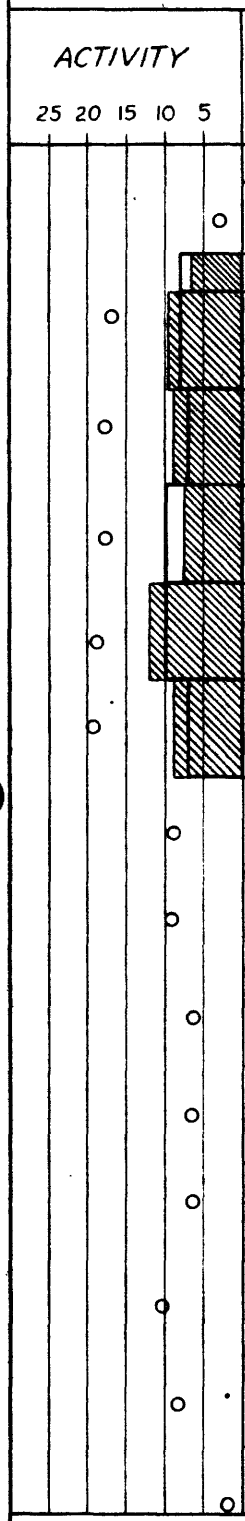
Field determination of activity expressed as equivalent 10^{-5} gm U/gm

Measured and sampled by A. L. Slaughter, W. H. Hass, and S. E. Clabaugh
June 18, 1944

Uranium content determined by chemical analysis, expressed in gm U/gm/10^{-5}

CONFIDENTIAL

Section S101, White County, Tenn.



Thickness in Feet	Sample No.	DESCRIPTION	Formation
		Limestone and chert	FT. PAYNE
1.8	30	Shale, gray-green, clayey, phosphate nodules and glauconite in basal 0.2 foot (Maury mbr.?)	RIDGE-TOP
1.0	29	Shale, black, fissile, petroliferous odor	CHATTANOOGA
2.5	28	Shale, black, fissile to massive, hard layers as much as 0.4 foot thick, thin seams of marcasite and scattered pyrite crystals, petroliferous odor, brown on weathered surfaces	
2.5	27		
2.5	26		
2.5	25		
2.5	24		
2.5	23	Shale, dark gray to black, fissile, lower part hard	
2.5	22	Shale, alternating gray and black layers	
2.5	21	Shale, alternating gray and black beds, soft, fissile	
2.5	20	Shale, black, fissile, few hard gray beds	
1.0	19	Shale, black, thin-bedded, upper part gray, blocky	
1.5		Covered	
2.5	18	Shale, black, fissile, tough, petroliferous odor, marcasite nodules 1 foot below top	
2.5	17	Shale, black, tough, petroliferous odor	
		Limestone, sandy, or calcareous sandstone, brown	

Scale
5 0 5 10 Feet

ACTIVITY:
o Count per minute at outcrop

Field determination of activity [illegible] equivalent to gm U/gm

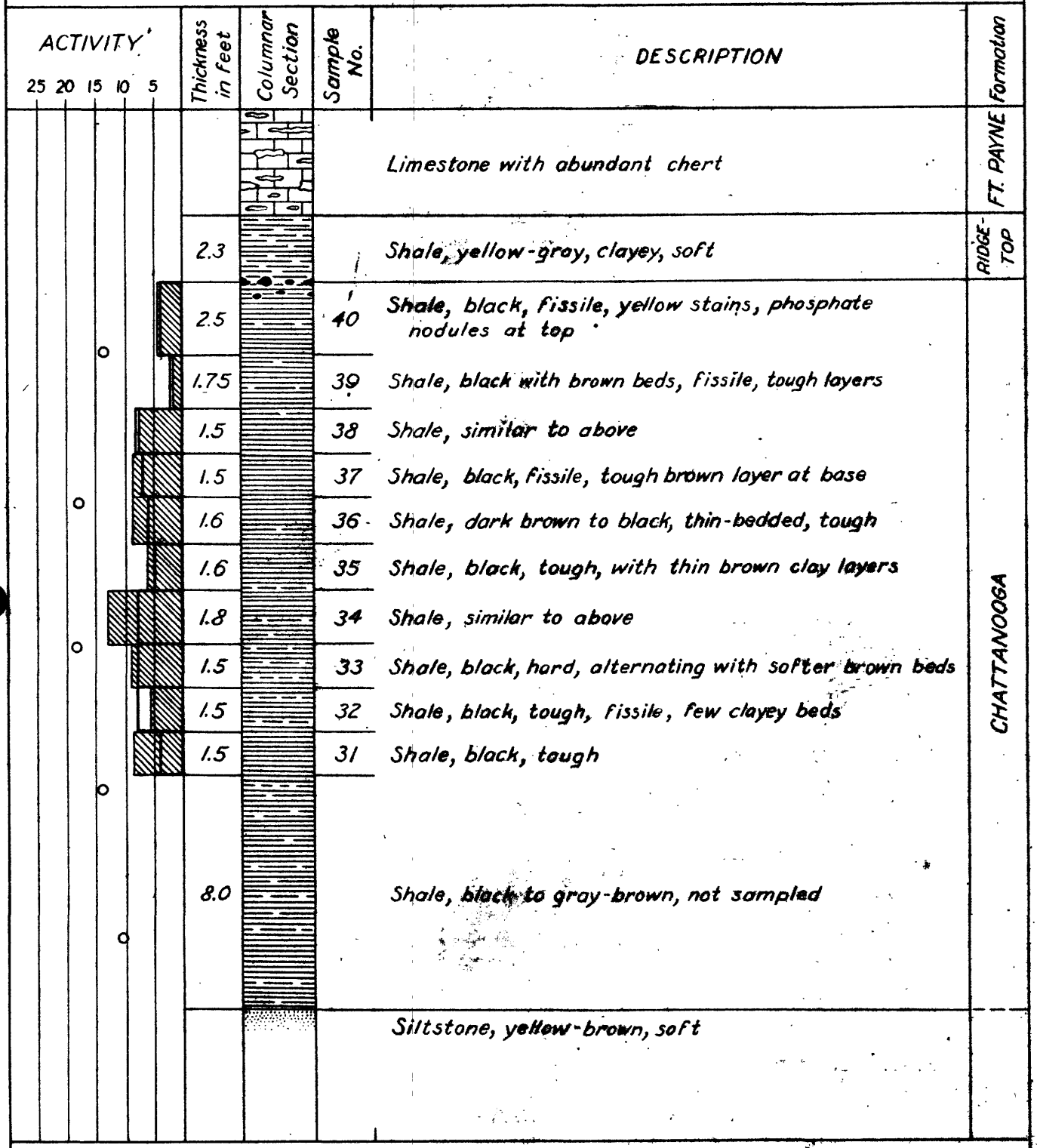
CONFIDENTIAL

Measured and sampled by A. L. Sloughter, W. H. Hass and S. E. Clabaugh June 19, 1944

Uranium content determined by chemical analysis, expressed in gm U/gm/10^{-5}

CONFIDENTIAL

Section S102, Jackson County, Tenn.



Scale

5 0 5 10 Feet

ACTIVITY:

○ Count per minute at outcrop

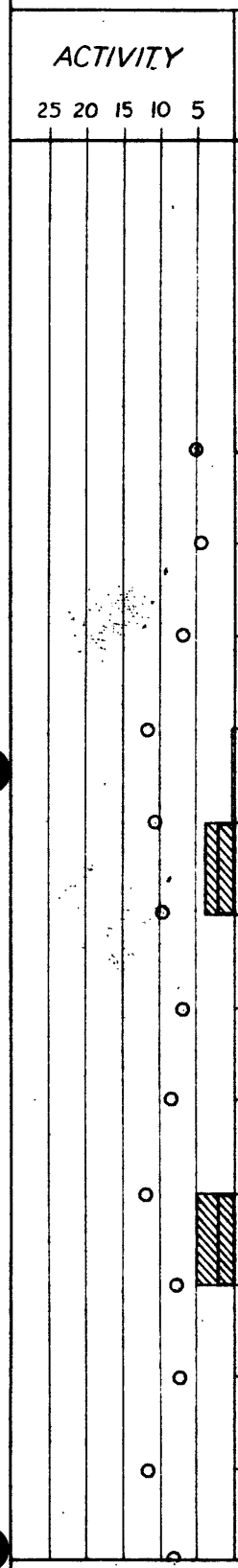
Field determination of activity expressed as

Measured and sampled by A. L. Slaughter, W. H. Hass, and S. E. Clabaugh June 20, 1944

CONFIDENTIAL

Uranium content determined by chemical analysis, expressed in gm U/gm/10^{-5}

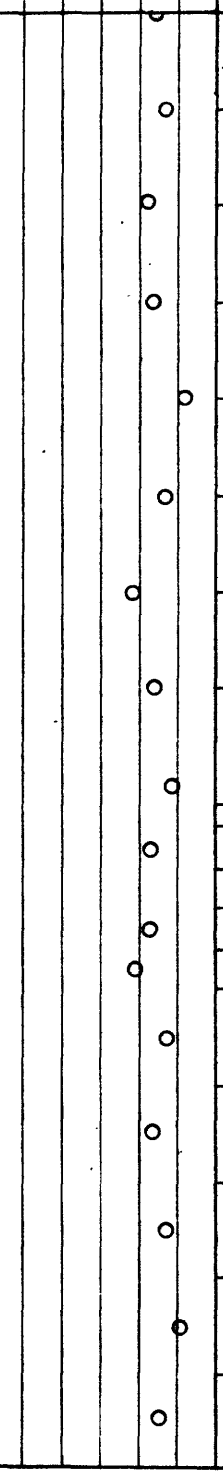
Section S103, Lee County, Va., page 1



Thickness in feet	Sample No.	DESCRIPTION	Member	Formation
		Shales, cherty shales, sandstones, and siltstones of the Price and Maccrady formations, about 290 feet thick. Activity low; average of 16 counts at outcrop, 4.1 per minute		PRICE SANDSTONE
5.0	41		Big Stone Gap member of Swartz, 1927	CHATTANOOGA SHALE of Swartz, 1927
5.0	42	Shale, black, fissile, brown stains on joints		
5.0	43			
5.0	44	Shale, black, fissile, dark clay in part		
5.0	45			
5.0	46	Shale, black, fissile, brown stains on joints		
5.0	47			
5.0	48	Shale, black, fissile, thin bed of siltstone with pyrite near base of sample		
5.0	49	Shale, black, fissile, hard and tough in part, pyrite-rimmed nodules near base.		
5.0	50	Shale, gray to black, fissile, pyrite-rimmed nodules near top, hard and massive shale in lower part		
5.0	51	Shale, upper part gray-black and fissile, lower part massive black shale		
5.0	52	Shale, black, massive, hard, bedding indistinct		

Section continued on page

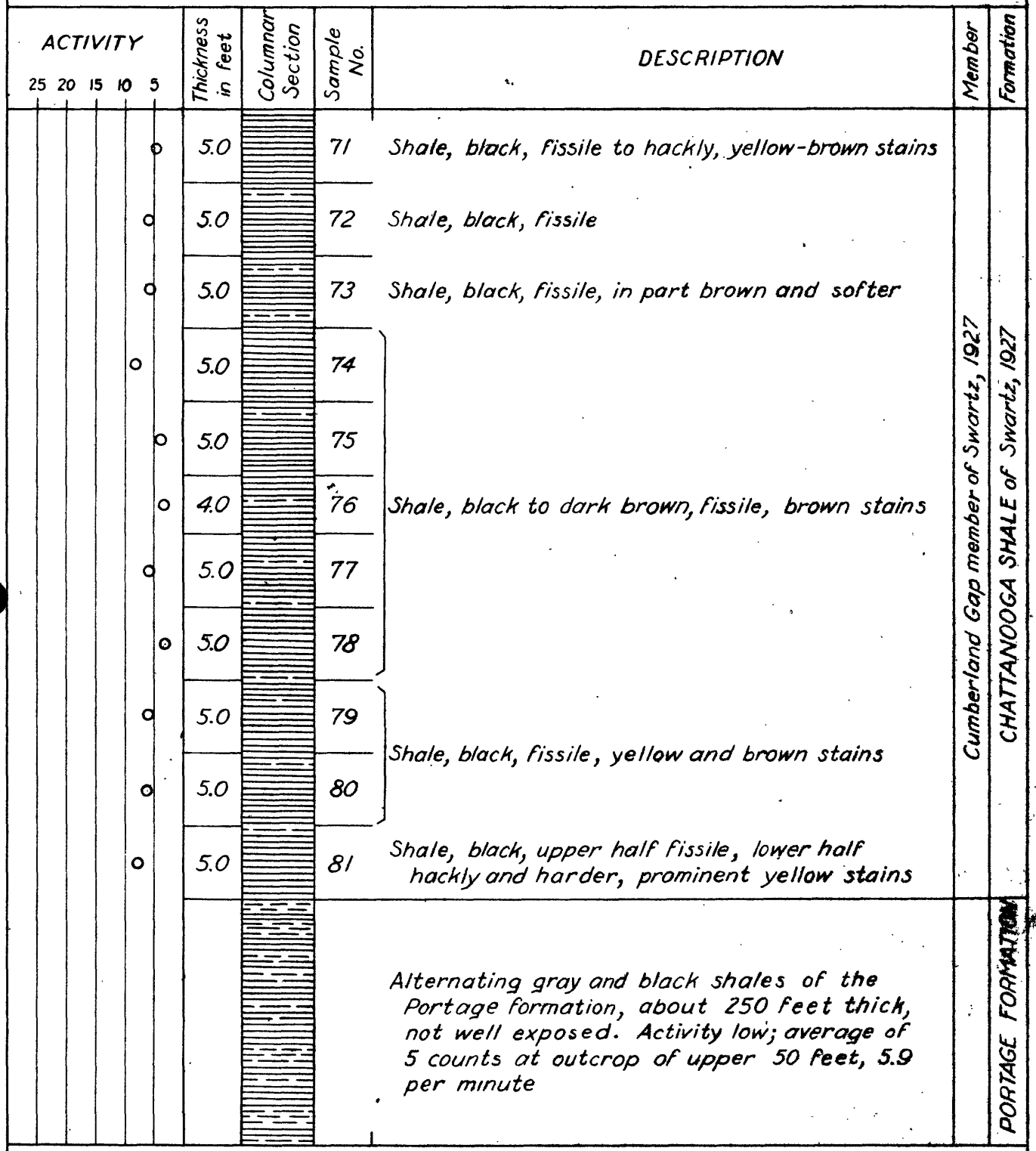
Section S103, Lee County, Va., page 2



Thickness in feet	Sample No.	DESCRIPTION	Member	Formation
5.0	53	Shale, black, fissile, middle part massive, hard	Big Stone Gap member of Swartz, 1927	CHATTANOOGA SHALE of Swartz, 1927
5.0	54	Shale, black, fissile, middle part harder, less thin-bedded; siltstone nodules in upper part		
5.0	55	Shale, black, fissile, brown and yellow stains		
5.0	56	Shale, black, fissile, some harder beds, soft siltstone nodules in lower part		
5.0	57	Shale, black, fissile to blocky, several thin layers of marcasite		
5.0	58	Shale, fissile to massive and hackly, hard massive layers have petroliferous odor and contain scattered crystals of pyrite or marcasite		
5.0	59			
6.0	60			
1.1	61	Shale, gray, soft, hackly	Olinger member of Swartz, 1927	
2.2	62	Shale, black, fissile, splintery		
2.0	63	Shale, gray, soft, hackly		
2.2	64	Shale, black, fissile to hackly		
2.0	65	Shale, gray, soft, hackly		
5.0	66	Shale, black, fissile, brown stains	Cumberland Gap mbr. of Swartz, '27	
5.0	67			
5.0	68			
5.0	69			
5.0	70			

Section continued on page 3

Section S103, Lee County, Va., page 3



Scale
10 5 0 10 20 feet

ACTIVITY:
o Count per minute at outcrop

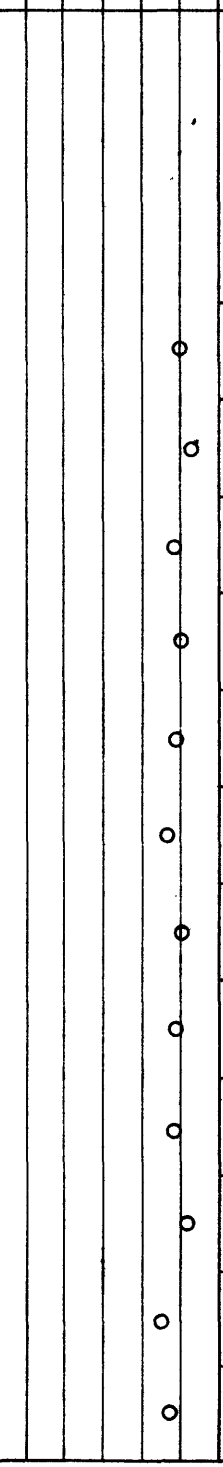
Field determination of activity expressed as counts per 10^{-5} gm U

Measured and sampled by A. L. Slaughter, W. H. Hass, and S. E. Clabaugh
June 23, 1944

Uranium content determined by chemical analysis, expressed in gm U/gm/10^{-5}

CONFIDENTIAL

Section S104, Wise County, Va., page 1

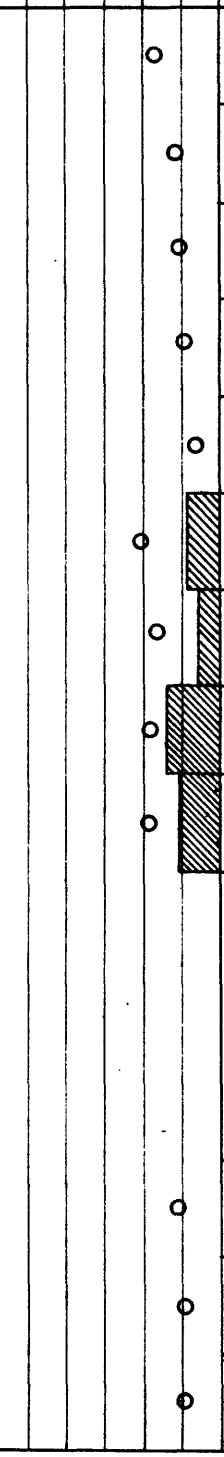


Thickness in feet	Sample No.	DESCRIPTION	Member	Formation
		Sandstone, massive, hard		PRICE SANDSTONE
		Shale, gray and brown to dark gray, sandy, numerous thin sandstone beds and lenticular layers of sandstone. Total thickness of sandy shale 62 feet. Activity low, average of 6 counts at outcrop, 5.7 per minute		
5.0	82	Shale, dark gray, fissile, sandy, several thin beds of sandstone	Big Stone Gap member of Swartz, 1927	CHATTANOOGA SHALE of Swartz, 1927
5.0	83			
5.0	84	Shale, dark gray to black, fissile, sandy, thin beds of sandstone, red-brown stains		
5.0	85			
5.0	86			
5.0	87			
5.0	88	Shale, dark gray to black, fissile		
5.0	89	Shale, dark gray to black, fissile, tough layers		
5.0	90			
5.0	91	Shale, dark gray to black, fissile, some clay beds		
5.0	92	Shale, gray to black, fissile, sandy bed near base		
5.0	93	Shale, dark gray-brown, upper part hard, not fissile		

Section continued on page 2

CONFIDENTIAL

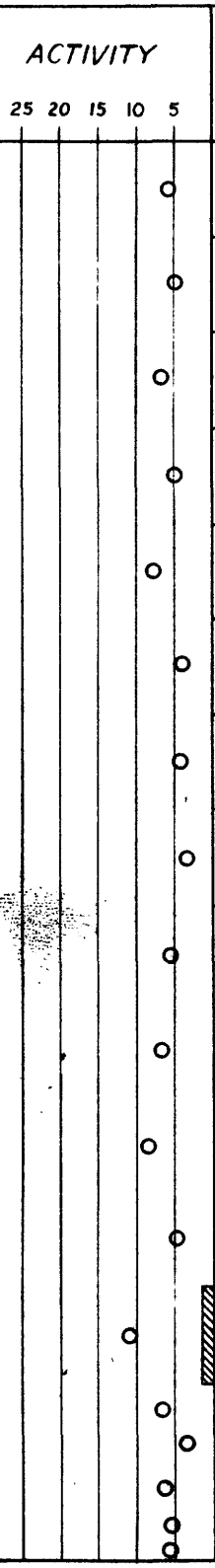
Section S104, Wise County, Va., page 2



Thickness in Feet	Sample No.	DESCRIPTION	Member	Formation
5.0	94	Shale, dark gray, upper part hard, tough; lower part softer, fissile	Big Stone Gap member of Swartz, 1927	CHATTANOOGA SHALE of Swartz, 1927
5.0	95			
5.0	96	Shale, brown to dark gray, fissile		
5.0	97			
5.0	98	Shale, brown to gray, fissile, softer, sandy		
5.0	99			
5.0	100	Shale, black, fissile to blocky and tough, hard nodules at base, brown and white stains on joints		
4.6	101			
5.0	102	Shale, gray, soft, thin beds of sandstone and black shale, some marcasite	Olinger mbr. of Swartz	
Approximately 15 ft.		Covered		
5.0	103	Shale, black, hard, petroliferous odor	Cumberland Gap mbr.	
5.0	104	Shale, black, hard, some marcasite in lower part		
5.0	105	Shale, black, fissile to massive and hard		

Section continued on page 3

Section S104, Wise County, Va., page 3



Thickness in feet	Sample No.	DESCRIPTION	Member	Formation
5.0	106	Shale, black, fissile, hard	Cumberland Gap member of Swartz, 1927	CHATTANOOGA SHALE of Swartz, 1927
5.0	107			
5.0	108	Shale, black, platy to massive and tough, petroliferous odor		
5.0	109			
5.0	110			
5.0	111			
5.0	112			
5.0	113	Shale, black, thin-bedded, fissile in part, brown stains		
5.0	114			
5.0	115			
5.0	116	Shale, black, fissile to platy and tough		
5.0	117			
5.0	118	Shale, black, platy, some sandy beds		
2.7	119	Shale, black, platy		
1.4	120	Shale, gray, tough and splintery		PORTAGE
2.9	121	Shale, black, upper part sandy, lower part fissile		
1.3		Shale, gray, not sampled		
1.1	122	Shale, black and gray, fissile, sandy		

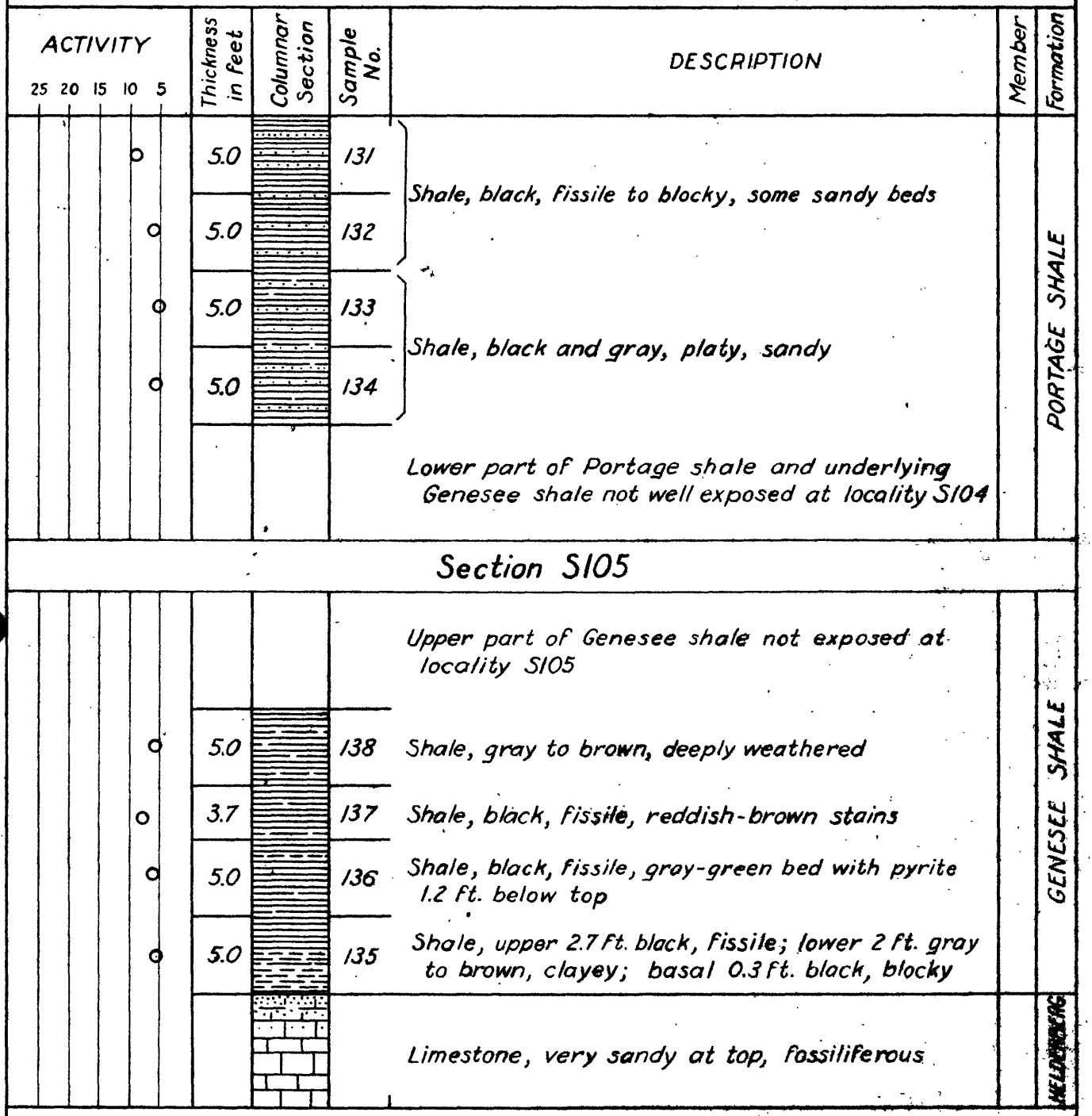
Section continued on page 4

Section S104, Wise County, Va., page 4

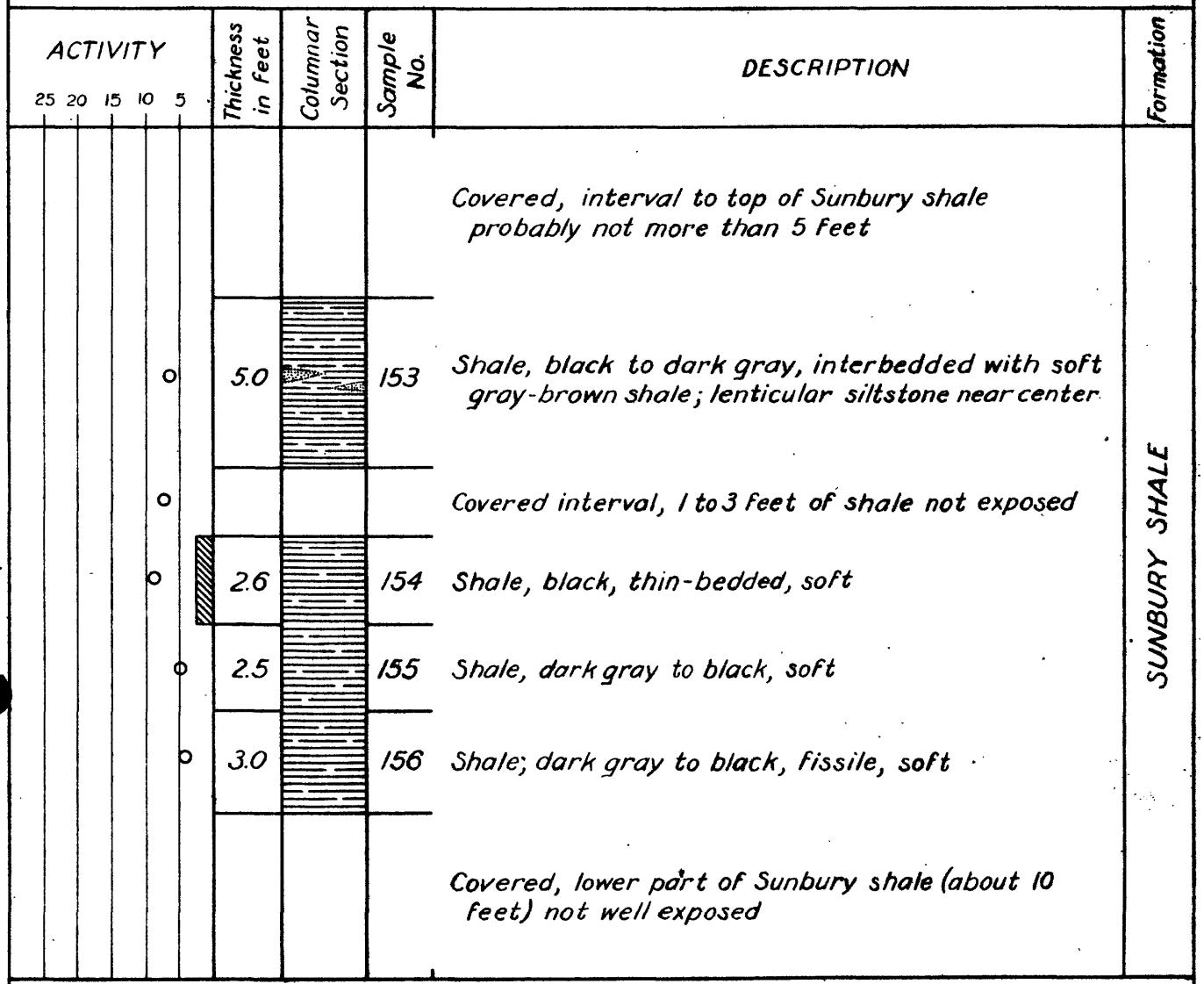
ACTIVITY 25 20 15 10 5	Thickness in feet	Columnar Section	Sample No.	DESCRIPTION	Member	Formation
	5.6			Shale, gray, with some sandstone; not sampled		PORTAGE SHALE
	2.0		123	Shale, dark gray to brown, very sandy		
	44			Shale and sandy shale, gray to dark gray, in part poorly exposed; not sampled		
	5.0		124	Shale, black and dark gray, interbedded		
	10			Shale, gray to black, sandy, softer, poorly exposed; not sampled		
	4.6		125	Shale, black, some beds of sandy gray shale		
	10			Shale, gray, softer, not well exposed, not sampled		
	5.0		126			
	5.0		127	Shale, black, fissile to platy, thin sandy beds		
	5.0		128			
	5.0		129	Shale, black, fissile to blocky and hard, some sandy beds		
	5.0		130			

Section continued on page 5

Section S104, page 5, and Section S105, Wise County, Va.



Section S108, Delaware County, Ohio



Scale

5 0 5 10 feet

ACTIVITY:

o Count per minute at outcrop

▨ Approximate activity of crushed rock expressed as equivalent 10^{-5} gm U/gm. Not determined for all samples

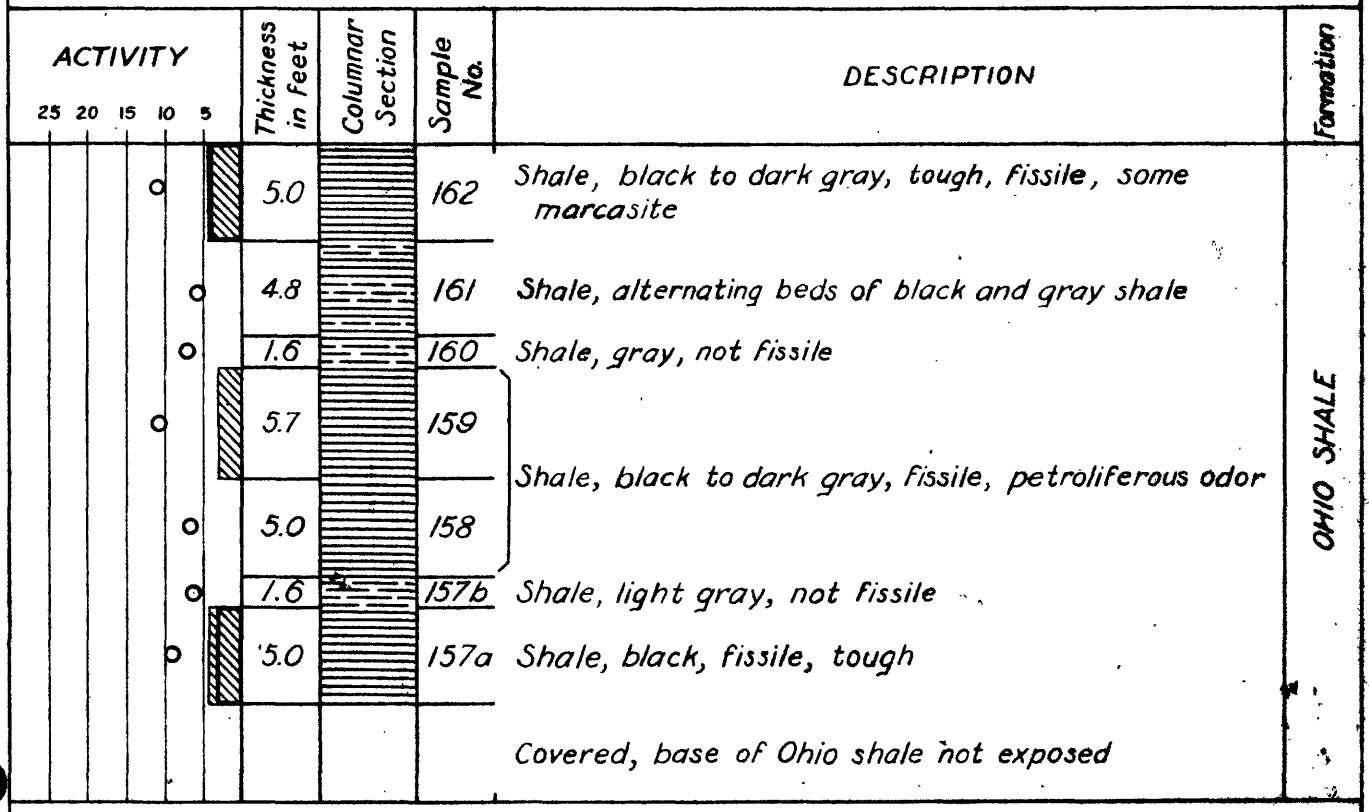
Measured and sampled by A. L. Slaughter, W. H. Hass, and S. E. Clabaugh; July 12, 1944

Section S109, Franklin County, Ohio, page 1

ACTIVITY (25 20 15 10 5)	Thickness in Feet	Columnar Section	Sample No.	DESCRIPTION	Formation
				Covered, upper part of Ohio shale not exposed at this locality. One sample (175) was chipped from large concretions which occur in most of the section below sample 167	OHIO SHALE
o	5.5		174	Shale, black, fissile, few thin gray shale beds	
o	5.0		173		
	19.7			Covered	
	6.3			Shale, gray, with two thin beds of black shale, not sampled	
o	2.5		172	Shale, fissile, alternating thin beds of gray and black shales	
o	3.0		171		
o	3.5		170	Shale, black, fissile	
o	4.0		169	Shale, black, massive to fissile (on weathered surfaces), petroliferous odor	
o	5.0		168	Shale, black, fissile	
o	5.0		167	Shale, black, fissile to massive, tough, petroliferous odor	
o	5.0		166		
o	5.0		165		
o	5.0		164		
o	5.0		163	Shale, black, fissile, thin gray shale beds near center and base	

Section continued on page 2

Section S109, Franklin County, Ohio, page 2.



Scale

10 5 0 10 20 feet

ACTIVITY:

o Count per minute at outcrop

Approximate activity of crushed rock expressed as equivalent 10^{-5} gm U/gm. Not determined for all samples

Uranium content determined by chemical analysis, expressed in gm U/gm/10^{-5}

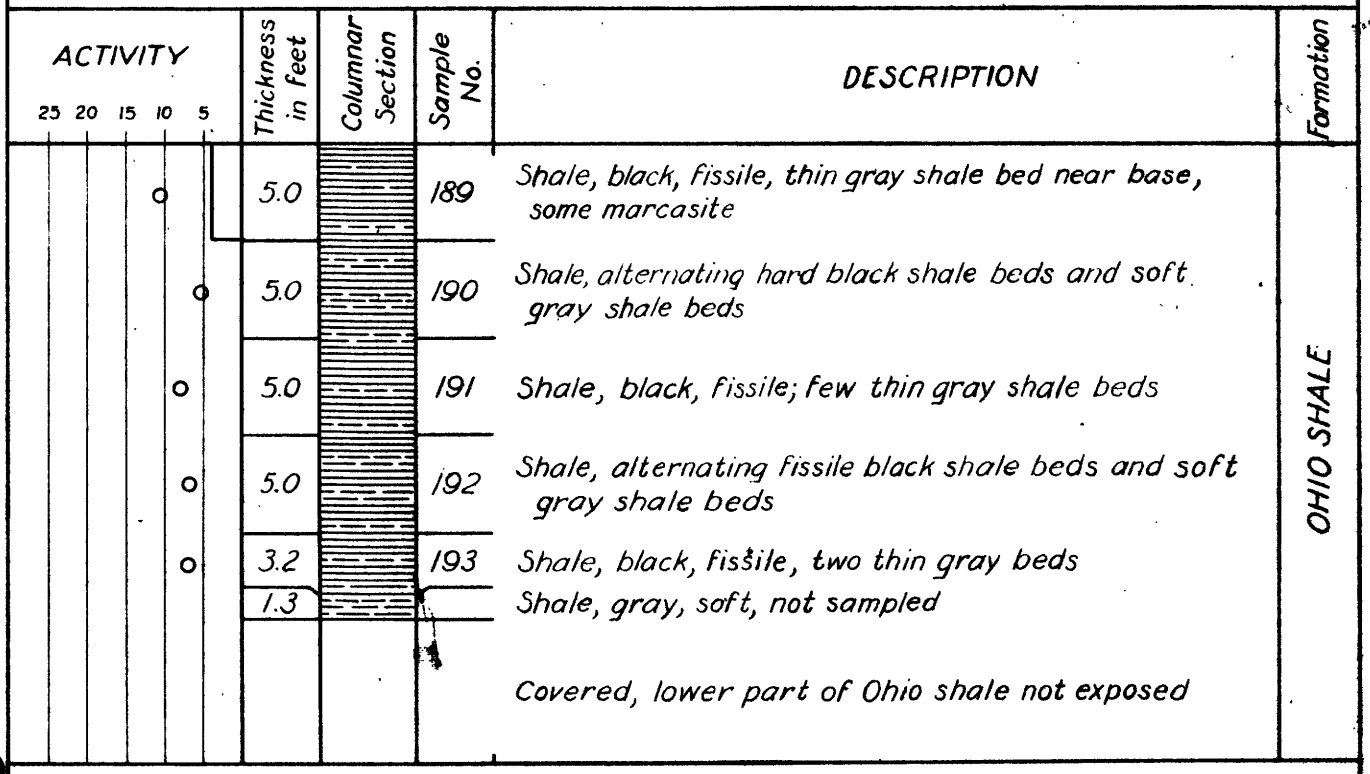
Measured and sampled by A.L. Slaughter, W.H. Hass, and S.E. Clabaugh; July 13, 1944

Section S110, Ross County, Ohio, page 1

ACTIVITY (25 20 15 10 5)	Thickness in Feet	Columnar Section	Sample No.	DESCRIPTION	Formation
				Shale, gray, not fissile, clayey, soft	BEDFORD SHALE
o	5.0		176	Shale, black, fissile to platy, tough	OHIO SHALE
o	5.0		177		
o	5.0		178		
o	5.0		179		
o	5.0		180	Shale, black, fissile, several thin zones of marcasite nodules	
o	5.0		181		
o	5.0		182		
o	5.0		183	Shale, black, fissile, calcareous layer with cone in cone structure 2 feet above base	
o	5.0		184	Shale, dark gray to black, fissile to massive and hard	
o	5.0		185	Shale, dark gray to black, fissile, zone of marcasite nodules 2 ft. above base	
o	5.0		186	Shale, black, fissile to blocky	
o	5.0		187	Shale, black to dark gray, fissile, some marcasite	
o	5.0		188		

Section continued on page 2

Section S110, Ross County, Ohio, page 2



Scale

10 5 0 10 20 feet

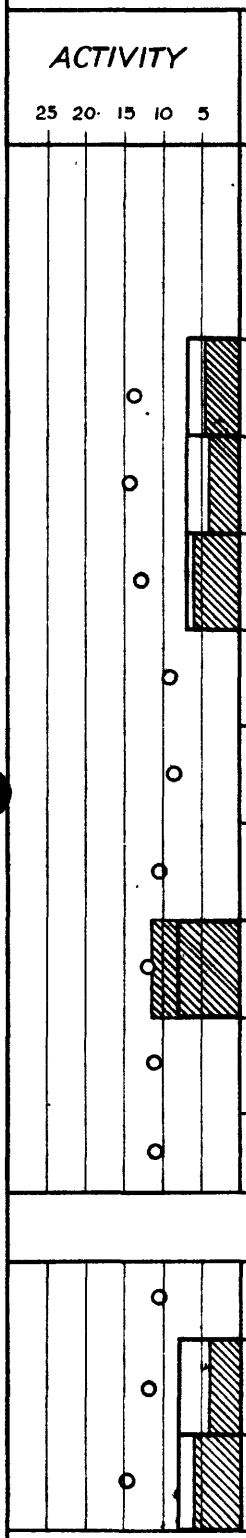
Activity:

o Count per minute at outcrop

□ Uranium content determined by chemical analysis, expressed in gm U/gm/10^{-5}

Measured and sampled by A. L. Slaughter, W. H. Hass, and S. E. Clabaugh; July 15, 1944

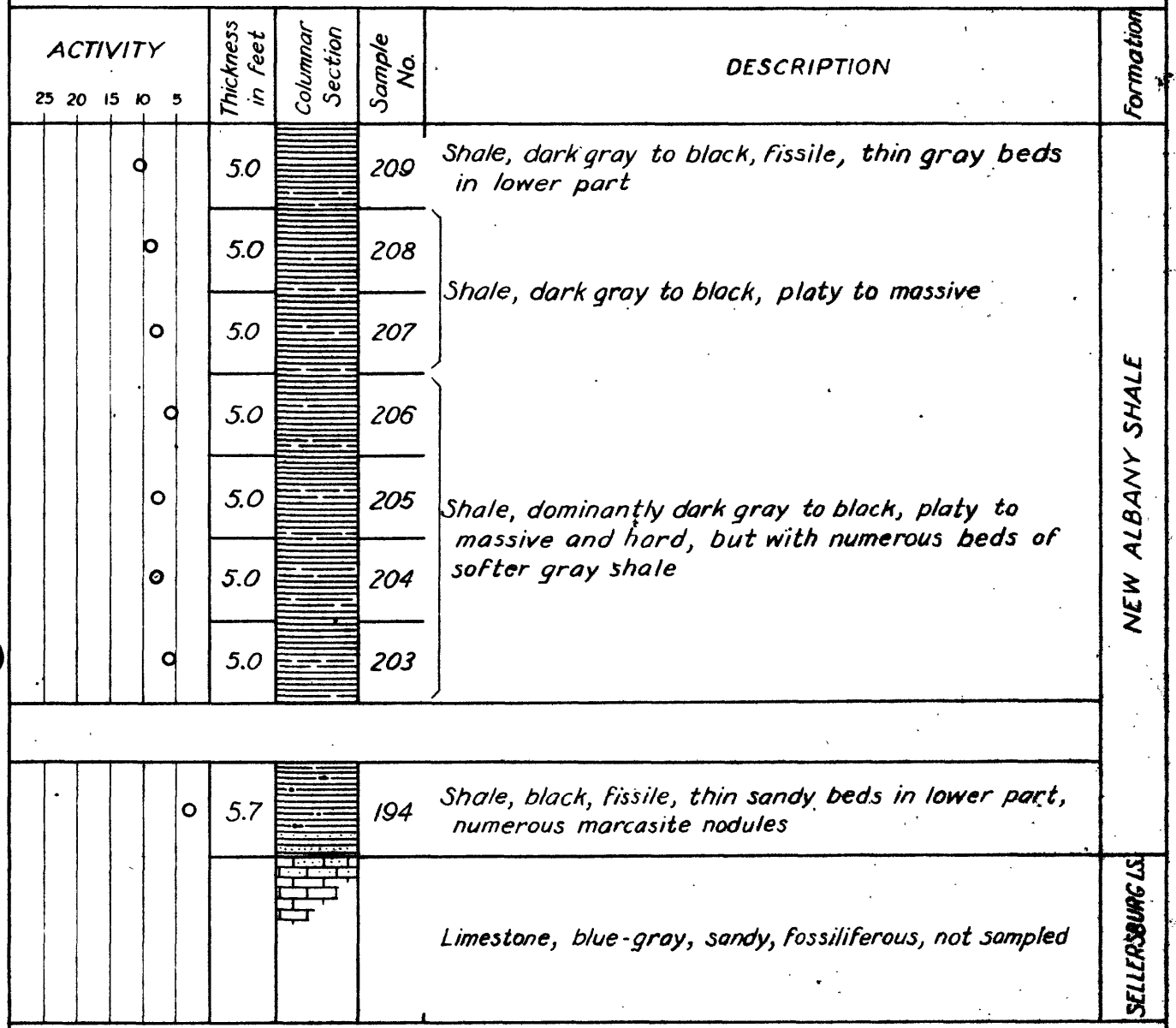
Section SIII, Floyd and Clark Counties, Ind., page 1



Thickness in feet	Sample No.	DESCRIPTION	Formation
		Limestone, tan to gray, fossiliferous, not sampled	ROCKFORD LS.
5.0	195	Shale, black, fissile, zone of siltstone lenses 4 feet below top	NEW ALBANY SHALE
5.0	196	Shale, black, fissile, one narrow calcareous bed, few marcasite nodules	
5.0	197	Shale, black, fissile, some harder beds with petroliferous odor, marcasite abundant	
5.0	198		
5.0	199		
5.0	200		
5.0	201		
5.0		Covered	
4.0	202	Shale, black, fissile	
		Interval omitted, thickness not determined	
4.0	212	Shale, black, very fissile at base, grading upward into platy siltstone	
5.0	211	Shale, black, extremely fissile, paper-thin beds, abundant iron sulfate coatings	
5.0	210		

Section continued on page 2

Section SIII, Floyd and Clark Counties, Ind., page 2



Scale

10 5 0 10 20 Feet

ACTIVITY:

○ Count per minute at outcrop

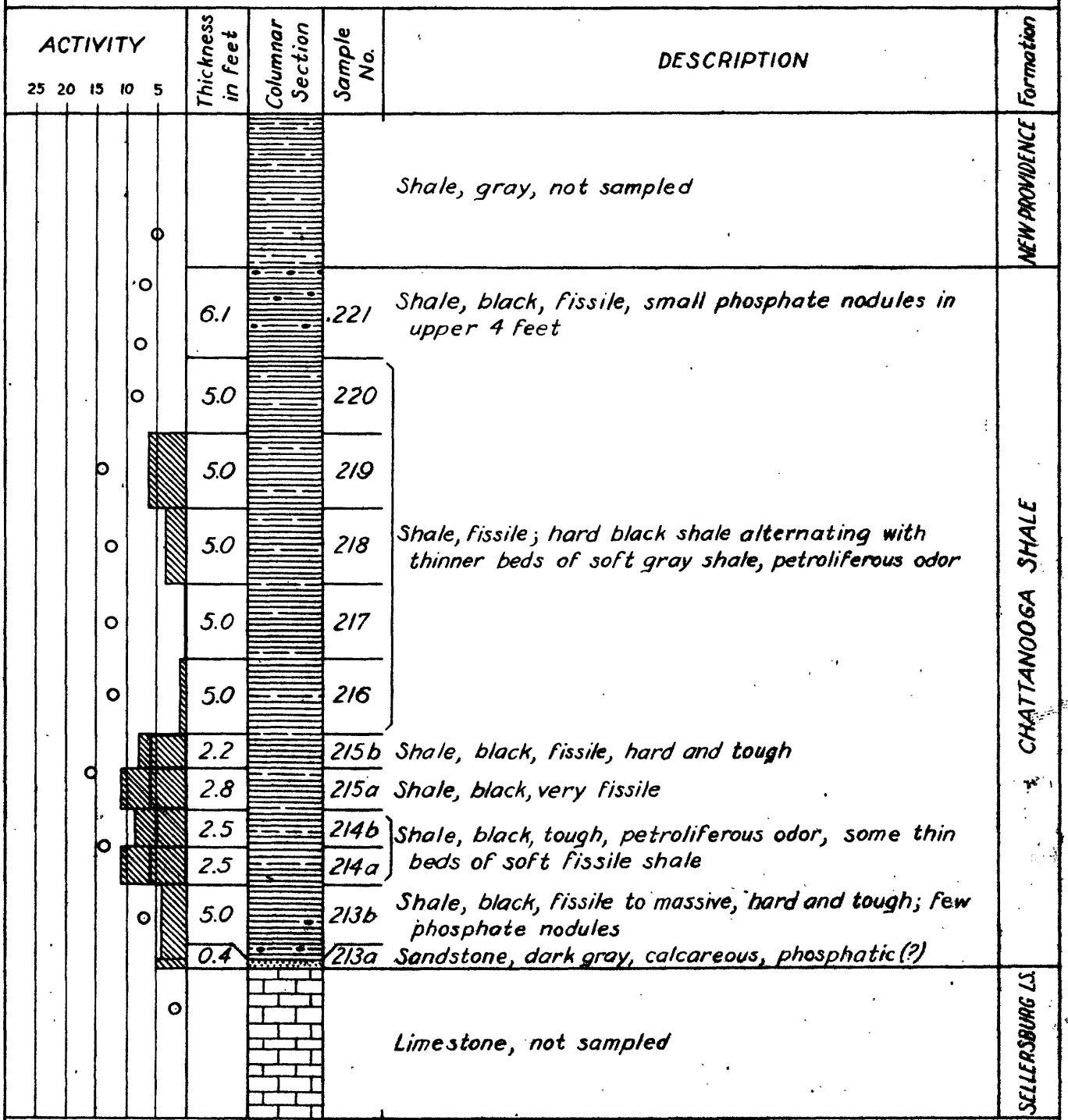
▨ Approximate activity of crushed rock expressed as equivalent 10^{-5} gm U/gm. Not determined for all samples

Measured and sampled by A. L. Slaughter, W. H. Hass, and S. E. Clabaugh; July 19-20, 1944

Uranium content determined by chemical analysis, expressed in gm U/gm/10^{-5}

CONFIDENTIAL

Section S112, Pulaski County, Ky.



○ Count per minute at outcrop

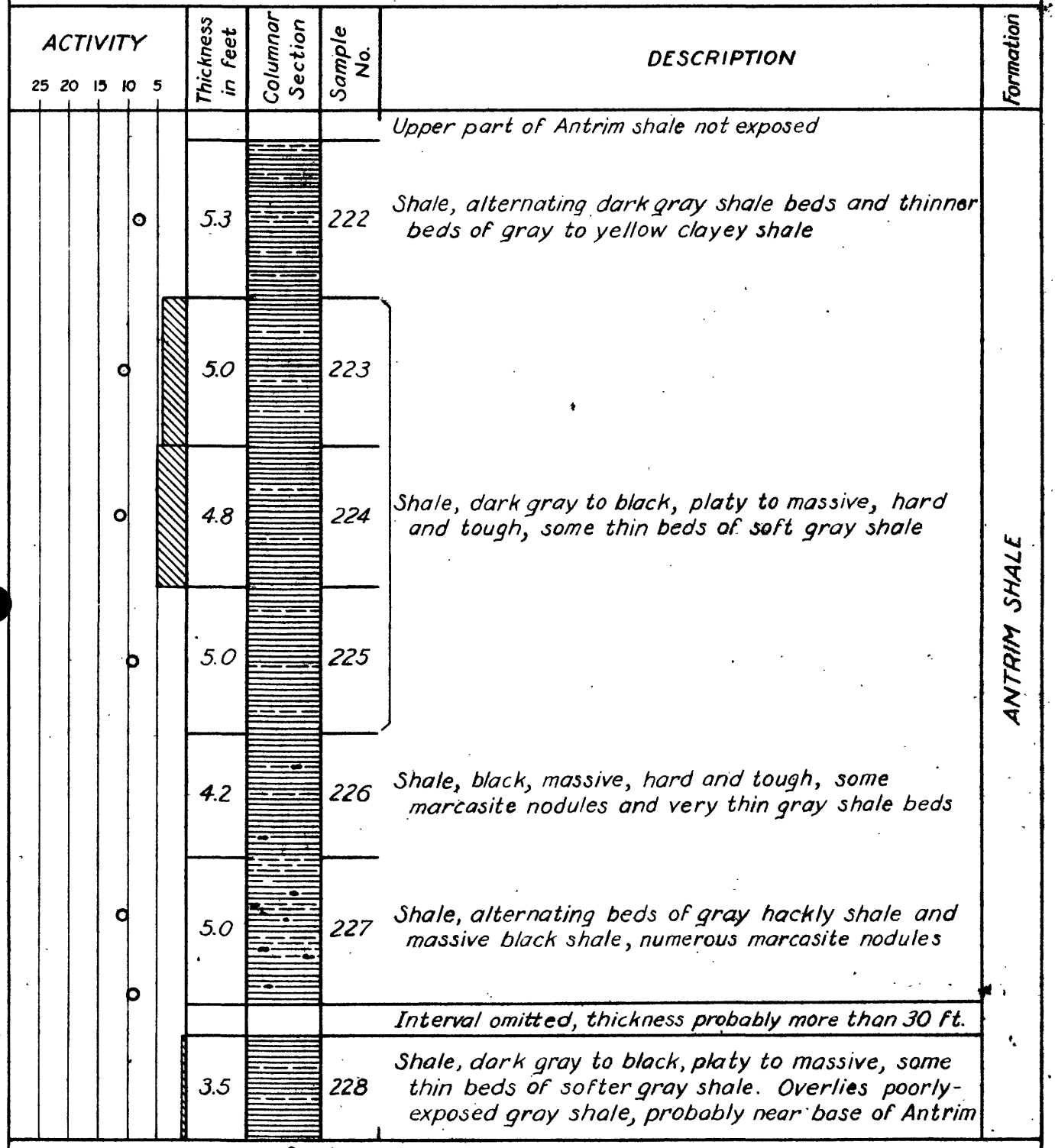
Approximate activity of crushed rock expressed as equivalent 10^{-5} gm U/gm. Not determined for all samples

Measured and sampled by A. L. Slaughter, W. H. Hass, and S. E. Clabaugh; July 23, 1944

CONFIDENTIAL

Uranium content determined by chemical analysis, expressed in gm U/gm/10^{-5}

Section S113, Alpena County, Mich.

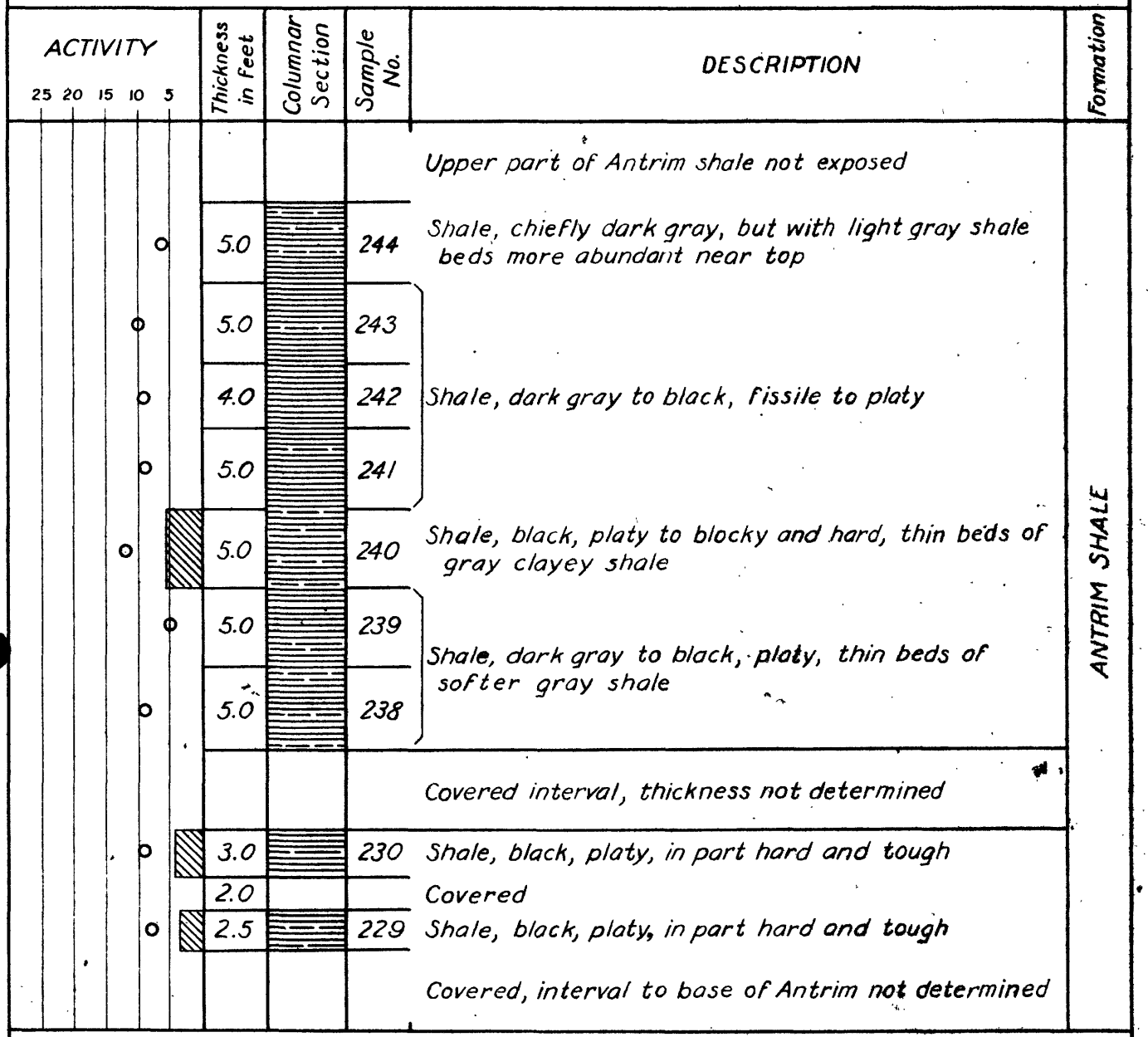


ACTIVITY:
o Count per minute at outcrop

Approximate activity of crushed rock expressed as equivalent 10^{-5} gm U/gm. Not determined for all samples

Measured and sampled by A. L. Slaughter, W. H. Hass, and S. F. Clabaugh; July 27, 1944

Section S114, Charlevoix County, Mich.



Scale

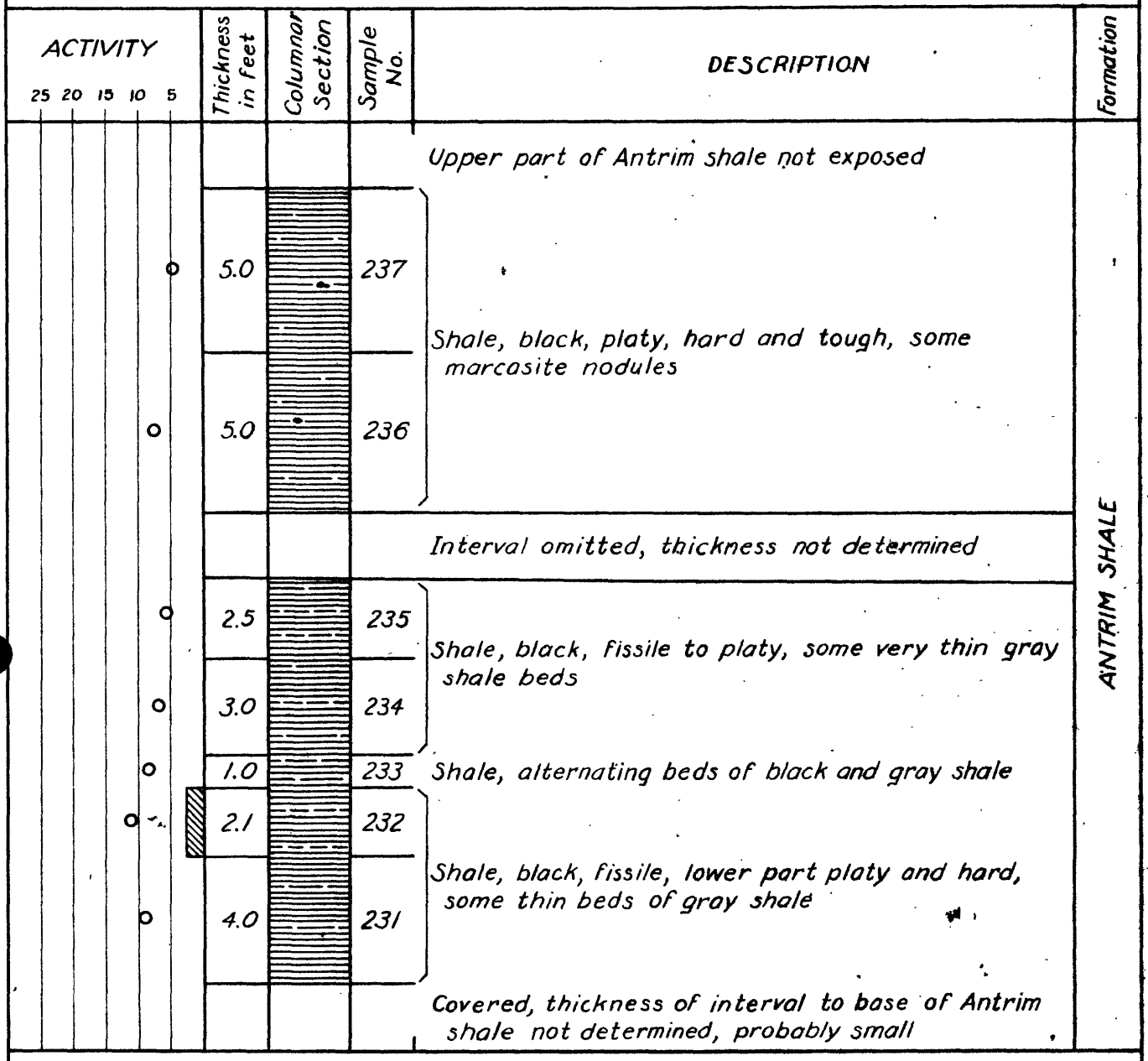
10 5 0 10 20 Feet

ACTIVITY:

- Count per minute at outcrop
- Approximate activity of crushed rock expressed as equivalent 10^{-5} gm U/gm. Not determined for all samples.

Measured and sampled by A. L. Slaughter, W. H. Hass, and S. E. Clabaugh; July 31, 1944

Section S115, Charlevoix County, Mich.



Scale

5 0 5 10 feet

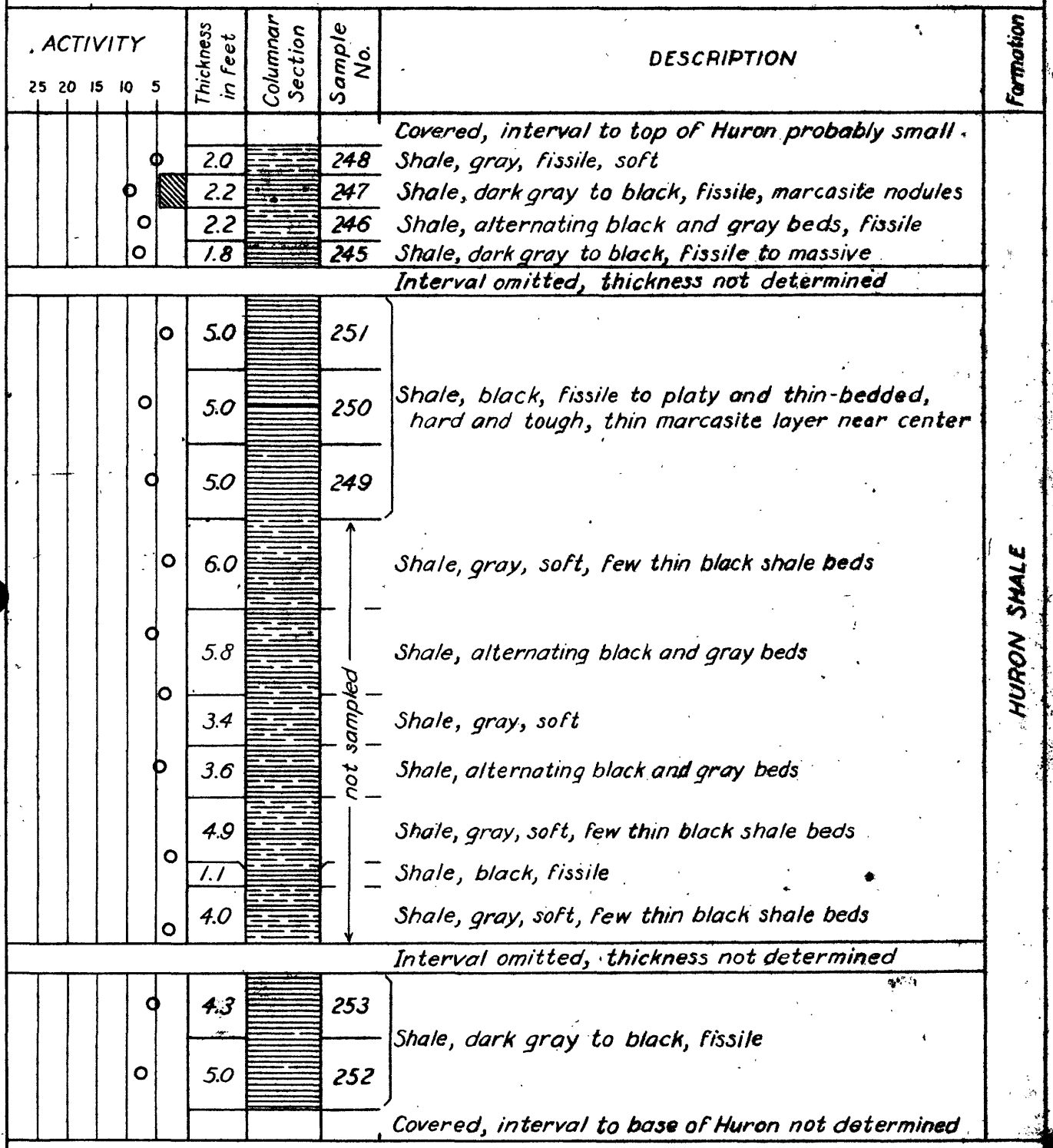
ACTIVITY:

o Count per minute at outcrop

▨ Approximate activity of crushed rock expressed as equivalent 10^{-5} gm U/gm. Not determined for all samples

Measured and sampled by A. L. Slaughter, W. H. Hass, and S. E. Clabaugh; July 30, 1944

Section S116, Erie and Huron Counties, Ohio



Scale

10 5 0 10 20 Feet

ACTIVITY:

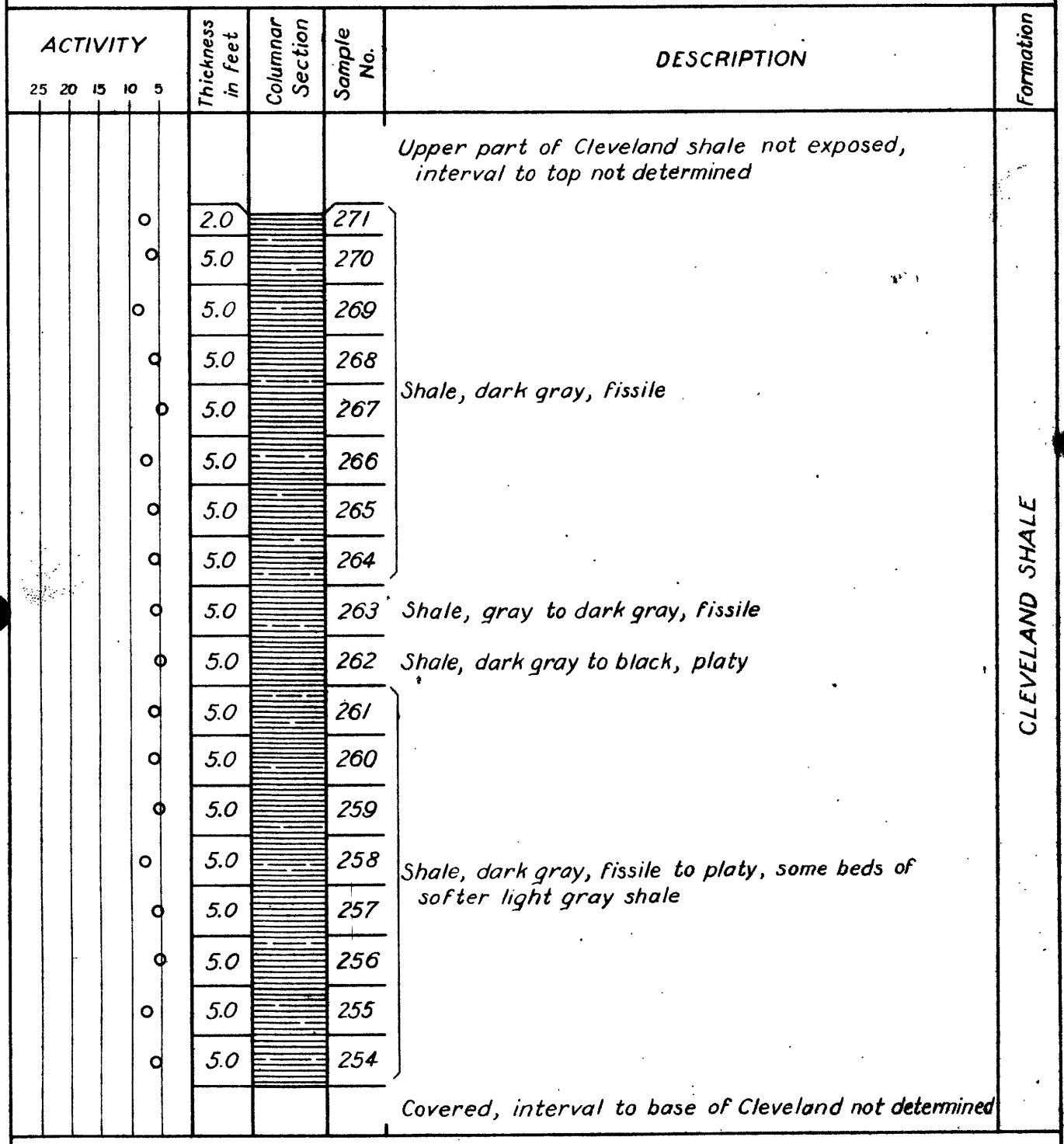
○ Count per minute at outcrop

▨ Approximate activity of crushed rock expressed as equivalent 10^{-5} gm U/gm. Not determined for all samples

Measured and sampled by A. L. Slaughter, W. H. Hass, and S. E. Clabaugh; August 3, 1944

CONFIDENTIAL

Section S117, Cuyahoga County, Ohio



Scale

15 10 5 0 15 30 feet

ACTIVITY:
· O Count per minute at outcrop

None tested

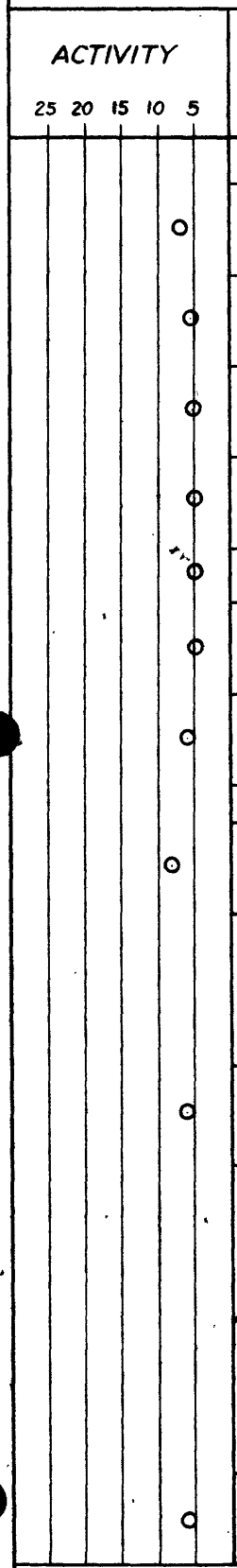
Approximate activity of crushed rock expressed as equivalent 10^{-5} gm U/gm. Not determined for all samples

Measured and sampled by A. L. Slaughter, W. H. Hass, and S. L. Clabaugh; August 4, 1944

CONFIDENTIAL

CONFIDENTIAL

Section S118, Erie County, N.Y., page 1



Thickness in feet	Sample No.	DESCRIPTION	Formation	Group
		Upper part of Dunkirk (about 15 ft.) not exposed here	DUNKIRK SHALE	CHEMUNG GROUP
5.0	318	Shale, black, platy to fissile, sandy		
5.0	317	Shale, black, platy; several thin gray beds; brown stains		
5.0	316			
5.0	315			
2.9	314	Alternating black and gray shales		
5.0	313	Shale, black, platy, several thin gray beds		
5.0	312			
2.0		Covered		
5.0	311	Shale, black, platy; several thin gray beds		
5.4	310	Shale, dominantly gray with a few beds of black shale. Sample 310 is from the basal 5.4 feet of a black, petroliferous, platy shale layer probably less than 50 feet below the base of the Dunkirk	RHINESTREET SHALE - "ANGOLA" and "HANOVER"	PORTAGE GROUP
		Alternating black and gray shales of upper Rhinestreet or lower "Angola". Not sampled		
5.0	309	Shale, dark gray to black, fissile to platy		

CONFIDENTIAL

Section continued on page 2

Section S118, Erie County, N. Y., page 2

ACTIVITY (25 20 15 10 5)	Thickness in Feet	Columnar Section	Sample No.	DESCRIPTION	Formation	Group
	5.0		308	Shale, beds of hard black shale alternating with beds of fissile gray shale	RHINESTREET SHALE	PORTAGE GROUP
	5.0		307	Shale, black to gray, fissile to hackly; bed of gray shale with large concretions ½ foot below top		
	5.0		306	Shale, upper part black, platy to massive, tough; lower part gray and softer		
	5.0		305	Shale, black, platy, tough, with thin gray shale beds		
	5.0		304	Shale, black, fissile to platy		
	5.0		303	Shale, black, platy, tough, lower ½ foot gray		
	5.0		302	Shale, platy, upper part black, lower part gray		
	5.0		301	Shale, platy, upper part black, lower part gray		
	5.0		300	Shale, black, platy to splintery, tough		
	5.0		299			
	5.0		298	Shale, black, fissile, zone of large concretions at top		
	5.0		297	Shale, black, hard, massive; softer and lighter in color near center		
	5.0		296	Shale, black, massive, hard, petroliferous odor		
	5.0		295	Shale, gray to black, calcareous at base, concretions in upper 1 foot zone		
	5.0		294	Shale, black, tough, alternating with softer gray shale beds		

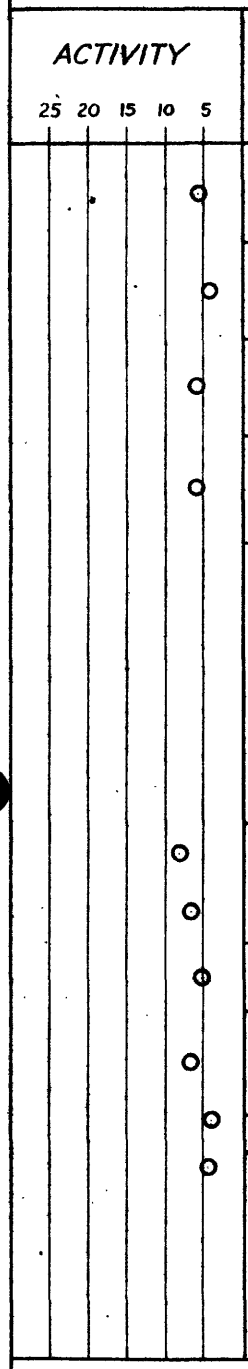
Section continued on page 3

Section S118, Erie County, N. Y., page 3

ACTIVITY (25 20 15 10 5)	Thickness in feet	Columnar Section	Sample No.	DESCRIPTION	Formation	Group
	5.3		293	Shale, light gray, zone of large concretions 1.9 feet below top; some thin limestone beds	RHINESTREET SHALE	PORTAGE GROUP
	5.7		292	Shale, black with 0.8 foot of gray shale near top		
	5.0		291	Shale, black, platy to massive, petroliferous odor, zone of large concretions 2 feet above base		
	5.0		290	Shale, black, platy, tough and hard in part, petroliferous odor		
	5.0		289			
	5.0		288			
	5.0		287	Shale, black, fissile to platy and tough, petroliferous odor, zone of large concretions at top of sample 287		
	5.0		286			
	5.0		285			
	4.7		284	Shale, gray to dark gray, fissile; thin calcareous bed near base		
	3.3		283	Shale, dark gray to black, fissile, zone of concretions at base		
	2.6		282	Shale, gray, soft, fissile to hackly		
	6.0		281	Shale, black, platy to fissile, tough		
	5.0		280	Shale, black, platy, tough, zone of large concretions near center		
	5.0		279	Shale, black, petroliferous odor; alternating with softer beds of gray shale		

Section continued on page 4

Section S118, Erie County, N. Y., page 4



Thickness in feet	Sample No.	DESCRIPTION	Formation	Group
5.0	278	Shale, black, fissile to platy; hard; zone of large calcareous concretions 6 inches above base	RHINESTREET	PORTAGE
5.0	277	Shale, black, fissile to platy, tough, hard, petroliferous odor		
5.0	276			
5.0	275	Shale, gray to black, darker at top, some calcareous concretions		
about 33		Shale, gray to olive; contains flattened calcareous concretions; not sampled	CASHAQUA	
6.2	274	Shale, black, fissile, tough, petroliferous odor	MIDDLESEX	
3.4	273	Shale, dark gray, hackly, lower part calcareous	WEST RIVER	GENESEE
5.3	272	Shale, dark gray, hard, calcareous; thin limestone beds near base; some thin black shale beds		
.4-.8		Limestone (Genundewa ls. lentil), chiefly a coquina of conodonts, pteropods, and other fossils; not sampled. Black shale and Tully pyrite absent	GENESEO	
		Shale, gray soft, not fissile; contains lenticular to concretionary limestone beds; not sampled	MOSCOW	HAMILTON

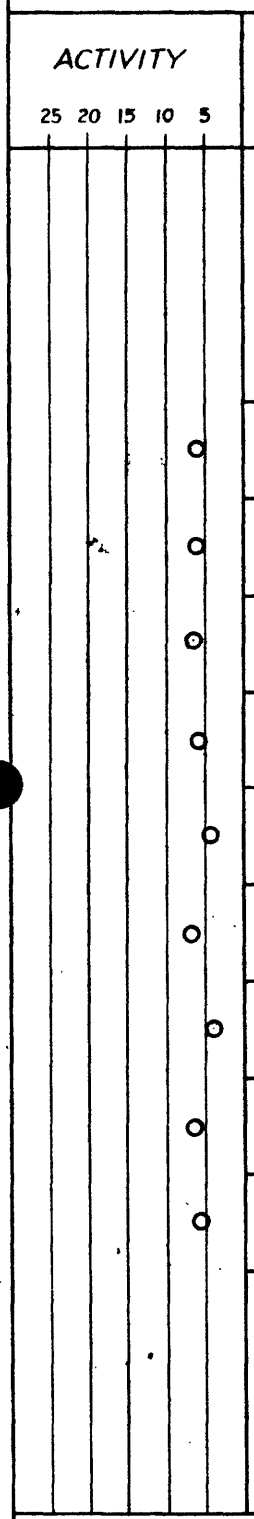
Scale

10 5 0 10 20 feet

ACTIVITY:
Count per minute at outcrop

Measured and sampled by A. L. Slaughter, W. H. Hass, and S. E. Clabaugh, August 5-10, 1944

Section S119, Yates County, N.Y.



Thickness in Feet	Sample No.	DESCRIPTION	Formation	Group
		Shale, dark gray, fissile to platy, some light gray shale beds; not sampled. Activity low; average of 9 counts in 50 feet of shales above Geneseo, 5.9 per minute	WEST RIVER	GENESEE
5.0	327	Shale, black, platy; zone of calcareous concretions 2 feet below top (equivalent to Genundewa ls. lentil)	GENESEO	
5.0	326	Shale, black, platy		
5.0	325	Shale, black, platy; two narrow gray shale beds near base		
5.0	324	Shale, black, platy to massive and tough, slight petroliferous odor. Thin irregular layer of pyrite at base of black shale (Tully pyrite)		
5.0	323			
5.0	322			
5.0	321			
5.0	320			
5.0	319			
		Shale, light gray, not fissile, calcareous; not sampled	MOSCOW	HAMILTON

Scale
10 5 0 10 20 Feet

ACTIVITY:
o Count per minute at outcrop

Measured and sampled by A. L. Slaughter, W. H. Hass, and S. E. Clabaugh, August 13, 1944

Section S120, Mineral and Hampshire Counties, W. Va., page 1

ACTIVITY 25 20 15 10 5	Thickness in feet	Columnar Section	Sample No.	DESCRIPTION	Formation or Member
				Shale, dark gray, increasingly more sandy and lighter in color upward; minor faulting and folding; not sampled	Harrell black shale of Woodward (1943); part of Jennings formation of Darton (1892)
	5.0		346		
	5.0		345	Shale, dark gray, platy, hard and tough	
	5.0		344		
	5.0		343	Shale, dark gray; beds of sandstone 0.3 foot thick at top and base	
	5.0		342	Shale, dark gray to light gray, very fissile	
	5.0		341	Shale, dark gray, fissile to platy, some thin sandstone beds	
	5.0		340	Shale, dark gray, lighter in color and softer at top	
	5.0		339		
	5.0		338	Shale, dark gray, fissile to platy, some thin gray beds and some harder sandy beds	
	5.0		337		
	5.0		336	Shale, dark gray, fissile to platy, sandstone 2 inches thick, 2 feet below top	
	5.0		335		
	5.0		334	Shale, dark gray, platy, some harder sandy beds	

Section continued on page 2

Section S120, Mineral and Hampshire Counties, W. Va., page 2

ACTIVITY (25 20 15 10 5)	Thickness in feet	Columnar Section	Sample No.	DESCRIPTION	Formation or Member
o	5.0		333	Shale, dark gray, platy, some sandy beds	Harrell black shale of Woodward, 1943; part of Jennings formation of Darton, 1892
o	5.0		332	Shale, dark gray or brown to black; badly contorted and broken; true thickness unknown but probably not more than 25 feet. Samples probably duplicate some beds and omit others.	
o	5.0		331		
o	5.0		330		
o	5.0		329		
o	5.0		328		
				Sandstone, shaly and calcareous, dark gray to brown; not sampled	Hamilton fm. of Woodward, 1943; part of Romney shale of Darton, 1892
				Lower part of impure sandstone and upper part of underlying dark shale not sampled	
o	5.0		347	Shale, black, fissile, zone of large concretions 3 or 4 feet below top	Marcellus black shale of Woodward, 1943; part of Romney shale of Darton, 1892
o	5.0		348	Shale, black, fissile to platy, hard and tough	
o	4.0		349		
				Most of the shale is deeply weathered and poorly exposed. Samples 347-349 are from exposures of black shale several miles distant which is probably stratigraphically above samples 350-362. Activity of remainder of shale probably low; average of 9 counts at exposures higher in section, 4.3 per minute	

Section continued on page 3

Section S120, Mineral and Hampshire Counties, W. Va., page 3

ACTIVITY (25 20 15 10 5)	Thickness in Feet	Columnar Section	Sample No.	DESCRIPTION	Formation or Member
o	5.0		362	Shale, black, platy; some sandy and clayey beds weather yellow	Marcellus black shale of Woodward, 1943; part of Romney shale of Darton, 1892
o	5.0		361		
o	5.0		360	Shale, black, fissile; breaks into small chips weather gray at edges; heavily iron-stained in part, with some limonite layers; deeply weathered and somewhat contorted	
o	5.0		359		
o	5.0		358		
o	5.0		357		
o	5.0		356		
o	5.0		355		
o	5.0		354		
o	5.0		353		
o	5.0		352		
o	5.0		351		
o	5.0		350		
				Covered, interval to base of black shale small, probably less than 25 feet	

Scale: 10 5 0 10 20 Feet

ACTIVITY: o Count per minute at outcrop

Measured and sampled by A. L. Slaughter, W. H. Hass, and S. E. Bisbaugh, August 16-18, 1944

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

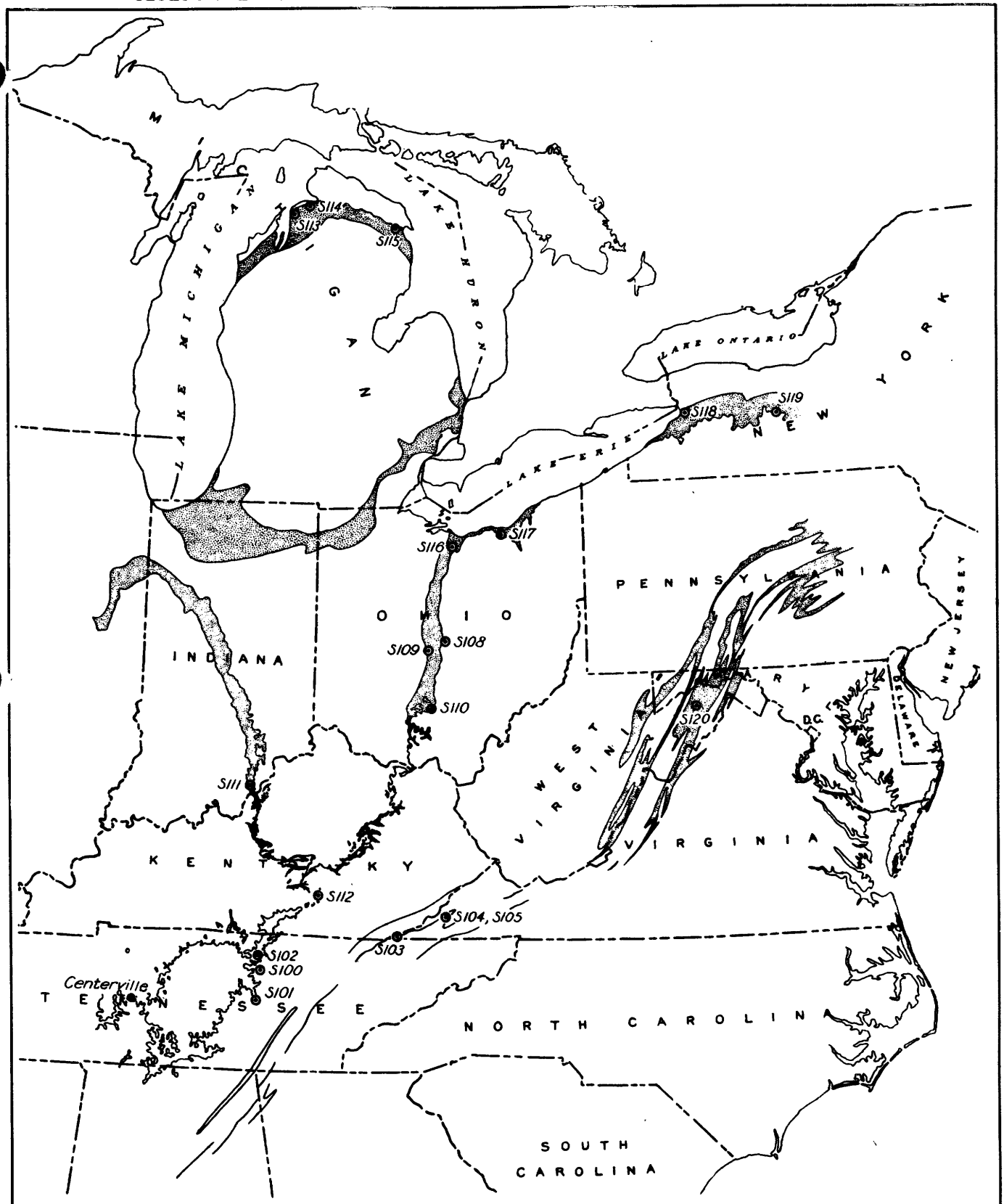


FIGURE 1.—INDEX MAP SHOWING SAMPLE LOCALITIES AND OUTCROP OF DEVONIAN AND LOWER CARBONIFEROUS BLACK SHALES OF THE EASTERN STATES

52443