Underclay Deposits of Somerset and Eastern Fayette Counties, Pennsylvania

GEOLOGICAL SURVEY BULLETIN 1363

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By JOHN W. HOSTERMAN

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A geological, mineralogical, and chemical study of underclay beds in the Allegheny Formation of southwestern Pennsylvania

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UNDERCLAY DEPOSITS OF SOMERSET AND EASTERN FAYETTE COUNTIES, PENNSYLVANIA

By JOHN W. HOSTERMAN

ABSTRACT

The most economically important underclay beds in Somerset, eastern Fayette, and part of eastern Westmoreland Counties, Pa., are in the Allegheny Group of Pennsylvanian age. The beds of local usage, from oldest to youngest, are called the Brookville, Clarion, Lower Kittanning, Upper Kittanning, Lower Freeport, Bolivar, and Upper Freeport. The Clarion, Lower Kittanning, Upper Kittanning, and Bolivar are the best clay beds from a potential economic standpoint. They contain flint and semiflint clay which is used primarily in making high-grade refractory clay products. The underclay beds are probably the result of the leaching of fine-grained sediments in an acid swamp.

INTRODUCTION

The area of underclay investigation is in Somerset, eastern Fayette, and part of eastern Westmoreland Counties in southwestern Pennsylvania, and includes a contiguous strip in Allegany and Garrett Counties, Md., and Preston County, W. Va. (pl. 1).

The approximate boundaries of the report area are Chestnut Ridge on the west and the Allegheny Front on the east. The southern boundary is approximately 4 miles south of the Pennsylvania line, and the northern boundary is contiguous with the north boundary of Somerset County. Most of the area is drained by the Youghiogheny and Casselman Rivers and their tributaries. These rivers flow northwestward into the Ohio River. A small area in southeastern Somerset County is drained by Wills Creek and its tributaries; this creek flows into the Potomac River.

The entire area is within the Allegheny Mountain section of the Appalachian Plateaus physiographic province. Immediately to the east is the Allegheny Front which separates the Appalachian Mountains of the Valley and Ridge province from the Allegheny Mountains. The three main ridges, Allegheny Mountain, Laurel Hill, and Chestnut Ridge, trend N. 30° E. and are 800 to 1,500 feet above the adjacent valleys.

The purpose of this project was to study the mineralogical and chemical composition of the economic clay beds in this area and to compile data on the occurrences of the clay. I am grateful to the mining personnel of Harbison-Walker Refractories Co., General Refractories Co., and Kaiser Refractories and Chemical Co. for allowing access to their strip mines. I wish to thank David L. Jones, Southwestern Mines, Inc., for his helpful cooperation.

GEOLOGY

The sedimentary rocks of the Allegheny Plateau lie in a series of rather open folds having flank dips of 5°–20°. Because three ridges, Chestnut Ridge, Laurel Hill, and Negro Mountain, are anticlinal and the intervening valleys are synclinal, younger rocks are exposed in the valleys, and the older rocks crop out along the ridges. Exceptions to this structure pattern are the Allegheny and Big Savage Mountains, which are on steeply dipping and opposite limbs of the Deer Park anticline, and Little Allegheny Mountain, which is on the steeply dipping limb of a syncline. The coal- and clay-bearing rocks are the youngest strata in the area; therefore, the strip mines and most old underground mines are in the valleys and on the lower slopes of the ridges.

The areal distribution of the sedimentary rocks is shown on the geologic maps of Pennsylvania and Maryland (Gray and others, 1960; Cleaves and others, 1968). Other geologic maps covering parts of the area are in Flint (1965), Hickok and Moyer (1940), and Richardson (1934).

The stratigraphic column of exposed rocks in the area is:

- Pennsylvanian System
  - Monongahela Group
  - Conemaugh Group
  - Allegheny Group
  - Pottsville Group
- Mississippian System
  - Mauch Chunk Formation
  - Loyalhanna Limestone
  - Pocono Formation
- Devonian
  - Catskill Formation
  - Jennings Formation

The total thickness of these strata is about 8,000 feet; however, this report is concerned only with a few hundred feet of the

Allegheny Group, which contains the economic clay deposits (pl. 1).

The Allegheny Group includes sedimentary rocks from the top of the Homewood Formation (Pottsville Group) to the top of the Upper Freeport coal, which usually underlies the Mahoning Sandstone Member of the Glenshaw Formation (Conemaugh Group). The group ranges in thickness from 140 feet on the western flank of Chestnut Ridge (Hickok and Moyer, 1940, p. 59) to 280 feet in Somerset County (Flint, 1965, p. 58). The measured sections (pl. 2) show that the thickness ranges from 207 feet near Ohiopyle, Fayette County (sample locs. 29 and 3), to 243 feet at Williams, Somerset County (sample loc. 55). The Allegheny Group is composed predominantly of shale, siltstone, and sandstone. Coal and clay make up only about 10–15 percent of the entire group but are important for their economic value. The group has been divided by Hickok and Moyer (1940, p. 59) into three formations, the Clarion, Kittanning, and Freeport (pl. 2).

The Clarion Formation includes strata from the top of the Homewood to the base of the underclay beneath the Lower Kittanning coal. It is approximately 60 feet thick and contains the Brookville and Clarion coal and underclay beds. The Mount Savage clay of Maryland (Waagé, 1950, p. 26) is equivalent to the Clarion clay of Pennsylvania.

The Kittanning Formation includes the strata between the base of the Lower Kittanning underclay and the top of the Upper Kittanning coal. This formation is about 55 feet (pl. 2) to 100 feet thick (Hickok and Moyer, 1940, p. 69), and it contains the Lower, Middle, and Upper Kittanning coal and clay beds.

The Freeport Formation includes strata between the top of the Upper Kittanning coal and the base of the Mahoning Sandstone Member or top of the Upper Freeport coal. This formation ranges in thickness from about 90 to 140 feet (pl. 2); it contains the Lower and Upper Freeport coal and clay beds. It also contains the Bolivar clay bed in Westmoreland and Fayette Counties.

UNDERCLAY BEDS

The underclay beds contain one, two, or three types of clay—flint, semiflint, and plastic. All underclay ranges from light gray (*N*7) to dark gray (*N*4)[1]. The differences in color are chiefly caused by the differing amounts of carbonaceous matter in the

[1] Munsell color designations (Kelly and Judd, 1955).

clay. A brief discussion of the mineralogical and chemical properties of the three types of clay follows.

Flint clay is a hard, nonplastic, refractory clay. It is composed of more than 95 percent kaolinite and only a trace of illite. However, as much as 50 percent quartz silt may be present in some flint clays. The best grade flint clay in the area is composed of 44.2 percent SiO_2, 37.6 percent Al_2O_3, and 14.1 percent H_2O (loc. 55, pl. 1; table 1). The Al_2O_3 and SiO_2 contents are slightly below the composition of theoretical kaolinite (46.54 percent SiO_2, 39.50 percent Al_2O_3, and 13.96 percent H_2O). The P.C.E. (pyrometric cone equivalent), a standard method of measuring the clay's resistance to heat, of high-grade flint clay ranges from 34 to 36 (1,760°C–1,810°C).

Semiflint clay is intermediate and gradational between flint and plastic clay in physical properties, clay-mineral composition, and chemical composition. Semiflint clay is composed of kaolinite, illite, and mixed-layer clay minerals. The amount of kaolinite, however, is more than twice the combined amount of illite and mixed-layer clay. Quartz is the major nonclay mineral which occurs as silt in amounts up to about 40 percent. The P.C.E. of semiflint clay is in the range of 31 to 33 (1,680°C–1,745°C). This clay is distinctly lower in heat-resisting properties than the flint clay because of the fluxing effect of the alkali content of the illite and mixed-layer clay minerals.

Plastic clay consists of a mixture of kaolinite, illite, and mixed-layer clay. The amount of kaolinite is about equal to the combined amount of illite and mixed-layer clay. The value of plastic clay is in its plasticity rather than its refractory properties, and consequently it is commonly used to bond the nonplastic flint and semiflint clays. Quartz is present as silt in amounts up to about 50 percent. The presence of quartz silt in the sample often misleads in the field identification of the type of clay; the quartz silt tends to make the clay harder so that plastic clay looks like semiflint, and semiflint clay looks like flint. The P.C.E. of plastic clay is below 30 (1,670°C).

The X-ray diffraction method of identifying clay minerals and the X-ray fluorescence method of determining their chemical composition are routine. Details of the sample preparation have been described by Hosterman (1969, p. 6–7). For X-ray diffraction, all samples were treated with ethylene glycol to test for the presence of expandable clay (montmorillonite), were heated to 300°C to check for the presence of collapsible clay (vermiculite), and were heated to 550°C to test for the presence of chlorite.

Neither montmorillonite nor vermiculite was found to be present. The samples that indicated the presence of chlorite were treated with 3*N* hydrochloric acid to check for the presence of chlorite and kaolinite. The clay mineral–quartz ratios (table 1) are based on the peak-height ratios obtained from the X-ray diffraction traces. These data give the amount of each mineral present to an accuracy of about ±10 percent.

The clay mineral–quartz ratios (table 1) were derived from the peak-height ratios of the following X-ray diffraction peaks: kaolinite at 7 A, illite at 9.8 A, mixed-layer at 10–12 A, chlorite at 14 A, and quartz at 4.26 A. The crystallinity of kaolinite ranged from the well-crystallized variety in flint clay with a (001) basal spacing at 7.13 A to the poorly crystallized variety in plastic clay with a (001) basal spacing at 7.3 A.

In the study area, the clays suitable for refractory uses occur as underclays in the Allegheny Group. In my opinion, the Mercer clay bed of the Pottsville Group, which has been mined extensively in central Pennsylvania, is not present as an economic clay in the study area. This opinion is supported by Waagé (1950, p. 15–22) and Flint (1965, p. 53). Clays have been mined from the Clarion, Lower Kittanning, Upper Kittanning, and Bolivar beds. Clays from the Brookville, Middle Kittanning, Lower Freeport, and Upper Freeport have not been mined commercially. Detailed discussion of the mineralogy and chemical composition of each bed follows.

BROOKVILLE UNDERCLAY BED

The Brookville is the oldest clay in the Allegheny Group. It is commonly only a few feet above the Homewood Formation. However, in many places, the Brookville clay is difficult to differentiate from the overlying Clarion clay, especially in Fayette County where only a few feet of shale separate the two clays, or where one clay or associated coal bed is absent. Seven samples of Brookville clay were taken from five localities (table 1; pl. 1). The clay bed averages about 3.5 feet in thickness and is predominantly plastic with local lenses of semiflint clay. Quartz is present in all samples and is abundant enough in some to make the clay silty. The amounts of silica, alumina, and potassium oxide give a good indication of the potential commercial value of the clay. The Brookville clay has an average chemical content of 63 percent SiO_2, 22 percent Al_2O_3, and 2.7 percent K_2O. The Brookville bed does not have much economic potential because it

TABLE 1.—*Chemical and mineralogical composition of some Allegheny Group underclays in Somerset, eastern Fayette, and part of eastern Westmoreland Counties, Pa.*

[Analyses by X-ray fluorescence methods; chemical results in weight percent; Tr., trace]

Type of clay	Sample thickness (ft)	Locality No. (pl. 1)	SiO_2	Al_2O_3	Fe_2O_3	K_2O	TiO_2	Loss on ignition	Sum	Kaolinite	Illite	Mixed layer	Chlorite	Quartz
										peak-height ratio				
Upper Freeport clay:														
Plastic, silty	--	1	64	23	1.4	3.0	1.4	6.5	99.3	3	3	Tr.	--	4
Plastic	2	2	54	26	2.4	3.3	1.1	8.8	95.6	5	3	Tr.	--	2
Plastic, silty	2	3	61	24	1.3	3.6	1.3	6.1	97.3	3	3	Tr.	--	4
Do	2	4	64	21	1.5	1.9	1.2	7.8	97.4	4	2	Tr.	--	4
Do	4	5	62	21	1.6	3.0	1.2	7.6	96.4	3	2	1	--	4
Semiflint, silty	6	6	62	23	1.0	1.0	1.3	8.7	97.0	5	1	Tr.	--	4
Plastic, silty	5	7	60	21	2.0	2.8	1.2	8.2	95.2	3	2	1	--	4
Plastic	6	8	58	21	[1]7.1	3.3	1.2	7.3	97.9	3	3	1	--	3
Plastic, silty	3	9	62	19	3.6	3.1	1.1	8.2	97.0	3	2	1	Tr.	4
Bolivar clay:														
Plastic	1.6	10	58	23	4.3	3.2	1.1	9.6	99.2	3	3	1	--	3
Do	1.6	10	61	19	[1]7.5	2.9	1.2	6.8	98.4	3	3	Tr.	--	4
Semiflint	2	10	60	25	1.6	1.8	1.3	8.7	98.4	5	2	Tr.	--	3
Flint	2	10	51	34	0.7		1.4	12.5	99.6	9	--	--	--	1
Do	2	10	59	28	0.8	0.4	1.2	10.0	99.4	7	Tr.	--	--	3
Plastic	2	10	62	24	1.8	3.2	1.1	6.0	98.1	3	3	--	--	4
Flint	2	10	59	27	1.6	0.1	1.5	9.7	98.9	7	--	--	--	3
Do	2	10	56	31	0.6	0.1	1.8	11.6	101.1	8	--	--	--	2
Flint, silty	2	10	68	21	0.8	0.6	1.3	7.5	99.2	5	Tr.	--	--	5
Do	3.5	11	62	24	1.5	0.3	1.4	9.1	98.3	6	--	--	--	4
Plastic	4	12	61	25	1.3	3.0	1.3	6.0	97.6	4	3	--	--	3
Plastic, silty	10	13	62	18	7.4	3.1	1.1	8.9	100.5	3	2	Tr.	--	5
Upper Kittanning clay:														
Plastic, silty	--	14	64	21	1.6	3.1	1.2	6.9	97.8	3	3	Tr.	--	4
Do	--	15	63	18	4.1	3.1	1.1	5.3	94.6	2	3	Tr.	1	4
Flint, silty	3	16	63	26	0.5	0.1	1.2	9.6	100.4	6	--	--	--	4
Plastic	4	17	50	31	1.5	3.0	1.6	9.4	96.5	6	3	Tr.	--	1

Plastic, silty	4	18	64	20	1.9	3.1	1.1	5.8	95.9	3	3	Tr.	--	4
Semiflint	1		58	25	2.1	1.9	1.4	10.4	98.8	5	2	Tr.	--	3
Plastic, silty	3	19	64	20	2.1	3.6	1.1	7.1	97.9	3	5	--	--	4
Flint	2	20	[2] 58.8	27.8	.59	.25	1.50	9.9	98.84	8	Tr.	--	--	2
Plastic	4	21	59	22	2.3	3.2	1.2	7.9	95.6	3	3	1	--	3
Do	3		64	23	.7	2.7	1.3	7.8	99.5	4	3	--	--	3
Flint	2	22	56	29	.9	.0	1.4	12.1	99.4	8	--	--	--	2
Semiflint	--	23	48	32	1.8	1.6	1.6	15.2	100.1	7	2	--	--	1
Flint	2.5	24	47	36	1.3	.4	2.0	11.8	98.5	9	Tr.	--	--	1
Do	3	25	--	--	--	--	--	--	--	7	--	--	--	3
Middle Kittanning clay:														
Plastic	3.2	24	50	30	1.7	3.0	1.4	11.7	97.8	5	3	1	--	1
Lower Kittanning clay:														
Plastic	--	26	62	23	1.7	3.1	1.2	6.7	97.7	4	3	Tr.	--	3
Semiflint	1.1	27	55	29	1.5	1.6	1.9	11.0	100.0	6	2	--	--	2
Plastic	2.5		54	28	2.1	3.2	1.6	9.5	98.4	5	3	Tr.	--	2
Plastic, silty	3	28	62	22	1.9	3.8	1.1	6.2	97.0	3	3	Tr.	--	4
Plastic	3	29	56	23	3.3	3.7	1.3	8.2	95.5	3	3	1	--	3
Flint	1		52	32	1.0	1.3	1.6	11.5	99.4	7	1	--	--	2
Plastic	4	30	56	28	1.6	3.0	1.4	9.2	99.2	4	3	1	--	2
Semiflint	3	31	[2] 44.2	34.2	2.5	2.4	1.5	12.7	97.5	8	2	Tr.	--	Tr.
Flint	4		[2] 44.2	37.0	1.6	.4	1.6	14.2	99.0	10	Tr.	--	--	--
Plastic	1		63	24	1.1	3.4	1.2	5.4	98.1	4	3	--	--	3
Do	2	32	45	32	2.6	2.3	1.5	15.2	98.6	6	2	Tr.	1	1
Flint	4		44	37	1.4	.2	1.4	14.3	98.3	10	--	--	--	--
Plastic	1	33	56	27	1.3	1.2	1.6	11.2	98.3	6	2	Tr.	--	2
Plastic, silty	4		64	22	1.1	2.3	1.2	6.6	97.3	4	2	Tr.	--	4
Do	6	34	67	20	1.5	3.0	1.1	7.2	99.8	3	3	Tr.	--	4
Semiflint	3	35	52	31	.9	.9	2.4	9.2	94.4	7	1	Tr.	--	2
Plastic, silty	2	36	69	17	1.3	1.5	1.6	7.8	98.2	3	1	1	--	5
Do	7	37	67	18	1.6	2.2	1.2	4.7	94.7	2	3	Tr.	--	5
Do	4	21	65	20	1.6	1.7	1.4	6.7	96.4	3	1	1	--	5
Flint	3	38	58	27	1.0	.0	1.2	13.0	100.2	7	--	--	--	3
Plastic, silty	6	39	64	21	1.4	2.7	1.1	7.0	99.4	3	2	1	--	4
Flint	--	40	53	32	.8	.0	1.9	11.7	99.4	9	--	--	--	1
Do	--	41	53	32	1.7	.6	1.8	10.8	99.9	8	Tr.	--	--	2

TABLE 1.—*Chemical and mineralogical composition of some Allegheny Group underclays in Somerset, eastern Fayette, and part of eastern Westmoreland Counties, Pa.*—Continued

Type of clay	Sample thickness (ft)	Locality No. (pl. 1)	SiO_2	Al_2O_3	Fe_2O_3	K_2O	TiO_2	Loss on ignition	Sum	Kaolinite	Illite	Mixed layer	Chlorite	Quartz
										peak-height ratio				
Clarion clay:														
Semiflint	5	42	63	25	1.1	2.3	1.2	7.2	99.8	5	2	--	--	3
Flint	7		63	25	.7	.4	1.3	8.1	98.5	7	Tr.	--	--	3
Plastic	1	43	50	31	2.1	3.1	1.3	9.0	95.5	5	3	Tr.	--	2
Do	4		54	27	2.3	2.1	1.6	9.5	96.5	5	2	1	--	2
Flint	3	44	54	34	.8	.1	1.6	9.5	100.0	9	Tr.	--	--	1
Semiflint	5	45	59	28	.8	1.8	1.5	9.1	100.2	5	2	--	--	3
Flint	3	46	60	27	1.0	.3	1.4	10.2	99.9	7	Tr.	--	--	3
Semiflint	1	47	62	22	1.5	1.8	2.1	9.2	98.6	5	2	--	--	3
Do	4	48	62	22	1.4	2.7	1.4	7.3	96.8	5	1	1	--	3
Plastic	2		62	22	1.5	3.1	1.1	7.9	97.6	4	3	--	--	3
Semiflint	4	49	[2] 49.9	31.4	2.5	3.1	2.1	10.2	99.2	6	3	--	--	1
Flint	2		[2] 52.8	32.3	.5	.2	2.2	11.9	99.9	8	--	--	--	2
Do	4	50	61	28	1.0	.3	1.4	8.1	99.8	7	--	--	--	3
Plastic, Silty	6		60	22	2.4	3.8	1.2	6.3	95.7	3	2	1	--	4
Do	2	51	63	20	2.9	3.4	1.2	6.3	96.8	2	3	--	1	4
Do	2		68	21	1.1	2.7	1.2	6.2	100.2	3	2	Tr.	--	5
Flint	--	52	63	27	.6	.2	1.4	7.3	99.5	7	Tr.	--	--	3
Plastic, silty	--	53	65	21	1.3	3.1	1.1	6.4	97.9	3	3	Tr.	--	4
Flint, silty	3		[2] 65.9	22	.76	.48	1.3	7.4	97.84	6	Tr.	--	--	4
Semiflint	2	54	[2] 55.8	26.3	1.66	2.0	2.9	8.0	96.66	7	2	--	--	1
Flint	3		[2] 65.8	20.4	1.7	.13	1.3	7.9	97.23	5	Tr.	--	--	5
Plastic	1		[2] 60.9	25.4	1.26	2.6	1.6	7.8	99.6	4	3	Tr.	--	3
Do	1		[2] 60.7	25.0	1.46	2.2	1.5	7.6	98.5	4	3	--	--	3
Flint	1	55	[2] 58.4	28.1	.87	.20	1.4	11.0	101.7	7	Tr.	--	--	3
Do	1		[2] 45.9	37.4	.87	.16	1.8	14.1	98.4	10	Tr.	--	--	--
Do	1		[2] 44.2	37.6	.96	0.0	1.6	14.1	98.6	10	--	--	--	--
Flint, silty	--	56	--	--	--	--	--	--	--	5	--	--	--	5

Semiflint	--	57	[2] 49.4	32.1	2.6	3.2	1.8	10.0	99.10	6	3	--	--	1
Flint	--		[2] 44.2	37.1	.96	.25	2.8	13.3	98.61	10	Tr.	--	--	--
Brookville clay:														
Plastic, silty	5	58	67	20	1.3	2.5	1.1	5.7	97.6	4	2	Tr.	--	4
Do	2	27	69	18	1.4	1.7	1.4	5.9	97.4	3	2	Tr.	--	5
Semiflint	1	45	60	25	1.3	2.4	2.0	8.3	99.0	5	2	Tr.	--	3
Plastic	4		61	24	1.5	3.4	1.4	6.5	97.8	3	3	1	--	3
Plastic, silty	3	59	65	21	1.4	3.1	1.1	6.1	97.7	2	3	1	--	4
Semiflint	1	47	50	28	2.3	2.1	1.5	12.8	96.7	6	2	Tr.	--	2
Plastic	2		56	24	2.2	3.3	1.3	12.0	98.8	4	3	Tr.	--	3

[1] Sample contains siderite. [2] Chemical analyses determined by rapid rock methods.

1. Roadcut on Poplar Run Road, 2 miles north of Pennsylvania Route 711 intersection.
2. Old strip mine 1,000 feet west of Pennsylvania Route 381, 1.6 miles south of Mill Run.
3. Roadcut on Pennsylvania Route 381, 2 miles northeast of Ohiopyle.
4. Strip mine on Roaring Run, 3.3 miles north of Jennerstown.
5. Roadcut 0.5 mile south of Draketown.
6. Strip mine 1 mile south of Ralphton.
7. Strip mine near U.S. Route 30, 1 mile northeast of Lambertsville.
8. Roadcut on Pennsylvania Turnpike, 5.7 miles east of Somerset interchange.
9. Railroad cut on Western Maryland Railroad, 0.75 mile south of Big Savage Tunnel.
10. Old mine along Youghiogheny River, 1.75 miles west of Mill Run.
11. Exposure along unimproved road, 2 miles south of Mill Run.
12. Roadcut on Pennsylvania Route 381, 1 mile north of Kaufmann.
13. Old strip mine along Pennsylvania Turnpike, 7 miles west of Somerset interchange.
14. Roadcut on Pennsylvania Route 653, at Scullton, 4 miles west of New Lexington.
15. Railroad cut on Baltimore and Ohio Railroad, 1 mile north of Confluence.
16. Strip mine near U.S. Route 219, 4 miles southeast of Somerset.
17. Strip mine near Mud Pike, 2 miles east of Bando.
18. Roadcut at end of bridge, 1 mile north of Casselman.
19. Railroad cut at east end of Pinkerton Tunnel on Baltimore and Ohio Railroad.
20. Old strip mine, 1.3 miles east of Beachly.
21. Roadcut and old underground mine on Pennsylvania Route 53, 1.2 miles north of Listonburg.
22. Roadcut at intersection of Pennsylvania Route 53 with U.S. Route 40.
23. Old strip mine, 3.5 miles southwest of Garrett.

TABLE 1.—*Chemical and mineralogical composition of some Allegheny Group underclays in Somerset, eastern Fayette, and part of eastern Westmoreland Counties, Pa.*—Continued

24. Old strip mine, 4.5 miles southwest of Garrett.
25. Old underground mine, about 2 miles southwest of Macdonaldton.
26. Outcrop on secondary road, 2.3 miles north of Rasler Run.
27. Railroad cut on Baltimore and Ohio Railroad, 1,000 feet southwest of Indian Head.
28. Exposure along Youghiogheny River, 2 miles west of Mill Run.
29. Roadcut on Pennsylvania Route 381, 1 mile northeast of Ohiopyle.
30. Roadcut at Cucumber Falls, near Ohiopyle.
31. Strip mine on Meadow Run, 1.75 miles south of Ohiopyle.
32. Strip mine on Meadow Run, 2 miles south of Ohiopyle.
33. Roadcut at King's Bridge on Pennsylvania Route 653, 2 miles west of New Lexington.
34. Strip mine 1 mile east of Acosta.
35. Roadcut at Bando.
36. Railroad cut on Western Maryland Railroad at Rockwood.
37. Railroad cut at west end of Shoofly Tunnel on Baltimore and Ohio Railroad, 0.75 mile east of Fort Hill.
38. Strip mine 0.7 mile west of Shanksville.
39. Strip mine 5.2 miles southeast of Garrett.
40. Old underground mine, 1 mile north of Hoblitzell.
41. Old underground mine at Pennsylvania-Maryland State line, 2 miles west of Ellerslie.
42. Strip mine on Ferguson Run, 1 mile southeast of Ferguson (off map).
43. Old strip mine 3 miles east of Lemont Furnace (off map).
44. Exposure 0.5 mile southwest of Normalville.
45. Railroad cut near Baltimore and Ohio station and roadcut on Pennsylvania Route 711 at Ohiopyle.
46. Exposure on Laurel Run, 1.8 miles south of Ohiopyle.
47. Railroad cut on Western Maryland Railroad at Huston, 2 miles northwest of Confluence.
48. Railroad cut on Western Maryland Railroad across the river from Fort Hill.
49. Strip mine 3.5 miles southeast of Fort Hill.
50. Roadcut 1 mile northeast of Friendsville (off map).
51. Strip mine 3.5 miles south of Rockwood.
52. Old strip mine on Tarkiln Run, 3.5 miles southwest of Grantsville.
53. Roadcut on Paint Creek, 3 miles east of Windber.
54. Old strip mine 0.75 mile east of Macdonaldton.
55. Old underground mine at Williams, 1.5 miles southeast of Fairhope.
56. Old underground mine 0.5 mile south of Williams.
57. Old underground mine and strip mine on east slope of Big Savage Mountain, 1.25 miles north of U.S. Route 40.
58. Exposure 2 miles southwest of Normalville.
59. Exposure 3 miles north of Bakersville.

lacks flint clay, its potassium content is high, and it is relatively thin.

The best exposure of the Brookville clay is near the Baltimore and Ohio Railroad station at Ohiopyle. At this locality (loc. 45, pl. 1), 5 feet of semiflint and plastic clay is exposed in the railroad cut. About 3 feet of semiflint and plastic Brookville clay is exposed along the Western Maryland Railroad at Huston (loc. 47), 2 miles northwest of Confluence.

CLARION UNDERCLAY BED

The Clarion (Mount Savage) clay bed has a stratigraphic position 10–30 feet above the Brookville. Twenty-nine samples of this clay were collected from 16 localities (table 1; pl. 1). The bed averages almost 5 feet in thickness and contains more flint clay than any other type of clay. Quartz is present as silt in many samples; however, a few samples are completely free of quartz. On the basis of the samples collected, this clay bed has an average of 59 percent SiO_2, 26 percent Al_2O_3, and 1.6 percent K_2O. The thickness and abundance of flint clay make the Clarion underclay economically the most important clay in the area.

The clay is currently mined by General Refractories Co. at two localities on Negro Mountain—about 3.5 miles south of Rockwood (loc. 51) and on the west slope near Fort Hill (loc. 49), Somerset County. The Clarion clay bed was mined by Kaiser Refractories and Chemical Co. on the east slope of Big Savage Mountain near the Allegany-Garrett County line, about 2.5 miles west of Mount Savage, Md. (loc. 57), and by Harbison-Walker Refractories Co. on Tarkiln Run, about 3.5 miles southwest of Grantsville, Garrett County, Md. (loc. 52). Other areas where the Clarion clay has been mined are at Williams on Wills Creek, Somerset County (loc. 55); at Glade City, 1.5 miles east of Meyersdale, Somerset County; near Macdonaldton, 3 miles east of Berlin, Somerset County (loc. 54); and on Chestnut Ridge, about 3 miles east of Lemont Furnace, Fayette County (loc. 43).

LOWER KITTANNING UNDERCLAY BED

The Lower Kittanning clay bed is approximately 40–50 feet above the Brookville and underlies one of the most extensively mined coal beds in the area. Twenty-three samples of this clay were collected from 17 localities (table 1; pl. 1). The clay bed averages 4 feet in thickness and contains more plastic clay than flint or semiflint clay. Quartz is present as silt in most samples, and siderite is present in a few samples. The Lower

Kittanning clay has an average of 58 percent SiO_2, 25 percent Al_2O_3, and 2.1 percent K_2O. The slightly higher amount of potassium in this clay, compared with the Clarion clay, is a reflection of the abundance of the plastic-type clay. Although the Lower Kittanning clay bed may locally be as thick as the Clarion clay bed, it contains large amounts of plastic clay and, consequently, is economically less important than the Clarion bed.

The Lower Kittanning clay bed is presently being mined about 2 miles south of Ohiopyle, Fayette County, by both Harbison-Walker Refractories Co. and Kaiser Refractories and Chemical Co. (locs. 31, 32). In this area, both companies are removing approximately 100 feet of overburden to mine 6 or 7 feet of clay. On the east flank of Negro Mountain about 6 miles west of Meyersdale (loc. 39), Lower Kittanning clay is mined and shipped to the Mount Savage Refractories Co. plant at Mount Savage, Allegany County, Md. In Somerset County, 0.7 mile west of Shanksville (loc. 38), Lower Kittanning flint clay is mined and shipped to Hiram Swank's Sons plant in Johnstown, and until recently, this same company operated an underground mine at Hollsopple. Another old underground mine in the Lower Kittanning clay bed is on Little Allegheny Mountain at the Pennsylvania-Maryland State line, about 2 miles west of Ellerslie (loc. 41).

MIDDLE KITTANNING UNDERCLAY BED

The Middle Kittanning clay bed is approximately 20–30 feet stratigraphically above the Lower Kittanning bed. This clay bed is not well exposed; as a result, only one sample was collected (table 1; pl. 1). At the few places where I observed the clay, it was very plastic, and I considered it to have very poor heat-resistant properties. The Middle Kittanning clay bed averages about 3 feet in thickness and does not have any economic potential as a high-grade refractory product.

UPPER KITTANNING UNDERCLAY BED

The Upper Kittanning clay bed has a stratigraphic position about 45–60 feet above the Lower Kittanning bed. Fourteen samples were collected from 12 localities (table 1; pl. 1). The clay averages a little more than 2 feet in thickness, and plastic clay is more abundant than flint or semiflint clay. Quartz is present as silt in all samples, and in five samples the silt is sufficiently abundant to make the clay very silty. The Upper Kittanning clay has an average chemical composition of 58 percent

SiO_2, 25 percent Al_2O_3, and 2.2 percent K_2O. The amount of potassium is a reflection of the amount of plastic clay present in the bed.

Upper Kittanning semiflint clay is mined from a strip pit along the Mud Pike, about 2 miles east of Bando (loc. 17), and is shipped to the Mount Savage Refractories Co. plant at Mount Savage, Allegany County, Md. General Refractories Co. mined a few tons of flint clay from the same bed at a strip pit near Silbaugh, about 5 miles southeast of Confluence or 1.3 miles east of Beachly, Somerset County (loc. 20). The Upper Kittanning is well exposed at the east end of Pinkerton Tunnel on the Baltimore and Ohio Railroad (loc. 19) and in an old underground mine on Pennsylvania State Route 53, 0.5 mile south of Beachly or 1.2 miles north of Listonburg (loc. 21).

LOWER FREEPORT UNDERCLAY BED

The Lower Freeport clay bed has a stratigraphic position approximately 80–110 feet above the Lower Kittanning bed. This bed was observed at only two places in the area. In a roadcut 1.5 miles northeast of Ohiopyle (section extending between locs. 29 and 3, pl. 1), the Lower Freeport clay is 2 feet thick, and in a roadcut at Cucumber Falls (loc. 30, pl. 1), the clay is 4 feet thick. Clay from this bed has not been mined. Judging from the physical appearance of the clay at these two localities, it is probably too thin to mine. It appears to have poor heat-resistant properties though no samples were taken from this clay bed.

BOLIVAR CLAY BED

The name Bolivar was first applied to clay mined in the vicinity of the town of Bolivar in northeastern Westmoreland County, Pa. During the past 100 years, the name Bolivar has been variously applied to several different beds by past workers. Waagé (1950, p. 147) and Flint (1965, p. 190) used the term Bolivar interchangeably with Upper Freeport clay, which lies immediately below the Upper Freeport coal bed. However, I prefer the usage of Hickok and Moyer (1940, p. 75) and Shaffner (1958, p. 30); they placed the Bolivar about 20–50 feet below the Upper Freeport coal. The Bolivar clay bed is stratigraphically about 120 feet above the Lower Kittanning; however, it is lenticular and is very often missing, particularly in Somerset County. Twelve samples of clay were taken from four localities in the study area. The clay bed has an average chemical composition of 60 percent SiO_2, 25 percent Al_2O_3, and 1.4 percent K_2O. The flint clay is slightly more abundant than the plastic or semiflint clay. Quartz is present in all samples and is so abundant in three that the clay is silty.

The Bolivar clay bed has been extensively mined around Bolivar, Westmoreland County, for more than 100 years, and the deposits are now virtually exhausted. The clay also has been mined on a small scale about 2 miles west of Mill Run, Fayette County, along the Youghiogheny River (loc. 10), where more than 17 feet of clay is exposed in a strip mine. Other exposures of Bolivar clay are in a roadcut 1 mile north of Kaufmann or 2 miles south of Mill Run (loc. 11) and in a pit along the Pennsylvania Turnpike near Clear Run or 7 miles west of Somerset interchange, where 10–12 feet of silty plastic clay can be seen.

UPPER FREEPORT UNDERCLAY BED

The Upper Freeport clay bed is stratigraphically approximately 140–180 feet above the Lower Kittanning coal bed and directly underlies the Upper Freeport coal bed. Nine samples of clay were collected from nine different localities (table 1; pl. 1). The clay bed averages about 3 feet in thickness and contains an average of 60 percent SiO_2, 21 percent Al_2O_3, and 2.6 percent K_2O. The amount of K_2O indicates that the Upper Freeport bed is predominantly a plastic clay. Quartz is present in all samples and is abundant enough in all but two to make the clay silty. The Upper Freeport clay bed probably could not be exploited profitably because it contains too much silt and lacks flint or semiflint clay.

ORIGIN OF THE UNDERCLAY

Several theories on the origin of underclay have been suggested by various authors: Derivation of colloidal material from an area of lateritic weathering and deposition in swamps (Bolger and Weitz, 1952, p. 89; Burst, 1952, p. 143); alteration of volcanic ash beds (Seiders, 1965, p. D53); and leaching of fine-grained sediments in acid swamps (Patterson and Hosterman, 1962, p. 80).

Detailed sampling and analysis of several clay beds were done to determine if the beds showed meaningful and systematic variations in chemical and mineralogical composition that might be helpful in explaining the genesis of the underclay deposits. The Bolivar clay was sampled at an old underground mine about 2 miles west of Mill Run, Fayette County, along the Youghiogeny River (loc. 10), where the bed is more than 17 feet thick and is composed of interbedded flint, semiflint, and plastic clay. The Upper Kittanning bed was sampled in a strip mine high wall on the east slope of Negro Mountain about 5 miles northwest of Meyersdale or 4.5 miles southwest of Garrett, Somerset County (loc. 24); here the bed is only 2.5 feet thick and is composed of flint clay. The Lower Kittanning was sampled in a roadcut at Kings Bridge on the Mud Pike, Somerset County (loc. 33), where the clay is all plastic and is 5 feet thick; it was also sampled in a coal strip mine 1 mile east of Acosta, Somerset County (loc. 34), where it contains 6 feet of plastic clay. None of these sets of samples showed any systematic increase or decrease in amount of SiO_2 or Al_2O_3 from top to bottom of the bed nor was there any uniform change in the clay mineralogy in the vertical section. The Clarion bed was sampled at the old underground mine at Williams, Somerset County (loc. 55), where it consists of 2 feet of plastic clay underlain by 3 feet of flint clay. Two sets of samples were collected at this locality, and both showed an increase in Al_2O_3 and a decrease in SiO_2 and K_2O from top to bottom of the bed. Also, the amount of kaolinite increased and the amount of illite decreased from top to base of the bed. These variations within the bed may be fortuitous. Low-quality plastic clay overlying high-quality flint clay contributes to the variations mentioned above; however, as shown on table 1, at different localities, plastic clay occurs both above and below the flint clay and is never constant in its relative position to flint or semiflint clay. Therefore, it seems unlikely that the underclays represent a soil profile or a residual accumulation from weathering in place.

The presence of root fossils, the absence of a soil profile or weathering profile, the lack of bedding, the intimate association with overlying coal beds, and the marine or brackish-water fossils in the enclosing black shales suggest that the clay was deposited in coastal swamps and lagoons. The mineralogical and chemical compositions indicate that the underclays were formed in low-gradient swamps whose acidic and reducing environments altered the ordinary fine-grained sediments of Pennsylvanian age. This hypothesis is supported by the observations of Schultz (1958, p. 363, 377–378) and of Patterson and Hosterman (1962, p. 79). Theoretically, alteration of clay by leaching takes place shortly after deposition but before burial by overlying sediments. The three types of underclay—plastic, semiflint, and flint—appear to represent progressive stages in the leaching process. The juvenile or unaltered underclay is the plastic type and is composed of poorly crystalline kaolinite, M*d* illite,[2] and mixed-layer clay minerals. The amount and degree of crystallinity of kaolinite increases successively from plastic to semiflint to flint clay. Conversely, the amount of illite and mixed-layer clay decreases. Quartz is present in all types of clay as silt or very fine sand and ranges in amounts from a minute trace to 50 percent. According to the leaching theory, kaolinite recrystallizes and forms concurrently with the removal of alkalies, iron, and silica from the illite and mixed-layer clay (Patterson and Hosterman, 1962, p. 80–81). Also, if the leaching process is sufficiently intense or long lasting, almost all the silica from quartz is leached, and diaspore and boehmite are formed as a result of silica being removed from kaolinite.

CONCLUSIONS

The economic potential of the underclay beds in the Allegheny Group in Somerset and eastern Fayette Counties does not seem as favorable as that of the Mercer clay bed of central Pennsylvania or the Olive Hill clay bed of northeastern Kentucky. Both the Mercer clay and the Olive Hill clay, which occur in the Pottsville Group of Early Pennsylvanian age, are composed of fairly continuous beds of quartz-free flint and semiflint clay (Pennsylvania Geological Survey, 1964; Hosterman, 1963). The underclay beds of the Allegheny Group, however, contain considerable quartz silt, and flint and semiflint clay occur in discontinuous lenses and pods intercalated in much plastic clay. An additional economic factor is that the Commonwealth of Pennsylvania is planning to restrict mining in the vicinity of Laurel Hill because this area is scheduled for development into a recreational area. There are, however, reserves of silty flint and semiflint clay available throughout Somerset and eastern Fayette Counties that should be sufficient to supply the declining market of high-grade refractory clay products. The best clay beds for future exploitation are Clarion, Lower Kittanning, Upper Kittanning, and Bolivar.

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[2] The term "1M*d*" is commonly used in the literature. The author, however, prefers to use M*d* because it represents disordered stacking of the unit cell in which the random stacking can be one, but it can also be more than one.

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