UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

Lithium in flint clay, bauxite, related high-alumina materials and associated sedimentary rocks in the United States--A preliminary survey

By

Harry A. Tourtelot and Elizabeth F. Brenner-Tourtelot

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Introduction

Potential great increase in the demand for lithium for use in batteries (Chilenskas and others, 1976) and for fusion power (Bogart, 1976), as well as for conventional uses, caused the U.S. Geological Survey in 1974 to begin an intensive assessment of the lithium resource potential of sedimentary rocks. Much of the sampling effort has been concentrated on evaporite-rich playa sediments in the western United states and volcanic-rich lacustrine and fluviatile sedimentary sequences that are of Cenozoic age and that might contain hectorite, a lithium-bearing smectite (Brenner-Tourtelot and others, 1977; Vine and Brenner-Tourtelot, 1977).

Spectrographic analyses of kaolinitic underclays and associated shales from Pennsylvania showed that these materials also commonly contain more than 100 parts per million (ppm) lithium. This amount is large compared to a generally accepted average abundance for lithium in clayey rocks of about 70 ppm (Heier and Billings, 1972, p. 3-k-1). Some of the underclay samples contain as much as 300 ppm lithium. The flint clay from Clearfield Count, PA, in the National Bureau of Standards, standard sample no. 97 contained almost 1,100 ppm lithium (National Bureau of Standards, 1951,1955). These data led to a preliminary sampling of flint clays in western Pennsylvania which yielded several samples containing about 900 ppm lithium and one containing 1,400 ppm (H. A. Tourtelot and Meier, 1976).

Consequently, samples of kaolinite and other high-alumina materials were solicited from colleagues and companies. In addition, working and abandoned clay pits, company stock piles, and outcrops were sampled in the refractory clay districts of Pennsylvania, Kentucky, and Missouri. The resulting body of data, although obviously incomplete with respect to all the refractory clay districts in the United States (fig.

1), gives an overview of the occurrence of lithium in

Figure 1 near here

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flint clay, bauxite, related high-alumina materials, and associated sedimentary rocks that is useful in assessing the potential of such rocks as a lithium resource.

The analyses are presented here to provide the basis for discussion of the occurrence of lithium in these rocks in a paper of the same title to be presented at "LI-77," a Symposium on Lithium Needs and Resources. This symposium, the second devoted to lithium (Vine, 1976), is to be held at the Corning Glass Center, Corning, NY, in October 1977 under the joint sponsorship of the Corning Glass Works and the U.S. Geological Survey.

Data

The lithium analyses, rock descriptions, and localities for all samples are presented in tables 1 thgough 4. Table 1 lists samples of flint clay, bauxite, and

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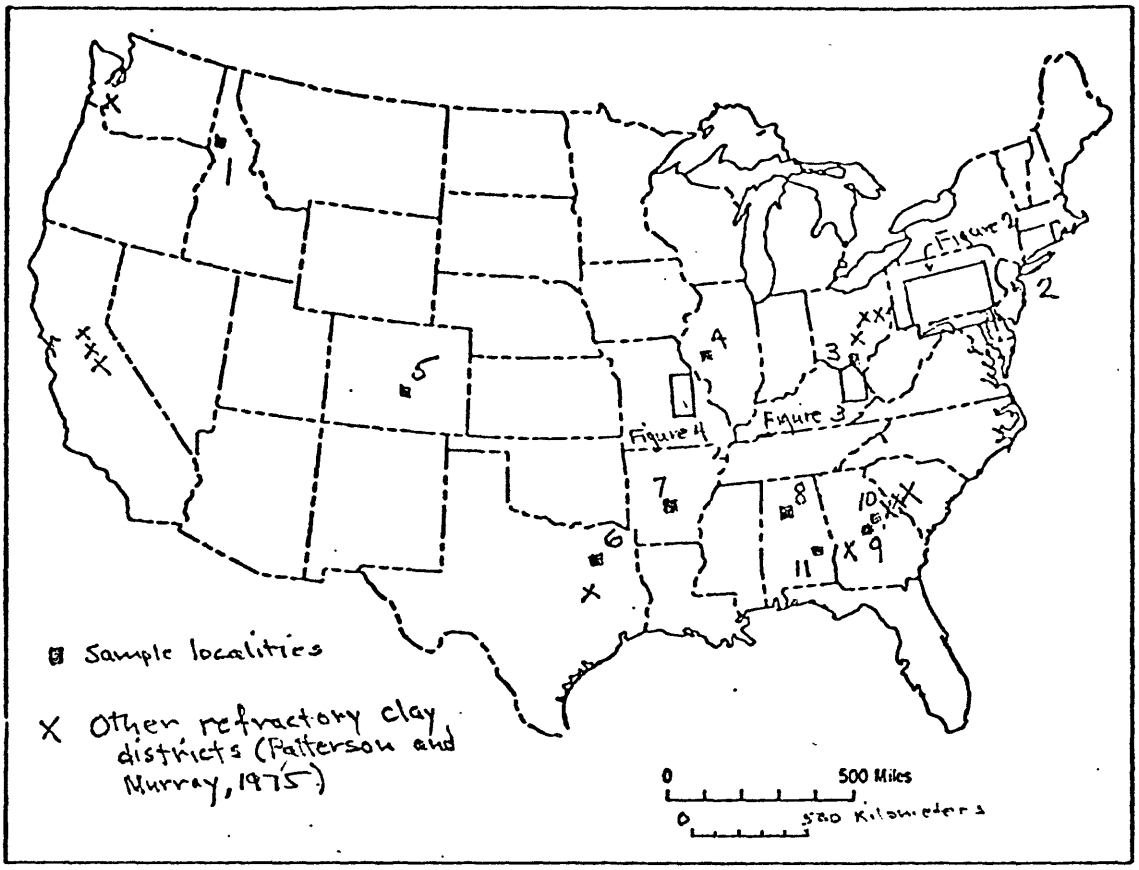
related high-alumina materials supplied by colleagues and companies. Most of the samples represent deposits currently being worked; others come from deposits previously worked but now abandoned, and some come from outcrops. Location data on the samples in table 1 are those that accompanied the samples and are very generalized. Tables 2, 3, and 4 report data on samples collected by H. A. Tourtelot in Pennsylvania, Kentucky, and Missouri, respectively.

Tables 2, 3, and 4 and figures 2, 3, and 4 near here

Rock descriptions of all samples in tables 2, 3, and 4 are based on field examinations supplemented by hand-lens observations in the laboratory on dry, clean, broken, or sawed surfaces. Locations of samples are given in terms of the Universal Transverse Mercator



FIGUTR 1. Map showing localities from which samples of flint clay, bauxite, and related materials were supplied by companies and individuals. The locations of figures 2, 3 and 4, and the location of other refractory clay districts also are shown. See Table 1 for lithium analyses.

TABLE 1. Lithium analyses of samples of flint clay, bauxite, and related high-alumina materials from various states

[See fig. 1 for location of all samples except those from Pennsylvania, the locations of which are shown on fig. 2. Lithium analyses made with atomic absorption methods by Mary C. Coss for the Arkansas samples and by A. L. Meier for all others. Samples from Arkansas supplied by Charles G. Stone, Arkansas Geological Commission, Little Rock, AR. The field numbers for these samples are preceded by TSAR and the laboratory numbers by MAP. Samples from Fayette and Somerset Counties, PA supplied by J. W. Hosterman, U. S. Geological Survey, Reston, VA; see Hosterman, 1963 for further information. Samples with field numbers ending in A represent the less-than-4-micrometer size fraction separated from the whole sample. Field numbers from 67 to 69 and from 140 to 141 are suffixed by -JH-66, as in 67-JH-66. All other field numbers are suffixed by -JH-67; laboratory numbers are preceded by MAP. Samples from Twiggs and Wilkinson Counties, GA with G field numbers, which are complete as they stand, were supplied by R. B. Hall, U. S. Geological Survey, Denver, CO; laboratory numbers are preceded by MAH. All other samples were supplied by the companies indicated. Field numbers for the samples from the Beulah mine, Pueblo Co., CO are complete as they stand; laboratory numbers are preceded by MAP. All other field numbers are preceded by T076 and laboratory numbers by MAS.]

Localities and Samples	Map Number	Field Number	Lab. Number	Lithium (ppm)
Latah Co., ID				
Latah City, ID, A. P. Green Refractories Co.	1			
Clay, very sandy; seems to be disintegrated igneous rock		ID89	504	64
Troy, ID, A. P. Green Refractories Co.	1			
Clay, light tannish gray; somewhat layered		ID90-1A	502	3
Clay, very sandy and micaceous		ID90-1B	496	23
Middlesex Co., NJ				
Woodbridge, NJ, A. P. Green Refractories Co.	2			
Clay, light gray to white, fragmental. "No. 1 fine"		NJ92-1	495	180
Clay, red and green mottled; "No. 1 red fat"		NJ92-2	505	110
Scioto Co., OH				
Sciotoville flint clay, Oak Hill, OH, A. P. Green Refractories Co.	3			
Clay, gray		OH93-1	506	660
Clay, gray; Wellston clay		OH93-2	511	150
Grundy Co. IL				
Morris Plant, A. P. Green Refractories Co.	4			
Clay, gray; "Laole clay"		IL91-1	497	160
Clay, greenish gray and gray; contains siderite pellets. "grundite"		IL91-2	499	27
Pueblo Co., CO				
Rock Creek mine, A. P. Green Refractories Co.	5			
Clay, dark gray, silty and sandy		C087-1	493	180
Flint clay, gray, fragmental; contains thin streaks of silt		C087-2	509	270

TABLE 1. Lithium analyses of samples of flint clay, bauxite, and related high-alumina materials from various States--continued

Localities and Samples	Map Number	Field Number	Lab. Number	Lithium (ppm)
Pueblo Co., CO -cont				
Beulah mine, General Refractories Co.	5			
North pit; samples represent 6 ins				
Flint clay, gray		N1	448	350
---do---, slightly splintery		N2	443	335
---do---		N3	457	330
Flint clay, gray; has marked conchoidal fracture		N4	446	340
---do---		N5	450	345
---do---		N6	431	370
---do---, slightly fragmental		N7	434	360
---do---		N8	456	335
Flint clay, dark gray, sandy		N9	433	275
Flint clay, dark brownish gray, very sandy		N10	441	175
South pit; samples represent 6 ins				
Flint clay, gray, silty		S1	451	300
---do---		S2	455	330
---do---		S3	437	305
---do---, silty and sandy		S4	435	315
---do---		S5	447	300
---do---		S6	453	320
---do---		S7	445	320
---do---		S8	452	290
---do---		S9	438	300
Flint clay, very sandy		S10	458	260
---do---		S11	454	250
---do---		S12	444	230
Hopkins Co., TX				
Sulphur Springs area, A. P. Green Refractories	6			
Clay, gray. "Lacey clay"		TX94-1	507	64
Clay, gray. "Lacey clay, high duty"		TX94-2	503	51
Saline Co., AR				
Old Section 14 mine, Alcoa Aluminum Co.	7			
Clay, white		1a	462	200
Clay, bauxitic		1B	463	210
Clay, white, plastic		2A	464	130
Clay, sideritic		2B	465	48
Bauxite?		3	466	125
Clay, yellowish gray		4A	467	270
Clay, gray, very plastic		4B	468	88
Sec. 11 mine, Alcoa Aluminum Co, "Hattie Hole"	7			
Shale, dark gray, lignitic		5A	469	50
Clay, white; interbedded with 5A		5B	470	69
Bauxite		6A	471	90
Bauxite, reddish gray		6B	472	140
Bauxite, kaolinitic		6C	473	71
Bauxite, granite-textured. Sec. 16		7A	474	190
---do---, yellowish gray		8B	475	370
Syenite, coarsely crystalline		8	476	32

TABLE 1. Lithium analyses of samples of flint clay, bauxite, and related high-alumina materials from various States--continued

Localities and Samples	Map Number	Field Number	Lab. Number	Lithium (ppm)
Saline Co., AR -cont				
Sec. 20 mine, Alcoa Aluminum Co.	7			
Bauxite, gray, pisolitic, very hard		9A	477	42
Bauxite, yellowish gray		9B	478	22
Bauxite, gray, clayey		9C	479	460
Bauxite, white, kaolinitic		9D	480	360
New Sec. 21 mine, Alcoa Aluminum Co.	7			
Sand and clay, lignitic		10	481	45
Bauxite, gray, very kaolinitic		11A	482	340
Bauxite		11B	483	46
---do---		11C	484	25
Mud, brown; from tailings		12	485	62
Pit E-32, Reynolds Metals Co.	7			
Bauxite		13A	486	210
Siderite? nodule		13B	487	61
Bauxitic clay		13C	488	160
Clay, greenish gray		14	489	88
Clay, gray		15A	490	120
Clay, gray, sandy		15B	491	32
Clay, kaolinitic		16	492	130
West 22 pit, Reynolds Metals Co.	7			
Bauxitic clay		17A	493	230
Bauxitic clay		17B	494	240
Clay, lignitic		18	495	180
Bauxite, conglomeratic		19	496	130
Pit RH-1, Reynolds Metals Co.	7			
Wood, lignitic; embedded in bauxite		20	497	5
Clay, gray, nonplastic		21A	498	160
Bauxite, gray, pisolitic, clayey; "high silica"		21B	499	105
Clay-siderite concretions in bauxite zone		22	500	71
Bauxite; from sulfur-rich area in bauxite zone		23	501	120
Pit PO-12, Reynolds Metals Co.,	7			
Bauxite, gray, pisolitic; "high-grade"		24A	502	28
Bauxite, yellow; "high-grade"		24B	503	10
Foreign localities, stock pile, Reynolds Metals Co.	7			
Bauxite from Guyana		25	504	2
Bauxite from Jamaica		26	505	4
Bauxite from Surinam		27	506	2
Near entrance to Aluminum Co. of America plant	7			
Shale, gray; Porters Creek Shale underlying bauxite		28	507	28
Clay pit, Acme Brick Co., Malvern	7			
Clay, gray; lower 12 ft		29A	508	190
Clay, gray, partly lignitic; upper 4 ft		29B	509	84
Clay pit, Malvern Brick and Tile Co., near Malvern	7			
Clay and lignitic clay		30	510	340

TABLE 1. Lithium analyses of samples of flint clay, bauxite, and related high-alumina materials from various States--continued

Localities and Samples	Map Number	Field Number	Lab. Number	Lithium (ppm)
Pulaski Co., AR				
Clay pit, A. P. Green Refractories Co.; near Old Blue Hole	7			
Clay; interbedded with lignite		31	511	115
Stock pile along Ark. Highway 338	7			
Bauxite		32A	512	29
Bauxite nodules		32B	513	5
Clay pit near Woodyardville, A. P. Green Refractories Co.	7			
Clay, gray		33A	514	91
Clay, gray; harder than above		33B	515	67
Walker Co., AL				
Reed property, A. P. Green Refractories	8			
Clay, brownish gray; "Cordova clay"		AL85-1	510	750
Twiggs Co., GA				
Thorpe property, A. P. Green Refractories Co.	9			
Kaolin, yellowish white, soft		GA88-1	500	140
Mine No. 30, J. M. Huber Corp	9			
Kaolin		G5	529	86
Mine No. 38, J. M. Huber Corp.	9			
Kaolin		G6	530	130
Wilkinson Co., GA				
Outcrop 1.5 mi northwest of Freeport Kaolin Co. Research Laboratories	10			
Kaolin, pisolitic		G1	526	49
Clay pit, Freeport Kaolin Co.	10			
Kaolin		G3	527	64
Barbour Co. AL				
Plant stock pile, Eufala, AL, A. P. Green Refractories Co.	11			
Kaolin, white; 40.3-50% Al_2O_3		AL86-1	498	72
Bauxite; 50-57.9% Al_2O_3		AL86-2	501	96
Bauxite; 58.2-68.8% Al_2O_3		AL86-3	494	60
Bauxite; 69-74.5% Al_2O_3		AL86-4	512	37
Bauxite; >85% Al_2O_3		AL86-5	508	46
Fayette Co., PA				
Bolivar Clay (Hosterman loc. 10)	M1			
Clay, plastic; 1.6 ft		54	522	100
---do---; 1.6 ft		55	542	61
---do---, < 4 micrometers		55A	532	87
Clay, semi-flint; 2 ft		56	539	80
---do---, < 4 micrometers		56A	519	72
Clay, flint; 2 ft		57	529	150
---do---, < 4 micrometers		57A	526	170
Clay, flint; 2 ft		58	528	160
Clay, plastic; 2 ft		59	537	54
Clay, flint; 2 ft		60	540	190
Clay, flint; 2 ft		61	533	230
Clay, flint, silty; 2 ft		62	543	120

TABLE 1. Lithium analyses of samples of flint clay, bauxite, and related high-alumina materials from various States--continued

Localities and Samples	Map Number	Field Number	Lab. Number	Lithium (ppm)
Somerset Co., PA				
Lower Kittanning Clay (Hosterman loc. 31)	H2			
Clay, semiflint; 3 ft		67	538	490
---do---, <4 micrometers		67A	518	420
Clay, flint; 4 ft		68	527	170
---do---, <4 micrometers		68A	531	180
Clay, plastic; 1 ft		69	544	43
---do---, <4 micrometers		69A	535	50
Clarion Clay (Hosterman loc. 55)	H3			
Clay, plastic; 1 ft		35	516	88
---do---, <4 micrometers		35A	524	120
Clay, flint; 1 ft		34	530	93
---do---, <4 micrometers		34A	536	140
Clay, flint; 1 ft		33	521	170
---do---; 1 ft		32	534	300
Brookville clay (Hosterman loc. 45; equals T076PA1)	H4			
Clay, semiflint; 1 ft		141	525	390
---do---, <4 micrometers		141A	520	530
Clay, plastic; 4 ft		140	517	360
---do---, <4 micrometers		140A	523	420

TABLE 2. Lithium analyses of samples of flint clay and related materials from Pennsylvania and Maryland

[See fig. 2 for locations. Lithium analyses made with atomic absorption methods by A. L. Meier. Samples collected by H. A. Tourtelot in July 1976. Quadrangle names are those of 7 1/2-minute quadrangle maps. Metric grid refers to the 1000-meter Universal Transverse Mercator grid system shown on the topographic maps. Where both North and East grid figures end in two or more zeros, the numbers were derived from 2-degree maps at a scale of 1/250,000 and consequently are less precise than the other grid figures. Field numbers are preceded by T076PA for samples from Pennsylvania and T076MD for samples from Maryland. Laboratory numbers are preceded by MAS.]

Localities and Samples	Map Number	Field Number	Lab. Number	Lithium (ppm)	Quadrangle	Metric Grid North	Metric Grid East
Clarion Co., PA							
Eckels pit; abandoned	1				Fryburg	4575000	633000
Flint clay, oolitic		33-1	032	370			
---do---upper 10 cm		33-2	049	330			
---do---middle 10 cm		33-3	045	330			
flint clay		33-4	042	380			
Flint clay; fragments have altered rims		33-5	027	440			
Flint clay; oolitic, complexly fragmental		33-6	031	400			
Flint clay, oolitic, fragmental; contains siderite		33-7	024	590			
Flint clay, oolitic, fragmental		33-8	041	510			
Siltstone, shaley; has flint-clay matrix		33-9	025	880			
Diaspore nodule		33-10	048	190			
Jefferson Co., PA							
Oneill pit; abandoned	2				Brookville	4555000	663500
Sandstone, fine-grained, micaceous		32-1	036	49			
---do---; has flint-clay matrix		32-2	068	120			
Flint clay		32-3	053	150			
Sandstone, fine-grained, micaceous; has flint-clay matrix		32-4	055	150			
Flint clay, very micaceous, sandy		32-5	030	190			
---do---sparsely, fragmental		32-6	052	230			
Apatite and flint clay, finely intermixed		32-7	035	150			
Flint clay		32-8	051	390			
Flint clay, oolitic		32-9	083	960			
Flint clay, very sandy		32-10	033	160			
Flint clay, slightly micaceous		32-11	065	210			
Flint clay		32-12	029	1250			
---do---, slightly sandy		32-13	063	560			
---do---, partly fragmental		32-14	057	160			
---do---		32-15	028	210			
---do---		32-16	034	220			
Flint clay, very sandy		32-17	026	200			
Flint clay		32-18	046	420			
Clearfield Co., PA							
Deemer pit, Harbison-Walker Refractories	3				Luthersburg	4445363	698575
Clay, black, hackly; lies between coal and flint clay		24-1A	115	560			
Flint clay		24-1	125	400			
Sandstone, white		24-2	095	24			
Flint clay, fragmental		24-3	087	250			
Clay, flakey to hackly		24-4	154	300			

TABLE 2. Lithium analyses of samples of flint clay and related materials from Pennsylvania and Maryland--continued

Localities and Samples	Map Number	Field Number	Lab. Number	Lithium (ppm)	Quadrangle	Metric North	Grid East
Clearfield Co., PA -cont.							
Deemer pit -cont.							
Sandstone, slabby; has flint-clay matrix		24-5	124	52			
Stockpile for mine							
Flint clay, fragmental		24A-1A	135	290			
---do---		24A-1B	113	210			
---do---		24A-1C	111	180			
---do---		24A-1D	100	190			
Clay, soft		24A-2	109	330			
Deemer pit, North American Refractories	4				Elliott Park	4546713	701850
Flint clay, granular; contains diaspore		26-1A	116	1050			
Flint clay, partly fragmental		26-1B	091	670			
---do---		26-1C	102	490			
Flint clay; contains chamosite		26-1D	155	770			
Flint clay, micaceous		26-1E	072	150			
Flint clay around diaspore nodule		26-2	081	1250			
Flint clay		26-3	090	1200			
---do---; slightly flakey and contains diaspore		26-4	089	1600			
---do---, slightly silty		26-5	114	1750			
Shale, dark gray, silty		26-6	173	74			
Diaspore; inner ring of nodule		26-71C	079	280			
Diaspore; outer ring of nodule		26-71D	074	2050			
Diaspore; porous central part of nodule		26-71E	076	37			
Flint clay; adhering to outer ring of diaspore nodule		26-78	067	1200			
---do---; another piece		26-79	092	1400			
Ralph Korb pit, Harbison-Walker Refractories	5				Luthersburg	4544638	699263
Flint clay; contains oxidized siderite		22-1	129	150			
Clay, massive		22-2	127	780			
Clay		22-3	187	730			
Flint clay, slightly sandy; lower half of 0.6 m bed		22-4A	139	450			
---do---; upper half of 0.6 m bed		22-4B	146	350			
Sandstone; has flint-clay matrix		22-5	103	200			
Shale, dark gray, carbonaceous		22-6	151	450			
Coal		22-7	088	68			
Flint clay; lower third of 0.6 m bed		22A-1	179	460			
Flint clay; middle third of 0.6 m bed		22A-2	140	280			
Flint clay; upper third of 0.6 m bed		22A-3	084	420			
Wise pit, North American Refractories	6				Elliott Park	4543500	699787
Flint clay, black		27-1	108	870			
Flint clay, very dark gray		27-2	059	750			
Flint clay, gray		27-3	064	770			
Flint clay, somewhat fragmental; contains siderite spherules		27-4	043	230			
---do---; contains much pyrite		27-4A	056	34			
Flint clay; only slightly fragmental		27-5	075	670			
Stockpile at NARCO plant, Curwensville, PA							
Clay, gray, plastic		27A-1	150	360			
Clay, gray; harder than above		27A-2	073	160			

TABLE 2. Lithium analyses of samples of flint clay and related materials from Pennsylvania and Maryland--continued

Localities and Samples	Map Number	Field Number	Lab. Number	Lithium (ppm)	Quadrangle	Metric Grid North	Metric Grid East
Clearfield Co., PA -cont.							
Sandstone, clayey		27A-3	051	63			
Clay, gray, plastic		27A-4	119	310			
Bell Run pit, Harbison-Walker Refractories	7				Luthersburg	4543213	696813
Flint clay, partly fragmental		23-1	137	1150			
Shale, dark gray, micaceous		23-2	211	240			
Clay, gray, hackly		23-3	144	950			
Coal, boney		23-4	203	200			
Flint clay?, very carbonaceous		23-5	128	120			
Coal, lower 15 cm; Mercer Bed		23-6	105	31			
Siltstone, dark gray		23-7	035	84			
Slope below Hillcrest Cemetary, Clearfield, PA	8				Clearfield	4544925	715463
Flint clay?, shaley		31	054	120			
I80 road cuts, east Clearfield exit	9				---do---	4546450	718975
Shale, dark gray, very hard		30-1	070	94			
Shale, dark gray, soft		30-2	037	780			
---do---		30-3	039	500			
---do---		30-4	060	660			
Shale, dark gray, carbonaceous		30-5A	071	190			
Shale, dark gray, hackly		30-5	058	70			
Shale, very dark gray		30-6A	044	290			
Shale, gray, flakey		30-6	059	280			
---do---		30-7A	040	77			
Shale, olive gray, flakey		30-7	047	74			
Road cut southeast of bridge at Shawville	10				Lecontes Mills	4549588	721938
Shale, olive gray		29-2	050	81			
Shale, dark gray		29A	052	240			
I80 road cut near Valley Fork	11				---do---	4543725	724438
Siltstone, gray		28-1	056	96			
Underclay		28-2	032	100			
shale, black; lies beneath coal		28-3	077	49			
Clinton Co., PA							
Twin Run pit	12				Howard Northwest	4557000	274438
Flint clay; contains diaspore and siderite		25-1	106	380			
---do---		25-2	090	720			
Flint clay, black, fragmental		25-3A	219	1800			
---do---		25-3B	112	2100			
---do---		25-3C	086	1700			
---do---		25-3D	093	2100			
Flint clay; contains boehmite		25-3E	096	990			
---do---		25-3F	099	630			
Flint clay, black, sparsely fragmental		25-4A	120	2100			
Flint clay, dark gray, partly fragmental		25-4B	122	1000			
shale, black, coaly		25-6	107	130			
Shale, gray, silty		25-7	074	150			
Lackawanna Co., PA							
I81, central Scranton exit	13				Scranton	4587000	421500
Shale, black, micaceous		17-1	143	52			
Shale, dark gray, micaceous		17-2	145	35			

TABLE 2. Lithium analyses of samples of flint clay and related materials from Pennsylvania and Maryland--continued

Localities and Samples	Map Number	Field Number	Lab. Number	Lithium (ppm)	Quadrangle	Metric North	Grid East
Luzerne Co., PA							
I81, 0.5 mi north of Mcosic exit	14				Avoca	4578525	440400
Shale, black, micaceous		18	197	160			
Dump at old pit at east edge Wilkes-Barre	15				Wilkes-Barre East	4566500	429025
Shale, black, micaceous, coaly		19-1	133	300			
Sandstone, dark gray, very micaceous		19-2	175	74			
J33 anthracite pit, J-H Coal Co., Jeddo	16				Hazleton	4538288	475225
Shale below Buck coal bed		21-2	131	22			
Coal, anthracite, Buck bed		21-3	207	9			
Ebervale mine, J-H Coal Co., Ebervale	17				---do---	4536713	419450
Shale, gray, hard, sheared		20-1	141	27			
Shale, cark gray, sandy		20-2	104	32			
Coal, anthracite, lower 30 cm,		20-3	132	15			
Shale, dark gray, sheared		20-4	097	33			
Sandstone, gray, very micaceous		20-5	157	27			
Coal, anthracite, Primrose bed		20-6	134	61			
Carbon Co., PA							
North side of pit southeast of Nesquahoning	18				Nesquahoning	4222500	430700
Shale, black		16-1	142	91			
Coal?, shaley		16-2	098	220			
Shale, Black		16-3	126	37			
---co---		16-4	110	81			
Schuylkill Co., PA							
Abandoned pit, Reading Anthracite Co.	19				Pottsville	4510300	403500
Shale, black		13	185	63			
St. Clair mine, Reading Anthracite Co.	20				---do---	4509900	402000
Shale, black		14	121	76			
Columbia Co., PA							
Abandoned pit just south of Centralia	21				Ashland	4516413	385500
Shale, black, flakey		15	206	35			
Schuylkill Co., PA							
Highway 61 between Pottsville and St. Clair	22				Pottsville	4507000	399900
Shale, dark gray; cut by quartz veins		11-1	174	95			
Shale, dark gray		11-2	205	190			
Siltstone, dark gray		11-3	195	47			
Shale, dark gray, hard, sheared, flakey		11-4	138	79			
Hadesville pit, Reading Anthracite Co.	23				---do---	4508500	398900
Claystone, dark gray, hard		12-1	147	66			
---do---; contains many plant fragments		12-2	164	64			
Sandstone, gray, very micaceous		12-3	136	5			
Shale, black, sheared		12-4	159	65			
Coal, anthracite, Mammoth bed		12-5	123	330			
I81, 1 mi north of Ravine	24				Pine Grove	4493000	381500
Shale, dark gray, very micaceous		10	169	45			
Fayette Co., PA							
Railroad cut at Ohiopyle	25				Ohiopyle	4414525	628800
Clay, gray; lower half of 1.5 m bed		1-2A	212	130			
---do---; upper half of 1.5 m bed		1-2B	186	200			
Clay, gray		1-3	183	320			
Siltstone, dark gray		1-4	218	360			

TABLE 2. Lithium analyses of samples of flint clay and related materials from Pennsylvania and Maryland--continued

Localities and Samples	Map Number	Field Number	Lab. Number	Lithium (ppm)	Quadrangle	Metric Grid North	Metric Grid East
Fayette Co., PA -cont.							
Railroad cut at Ohiopyle -cont.							
Clay, dark gray to black		1-5	214	390			
Coal		1-6	172	4			
Siltstone, gray		1-7	153	78			
Strip pit, Kaiser Refractories Co.	26				Ohiopyle	4410450	629475
Siltstone, gray, slightly micaceous		2-1	181	72			
Clay, dark gray, silty; lower half of 1.5 m bed		2-2A	202	91			
---do---; upper half of 1.5 m bed		2-2B	200	95			
Clay, light gray		2-3	192	86			
Flint clay?, black		2-4	184	180			
Sandstone, very micaceous		2-5	198	10			
Stockpile for mine							
Flint clay, brown, fragmental		2-7B	156	320			
Flint clay, black		2-7C	196	280			
Flint clay, black		2-8	209	200			
Flint clay, black, fragmental		2-9	190	190			
Flint clay, brown, fragmental		2-10	215	170			
Somerset Co., PA							
Ft. Hill pit, General Refractories Co.	27				Markleton	4408225	651438
Clay, light gray		3-1	170	78			
Clay, semi-flint		3-2	177	77			
Siltstone, slightly micaceous		3-3	210	120			
Siltstone, black coaly		3-4	213	72			
Coal		3-5	188	21			
Clay, black, coaly		3-6	208	83			
Coal		3-7	216	50			
Clay, light gray		3A-1	151	160			
Flint clay, grayish-brown		3a-2	176	140			
Clay, light gray		3a-3	171	60			
Garrett Co., MD							
I80, exit 1 mi south of Finzel	28				Frostburg	4392938	674713
Clay, gray		7-1	180	60			
Clay, gray, silty		7-2	168	96			
Flint clay, dark gray		7-3	148	75			
---do---	29				---do---	4392825	674750
Clay, dark gray, hackly		6-1	156	390			
Shale, black, coaly		6-2	101	210			
Clay, gray, hackly		6-3	117	200			
---do---	30				---do---	4392625	674788
Clay, gray, soft		4-1	157	29			
Clay, gray, semi-plastic, silty		4-2	194	60			
Flint clay to semi-flint clay		4-3	130	120			
Clay, light gray, hackly		4-4	199	39			
---do---	31				---do---	4392475	674888
Clay, yellowish gray		5-1	178	82			
Clay, gray, plastic		5-2	118	280			
Clay, gray		5-4	158	17			
Shale, black, coaly		5-5	193	350			
Allegheny Co. MD							
Frostburg exit, I80	32				---do---	4389363	676263
Shale, gray, silty		8	182	29			

TABLE 2. Lithium analyses of samples of flint clay and related materials from Pennsylvania and Maryland--continued

Localities and Samples	Map Number	Field Number	Lab. Number	Lithium (ppm)	Quadrangle	Metric Grid North	Metric Grid East
Garrett Co., MD							
Coal pit 1.2 mi east of top of Backbone Mountain	33				Table Rock	4351300	638975
Shale, dark gray		9-1	191	100			
Clay, gray		9-2	201	130			
Clay, dark gray		9-5	162	110			

TABLE 3. Lithium analyses of samples of flint clay and related materials from Kentucky

[See fig. 3 for locations. Lithium analyses made with atomic absorption methods by A. L. Meier. Samples collected by H. A. Tourtelot in August 1976. Quadrangle names are those of 7 1/2-minute quadrangle maps. Metric grid refers to the 1000-meter Universal Transverse Mercator grid system shown on the topographic maps. Where both North and East grid figures end in two or more zeros, the numbers were derived from 2-degree maps at a scale of 1/250,000 and consequently are less precise than the other grid figures. Field numbers are preceded by T076KY and laboratory numbers by MAS.]

Localities and Samples	Map Number	Field Number	Lab. Number	Lithium (ppm)	Quadrangle	Metric Grid North	Metric Grid East
Greenup Co., KY							
Whetstone Branch outcrops	1				Load	4269700	336100
Shale, olive gray		57-1	470	260			
Flint clay, grayish brown, slabby		67-2	419	390			
Flint clay, light grayish brown, massive		67-3	438	360			
Clay?, olive gray, very silty and sandy		67-4	432	130			
Flint clay, tannish gray, slightly slabby		67-5	453	360			
Allcorn Branch outcrops	2				---do---	4267400	333200
Flint clay?, tannish gray; contains rimmed pellets and carbonaceous clay		66-1	452	230			
Flint clay, yellowish gray; contains many rimmed fragments		66-2	454	230			
Flint clay?, grayish tan, blocky, contains many rimmed pellets		66-3	440	230			
Carter Co., KY							
Burge-Fultz mine	3				Wesleyville	4257225	307700
Flint clay, medium gray, slightly sandy		64-1	475	200			
Shale, dark gray; contains coaly streaks		64-2	438	220			
Flint clay, grayish tan; contains many obscure rimmed pellets		64-3	463	100			
Flint clay, grayish tan, pelletal		64-4A	473	180			
Flint clay, dark gray		64-4B	425	290			
Flint clay?, light olive gray, sandy		64-5	484	230			
Hilger mine, General Refractories Co. Refractories	4				---do---	4256550	306500
Clay, dark gray, plastic		63-1	466	250			
Nodule, phosphatic, clayey?		63-1A	459	40			
Clay, black		53-1B	429	230			
Clay, dark gray, shaley		63-1C	465	230			
Flint clay, light grayish tan; contains minute scattered pyrite		63-2	450	370			
Clay, light olive gray, plastic		63-3	415	430			
Clay, light gray, hard, very sandy		63-4	413	140			
Clay, light olive gray; stained red		63-5	421	160			
Messer mine, Harbison-Walker Refractories	5				Tygarts Valley	4257733	317450
Shale, dark gray		65-1	477	230			
Clay, light gray, semi-hard		65-2	437	220			
Flint clay, tan		65-3	472	180			
Clay, dark gray, shaley		65-4A	430	890			
Clay, olive gray, shaley		65-4B	439	150			
Shale, dark gray, weathering olive		65-6	430	130			

TABLE 3. Lithium analyses of samples of flint clay and related materials from Kentucky--continued

Localities and Samples	Map Number	Field Number	Lab. Number	Lithium (ppm)	Quadrangle	Metric Grid North	Metric Grid East
Boyd Co., KY							
I64 road cut near Rush	6				Rush	4247813	344938
Shale, black, carbonaceous		73-1	491	95			
Clay, light brown, hard		73-2	486	50			
Shale, black, coaly		73-3	407	120			
Flint clay, light brown		73-4	423	53			
Clay, light gray		73-5	455	63			
Flint clay, dark gray		73-6	445	120			
Clay, light brown, silty, micaceous		73-7	443	56			
Clay, gray, slightly sandy		73-8	412	68			
Clay, dark gray, plastic		73-9	420	48			
Carter Co., KY							
Cooper and Carroll mine, General Refractories Co.	7				---do---	4242063	338488
Clay, light gray, very silty		72-1	405	140			
Shale, light grayish green, silty		72-2	441	70			
Clay, gray, plastic		72-3	447	69			
Clay, light gray, plastic		72-4	409	58			
Clay, light tan, slightly silty; contains plant fragments		72-5	437	46			
Shale, tan, silty		72-6	416	53			
Trough Camp pit	8				Olive Hill	4246095	306288
Shale, dark gray		68-1	483	180			
Shale, olive gray, silty; contains siderite and pyrite		68-2	449	240			
Clay, dark gray, semi hard		68-3	457	530			
Flint clay, gray		68-4	464	210			
P. Burchett mine	9				---do---	4240575	298800
Shale, dark gray, silty no		70-1	481	280			
Shale, dark gray to black		70-2	485	370			
Shale, dark tannish gray		70-3	476	580			
Flint clay, gray		70-4	436	750			
Semi-flint clay?, gray		70-5	456	290			
I64 roadcut near Upper Tygart	10				Soldier	4241700	299238
Flint clay, light gray, massive		71-1	468	180			
Flint clay, grayish tan		71-2	482	460			
Shale, gray weathering reddish brown		71-3	414	120			
Shale, black weathering gray no		71-4	424	140			
Shale, black		71-5	461	660			
Flint clay, dark gray		71-6	427	740			
Clay, light gray, semi-hard		71-7	406	600			
Shale, green		71-8	417	69			
Burchett Dry Creek mine	11				---do---	4239000	300438
Shale, dark gray		69-1	442	200			
Shale, dark gray to black		69-2	448	300			
Flint clay, tannish gray, sparsely pelletal		69-3	431	580			
Clay, light gray, plastic		69-4	410	230			
Clay, gray, splotched with red		69-5	426	180			

TABLE 3. Lithium analyses of samples of flint clay and related materials from Kentucky--continued

Localities and Samples	Map Number	Field Number	Lab. Number	Lithium (ppm)	Quadrangle	Metric Grid North	Metric Grid East
Rowan Co., KY							
Abanconed stock pile or dump	12				Haldeman	4232295	287913
Flint clay		74-1	479	500			
Morgan Co., KY							
Outcrop at road tunnel	13				Wrigley	4212488	297800
Flint clay, grayish tan, sandy		81-1	418	520			
Limestone quarries on Licking River	14				Ezel	4205675	289263
Flint clay, grayish brown, slightly carbonaceous		75-1	428	450			
Clay, light grayish tan		75-2	451	350			
Clay, grayish green, very silty		75-3	422	30			
Wolfe Co., KY							
Mountain Parkway road cut near Compton	15				Compton	4180163	272700
Shale, black		80-1	408	100			
Mountain Parkway road cut	16				Landsaw	4180200	286188
Shale, black		79-1	474	36			
Mountain Parkway road cut	17				Cannel City	4181750	291788
Shale, light gray; contains siderite nodules		76-1	460	110			
Flint clay, tannish brown, very fragmental		76-2	458	160			
Clay, greenish gray, slightly silty		76-3	411	140			
Clay, light brownish gray, flaky		76-4	433	160			
Magoffin Co., KY							
Mountain Parkway interchange 30	18				Salyersville South	4177800	314188
Flint clay, Fireclay bed		78-1A	434	110			
---do---		78-1B	446	110			
Highway 114 road cut	19				Ivyton	4176713	325125
Shale, black, carbonaceous, pyritic		77-1	439	53			
---do---, slightly shaley		77-3	462	100			
Clay, dark gray, slightly silty		77-4	459	92			
Shale, black, carbonaceous		77-5	444	150			

TABLE 4. Lithium analyses of samples of flint clay and related materials from Missouri

[See fig. 4 for locations. Lithium analyses made with atomic absorption methods made with A. L. Meier. Samples collected by H. A. Tourtelot in August 1976. Quadrangle names are those of 7 1/2-minute quadrangle topographic maps unless designated as 15-minute maps. Metric grid refers to the 1000-meter Universal Transverse Mercator grid system shown on the topographic maps. Where both North and East grid figures end in two or more zeros, the numbers were derived from 2-degree maps at a scale of 1/250,000 and consequently are less precise than the other grid figures. Field numbers are preceded by T076MO and laboratory numbers by MAS.]

Localities and Samples	Map Number	Field Number	Lab. Number	Lithium (ppm)	Quadrangle	Metric Grid North	Metric Grid East
Audrain Co., MO							
Azdell pit, A. P. Green Refractories	1				Santa Fe	4347250	604825
Clay, ferruginous		36-1	295	230			
Clay, red and brown mottled		36-1	295	230			
Clay, light gray, hard		36-2	302	750			
---do---		36-3	393	760			
---do---		36-4	252	870			
Clay, gray, plastic		36-5	225	240			
---do---		36-6	251	210			
Clay, greenish-gray		36-7	340	89			
Blum pit, A. P. Green Refractories	2				Mexico East	4344325	602763
Sandstone, clayey; bottom of pit		35-1	346	95			
Clay, sandy and silty, slightly ferruginous		35-2	299	280			
Clay, light gray, slightly silty; bottom 1 ft of 4.5 ft		35-3	270	210			
---do---; middle 1 ft of 4.5		35-4	256	200			
---do---; upper 1 ft of 4.5		35-5	232	170			
---do---, slightly ferruginous; top 1.5 ft of 4.5 ft		35-6	400	170			
Clay, dark gray, carbonaceous; forms 1 cm nodules in 3 and 4		35-7	328	100			
Stockpile, North American Refractories (NOT LOCATION OF SAMPLES: SEE BELOW)	3				Perry 15'	4346500	622000
Walters plastic clay							
Clay, dark gray, plastic		41-1A	332	420			
---do---		41-1B	293	360			
---do---		41-1C	263	340			
---do---, sandy		41-1D	394	140			
Weeks flint clay							
Clay, gray		41-2A	231	650			
Clay, purplish gray		41-2B	270	190			
Clay, very dark gray		41-2C	339	460			
Clay, creamy gray		41-2D	222	340			
Wynn burley clay							
Clay, gray, granular, fragmental		41-3A	335	3200			
Clay, light gray, oolitic		41-3B	274	2100			
Clay, gray, pelletal and oolitic		41-3C	358	1600			
Flint clay, calcined		41-4	260	580			
Matthews pit 3, hole 5, ground samples							
5 - 8 ft		41-5A	316	4800			
8 -13 ft		41-5B	277	4000			
13-18 ft		41-5C	240	5100			
18-23		41-5D	265	4100			
23-28 ft		41-5E	253	3000			
28-33 ft		41-5F	364	2300			
33-38 ft		41-5G	313	3200			

TABLE 4. Lithium analyses of samples of flint clay and related materials from Missouri--continued

Localities and Samples	Map Number	Field Number	Lab. Number	Lithium (ppm)	Quadrangle	Metric Grid North	Metric Grid East
Audrain Co., MO -cont.							
Matthews pit 3, hole 9, ground samples							
5 - 8 ft		41-6A	376	650			
8 -13 ft		41-6B	351	810			
13-18 ft		41-6C	255	720			
18-23 ft		41-6D	338	700			
23-28 ft		41-6E	308	590			
28-33 ft		41-6F	374	930			
33-38 ft		41-6G	247	1100			
38-43 ft		41-6H	348	1300			
43-48 ft		41-6I	298	1450			
48-53 ft		41-6J	365	2000			
53-58 ft		41-6K	331	4100			
Clarence Matthews hole 1, core pieces							
Clay, creamy gray; somewhat mottled		41-7A	288	730			
---do---, 8 ft		41-7B	300	710			
---do---, 10 ft		41-7C	267	810			
---do---, 12 ft		41-7D	249	700			
---do---, 14 ft		41-7E	257	640			
---do---, 16 ft		41-7F	229	610			
---do---, 17.9 ft		41-7G	329	600			
Clay, medium dark gray, 18.1 ft		41-7H	221	850			
---do---, 20 ft		41-7I	354	950			
Clay, light gray, 22 ft		41-7J	333	1100			
---do---, 24 ft		41-7K	341	1550			
---do---, 26 ft		41-7L	317	1850			
Miscellaneous localities							
Bauxite, Surinam, calcined		41-8A	251	61			
Flint clay, unknown, calcined		41-8B	383	1000			
Clay, plastic, Ironton, OH		41-8C	366	130			
Sims pit, A. P. Green Refractories	4				Mexico East	4332675	599113
Clay, gray; contains black mottles		34-2	337	240			
Clay, dark gray, carbonaceous		34-3	39	390			
Callaway Co., MO							
Hughes mine, Harbison-Walker Refractories	5				Fulton 15'	4289500	589900
Clay, gray; main bed		42-1	359	240			
Clay, dark gray; lies on top of 1		42-2A	345	240			
Clay, black; forms irregular masses in 1		42-2B	278	400			
Clay, gray		42-3	233	180			
Clay, green; surrounds masses of gray clay		42-3A	387	61			
Clay, gray; surrounds masses of 2B and is surrounded by 3A		42-3B	264	270			
Clay, gray		42-3C	253	330			
Clay, gray, shaley		42-4	378	320			
Shale, grayish green		42-5A	324	82			
Sandstone, sideritic		42-5B	314	19			
Calcite, spherulitic; forms large masses in 1		42-6A	259	71			
Clay, gray; surrounds calcite		42-6B	311	260			

TABLE 4. Lithium analyses of samples of flint clay and related materials from Missouri--continued

Localities and Samples	Map Number	Field Number	Lab. Number	Lithium (ppm)	Quadrangle	Metric Grid North	Metric Grid East
Montgomery Co., MO							
Unknown pit	6				Pinnacle Lake	4303425	632838
Flint clay, creamy gray		62-1	312	260			
Clay, dark gray; mixed with 2B		62-2A	279	220			
Clay, light gray		62-2B	279	220			
Warren Co., MO							
Potthast pit 12, Harbison-Walker Refractories	7				Warrenton	4290525	656138
Flint clay?, creamy gray		44-1	353	100			
Flint clay?, creamy gray with light mottles		44-2	313	200			
Flint clay, light gray, limy; "rough"		44-3	367	230			
Flint clay, light gray		44-4	373	420			
Clay, light gray, soft; "jantz"		44-5	393	1400			
Gerding pit, Harbison-Walker Refractories	8				---do---	4293513	658900
Clay, gray; alkali-rich?		45-1	358	66			
Clay, light gray; "honeycomb"		45-2	391	1200			
Clay, creamy tan; has vague layering		45-3	370	1900			
Truesdale stockpile, Warrenton, MO Not on map.							
Flint clay; "rough"		45A-1	326	560			
---do---		45A-2	291	320			
---do---		45A-3	276	570			
---do---		45A-4	236	870			
---do---; somewhat tinged with green		45A-5	248	1150			
Flint clay		45A-6	287	310			
---do---		45A-7	357	740			
---do---		45A-8	396	980			
Potthast pit, Harbison-Walker Refractories	9				---do---	4290500	656475
Clay, red and purple		43-1	309	390			
Clay, creamy gray		43-2	304	340			
Clay, gray, slightly ferruginous		43-3	402	820			
Clay, creamy gray		43-4	284	300			
Clay, creamy gray and red		43-5	384	410			
Osage Co., MO							
Ochesky pit, abandoned	10				Fredericksburg	4268913	614750
Flint clay, light gray, pelletal		46-1	242	2000			
Flint clay, slabby, pelletal		46-2	283	2200			
Flint clay, massive, pelletal		46-3	330	1150			
Flint clay, very light gray, pelletal, fragmental		46-4	321	1050			
Flint clay, very light gray, very sparsely pelletal and fragmental		46-5	355	2000			
Flint clay, gray, carbonaceous, fragmental		46-6A	239	2700			
Flint clay, carbonaceous, fragmental		46-6B	293	1900			
---do---		46-6C	243	2000			
Flint clay		46-7	220	3100			
Flint clay, dark gray		46-8	386	1800			
Flint clay, gray; contains darker wisps of clay		46-9	398	640			

TABLE 4. Lithium analyses of samples of flint clay and related materials from Missouri--continued

Localities and Samples	Map Number	Field Number	Lab. Number	Lithium (ppm)	Quadrangle	Metric North	Grid East
Osage Co., MO -cont.							
Ochesky pit -cont.							
Clay, brownish red		46-10	232	71			
Road cut 2.5 km south of Ochesky pit	11				Fredericksburg	4266425	615293
Clay, red and buff mottled, very sandy		47-1	362	290			
Gasconade Co., MO							
Stockpile near Swiss, A. P. Green Refractories	12				Swiss	4270363	633020
Flint clay, dark gray, pile 23; "alkali"		61-1	399	3600			
Flint clay, gray, pile 19		61-2	375	300			
Brandhorst pit and stockpile, A. P. Green Refractories	13				Rosebud	4260992	632613
Diaspore; contains more than 68 percent Al2O3		50-1	404	1750			
Diaspore; contains flint clay; 65 percent Al2O3		60-2	382	3100			
Flint clay; contains diaspore; 60 percent Al2O3		50-3	325	2600			
Flint clay, gray, slightly pelletal; contains diaspore; 55 percent Al2O3		60-4	246	3600			
Stock pile near Drake, Kaiser Refractories	14				---do---	4260455	634208
Clay, gray, crumbly		59	369	760			
Posey pit, abandoned	15				Bland 15'	4256685	628717
Flint clay, pelletal; contains diaspore?		39-1	297	1650			
Clay, red, ferruginous		39-2	322	220			
Clay, gray, slightly pelletal		39-3	238	1200			
Unknown abandoned pit, 1 mi northeast of Bueker pit	16				---do---	4255828	628822
Flint clay, slightly sandy		38	259	550			
Bueker pit, abandoned	17				---do---	4255065	627880
Flint clay, creamy gray		37-1A	360	960			
---do---, mottled with darker gray		37-1B	377	630			
---do---, pelletal		37-1C	258	800			
Diaspore?		37-2	294	280			
---do---, pelletal		37-2A	371	1800			
Flint clay, gray, slightly ferruginous, 1.5 m		37-3	344	440			
Flint clay, gray and purple, 0.5 m		37-4	350	360			
Flint clay, yellowish tan, 0.5 m		37-5	318	310			
Clay, grayish green, limy		37-6	272	42			
Edel-Tappmeyer pit, Harbison-Walker Refractories	18				Rosebud	4252375	641180
Flint clay, creamy gray		58-1	381	280			
Flint clay, dark gray; contains sparse tan fragments		58-2	403	1850			
Clay, dark gray to black		58-3	336	2400			
Flint clay		58-4	292	1150			
---do---		58-5	224	1600			
Flint clay, light gray, brecciated?		58-6	397	2200			
---do---; contains siderite		58-7	228	1650			

TABLE 4. Lithium analyses of samples of flint clay and related materials from Missouri--continued

Localities and Samples	Map Number	Field Number	Lab. Number	Lithium (ppm)	Quadrangle	Metric Grid North	Grid East
Gasconade Co., MO -cont.							
Edel-Tappmeyer pit -cont.							
Shale, black, very flakey; exposed in pit floor		58-8	254	250			
Roy Jett pit, Harbison-Walker Refractories	19				Bland 15'	4241078	626867
Flint clay		57-1	271	380			
Flint clay		57-2	339	1600			
Flint clay; contains diaspore? pellets		57-3	319	1050			
Clay, gray, fragmental, soft		57-4A	241	2300			
---do---		57-4B	230	2300			
---do---		57-4C	395	2300			
Flint clay		57-5	342	500			
Osage Co., MO							
Stock pile at Belle, Harbison-Walker Refractories	20				---do---	4239046	613209
Diaspore, very porous; old on pile		48-1A	315	64			
---do---		48-1B	289	120			
Diaspore, somewhat porous; new on pile		48-2	237	1550			
Flint clay, light gray, pelletal		48-5A	327	520			
Flint clay, grayish cream, textureless		48-5B	281	230			
Flint clay, creamy gray, slightly pelletal		48-6	307	520			
Gasconade Co., MO							
Selveridge pit, A. P. Green Refractories	21				High Gate	4232938	619563
Clay, red and white banded		40-1	347	110			
Flint clay, light gray		40-2	303	130			
Clay, light gray; veined with darker		40-3	349	290			
Clay, light creamy gray, textureless		40-4	234	610			
Maries Co., MO							
Wallace pit, Harbison-Walker Refractories	22				---do---	4226670	611280
Flint clay, bottom of working face		56-1	296	280			
---do---, middle of working face		56-2	343	340			
---do---, top of working face		56-3	244	320			
Sandstone; has flint-clay matrix and		56-4	352	100			
Flint clay, red and white zebra-banded		56-5	392	430			
Flint clay, pelletal		56-6	223	710			
Flint clay, slightly sandy		56-7	273	320			
Flint clay, very sandy		56-8	262	120			
Unkown pit, abandoned	23				---do---	4225438	610413
Flint clay, light gray, finely pelletal		55-1	235	1200			
Flint clay, coarsely pelletal		55-2	275	1200			
Flint clay, light gray, fragmental		55-3	335	120			
---do---	24				Safe	4213875	610888
Diaspore?, red		50-1	379	280			
Diaspore?, white		50-2	356	1600			
Unknown pit, abandoned	25				Safe	4212438	614208
Flint clay, light gray, very pelletal		49-1	268	1800			
Flint clay, grayish brown, slightly pelletal		49-2	227	640			

TABLE 4. Lithium analyses of samples of flint clay and related materials from Missouri--continued

Localities and Samples	Map Number	Field Number	Lab. Number	Lithium (ppm)	Quadrangle	Metric Grid North	Grid East
Phelps Co., MO							
Unknown pit, abandoned	26				Safe	4210825	612763
Flint clay, very light gray, textureless		51-1	372	560			
Flint clay, purplish red		51-2	323	180			
---do---	27				---do---	4210675	612913
Flint clay, white, very sandy		52-1	320	120			
Flint clay, red, slightly sandy; has white blotches		52-2	245	150			
Clay, light gray, sandy		52-3	285	120			
Shale, red; in bedrock		52-4	351	32			
---do---	28				---do---	4209375	611000
Flint clay, textureless		53-1	305	1500			
Flint clay, slightly mottled		53-2	388	670			
---do---	29				---do---	4207413	611913
Flint clay, slightly pelletal		54	401	310			

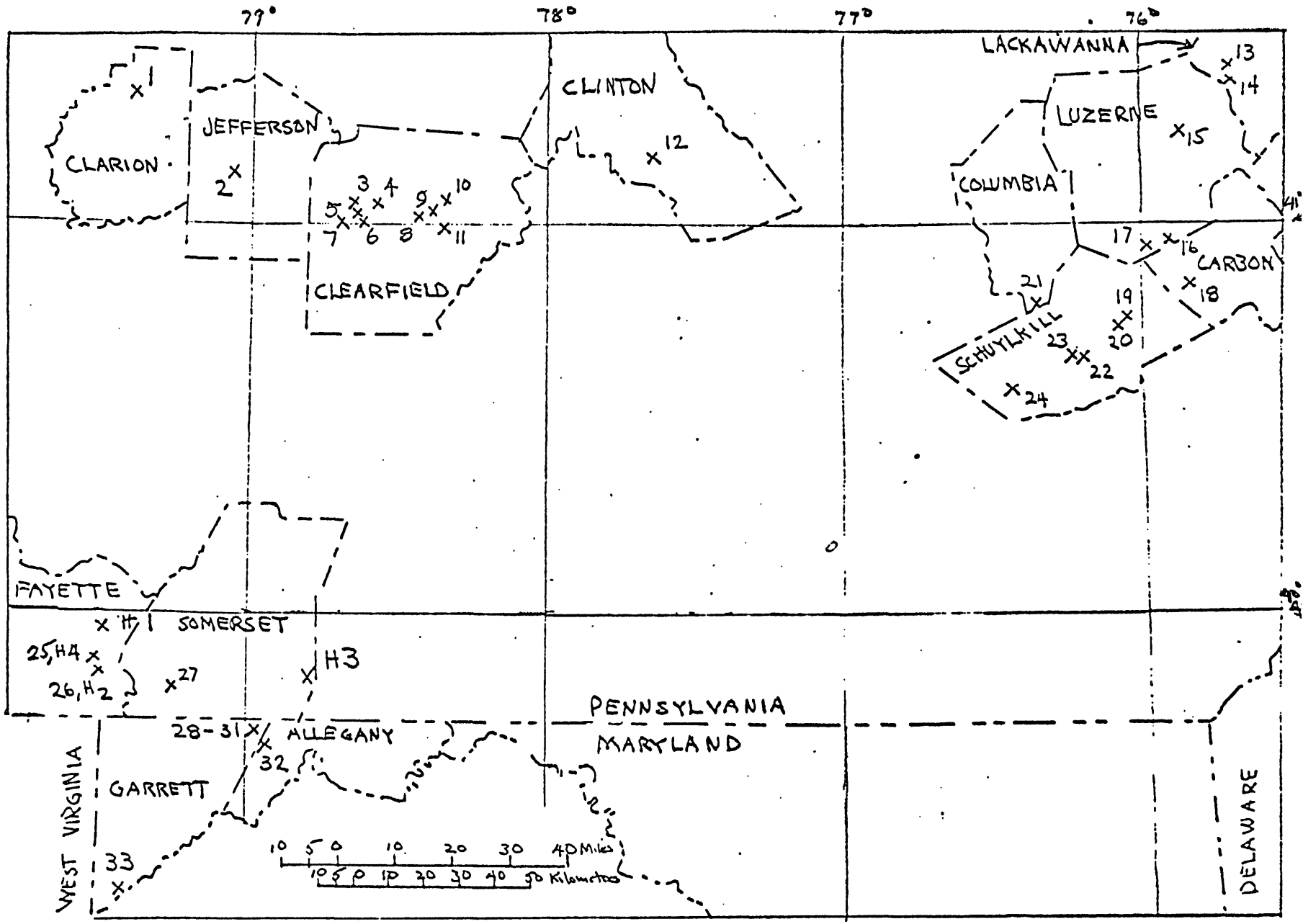


FIGURE 2. Map showing localities in Pennsylvania and Maryland from which samples of flint clay and associated sedimentary rocks were collected. (See fig. 1.) Samples at localities marked H were collected by J. W. Hosterman. See tables 1 and 2 for lithium analyses of all samples and table 5 for spectrographic analyses of selected samples.

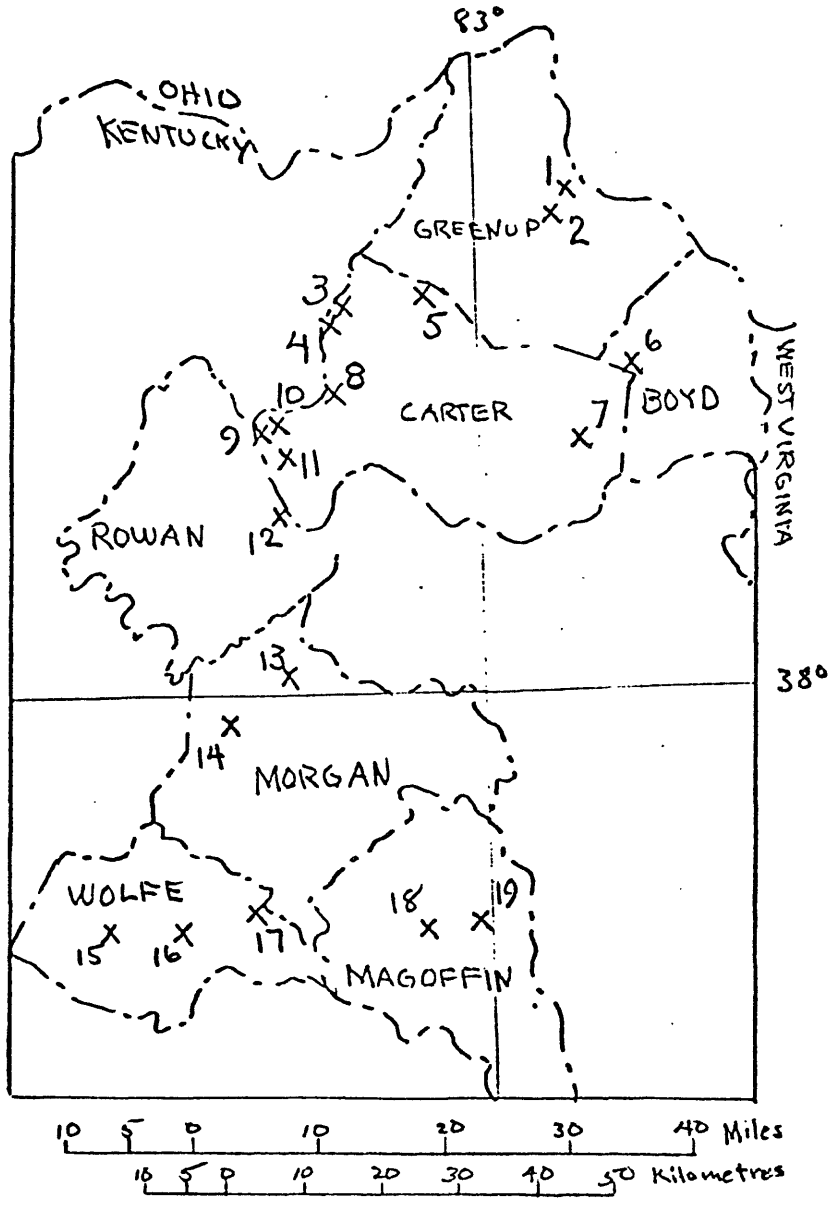


FIGURE 3. Map showing localities in eastern Kentucky from which samples of flint clay and associated sedimentary rocks were collected. (See fig. 1.) See table 3 for lithium analyses of all samples and table 5 for spectrographic analyses of selected samples.

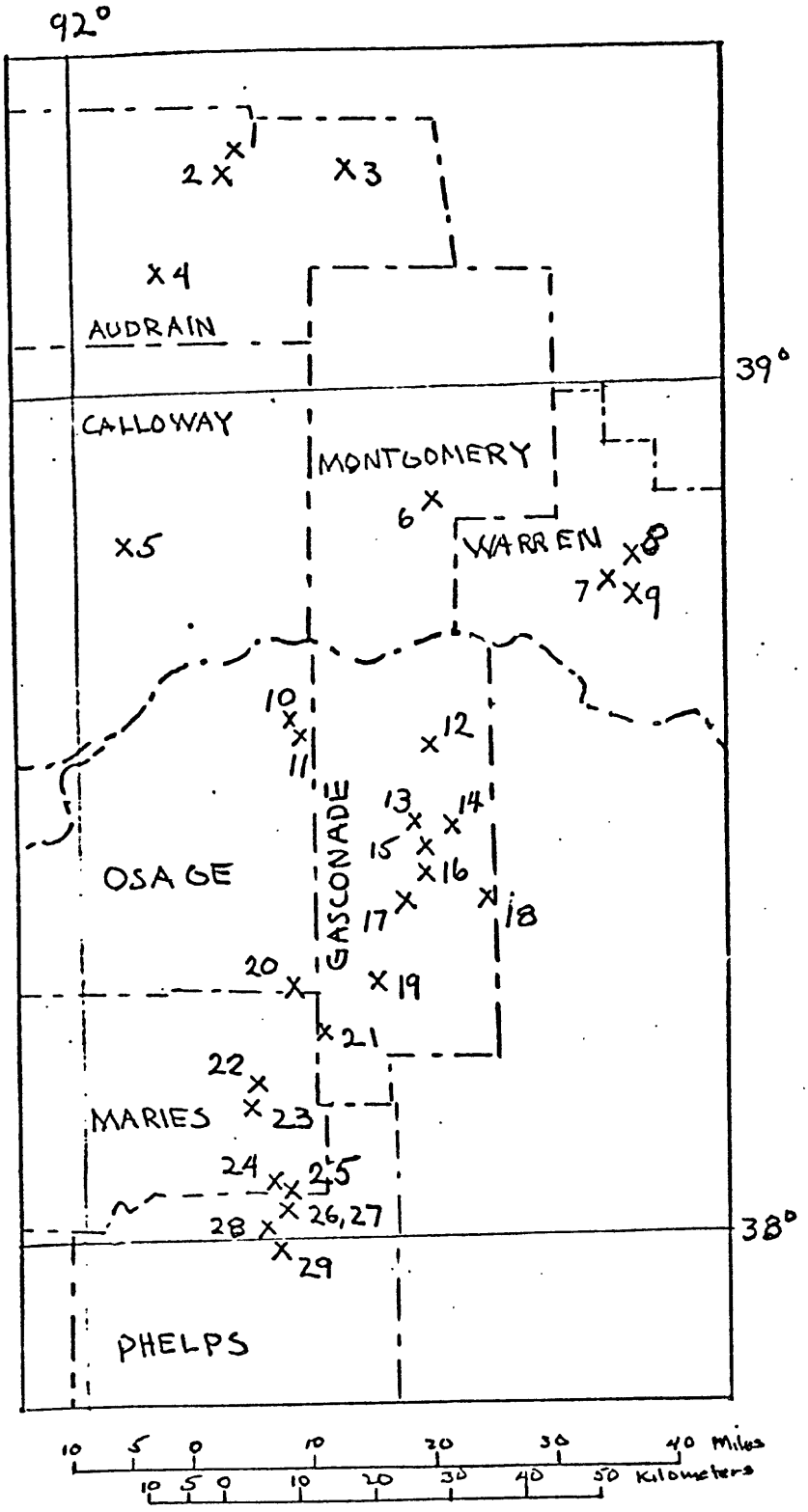


FIGURE 4. Map showing localities in east-central Missouri from which samples of flint clay and associated sedimentary rocks were collected. (See fig. 1.) See table 4 for lithium analyses of all samples and table 5 for spectrographic analyses of selected samples.

TABLE 5. Lithium and 6-step spectrographic analyses of selected samples from Pennsylvania, Kentucky, and Missouri

[Lithium analyses made with atomic absorption methods by A. L. Meier. Spectrographic analyses made by L. A. Bradley. Samples collected by H. A. Tourtelot in July and August 1976. The 6-step spectrographic method is semi-quantatative. Results are to be identified with geometric brackets whose boundaries are 1.2, 0.83, 0.56, 0.38 0.26, 0.18, 0.12, etc., but are reported arbitrarily as mid-points of these brackets, 1., 0.7, 0.5, 0.3, 0.2, 0.15, 0.1, etc. The precision of a reported value is approximately plus or minus one bracket at 68%, or two brackets at 95% confidence. G = Greater than 10 %. N = Not detected. L = Detected, but below limit of determination. See tables 2, 3, and 4 for lithium analyses of related samples and map numbers; see figure 2, 3, and 4 for locations. Sample numbers are field numbers and are preceded by T076 and PA, KY, or MO, as appropriate for each state. Laboratory numbers apply to spectrographic analyses and are preceded by D]

TABLE 5. Lithium and 6-step-spectrographic analyses of selected samples from PA, KY, and MO--continued

SAMPLE	LAB. NO.	Si	%-S	Al	%-S	Ti	%-S	Fe	%-S	Mg	%-S	Ca	%-S	Na	%-S	K	%-S	Li	%-AA
Ft. Hill pit, Somerset Co., PA; General Refractories Co.																			
3 - 1	184544		10.0G		10.0G		0.30		0.7		0.15		0.02		0.50		3.00		0.008
3 - 2	184568		10.0G		10.0G		0.50		0.7		0.30		0.03		0.50		5.00		0.008
3 - 3	184552		10.0G		7.0		0.30		0.5		0.30		0.02		0.30		3.00		0.012
3 - 4	184553		10.0G		7.0		0.50		1.0		0.20		0.02		0.15		1.50		0.007
3 - 6	184562		7.0		7.0		0.20		0.7		0.20		0.02		0.10		1.50		0.008
3A- 1	184536		10.0G		10.0		0.30		0.7		0.50		0.02		0.30		5.00		0.016
3A- 2	184532		10.0G		10.0		0.30		0.3		0.03		0.01		0.05		0.00N		0.014
Dump at old pit, east edge of Wilkes-Barre, Luzerne Co., PA																			
19 - 1	189302		10.0G		10.0		0.30		0.7		0.50		0.02		0.50		3.00		0.030
Ralph Korb pit, Clearfield Co., PA; Harbison-Walker Refractories																			
22 - 1	184529		10.0		10.0G		0.30		1.5		0.15		0.02		0.20		3.00		0.015
22 - 2	184547		10.0		10.0G		0.70		0.7		0.15		0.02		0.50		3.00		0.078
22 - 3	184550		10.0G		10.0G		1.00		0.7		0.20		0.05		0.50		3.00		0.073
22 - 4A	184535		10.0G		10.0		0.30		0.7		0.15		0.01		0.15		1.50		0.045
Bell Run pit, Clearfield Co., PA; Harbison-Walker Refractories																			
23 - 1	189287		10.0		10.0G		1.00		0.7		0.10		0.01		0.15		0.70		0.115
23 - 3	189288		10.0G		10.0G		0.30		1.0		0.30		0.03		0.30		3.00		0.095
Deemer pit, Clearfield Co., PA; North American Refractories																			
26 - 1A	189278		7.0		10.0G		0.50		1.0		0.07		0.01		0.07		0.00N		0.105
26 - 1B	189291		10.0		10.0G		0.30		0.5		0.03		0.07		0.05		0.00N		0.067
26 - 2	189297		7.0		10.0G		0.50		0.7		0.05		0.02		0.07		0.00N		0.125
26 - 3	189299		10.0		10.0G		0.50		0.7		0.10		0.02		0.15		1.00		0.120
26 - 4	189301		10.0		10.0		0.50		1.5		0.15		0.02		0.30		5.00		0.160
26 - 5	189265		10.0		10.0G		0.50		1.5		0.30		0.02		0.50		3.00		0.175
26 -71D	189272		3.0		10.0G		0.70		1.0		0.10		0.01		0.00L		0.00N		0.205
26 -71C	189273		1.5		10.0G		0.70		1.5		0.03		0.02		0.00L		0.00N		0.028
26 -71E	189268		0.3		10.0G		0.70		0.3		0.01		0.01		0.00L		0.00N		0.004
26 -79	189280		2.0		10.0G		0.50		0.5		0.05		0.01		0.05		0.00N		0.140
Wise pit, Clearfield Co., PA; North American Refractories																			
27 - 1	189283		10.0		10.0		1.00		0.7		0.15		0.02		0.20		1.50		0.087
27 - 2	189295		10.0		10.0		0.50		0.7		0.10		0.07		0.20		1.00		0.075
27 - 4	189281		10.0G		10.0		0.30		2.0		0.03		0.02		0.05		0.00N		0.023
I80 road cuts, east Clearfield exit, Clearfield Co., PA																			
30 - 1	189294		10.0G		10.0		0.30		1.0		0.50		0.03		0.30		3.00		0.009
30 - 2	189284		10.0G		10.0		0.30		1.0		0.30		0.02		0.30		3.00		0.078

TABLE 5. Lithium and 6-step-spectrographic analyses of selected samples from PA, KY, and MO-continued

SAMPLE	P	%-S	Ag ppm-S	B ppm-S	Ba ppm-S	Be ppm-S	Ce ppm-S	Co ppm-S	Cr ppm-S	Cu ppm-S	Ga ppm-S
Ft. Hill pit, Somerset Co., PA; General Refractories Co.-continued											
3 - 1		0.0N	0.00L	50.	300.	2.0	200.	10.	100.	100.	50.
3 - 2		0.0N	0.00N	50.	300.	1.5	0.L	7.	100.	20.	70.
3 - 3		0.0N	0.00N	70.	200.	0.0L	0.N	7.	70.	50.	30.
3 - 4		0.0N	0.00N	50.	300.	3.0	0.L	30.	70.	50.	20.
3 - 6		0.0N	0.00N	0.L	300.	1.5	0.L	7.	70.	20.	15.
3A- 1		0.0N	0.00N	70.	300.	1.5	0.N	10.	70.	30.	50.
3A- 2		0.0N	0.00N	0.L	70.	2.0	0.L	15.	100.	70.	50.
Dump at old pit, east edge of Wilkes-Barre, Luzerne Co., PA-continued											
19 - 1		0.0N	0.00N	30.	500.	3.0	0.L	0.L	70.	50.	50.
Ralph Korb pit, Clearfield Co., PA; Harbison-Walker Refractories-continued											
22 - 1		0.0N	0.00N	30.	300.	2.0	200.	0.L	70.	15.	50.
22 - 2		0.0N	0.70	50.	200.	0.0L	0.N	0.L	150.	10.	70.
22 - 3		0.0N	0.50	50.	200.	0.0L	0.L	0.L	150.	10.	100.
22 - 4A		0.0N	0.00N	50.	150.	0.0L	0.N	0.L	150.	7.	50.
Bell Run pit, Clearfield Co., PA; Harbison-Walker Refractories-continued											
23 - 1		0.0N	0.00N	70.	70.	1.5	0.N	0.L	150.	10.	70.
23 - 3		0.0N	0.00N	50.	200.	1.5	0.N	0.L	70.	15.	30.
Deemer pit, Clearfield Co., PA; North American Refractories-continued											
26 - 1A		0.0N	0.00N	20.	30.	0.0N	0.N	7.	150.	15.	70.
26 - 1B		0.0N	0.00N	20.	100.	0.0N	0.N	0.L	100.	10.	30.
26 - 2		0.0N	0.00N	20.	70.	0.0N	0.N	0.L	150.	20.	100.
26 - 3		0.0N	0.00N	20.	150.	0.0N	0.L	0.L	100.	15.	70.
26 - 4		0.0N	0.00L	30.	150.	0.0L	0.N	0.L	150.	50.	100.
26 - 5		0.0N	0.00N	70.	200.	1.5	0.L	7.	150.	30.	70.
26 -71D		0.0N	0.00N	30.	500.	0.0N	0.N	0.L	200.	50.	70.
26 -71C		0.0N	0.00N	20.	300.	0.0N	0.N	0.L	200.	30.	100.
26 -71E		0.0N	0.00N	20.	150.	0.0N	0.N	0.L	300.	20.	150.
26 -79		0.0N	0.00N	0.L	150.	0.0L	0.N	5.	200.	30.	70.
Wise pit, Clearfield Co., PA; North American Refractories-continued											
27 - 1		0.0N	0.70	30.	100.	1.5	0.L	7.	150.	100.	50.
27 - 2		0.0N	0.00N	50.	100.	0.0L	0.N	0.L	150.	30.	50.
27 - 4		0.0N	0.00N	70.	20.	0.0N	0.N	0.L	100.	10.	30.
I80 road cuts, east Clearfield exit, Clearfield Co., PA-continued											
30 - 1		0.0N	0.00N	50.	500.	1.5	0.L	0.L	70.	10.	30.
30 - 2		0.0N	0.00N	50.	150.	1.5	0.N	0.L	100.	15.	50.

TABLE 5. Lithium and 6-step-spectrographic analyses of selected samples from PA, KY, and MO-continued

SAMPLE	Ge ppm-S	La ppm-S	Mn ppm-S	Mo ppm-S	Nb ppm-S	Nd ppm-S	Ni ppm-S	Pb ppm-S	Sc ppm-S	Sn ppm-S
Ft. Hill pit, Somerset Co., PA; General Refractories Co.-continued										
3 - 1	0.N	100.	30.	3.	20.	100.	30.	70.	20.	0.N
3 - 2	0.N	70.	50.	3.	20.	70.	20.	30.	30.	0.N
3 - 3	0.N	0.L	30.	3.	15.	0.N	15.	30.	10.	0.N
3 - 4	15.	50.	20.	5.	20.	0.N	70.	20.	20.	0.N
3 - 6	0.N	50.	15.	0.N	15.	0.N	15.	15.	15.	0.N
3A- 1	0.N	50.	70.	0.L	15.	0.N	20.	20.	15.	0.N
3A- 2	0.N	70.	15.	3.	15.	0.N	70.	50.	20.	0.N
Dump at old pit, east edge of Wilkes-Barre, Luzerne Co., PA-continued										
19 - 1	0.N	0.L	50.	5.	15.	0.L	30.	30.	15.	0.L
Ralph Korb pit, Clearfield Co., PA; Harbison-Walker Refractories-continued										
22 - 1	0.N	150.	30.	3.	20.	150.	50.	50.	15.	0.N
22 - 2	0.N	0.L	15.	3.	30.	0.N	30.	50.	30.	10.
22 - 3	0.N	0.L	20.	3.	30.	0.N	30.	70.	30.	15.
22 - 4A	0.N	0.L	20.	5.	20.	0.N	20.	30.	10.	0.N
Bell Run pit, Clearfield Co., PA; Harbison-Walker Refractories-continued										
23 - 1	0.N	0.N	20.	10.	30.	0.B	20.	20.	7.	10.
23 - 3	0.N	0.N	70.	0.L	15.	0.B	20.	20.	15.	0.L
Deemer pit, Clearfield Co., PA; North American Refractories-continued										
26 - 1A	0.N	0.N	15.	30.	30.	0.B	20.	50.	20.	15.
26 - 1B	0.N	0.L	15.	0.N	15.	0.N	10.	50.	10.	0.L
26 - 2	0.N	0.N	10.	10.	20.	0.B	15.	30.	20.	15.
26 - 3	0.N	0.N	50.	7.	20.	0.N	20.	15.	15.	0.L
26 - 4	0.N	0.N	70.	7.	20.	0.B	50.	70.	15.	10.
26 - 5	0.N	0.L	70.	7.	30.	70.	30.	50.	30.	15.
26 -71D	0.N	0.N	15.	10.	30.	0.B	15.	70.	30.	15.
26 -71C	0.N	0.N	10.	15.	30.	0.B	7.	50.	30.	15.
26 -71E	30.	0.N	7.	15.	30.	0.B	0.L	50.	30.	15.
26 -79	0.N	0.N	30.	7.	20.	0.B	10.	30.	30.	15.
Wise pit, Clearfield Co., PA; North American Refractories-continued										
27 - 1	0.N	0.L	70.	7.	30.	0.L	30.	70.	20.	0.L
27 - 2	0.N	0.N	30.	7.	20.	0.B	20.	50.	15.	0.L
27 - 4	0.N	0.N	300.	0.N	15.	0.B	10.	30.	10.	0.L
I80 road cuts, east Clearfield exit, Clearfield Co., PA-continued										
30 - 1	0.N	70.	30.	0.N	15.	0.L	10.	30.	15.	0.L
30 - 2	0.N	0.L	20.	3.	15.	0.N	30.	30.	15.	0.L

30

TABLE 5. Lithium and 6-step-spectrographic analyses of selected samples from PA, KY, and MO-continued

SAMPLE	Sr ppm-S	V ppm-S	Y ppm-S	Yb ppm-S	Zn ppm-S	Zr ppm-S
			Ft. Hill pit, Somerset Co., PA; General Refractories Co.-continued			
3 - 1	1000.	150.	30.	3.0	0.N	150.
3 - 2	300.	150.	30.	3.0	0.N	150.
3 - 3	150.	70.	20.	2.0	0.N	150.
3 - 4	100.	70.	30.	3.0	0.N	300.
3 - 6	50.	70.	30.	2.0	0.N	70.
3A- 1	100.	100.	30.	3.0	0.N	100.
3A- 2	50.	100.	30.	3.0	0.N	100.
			Dump at old pit, east edge of Wilkes-Barre, Luzerne Co., PA-continued			
19 - 1	150.	150.	30.	3.0	0.N	150.
			Ralph Korb pit, Clearfield Co., PA; Harbison-Walker Refractories-continued			
22 - 1	200.	100.	30.	3.0	0.N	150.
22 - 2	100.	150.	30.	3.0	0.N	200.
22 - 3	100.	150.	30.	5.0	0.N	200.
22 - 4A	70.	100.	20.	2.0	0.N	150.
			Bell Run pit, Clearfield Co., PA; Harbison-Walker Refractories-continued			
23 - 1	30.	70.	30.	3.0	0.N	300.
23 - 3	70.	100.	15.	2.0	0.N	150.
			Deemer pit, Clearfield Co., PA; North American Refractories-continued			
26 - 1A	20.	150.	30.	2.0	0.N	200.
26 - 1B	30.	70.	10.	1.0	0.N	100.
26 - 2	30.	200.	20.	3.0	0.N	150.
26 - 3	50.	150.	20.	1.5	0.N	150.
26 - 4	70.	100.	20.	1.5	0.N	150.
26 - 5	150.	150.	30.	3.0	0.N	200.
26 -71D	100.	200.	20.	3.0	0.N	200.
26 -71C	100.	200.	30.	3.0	0.N	200.
26 -71E	50.	300.	15.	3.0	0.N	200.
26 -79	50.	200.	20.	2.0	0.N	150.
			Wise pit, Clearfield Co., PA; North American Refractories-continued			
27 - 1	70.	100.	30.	3.0	0.N	200.
27 - 2	30.	100.	30.	3.0	0.N	200.
27 - 4	15.	150.	15.	1.5	0.N	150.
			I80 road cuts, east Clearfield exit, Clearfield Co., PA-continued			
30 - 1	70.	150.	30.	2.0	0.N	100.
30 - 2	70.	100.	20.	2.0	0.N	150.

TABLE 5. Lithium and 6-step-spectrographic analyses of selected samples from PA, KY, and MO-continued.

SAMPLE	LAB. NO.	Si	%-S	Al	%-S	Ti	%-S	Fe	%-S	Mg	%-S	Ca	%-S	Na	%-S	K	%-S	Li	%-AA
I80 road cuts, east Clearfield exit, Clearfield Co., PA-continued																			
30 - 3	189292		10.0G		10.0G		0.50		1.5		0.30		0.01		0.50		3.00		0.050
30 - 5A	189303		10.0G		7.0		0.30		1.5		0.50		0.07		0.30		3.00		0.019
Galbraith property, Clearfield Co., PA; General Refractories																			
GA - 1	184563		10.0		10.0G		0.70		0.7		0.15		0.02		0.20		1.50		0.088
GA - 6	184565		10.0		10.0G		0.70		0.7		0.15		0.02		0.20		1.50		0.055
GA - 9	184567		10.0		10.0		0.30		0.3		0.05		0.01		0.07		0.00N		0.032
Curwensville-Anderson area. Clearfield Co., PA; General Refr.																			
KA - 1	184543		10.0		10.0G		0.70		1.5		0.20		0.03		0.30		3.00		0.140
KA - 2	184556		10.0		10.0		0.50		1.0		0.15		0.02		0.30		1.50		0.085
Jeffries mine, Clearfield Co., PA; General Refr.																			
L - 4	189279		1.0		10.0G		0.50		0.3		0.01		0.01		0.05		0.00N		0.004
Twin Run pit, Clinton Co., PA																			
25 - 2	189296		7.0		10.0G		0.50		1.5		0.10		0.02		0.07		0.70		0.072
25 - 3A	189271		7.0		10.0		0.50		1.0		0.15		0.03		0.15		1.50		0.018
25 - 3B	189267		10.0		10.0G		0.70		1.0		0.20		0.02		0.30		2.00		0.210
25 - 3E	189264		10.0		10.0G		0.30		0.7		0.50		0.01		0.07		0.70		0.099
25 - 3F	189282		5.0		10.0G		0.30		0.3		0.05		0.03		0.07		0.70		0.063
25 - 4A	189285		7.0		10.0G		0.50		0.7		0.15		0.01		0.10		2.00		0.210
25 - 4B	189270		7.0		10.0G		0.70		0.7		0.10		0.01		0.07		0.70		0.100
Oneill pit, Jefferson Co., PA; abandoned																			
32 - 3	189286		10.0G		10.0G		0.50		0.3		0.07		0.03		0.10		0.70		0.043
32 - 6	189277		10.0		10.0G		0.30		0.3		0.10		0.03		0.15		1.00		0.023
32 - 7	189293		10.0		10.0G		0.30		0.7		0.10		5.00		0.20		2.00		0.015
32 - 9	189274		10.0G		10.0G		0.30		0.7		0.07		0.02		0.05		0.00N		0.096
32 -11	189266		10.0		10.0G		0.30		0.3		0.10		0.03		0.15		1.50		0.021
32 -12	189269		10.0G		10.0G		0.50		0.7		0.07		0.02		0.10		0.00N		0.125
32 -13	189289		10.0		10.0		0.50		0.5		0.07		0.01		0.15		1.00		0.056
32 -14	189275		10.0G		10.0G		0.50		0.2		0.02		0.01		0.00L		0.00N		0.016
32 -18	189276		10.0G		10.0G		0.50		0.3		0.07		0.03		0.07		0.00N		0.042
Eckels pit, Clarion Co., PA; abandoned																			
33 - 1	189290		10.0		10.0		0.30		0.7		0.02		0.00		0.05		0.00N		0.037
33 - 7	189300		7.0		10.0G		0.50		1.5		0.02		0.02		0.07		0.00N		0.059
33 - 9	189298		10.0		10.0G		0.50		0.7		0.07		0.01		0.15		0.70		0.088
Hilger pit, Carter Co., KY; General Refractories Co.																			
63 - 1	184540		10.0G		10.0G		0.30		1.5		0.70		0.10		0.50		7.00		0.025

TABLE 5. Lithium and 6-step-spectrographic analyses of selected samples from PA, KY, and MO-continued

SAMPLE	P	%-S	Ag ppm-S	B ppm-S	Ba ppm-S	Be ppm-S	Ce ppm-S	Co ppm-S	Cr ppm-S	Cu ppm-S	Ga ppm-S
I80 road cuts, east Clearfield exit, Clearfield Co., PA-continued											
30 - 3		0.0N	0.00N	70.	300.	1.5	0.N	0.L	70.	15.	50.
30 - 5A		0.0N	0.00N	50.	200.	3.0	0.L	10.	70.	50.	30.
Galbraith property, Clearfield Co., PA; General Refractories-continued											
GA - 1		0.0N	0.00N	30.	150.	1.5	0.N	0.L	100.	20.	70.
GA - 6		0.0N	0.00L	50.	150.	1.5	0.N	70.	150.	20.	70.
GA - 9		0.0N	0.00N	30.	50.	0.0N	0.N	0.L	150.	15.	50.
Curwensville-Anderson area, Clearfield Co., PA; General Refr.-continued											
KA - 1		0.0N	0.70	50.	150.	1.5	0.L	5.	150.	100.	70.
KA - 2		0.0L	0.50	30.	150.	1.5	0.L	0.L	100.	100.	70.
Jeffries mine, Clearfield Co., PA; General Refr.-continued											
L - 4		0.0N	0.00N	0.L	30.	0.0N	0.N	0.N	200.	10.	70.
Twin Run pit, Clinton Co., PA-continued											
25 - 2		0.0N	0.00N	0.L	200.	0.0N	0.N	5.	150.	50.	70.
25 - 3A		0.0N	0.00N	30.	300.	1.5	0.L	0.L	150.	100.	50.
25 - 3B		0.0N	0.00N	50.	150.	0.0L	0.N	5.	150.	70.	70.
25 - 3E		0.0N	0.00N	30.	150.	0.0N	0.N	0.L	150.	30.	50.
25 - 3F		0.0N	0.00N	0.L	150.	0.0N	0.N	7.	150.	20.	30.
25 - 4A		0.0N	0.00N	30.	70.	0.0L	0.N	5.	100.	15.	50.
25 - 4B		0.0N	0.70	20.	70.	0.0N	0.N	0.L	150.	30.	100.
Oneill pit, Jefferson Co., PA; abandoned-continued											
32 - 3		0.0N	0.00N	50.	100.	0.0L	200.	0.L	100.	20.	30.
32 - 6		0.0N	0.00L	50.	100.	0.0N	0.L	0.L	70.	15.	30.
32 - 7		3.0	0.00N	20.	300.	1.5	0.N	0.L	70.	15.	30.
32 - 9		0.0N	0.00N	30.	70.	0.0L	200.	0.L	700.	30.	30.
32 -11		0.0N	0.00N	30.	150.	0.0L	0.L	0.L	100.	30.	30.
32 -12		0.0N	0.50	50.	70.	0.0N	0.L	7.	150.	30.	50.
32 -13		0.0N	0.00N	50.	70.	0.0L	0.L	0.L	70.	20.	30.
32 -14		0.0N	0.00N	50.	30.	0.0L	0.N	0.L	100.	20.	30.
32 -18		0.0N	0.00N	30.	100.	0.0L	200.	0.L	100.	15.	30.
Eckels pit, Clarion Co., PA; abandoned-continued											
33 - 1		0.0N	0.00N	20.	30.	0.0N	0.N	0.L	70.	7.	30.
33 - 7		0.0N	0.00N	50.	20.	0.0N	0.N	0.N	150.	20.	70.
33 - 9		0.0N	0.00N	70.	70.	0.0N	0.L	0.L	150.	10.	70.
Hilger pit, Carter Co., KY; General Refractories Co.-continued											
63 - 1		0.0N	0.00N	70.	300.	3.0	0.L	15.	100.	30.	50.

TABLE 5. Lithium and 6-step-spectrographic analyses of selected samples from PA, KY, and MO-continued

SAMPLE	Ge ppm-S	La ppm-S	Mn ppm-S	Mo ppm-S	Nb ppm-S	Nd ppm-S	Ni ppm-S	Pb ppm-S	Sc ppm-S	Sn ppm-S
I80 road cuts, east Clearfield exit, Clearfield Co., PA-continued										
30 - 3	0.N	0.L	20.	3.	20.	0.L	15.	30.	15.	0.L
30 - 5A	0.N	70.	300.	0.N	15.	70.	30.	30.	15.	0.L
Galbraith property, Clearfield Co., PA; General Refractories-continued										
GA - 1	0.N	0.N	50.	3.	30.	0.B	70.	30.	15.	0.N
GA - 6	0.N	0.N	50.	3.	30.	0.B	70.	30.	20.	10.
GA - 9	0.N	0.N	20.	3.	20.	0.B	15.	15.	15.	10.
Curwensville-Anderson area, Clearfield Co., PA; General Refr.-continued										
KA - 1	0.N	0.L	70.	7.	20.	0.N	100.	100.	30.	10.
KA - 2	0.N	70.	30.	7.	20.	70.	50.	70.	30.	10.
Jeffries mine, Clearfield Co., PA; General Refr.-continued										
L - 4	0.N	0.N	5.	10.	15.	0.B	0.L	30.	15.	15.
Twin Run pit, Clinton Co., PA-continued										
25 - 2	0.N	0.N	15.	20.	20.	0.B	20.	30.	30.	10.
25 - 3A	0.N	0.L	15.	3.	30.	0.N	30.	50.	20.	0.L
25 - 3B	0.N	0.N	30.	3.	20.	0.B	50.	30.	15.	10.
25 - 3E	0.N	0.N	7.	15.	30.	0.B	20.	30.	30.	10.
25 - 3F	0.N	0.N	7.	20.	15.	0.B	15.	50.	15.	0.L
25 - 4A	0.N	0.N	15.	7.	15.	0.B	30.	20.	15.	0.L
25 - 4B	0.N	0.N	7.	15.	30.	0.B	20.	50.	30.	15.
Oneill pit, Jefferson Co., PA; abandoned-continued										
32 - 3	0.N	70.	15.	3.	20.	150.	30.	50.	15.	0.L
32 - 6	0.N	70.	15.	0.N	15.	70.	30.	50.	7.	15.
32 - 7	0.N	0.L	30.	0.N	10.	0.N	20.	30.	20.	10.
32 - 9	0.N	70.	15.	3.	20.	150.	20.	50.	15.	0.L
32 -11	0.N	0.L	15.	0.N	15.	70.	20.	50.	7.	10.
32 -12	0.N	0.L	10.	3.	30.	70.	50.	50.	15.	10.
32 -13	0.N	50.	10.	0.L	15.	0.L	30.	50.	15.	0.L
32 -14	0.N	0.N	7.	3.	20.	0.B	20.	30.	10.	10.
32 -18	0.N	70.	15.	3.	30.	150.	30.	50.	15.	15.
Eckels pit, Clarion Co., PA; abandoned-continued										
33 - 1	0.N	0.N	10.	3.	15.	0.B	10.	30.	15.	0.L
33 - 7	0.N	0.N	50.	3.	20.	0.B	15.	20.	15.	10.
33 - 9	0.N	0.L	15.	7.	20.	0.L	20.	30.	10.	10.
Hilger pit, Carter Co., KY; General Refractories Co.-continued										
63 - 1	0.N	50.	150.	0.N	15.	0.N	50.	20.	15.	0.N

TABLE 5. Lithium and 6-step-spectrographic analyses of selected samples from PA, KY, and MO-continued

SAMPLE	Sr ppm-S	V ppm-S	Y ppm-S	Yb ppm-S	Zn ppm-S	Zr ppm-S
			I80 road cuts, east Clearfield exit, Clearfield Co., PA-continued			
30 - 3	70.	150.	30.	3.0	0.N	150.
30 - 5A	150.	100.	30.	3.0	0.N	100.
			Galbraith property, Clearfield Co., PA; General Refractories-continued			
GA - 1	50.	70.	30.	3.0	0.N	150.
GA - 6	30.	150.	30.	3.0	700.	200.
GA - 9	20.	150.	20.	2.0	0.N	150.
			Curwensville-Anderson area. Clearfield Co., PA; General Refr.-continued			
KA - 1	100.	100.	30.	3.0	300.	200.
KA - 2	100.	150.	20.	3.0	0.N	150.
			Jeffries mine, Clearfield Co., PA; General Refr.-continued			
L - 4	30.	200.	15.	1.5	0.N	300.
			Twin Run pit, Clinton Co., PA-continued			
25 - 2	70.	300.	30.	3.0	0.N	200.
25 - 3A	300.	150.	20.	3.0	0.N	150.
25 - 3B	70.	150.	20.	3.0	0.N	150.
25 - 3E	70.	150.	30.	3.0	0.N	200.
25 - 3F	50.	150.	20.	2.0	0.N	150.
25 - 4A	100.	150.	15.	1.5	0.N	150.
25 - 4B	70.	200.	30.	3.0	0.N	150.
			Oneill pit, Jefferson Co., PA; abandoned-continued			
32 - 3	150.	70.	50.	3.0	0.N	200.
32 - 6	70.	100.	20.	1.5	0.N	150.
32 - 7	150.	100.	50.	3.0	0.N	100.
32 - 9	150.	150.	20.	3.0	0.N	150.
32 -11	50.	100.	20.	2.0	0.N	150.
32 -12	70.	150.	30.	3.0	0.N	200.
32 -13	70.	70.	30.	3.0	0.N	300.
32 -14	20.	150.	15.	2.0	0.N	150.
32 -18	150.	70.	50.	3.0	0.N	200.
			Eckels pit, Clarion Co., PA; abandoned-continued			
33 - 1	20.	100.	15.	1.5	0.N	150.
33 - 7	30.	200.	15.	2.0	0.N	150.
33 - 9	50.	100.	30.	3.0	0.N	200.
			Hilger pit, Carter Co., KY; General Refractories Co.-continued			
63 - 1	150.	100.	20.	2.0	0.N	150.

TABLE 5. Lithium and 6-step-spectrographic analyses of selected samples from PA, KY, and MO-continued

SAMPLE	LAB. NO.	Si	%-S	Al	%-S	Ti	%-S	Fe	%-S	Mg	%-S	Ca	%-S	Na	%-S	K	%-S	Li	%-AA
Hilger pit, Carter Co., KY; General Refractories Co.-continued																			
63 - 2	184541		10.0		10.0G		0.30		0.3		0.07		0.02		0.07		0.00N		0.037
63 - 3	184555		10.0G		7.0		0.30		0.3		0.15		0.03		0.15		0.70		0.043
63 - 4	184566		10.0G		7.0		0.20		0.7		0.15		0.05		0.15		1.50		0.014
63 - 5	184564		10.0G		7.0		0.30		1.0		0.15		0.05		0.20		3.00		0.016
Azdell pit, Audrain Co., MO; A. P. Green Refractories																			
36 - 1	184530		10.0G		10.0		0.30		1.5		0.15		0.07		0.10		0.70		0.023
36 - 2	184538		10.0		10.0		0.30		0.2		0.05		0.03		0.07		0.00N		0.075
36 - 3	184537		10.0		10.0G		0.30		0.3		0.07		0.03		0.07		0.00N		0.076
36 - 4	184533		10.0G		10.0G		0.30		0.3		0.10		0.03		0.15		0.70		0.087
36 - 5	184545		10.0G		10.0		0.30		1.0		0.30		0.15		0.10		1.50		0.024
36 - 6	184548		10.0G		10.0		0.30		1.0		0.30		0.15		0.15		1.50		0.021
Bueker pit, Gasconade Co., MO; abandoned																			
37 - 3	184561		10.0		10.0G		0.30		1.0		0.20		0.20		0.15		2.00		0.044
37 - 4	184546		10.0		10.0		0.30		1.5		0.15		0.10		0.15		3.00		0.036
37 - 5	184560		10.0		10.0G		0.50		1.5		0.30		0.70		0.15		3.00		0.031
37 - 6	184549		10.0		7.0		0.20		3.0		1.00		10.00		0.30		3.00		0.004
Hughes mine, Callaway Co., MO; Harbison-Walker Refractories																			
42 - 1	184557		10.0G		10.0G		0.70		1.0		0.70		0.07		0.30		5.00		0.024
42 - 2	184569		10.0G		10.0		0.30		0.7		0.15		0.10		0.15		2.00		0.032
42 - 3A	184551		10.0G		10.0		0.50		2.0		1.00		0.20		0.30		7.00		0.006
42 - 3B	184542		10.0		10.0		0.30		0.7		0.10		0.05		0.15		1.50		0.027
42 - 3C	184559		10.0G		10.0		0.50		0.5		0.15		0.07		0.15		1.50		0.033
42 - 4	184539		10.0G		10.0		0.30		1.0		0.30		0.15		0.10		1.50		0.032
Edel-Tappmeyer pit, Gasconade Co., MO; Harbison-Walker Refr.																			
58 - 1	184531		10.0G		10.0G		0.50		0.2		0.05		0.02		0.00L		0.00N		0.028
58 - 2	184534		5.0		7.0		0.30		0.3		0.07		0.70		0.15		3.00		0.185
58 - 3	184554		10.0		10.0G		0.50		0.5		0.15		0.07		0.30		3.00		0.240

TABLE 5. Lithium and 6-step-spectrographic analyses of selected samples from PA, KY, and MO-continued

SAMPLE	P	%-S	Ag ppm-S	B ppm-S	Ba ppm-S	Be ppm-S	Ce ppm-S	Co ppm-S	Cr ppm-S	Cu ppm-S	Ga ppm-S
Hilger pit, Carter Co., KY; General Refractories Co.-continued											
63 - 2		0.0N	0.00N	30.	70.	1.5	0.N	0.L	70.	10.	30.
63 - 3		0.0N	0.00N	50.	100.	1.5	0.L	0.L	150.	10.	30.
63 - 4		0.0N	0.00N	50.	100.	1.5	0.L	0.L	100.	10.	30.
63 - 5		0.0N	0.00N	50.	150.	1.5	0.L	0.L	100.	10.	30.
Azdell pit, Audrain Co., MO; A. P. Green Refractories-continued											
36 - 1		0.0N	0.00N	70.	70.	1.5	0.L	5.	150.	20.	30.
36 - 2		0.0N	0.00L	50.	15.	1.5	0.L	0.L	150.	15.	30.
36 - 3		0.0N	0.00N	50.	20.	0.0L	0.N	0.L	150.	5.	30.
36 - 4		0.0N	0.50	70.	50.	1.5	0.L	0.L	150.	7.	30.
36 - 5		0.0N	0.00N	70.	30.	2.0	0.L	0.L	150.	10.	50.
36 - 6		0.0N	0.00N	70.	15.	2.0	0.N	5.	150.	50.	30.
Bueker pit, Gasconade Co., MO; abandoned-continued											
37 - 3		0.0N	0.00N	50.	70.	1.5	0.N	5.	150.	10.	50.
37 - 4		0.0N	0.00N	50.	30.	1.5	0.N	0.L	150.	20.	50.
37 - 5		0.3	0.00N	70.	50.	2.0	0.L	15.	150.	100.	50.
37 - 6		0.7	0.00N	50.	300.	3.0	0.L	20.	100.	20.	30.
Hughes mine, Callaway Co., MO; Harbison-Walker Refractories-continued											
42 - 1		0.0N	0.00N	70.	300.	2.0	0.L	0.L	100.	20.	50.
42 - 2		0.0N	0.00N	70.	50.	2.0	0.L	0.L	150.	10.	50.
42 - 3A		0.0L	0.00N	70.	300.	3.0	200.	0.L	300.	10.	70.
42 - 3B		0.0N	0.00N	70.	70.	2.0	0.N	0.L	150.	2.	30.
42 - 3C		0.0N	0.00N	70.	70.	2.0	0.L	0.L	100.	3.	30.
42 - 4		0.0N	0.00N	70.	150.	3.0	200.	0.L	150.	70.	30.
Edel-Tappmeyer pit, Gasconade Co., MO; Harbison-Walker Refr.-continued											
58 - 1		0.0N	0.00N	30.	30.	1.5	0.N	0.L	150.	20.	30.
58 - 2		2.0	0.00N	150.	1500.	7.0	300.	0.L	100.	500.	50.
58 - 3		0.0N	0.50	150.	200.	3.0	200.	0.L	150.	150.	50.

TABLE 5. Lithium and 6-step-spectrographic analyses of selected samples from PA, KY, and MO-continued

SAMPLE	Ge ppm-S	La ppm-S	Mn ppm-S	Mo ppm-S	Nb ppm-S	Nd ppm-S	Ni ppm-S	Pb ppm-S	Sc ppm-S	Sn ppm-S
Hilger pit, Carter Co., KY; General Refractories Co.-continued										
63 - 2	0.N	0.N	15.	0.N	20.	0.B	30.	50.	10.	10.
63 - 3	0.N	0.L	20.	0.N	20.	0.N	50.	30.	7.	0.N
63 - 4	0.N	50.	150.	0.N	15.	0.N	20.	50.	7.	0.N
63 - 5	0.N	70.	70.	0.N	15.	0.N	20.	20.	20.	0.N
Azdell pit, Audrain Co., MO; A. P. Green Refractories-continued										
36 - 1	0.N	50.	7.	0.N	20.	70.	70.	20.	15.	0.N
36 - 2	0.N	50.	2.	7.	15.	0.N	70.	30.	20.	0.N
36 - 3	0.N	0.L	2.	3.	20.	0.N	70.	10.	15.	0.N
36 - 4	0.N	70.	7.	5.	10.	0.N	70.	15.	30.	0.N
36 - 5	0.N	70.	15.	3.	20.	70.	70.	15.	30.	0.N
36 - 6	0.N	0.N	15.	7.	20.	0.B	50.	15.	15.	0.N
Bueker pit, Gasconade Co., MO; abandoned-continued										
37 - 3	0.N	0.N	30.	0.L	20.	0.B	50.	15.	15.	0.N
37 - 4	0.N	0.N	15.	0.N	20.	0.B	50.	10.	15.	0.N
37 - 5	0.N	50.	50.	0.L	20.	70.	70.	10.	15.	0.N
37 - 6	0.N	100.	300.	10.	15.	100.	70.	15.	15.	0.N
Hughes mine, Callaway Co., MO; Harbison-Walker Refractories-continued										
42 - 1	0.N	70.	20.	0.L	20.	70.	15.	15.	15.	0.N
42 - 2	0.N	50.	15.	0.L	15.	0.N	50.	30.	30.	0.N
42 - 3A	0.N	100.	50.	3.	20.	150.	30.	20.	30.	0.N
42 - 3B	0.N	0.L	10.	3.	15.	0.N	20.	20.	15.	0.N
42 - 3C	0.N	0.L	7.	0.L	20.	0.N	30.	30.	15.	0.N
42 - 4	0.N	70.	15.	5.	20.	100.	50.	15.	20.	0.N
Edel-Tappmeyer pit, Gasconade Co., MO; Harbison-Walker Refr.-continued										
58 - 1	0.N	0.N	3.	3.	20.	0.B	50.	15.	20.	0.N
58 - 2	0.N	100.	3.	3.	15.	150.	30.	30.	30.	0.N
58 - 3	0.N	100.	7.	7.	20.	150.	30.	30.	30.	0.N

TABLE 5. Lithium and 6-step-spectrographic analyses of selected samples from PA, KY, and MO-continued

SAMPLE	Sr ppm-S	V ppm-S	Y ppm-S	Yb ppm-S	Zn ppm-S	Zr ppm-S
			Hilger pit, Carter Co., KY; General Refractories Co.-continued			
63 - 2	15.	70.	30.	3.0	0.N	150.
63 - 3	30.	70.	20.	1.5	0.N	150.
63 - 4	50.	70.	20.	2.0	0.N	150.
63 - 5	100.	70.	30.	3.0	0.N	150.
			Azdell pit, Audrain Co., MO; A. P. Green Refractories-continued			
36 - 1	300.	150.	15.	1.5	0.N	150.
36 - 2	150.	300.	15.	1.5	0.N	100.
36 - 3	70.	150.	10.	1.5	0.N	150.
36 - 4	150.	200.	10.	1.5	0.N	100.
36 - 5	300.	150.	30.	2.0	0.N	150.
36 - 6	150.	100.	15.	1.5	0.N	100.
			Bueker pit, Gasconade Co., MO; abandoned-continued			
37 - 3	70.	150.	30.	2.0	0.N	100.
37 - 4	50.	150.	20.	2.0	0.N	150.
37 - 5	70.	150.	50.	3.0	0.N	150.
37 - 6	200.	100.	70.	5.0	0.N	70.
			Hughes mine, Callaway Co., MO; Harbison-Walker Refractories-continued			
42 - 1	150.	100.	70.	5.0	0.N	200.
42 - 2	100.	70.	15.	1.5	0.N	100.
42 - 3A	1500.	300.	50.	3.0	0.N	150.
42 - 3B	200.	70.	20.	2.0	0.N	100.
42 - 3C	100.	100.	20.	2.0	0.N	150.
42 - 4	700.	150.	50.	3.0	0.N	150.
			Edel-Tappmeyer pit, Gasconade Co., MO; Harbison-Walker Refr.-continued			
58 - 1	30.	200.	30.	3.0	0.N	300.
58 - 2	20000.	150.	100.	5.0	0.N	100.
58 - 3	500.	150.	30.	3.0	0.N	150.

grid system that is shown on almost all standard topographic maps published by the U.S. Geological Survey. Although perhaps less familiar than section, township, and range locations, or latitude and longitude, the system is easy to use and it is applicable to regions where land surveys do not exist, thus permitting uniformity in location data.

Field sampling was designed to obtain lithium data on what appeared to be genetically related rock units, such as flint clay grading into a more plastic clay, or on closely associated rock units that indicated a change in original depositional conditions, such as a black shale within or at the top of a fllint clay unit. Forty samples of these kinds of related units were selected at the end of field work for half of the spectrographic analyses shown in table 5. Later, when lithium analyses

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Table 5 near here

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of the Pennsylvania samples were received, an additional 40 samples were selected to investigate minor- and trace-element associations in the samples from Pennsylvania that had lithium contents as large as 2,100 ppm and samples closely related to them. The field numbers and location names in table 5 permit comparison of the data on the samples with other samples in tables 2, 3, and 4 that were not selected for spectrographic analysis

Distribution of lithium

The body of data presented here permits the following inferences and conclusions. These conclusions vary in significance and should be regarded as more or less tentative according to the degree to which the samples represent rock types or districts.

1. The clays in the widespread and important districts of refractory clay deposits of Cretaceous and younger ages along the Atlantic and Gulf Coastal Plains contain generally less than 100 ppm lithium.
2. The bauxite deposits and related rocks of Arkansas range considerably in lithium content, but only about half the samples contain more than 100 ppm and the maximum value found was 460 ppm.
3. Bauxite from Guyana, Jamaica, and Surinam (table 1, Map Number 7, foreign localities; table 4,

North American Refractories stock pile) is an important supply for U.S. industry, but contains very little lithium.

4. Flint clays of Cretaceous age in Colorado contain from 175 to 370 ppm lithium.

5. Flint clays and related rocks of Pennsylvanian age in Alabama, Ohio, Pennsylvania, Kentucky, and Missouri very commonly contain several hundred parts per million lithium, with maximum values as large as 4,000 to 5,100 ppm in the Missouri samples.

6. Samples from Pennsylvania and Maryland suggest large regional variation in lithium content of similar seeming materials as well as large local variation. For example, samples from southern Pennsylvania and adjacent Maryland have maximum lithium contents of nearly 500 ppm, and some of the larger values are in shale and clay unsuitable for refractory use. In contrast, values larger than 1,000 ppm are relatively common in the belt of flint clay deposits extending east from Clarion County through Jefferson and Clearfield Counties to Clinton County, PA. The one deposit sampled in Clinton County produced three samples containing more than 2,000 ppm lithium, whereas only one sample from the five deposits sampled in Clearfield County contained as much as 2,000 ppm. Local variation within Clearfield County also seems large. About half of the samples from the Deemer pit in the Elliott Park quadrangle contain from about 1,000 ppm lithium to more than 2,000. However, samples from the Wise pit, only 4 km to the southwest in the same quadrangle and presumably in the same clay bed, contain only 230 to 870 ppm lithium.

7. Shale and clay in the anthracite district of Pennsylvania, presumably representing rocks of the same age as those in central Pennsylvania but deposited much closer to the source area, contain generally less than 100 ppm lithium. Thus a , lithium mineral eroded from the source area, introduced into the Pennsylvanian sedimentational system, and accumulated in the flint clays and associated rocks does not seem a reasonable explanation for the lithium content of flint clays.

8. The maximum lithium content of flint clays and associated rocks in Kentucky is 890 ppm and only 16 of the 88 samples from Kentucky contain more than 300 ppm. These results may reflect lack of access to a wide variety of deposits, since relatively little mining is going on there now.

9. The flint clay deposits of Missouri contain the largest amounts of lithium so far known in such materials. Samples from drill hole 5, representing the

upper 10 m (33 ft) of clay in the Matthews Pit 3 of North American Refractories in Missouri (exact location of the pit not known), average 3,700 ppm lithium; the richest sample contains 5,100 ppm lithium and the least rich, 2,300 ppm. Five samples representing 7.6 m (25 ft) at the bottom of the sampled section in another drill hole at the same pit contain from 1,100 to 4,100 ppm lithium. Samples containing more than 1,000 ppm lithium are common among the Missouri samples, although there may be only one such sample from a deposit. Half of the 12 samples from the abandoned Ochesky pit, Osage County, MO, contain more than 2,000 ppm lithium, with a maximum value of 3,100 ppm; and, of the other half of the samples, all but one contains more than 1,000 ppm. As seen in Pennsylvania, there is a pattern of large local variation of lithium content from pit to pit.

Mineralogy and geochemistry

X-ray diffraction analyses of six of the richest samples from Missouri and Pennsylvania suggest that the lithium-bearing mineral in these samples is a dioctahedral chlorite very similar to cookeite. Cookeite is a lithium-bearing chlorite (1.5 percent Li) known previously only from hydrothermal, late-stage magmatic, and metamorphic settings, although Flehmig and Menschel (1972) reported cookeite as a minor diagenetic alteration product of biotite in sandstone. None of these parageneses is appropriate for the depositional and diagenetic history of flint clay deposits. A cookeite-type chlorite, however, is probably responsible for the lithium content of all samples containing more than 1,000 ppm lithium, which would correspond to about 5 percent of cookeite in those samples. X-ray analysis of whole-rock samples is equivocal in the identification of such a mineral present in amounts of less than 5 percent, and lithium in samples containing less than about 1,000 ppm may occur in other ways or in other minerals than dioctahedral chlorite. Patterson and Hosterman (1962, p. F64) reported the occurrence of a chlorite, suggested as probably an aluminous variety, in Kentucky flint clays in amounts of about 5 ppercent. This finding suggests that a cookeite-type lithium-bearing chlorite does occur in Kentucky flint clays but that no samples containing much of it were collected in the present study.

The cookeite-type dioctahedral chlorite seems to amount to about half the sample in two samples in which it is associated with boehmite. In four other samples

the chlorite is the predominant mineral in seemingly equal amounts, yet the lithium contents of the six samples range from about 2,000 to 5,100 ppm. Although the admixture of boehmite could explain the lower lithium contents of those samples because of dilution, the range of lithium contents of the other samples in which the dioctahedral chlorite is the principal mineral suggests that the lithium content of the chlorite itself is variable. This would not be surprising considering the apparent low-temperature, diagenetic origin of the chlorite. Another possibility is that the samples contain variable but large amounts of poorly organized alumina and silica that are amorphous to X-rays. This condition would not be revealed by ordinary chemical analysis or routine firing tests.

Preliminary study of the spectrographic analyses in table 5 does not suggest any systematic trends of relations between the elements. Several samples seem to have unusual compositions, however. Sample 32-9 from the Oneill pit, Jefferson County, Pa, for instance, contains 700 ppm chromium. Several samples contain as much as 100 ppm copper but sample 58-2 from the Edel-Tappmeyer pit, Gasconade County, Mo, contains 500 ppm copper. In addition, this sample contains 20,000 ppm (2 percent) strontium and 2 percent phosphorous. Tin occurs in many of the samples from Pennsylvania but in only one of the samples from Kentucky and in none of the samples from Missouri. The effect of such metal contents on firing characteristics and on other attributes important for industrial use of the clay could be large. Perhaps some of the unexpected and unexplained failures of clays to pass utilization tests are the result of minor amounts of metals not ordinarily analyzed for.

Conclusions

Flint clays and related aluminous rocks of Pennsylvanian age in central Pennsylvania and in Kentucky and Missouri constitute an unevaluated potential resource for lithium. The greatest potential may be in the deposits in Missouri. The apparent occurrence of the lithium in a cookeite-type dioctahedral chlorite suggests that relatively pure deposits of such chlorite may exist with tonnages and grades suitable for eventual utilization as a lithium resource, considering that an extractive industry already is dealing with such materials. The clay in many of the deposits that various companies have

evaluated and abandoned because the clay was unsuitable for normal refractory use might prove to have been unsatisfactory because of potentially utilizable amounts of lithium. In addition, deposits already being worked might contain significant tonnages of lithium-rich clay that are being discarded to waste simply because the large lithium content, and perhaps the content of other trace elements, makes the clay unsuitable for normal refractory use.

Natural lithium-bearing clay such as flint clays and associated kinds might be more suitable for some ceramic uses than artificial mixtures, or knowledge of the existance of such clays might lead to the development of new uses and hence utilization of clay now discarded. The added value of recovering a lithium-rich clay product might make beneficiation processes economically possible for refractory clay materials. So far, such beneficiation processes, so widely used for kaolin products for the paper and other industries (Patterson and Murray, 1975), have not proven practical in upgrading refractory clays. Further investigations by companies faced with incomplete utilization of materials that they are mining now or could be mining in the future and by other scientists seem warrented.

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References cited

Bogart, S. L., 1976, Fusion power and the potential lithium requirement, in Vine, J. D., ed., Lithium resources and requirements by the year 2000: U.S. Geol. Survey Prof. Paper 1005, p. 12-21.

Brenner-Tourtelot, E. F., Vine, J. D., and Bohannon, R. G., 1977, Lithium in the playa environment, in Greer, Deon, ed., Internat. Conf. on terminal Lakes, Proc. (in press).

Chilenskas, A. A., Bernstein, G. J., and Irvins, R. O., 1976, Lithium requirements for high-energy lithium-aluminum/iron-sulfide batteries for load-leveling and electric-vehicle applications, in Vine, J. D., ed., Lithium resources and requirements by the year 2000: U.S. Geol. Survey Prof. Paper 1005, p. 5-9.

Flehmig, W., and Menschel, G., 1972, Lithium content and appearance of cookeite (lithium chlorite) in Permian sandstones of North Hessen: Contrib. Mineralogy and Petrology, v. 34, p. 211-223.

Heier, K. S., and Billings, G. K., 1972, Lithium [chap.] 3 in Part B of Wedepohl, K. H., ed., Handbook of geochemistry, Volume 2-1: Berlin, Springer-Verlag, looseleaf.

Hosterman, J. W., 1972, Underclay deposits of Somerset and eastern Fayette Counties, Pennsylvania: U. S. Geol. Survey Bull. 1363, 17 p.

National Bureau of Standards, 1931, Certificate of analyses, standard sample 97: Flint clay, 1 p.

_____1955, Revised values for alkalies, standard samples 76, 77, 97, 98, 102, and 104: Flint clay, 1 p.

Patterson, S. H., and Hosterman, J. W., 1962, Geology and refractory clay deposits of the Haldeman and Wrigley quadrangles, Kentucky: U.S. Geol. Survey Bull. 1122-F, 113 p.

Patterson, S. H., and Murray, H. H., 1975, Clays in Lafond, S. J., ed.-in-chief, Industrial rocks and Minerals, 4th ed.: New York, NY Am. Inst. Mining. Eng., p. 519-585.

Tourtelot, H. A., and Meier , A. L., 1976, Lithium in clayey rocks of Pennsylvanian age, western Pennsylvania, in Vine, J. D., ed., Lithium resources and requirements by the year 2000: U.S. Geol. Survey Prof. Paper 1005, p. 128-136.

Vine, J. D., 1976, Lithium resources and requirements by the year 2000: U.S. Geol. Survey Prof. Paper 1005, p. 128-136.

Vine, J. D., and Brenner-Tourtelot, E. F., 1977, New energy-related uses for lithium encourages search for new sources: Field Guide, 1977 Field Trip, Rocky Mountain Assoc. Geologists Guidebook.