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NON-BAUXITIC ALUMINA RESOURCES IN VIRGINIA

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ABSTRACT

The United States currently is importing approximately 97 percent of the bauxite and alumina that is used in domestic manufacturing. In 1988, U.S. production was from four surface mines that were operated in Alabama, Arkansas, and Georgia and produced 560,000 metric tons of bauxite, the primary ore of alumina and the metal aluminum. The prices for alumina have risen more than the rate of inflation because the production of aluminum did not keep up with the demand in 1987 and 1988.

Many rock materials, other than bauxite, contain appreciable amounts of alumina (Al_2O_3). The Virginia Division of Mineral Resources has completed a reconnaissance non-bauxitic alumina resources study. Samples for this study were examined from six categories of rock materials: phyllite-schist, saprolite-clay, kyanite-staurolite, anorthosite, syenite, and emery rock. Approximately 100 locations in 34 counties and independent cities throughout Virginia were examined, sampled and the samples were analyzed; some of these samples were previously analyzed and the data were published elsewhere. Several Division of Mineral Resources (DMR) repository samples were also analyzed for this study. Data on 61 samples that contain at least 20 percent Al_20_3 and represent 22 counties are presented in this report. The samples were analyzed by X-ray fluoresence for alumina, silica, and total iron by the DMR laboratory. Coal ash was not sampled or analyzed. Previously published analyses of Virginia coals indicate appreciable amounts of alumina and they are discussed in this report.

INTRODUCTION

During the period 1984 to 1987, the majority of the bauxite imported into the United States was from Guinea, Jamaica, Australia, and Brazil, whereas the majority of processed alumina was imported from Australia, Surinam, and Jamaica (Baumgardner, 1989). World resources (reserves plus subeconomic and undiscovered deposits) of 55 to 75 billion short tons of bauxite are adequate to meet growing long term demands for alumina. The resources of bauxite in the United States, primarily in Arkansas, are calculated to be 300 to 325 million short tons (Baumgardner, 1989). An increase in world demand, combined with production levies, nationalization of many foreign bauxite mining operations, and cartels among alumina producers, however, has placed the United States in a precarious position with regard to alumina availability. Costs of imported bauxite are escalating and there may be other constraints on availability.

Bauxite, the most economic source of alumina, is processed by using an alkaline leach (Bayer process) in which the bauxite is subjected to pressure and moderately high temperature. This extraction process makes bauxite the most energy efficient source of alumina.

Large domestic deposits of non-bauxitic alumina resources exist. Barclay and Peters (1975) noted that non-bauxitic alumina resources contain less alumina and more gangue minerals than bauxite and that processing equipment must be larger and maintenance and depreciation costs will be greater. Non-bauxitic resources are more chemically complex and cause greater corrosive problems and energy re-

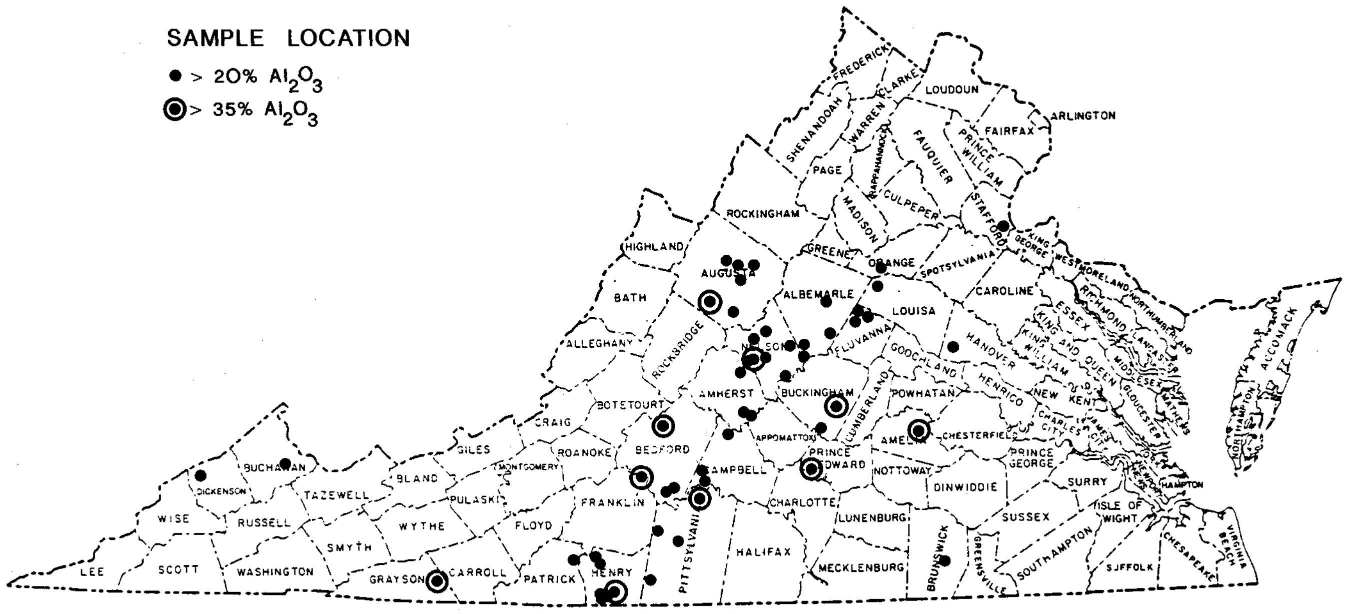

Figure 1. Location of 61 samples in Virginia that contain at least 20 percent alumina.

quirements are at least twice as much per ton. This study was initiated to determine the availability of such deposits in Virginia.

This DMR study was conducted in 34 counties that are located in five physiographic provinces (Coastal Plain, Piedmont, Blue Ridge, Valley and Ridge, and Appalachian Plateaus). All samples were analyzed by X-ray fluorescence (XRF) for alumina, silica, and total iron by the DMR laboratory. Several repository (R) samples were also analyzed. These samples are noted by an asterisk (*) in Table 2. Sixty-one of the samples analyzed contain at least 20 percent Al_2O_3 (Figure 1, Table 2).

ROCK MATERIAL CATEGORIES

Rock material categories, other than bauxite, which were investigated in Virginia include phyllite-schist, saprolite-clay, kyanite-staurolite, anorthosite, syenite and emery rock (Table 1).

PHYLLITE-SCHIST

In Virginia, rocks analyzed as phyllite and schist include a paragonite-bearing unit in Albemarle and Fluvanna counties with an outcrop width of 1500 to 2000-feet. The paragonite, a sodium mica, occurs in muscovite-paragonite and chlorite-muscovite-paragonite phyllites. Milici and others (1966) note that the similarity of analyses of these Candler phyllites in Albemarle and Fluvanna counties with weathered volcanic ash and pumice may indicate the presence of a volcanic terrain as the source for these beds. The samples analyzed consistently ranged from 25 to 30 percent Al_2O_3. Several samples have been analyzed from this rock unit in the past and their alumina content ranges from 13.9 percent to 31.3 percent (Smith and others, 1964). Samples of muscovite schist and sericite schist from other parts of the state were also sampled and analyzed in the current survey. The highest Al_2O_3 content of an individual sample in this overall lithologic category is 31.8 percent, from a sample (77A-B) of phyllite in Campbell County (Figure 2).

SAPROLITE-CLAY

The saprolite-clay category consists of a variety of lithologies from which samples of clay residuum were examined. A large area of clay residuum is over an anorthosite body in the Piney River area of Amherst and Nelson counties. In 1942, the U. S. Bureau of Mines drilled numerous holes in the area and located eight small kaolin bodies (Lintner, 1942). Kaolin tonnages (above 30 percent alumina) for the eight bodies are 245,300 short tons for clay with an Al_2O_3 content exceeding 35 percent and 1,199,560 short tons for clay with an Al_2O_3 content between 30 and 35 percent.

The largest deposit located in the Piney River area was on the Bart Thompson and Conrad Campbell farms (Figure 3). This kaolin deposit contains 157,800 short tons of greater than 35 percent Al_2O_3 and 516,910 short tons of 30 to 35 percent Al_2O_3 (Lintner, 1942). During the present study, two samples were analyzed from the Bart Thompson property;

Table 1. Summary of chemical analyses for six categories of non-bauxitic alumina resource rock material occurring in Virginia.

Non-bauxitic alumina resource rock categories	Number of Samples having greater than 20% Al_2O_3	Counties	Al_2O_3 (Percent) Low	Al_2O_3 (Percent) High	SiO_2 (Percent) Low	SiO_2 (Percent) High	Fe_2O_3 (Percent) Low	Fe_2O_3 (Percent) High
Phyllite-schist	22	Albemarle, Amherst, Bedford, Campbell, Fluvanna, Louisa, Nelson, Orange, Pittsylvania	20.8	31.8	38.5	68.6	5.3	14.2
Saprolite-clay	26	Albemarle, Amherst, Augusta, Bedford, Brunswick, Buchanan, Dickenson, Hanover, Henry, Nelson, Pittsylvania, Powhatan, Stafford	20.5	38.5	33.2	66.7	0.1	4.0
Kyanite-staurolite	6	Amelia, Buckingham, Grayson, Prince Edward	30.8	53.9	24.2	47.3	1.0	14.6
Anorthosite	1	Nelson	24.1		55.5		0.9	
Syenite	4	Augusta	20.3	23.0	54.6	62.4	2.8	4.4
Emery rock	2	Henry, Pittsylvania	30.6	44.3	20.8	25.0	26.5	27.6

test values for Al_2O_3 range from 33.9 up to 35.55 percent (sample 133A-C2).

A sample of kaolin residuum was analyzed from the Allen bauxite mine in Augusta County. A sample (176C-A) taken from the northeast end of the pit contains 38.5 percent Al_2O_3.

A number of samples were collected and evaluated from saprolitic alaskite dikes and pegmatites in the southern Piedmont province. The alaskite is predominantly medium- to coarse-grained and consists of almost equal amounts of quartz and microcline intergrown with muscovite. The pegmatites are mainly coarse grained and contain very little quartz. Saprolite was mined for kaolin in the Oak Level area of Henry County in the early 1900s by John Sant and Co. (Watson, 1907). A sample (49C-A2) of saprolite from the area contains 32.15 percent Al_2O_3 (Figure 4). A sample (50D-A) of kaolin clay from a pegmatite in western Henry County contains an Al_2O_3 content of 33.5 percent (Figure 5).

During the 1950s, several aluminum companies investigated saprolite deposits in southern Virginia, western portions of North and South Carolina, northern Georgia and into Alabama. Several samples of saprolite near Shelby, North Carolina and Gaffney, South Carolina are reported to contain up to 36 percent Al_2O_3. The Gibbsite Corporation of America proposed to mine saprolite in northwest North Carolina and southwest Virginia around 1970. The request was withdrawn after community protest, and the venture was deemed uneconomical.

In late 1980, Gibbsite Corporation of America leased 10,000 acres near Elk Creek in Grayson County with the intent to produce alumina from "gibbsite sands." The leased area consists of saprolite over granite gneiss and granodiorite gneiss. A chemical analysis of four samples from the area (by the DMR in April, 1981) indicates an Al_2O_3 content of 23 to 27 percent. X-ray diffraction of the samples detected kaolinite, plagioclase, and potassium feldspar. No gibbsite was detected in the four samples. Gibbsite Corporation did not exercise its option to mine.

Underclays and overclays associated with coals in the Appalachian Plateaus province consist of medium- to dark-gray, silty clays under and over coal beds. A sample (89B-A) above the Upper Clintwood coal bed was analyzed and contains 20.5 percent Al_2O_3. This sample was previously analyzed by the U.S. Bureau of Mines and determined to possess good plasticity and to be suitable for structural clay products (Sweet, 1982).

KYANITE-STAUROLITE

Alumina values for the kyanite-staurolite category are relatively high; alumina content of pure kyanite is 63 percent. Kyanite-bearing quartzite as well as loose kyanite crystals were sampled from 3 counties in the kyanite belt in central and southwest Virginia. Appreciable reserves of this material are present, but they are located on the property of an active producer. Large kyanite crystals, up to 18 cm, from Grayson County, contain an Al_2O_3 content of 37.1 percent. A sample from an exposure of staurolite-sericite (most of the staurolite has altered to sericite) in Patrick County has an alumina content of 31.4 percent. The unit that contains this rock material is exposed for one-half mile along strike in this area. Loose

Figure 2. Exposure of Candler phyllite (sample 77A-B), south of Evington, Campbell County.

Figure 3. Kaolin clay residuum over anorthosite (sample 133A-C2), Thompson property, Piney River area, Nelson County.

Figure 4. Clay saprolite over pegmatite (sample 49C-A2), Oak Level, northern Henry County.

Figure 5. Kaolin clay residuum over pegmatite (sample 50D-A), near Philpott Reservoir, northwestern Henry County.

Figure 6. Pit of Whittles emery prospect (sample 47B-A), north of Chatham, Pittsylvania County.

kyanite crystals, hand picked from the reclaimed Baker Mountain pit of Kyanite Mining Corporation, were sampled. Analyses indicate these crystals contain 53.9 percent Al_2O_3.

ANORTHOSITE

Anorthosite, consisting almost entirely of plagioclase feldspar, is present as a large body in Amherst and Nelson counties around Piney River. The rock has been mined for glass-grade raw material and presently is being quarried for crushed stone. The Montpelier meta-anorthosite, north of Richmond in Hanover County, is mined by The Feldspar Corporation for glass-grade raw material. A sample from Nelson County (155C-C) was analyzed and contains 24.1 percent Al_2O_3.

SYENITE

Syenites are basically coarse-grained igneous rocks that consist mainly of potash feldspars (orthoclase, microcline, perthite), micas, pyroxenes, amphiboles, and virtually no quartz. A small amount of plagioclase feldspar may be present. These alkalic bodies of Jurassic age (Zartman and others, 1967) intrude sedimentary rocks of Paleozoic age in the central Shenandoah Valley across north-central Augusta County into southern Rockingham County (Johnson and others, 1971; Rader and others, 1986).

Several of these dikes were sampled in Augusta County; the dark-green porphyritic dikes consist of syenite with crystals of natrolite and analcime. Nepheline (a feldspathoid) is also present in two of the dikes. An analysis of a sample (176A-B) from a dike intruding limestone of the Edinburg Formation in the wall of a Luck Stone Corporation quarry contains 23.0 percent Al_2O_3.

EMERY ROCK

Emery rock is a granular rock composed of corundum, magnetite, and spinel, and is the result of the metamorphism of highly aluminous sediments. Corundum, by itself, does not occur in large deposits of high purity material. Emery rock in Virginia occurs with schist recrystallized in response to increased temperatures and pressures caused by the intrusion of a gabbro (Marr, 1984).

Emery rock was examined in Henry and Pittsylvania counties. In both counties, sampled sites border a gabbro of the Rich Acres Formation. The Pittsylvania County site, west of Whittles, consists of three pits (Figure 6). A composite sample from the three pits contains 30.6 percent Al_2O_3.

Watson (1923) reported that five tons of emery were removed from a Pittsylvania County site (not sampled) east of Chatham Church. Old production records (DMR files) indicate that more than 8400 tons of emery were produced from Pittsylvania County from 1918 through 1928 by Niagara Emery Mills, Inc. and Hampden Corundum Wheel Co. The main use of the material was probably as an abrasive. Loose specimens of emery rock were also collected at a small prospect in Henry County, 2 miles northeast of Ridgeway. Analysis of a composited sample indicates that it contains 44.3 percent Al_2O_3.

COAL ASH

Patterson and Dyni (1975, p. 42) note that 50 million tons of ash (from burned coal) containing 8 to 40 percent Al_2O_3 is produced in the United States each year.

Ash is produced at coal burning electric generating facilities in Virginia. The *Keystone Coal Industry Manual* (1988) notes that more than 8.5 million tons of coal are burned annually at power plants throughout Virginia. The U.S. Geological Survey reports that the analyses of 4500 coal samples from the Appalachian Basin contain an average percentage of 9.5 percent ash. Analyses of the ash samples indicate that they contain an average of 24 percent Al_2O_3. Utilization of these figures at face value indicates a potential of 194,454 tons of alumina from this waste material.

Henderson and others (1981 and 1985) note, by county, range of alumina percentages of the ash portion of 217 coal samples from Virginia (Table 3).

Table 2. Summary of chemical analyses for non-bauxitic alumina resources in Virginia.

County/Sample	Rock Material	Quadrangle	U.T.M. Location	Al_2O_3	SiO_2	Fe_2O_3	Comments
Albemarle							
131B-A	weathered phyllite	Howardsville	N4,180,440, E706,490; Zone 17	23.1	38.5	9.4	
131B-B	weathered phyllite	Howardsville	N4,180,420, E706,490; Zone 17	28.3	38.5	7.3	
131B-C	weathered phyllite	Howardsville	N4,180,400, E706,490; Zone 17	26.0	43.8	9.9	
153C-A	phyllite	Scottsville	N4,191,990, E723,940; Zone 17	25.9	57.6	3.2	
154C-C	phyllite	Schuyler	N4,181,100, E706,330; Zone 17	28.4	46.6	10.3	
173C-A	weathered felsite saprolite	Charlottesville East	N4,219,420, E722,420; Zone 17	29.8	66.7	0.7	
Amelia							
101C-A	kyanite crystals (loose)	Amelia Court house	N4,138,500, E241,480; Zone 18	52.9	31.1	11.9	
Amherst							
106A-A	phyllite	Kelly	N4,146,760, E675,580; Zone 17	21.8	43.6	8.9	
106A-B	phyllite	Kelly	N4,147,000, E673,370; Zone 17	28.7	40.0	10.8	
133A-A	kaolin clay	Piney River	N4,174,740, E670,250; Zone 17	34.3	42.0	1.2	
Augusta							
156A-A	kaolin clay	Big Levels	N4,202,870, E665,260; Zone 17	28.9	55.5	0.6	
176A-A	analcime syenite	Staunton	N4,234,460, E670,320; Zone 17	21.6	62.4	2.8	
176A-B	nepheline syenite	Staunton	N4,231,390, E666,380, Zone 17	23.0	61.0	2.8	
176C-A	kaolin clay	Greenville	N4,208,710, E655,640; Zone 17	38.5	55.5	0.5	
189C-A	nepheline syenite	Stokesville	N4,241,240, E659,570; Zone 17	22.1	54.6	3.8	
189C-B	natrolite syenite	Stokesville	N4,241,570, E661,160; Zone 17	20.3	59.3	4.4	
Bedford							
77C-A	phyllite	Leesville	N4,102,390, E633,480; Zone 17	27.3	48.2	9.5	
77C-B	phyllite	Leesville	N4,102,820, E633,520, Zone 17	27.5	39.6	10.0	
78A-A	halloysite clay	Moneta	N4,114,950, E624,500; Zone 17	35.7	33.2	0.2	Wheatley Mine
108A-A	halloysite clay	Peaks of Otter	N4,142,010, E628,160; Zone 17	35.7	41.3	0.3	
Brunswick							
41D-A	clay residuum	Lawrenceville	N4,072,690, E251,460; Zone 18	23.0	64.0	2.3	*R-4364 (Sweet, 1973)
Buchanan							
87B-A	underclay	Keen Mountain	N4,117,580, E414,810; Zone 17	20.8	39.1	4.0	
Buckingham							
103B-A	kyanite	Willis Mountain	N4,150,430, E724,320; Zone 17	51.3	24.2	1.0	
104A-A	kyanite	Andersonviille	N4,140,460, E714,580; Zone 17	30.8	41.1	14.6	
Campbell							
77A-A	phyllite	Lynch Station	N4,119,940, E648,140; Zone 17	26.6	46.4	11.4	
77A-B	phyllite	Lynch Station	N4,118,390, E648,740; Zone 17	31.8	45.4	7.9	
106C-A	phyllite	City Farm	N4,134,660, E661,750; Zone 17	22.8	38.6	9.8	In City of Lynchburg
Dickenson							
89B-A	underclay	Clintwood	N4,110,150, E369,560; Zone 17	20.5	37.3	2.9	*R-7532 (Sweet, 1982)
Fluvanna							
153A-A	phyllite	Boyd Tavern	N4,202,230, E735,980; Zone 17	31.1	40.8	14.2	
153A-B	phyllite	Boyd Tavern	N4,200,970, E735,490; Zone 17	26.2	49.5	10.8	
153A-C	phyllite	Boyd Tavern	N4,206,900, E741,160; Zone 17	26.4	48.6	10.5	
153A-D	phyllite	Boyd Tavern	N4,208,320, E737,140; Zone 17	29.6	41.1	12.9	
Grayson							
21B-A	kyanite	Galax	N4,054,960, E503,560; Zone 17	37.1	47.3	7.0	Nuchols prospect
Hanover							
150C-A	kaolin clay	Montpelier	N4,184,200, E260,920; Zone 18	25.1	56.5	0.4	The Feldspar Corp.prop.
Henry							
17C-A	weathered mica schist	Price	N4,046,480, E600,020; Zone 17	24.2	40.8	10.6	
17C-B	kaolin clay	Price	N4,045,580, E600,200; Zone 17	37.1	41.6	0.2	
17D-A	emery rock	Northwest Eden	N4,052,880, E604,410; Zone 17	44.3	20.8	27.6	*R-4691 corundum
17D-B	alaskite saprolite	Northwest Eden	N4,050,290, E601,690; Zone 17	22.75	64.83	0.53	*R-7481 (Sweet,1982)
49C-A	alaskite saprolite	Bassett	N4,073,590, E592,040; Zone 17	30.27	56.43	0.60	*R-7476-A(Sweet,1982)
49C-A2	alaskite saprolite	Bassett	N4,073,590, E592,040; Zone 17	32.15	54.32	0.36	*R-7476-B(Sweet,1982)
49C-B	alaskite saprolite	Bassett	N4,073,680, E592,040; Zone 17	20.84	68.87	0.86	*R-7478 (Sweet,1982)
50D-A	kaolin clay	Philpott Reservoir	N4,068,770, E585,900; Zone 17	33.5	45.7	0.7	
Louisa							
172C-C	phyllite	Boswells Tavern	N4,218,280, E747,110, Zone 17	23.2	68.6	5.3	
Nelson							
132A-B	phyllite	Shipman	N4,168,550, E692,560; Zone 17	27.7	44.1	10.4	
132A-B	kaolin clay	Piney River	N4,177,900, E675,120; Zone 17	23.5	56.1	0.9	
133A-C	kaolin clay	Piney River	N4,177,260, E672,070; Zone 17	33.9	42.2	2.3	

Table 2. (cont'd)

County/Sample	Rock Material	Quadrangle	U.T.M. Location	Al_2O_3	SiO_2	Fe_2O_3	Comments
Nelson (cont'd)							
133A-C2	kaolin clay	Piney River	N4,177,260, E672,070; Zone 17	35.55	45.85	2.09	*R-7525 (Sweet, 1982)
133A-D	kaolin clay	Piney River	N4,178,550, E675,220; Zone 17	33.91	47.84	0.88	*R-7526-A(Sweet1982)
133A-D2	kaolin clay	Piney River	N4, 178,550,E675,220;Zone 17	31.22	50.70	0.87	*R-7526-B(Sweet,1982)
154C-A	weathered mica schist	Schuyler	N4,186,940, E701,830; Zone 17	21.8	54.5	8.2	
155C-C	anorthosite	Horseshoe Mtn.	N4,180,020, E677,760; Zone 17	24.1	55.5	0.9	
155C-D	kaolin residuum	Horseshoe Mtn.	N4,181,010, E677,770; Zone 17	31.2	52.4	0.5	
Orange							
172A-A	phyllite	Orange	N4,227,400, E757,690; Zone 17	21.4	53.5	8.9	
Patrick							
50D-B	staurolite crystals (loose)	Philpott Reservoir	N4,067,540, E581,030; Zone 17	31.4	49.6	11.2	
Pittsylvania							
16B-A	kaolin clay	Axton	N4,057,960, E620,530; Zone 17	20.8	46.4	0.1	Vicama (Martin) Mine
47B-A	emery rock	Pittsville	N4,084,500, E640,340; Zone 17	30.6	25.0	26.5	Whittles prospect
48A-A	phyllite	Sandy Level	N4,093,920, E624,540; Zone 17	20.8	48.9	9.3	
77D-A	kaolin clay	Altavista	N4,103,250, E647,560; Zone 17	37.99	45.40	0.47	*R-7482 (Sweet, 1982)
Powhatan							
128D-A	halloysite clay	Fine Creek Mills	N4,159,900, E254,260; Zone 18	34.0	40.0	0.2	
Prince Edward							
74B-A	kyanite	Madisonville	N4,119,700, E708,790; Zone 17	53.9	39.1	1.4	
Stafford							
182D-A	clay	Passapatanzy	N4,249,220, E293,400; Zone 18	22.4	63.5	3.9	*R-310 (Johnson & Tyrell,1967)

*Repository sample, Virginia Division of Mineral Resources.

Table 3. Alumina content of ash from Virginia coal.

County	No. of samples	Percent Alumina (Al_2O_3)
Buchanan	30	11-36
Dickenson	61	14-35
Lee	1	29
Russell	17	18-28
Wise	108	14-36

CONCLUSIONS

Bauxite is the richest aluminum bearing rock of the earth's crust of all aluminum bearing rocks occurring in large quantities. Most of the non-bauxitic materials are silicates and are refractory, resistant to most acids, and difficult to process. Most of the alumina production from non-bauxitic materials occurs in the Soviet Union where a nepheline syenite containing apatite is quarried and processed.

For marginal non-bauxitic alumina resources in Virginia to be economical, the domestic bauxite supply would have to be depleted and/or the international supply would have to be unobtainable because of: alumina cartels, export restrictions of raw materials by foreign counties, moratoriums on exploration, or legal controversies.

Of the available rock materials in Virginia, the paragonite-bearing phyllites in Albemarle and Fluvanna counties and sericite schists in the southern Piedmont province appear to offer the largest quantity of potential non-bauxitic alumina resources.

Other possibilities center around the large anorthosite body in the Piney River area in Nelson County where kaolin residuum contains a high percentage of Al_20_3. The U.S. Bureau of Mines has also investigated a process to extract aluminum from anorthosite by leaching with hydrochloric acid and fluoride (Bremner and others, 1982). This process has eliminated the energy-intensive calcination process necessary in the lime-soda ash sintering process. The potential for large reserves exists in the Piney River area.

Aluminum oxide is recoverable from coal ash. The energy required to heat the ash to extract the alumina, however, makes this source uneconomical. There is also the consideration of whether or not there is enough ash at any one site for economic production of alumina. However, the amount of coal ash would increase if there is increased use of coal at power-generating stations.

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