Bauxite Deposits of Virginia

GEOLOGICAL SURVEY BULLETIN 1199-K

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By WALTER C. WARREN, JOSIAH BRIDGE, *and* ELIZABETH F. OVERSTREET

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Distribution, occurrence, and production of bauxite

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BAUXITE DEPOSITS OF VIRGINIA

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ABSTRACT

The northernmost bauxite deposits known to occur in the eastern United States are scattered over a distance of about 75 miles along the eastern part of the Valley and Ridge province in Virginia. The deposits of bauxite and associated white kaolin, which occur as pockets in residual material in areas underlain by carbonate rock, are considered to represent ancient sinkhole fillings. Only the deposits in the Spottswood district and in adjacent areas in Augusta County, which occur in association with rocks of Middle Cambrian to early Ordovician age, are large enough to have yielded production of more than nominal economic value, and even these deposits are small. Small deposits occur also along the west flank of the Blue Ridge in areas underlain by the Tomstown Dolomite of Early Cambrian age. All the known deposits in Virginia are slightly below the level of the Harrisburg (Valley Floor) peneplain. They are believed to have formed during the Paleocene-Eocene interval.

Three mines in the Spottswood district were opened in 1940, 1941, and 1942 and were operated by the Republic Mining and Manufacturing Co. (now Aluminum Co. of America) intermittently until 1946. Except for about eight carloads shipped from the Houston mines in 1915, all production in Virginia has come from these three mines. Production amounted to about 30,000 long tons. The grade of bauxite shipped ranged from 49 to 59 percent Al_2O_3, but most of the ore shipped contained 51 to 52 percent Al_2O_3 and was classed as "high-silica nonrestricted ore" by the Federal Government during World War II. All of it was sold for use in the refractories industries and for production of alum.

INTRODUCTION

The northernmost known deposits of bauxite in the eastern United States (fig. 1) occur in Virginia. They are scattered over a relatively small part of the Appalachian Valley that extends southwestward over a distance of about 75 miles, from a locality a few miles north of Staunton in Augusta County to one a few miles north of Roanoke in Roanoke County. Nearly all of the relatively small tonnage of bauxite so far produced in Virginia was taken from the three largest of these deposits, which are in the Spottswood district (pl. 1), in Augusta County in the vicinity of the divide between the Shenandoah and James River basins.

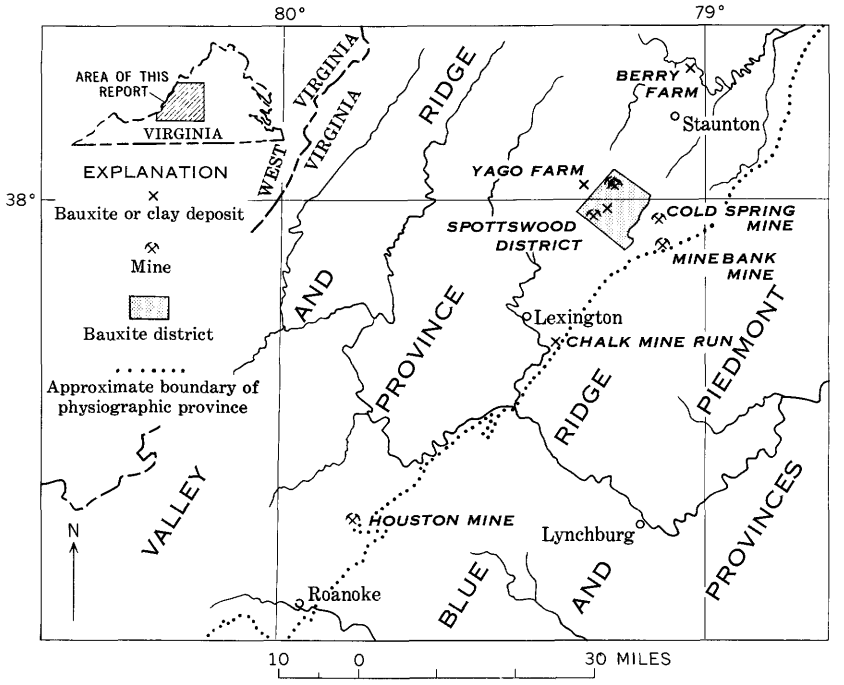

FIGURE 1.—Location of known bauxite and related clay deposits in Virginia.

All the bauxite deposits of Virginia are in localities that may be reached conveniently over primary and secondary roads. The chief transportation routes are U.S. Highway 11 and the main line of the Norfolk and Western Railway. Within the Spottswood district, the highway lies west of that railway line and is paralleled, still farther west, by the right-of-way of a branch line, inoperative since the early 1940's, of the Baltimore & Ohio Railroad. Most of the bauxite that was mined in this district was shipped from Lofton station, on the Norfolk and Western Railway and from Spottswood station on the Baltimore & Ohio Railroad.

The geologic investigation leading to the present report was begun by Josiah Bridge, who examined the deposits in Augusta County in 1941. The deposits investigated by Bridge were examined the following year by Walter C. Warren, who mapped those in the Spottswood district in detail and made brief visits to scattered deposits farther south. All the deposits were revisited by Bridge and Elizabeth F. Overstreet at various times during later years, and the present report, prepared by Overstreet, is a compilation of information gathered by all three authors. All chemical analyses used in preparation

of this report were made by the U.S. Bureau of Mines, and all the X-ray analyses were made by Overstreet.

In the geologic studies leading to the present report, the bauxite deposits of the Spottswood district have received more attention than others described here, primarily because they are the largest in Virginia. The deposits occurring elsewhere in the State are associated with stratigraphic units equivalent to formations exposed in the Spottswood district and in adjacent areas and probably resemble the bauxite deposits of this district in their manner of occurrence.

GEOLOGY

The geologic structure of the part of the Appalachian Valley between the latitudes of Staunton and Roanoke is broadly that of a homocline which strikes northeast and dips southeast. In many localities, however, the structure differs greatly from that of the valley as a whole, and many anticlinal and synclinal flexures are present, as well as numerous faults, most of which are thrust faults. Deformation of the strata is greatest along the southeast side of the valley.

GEOMORPHOLOGY

All the known occurrences of bauxite in Virginia are in the Valley and Ridge province of the Appalachian Mountains (Fenneman, 1938, p. 195–278). All the deposits occur within two major drainage basins: the Shenandoah and James River basins, which within the province drain northeast and southwest, respectively. The surface configuration of the Spottswood district, which includes a part of the divide between these two basins, is that of a series of northeast-trending ridges that stand 50 to 100 feet above the bottoms of the intervening valleys. The dominant northeasterly "grain" delineated by these ridges, which is comparable to that of the terrain in many other parts of the Appalachian Valley, has resulted from differential erosion of alternating hard and soft bedrock strata.

Remnants of an ancient land surface, the Valley Floor or Harrisburg peneplain, which is believed by many geologists to have developed early in the Tertiary Period and to have been largely cut away by erosion in the long time interval that has since elapsed, occur locally some hundreds of feet above the present valley floor (Bridge, 1950, p. 192–193). Extensive gravel-covered remnants of this surface, occurring along the base of the Blue Ridge Mountains in Augusta County, define a pediment that is described by Knechtel (1943, p. 165) as "dotted with sink holes, many of which are several hundred feet in diameter, making a karst topography caused by weathering of the underlying bedrock which is chiefly shale, dolomite, and limestone."

The bauxite in all the deposits to be described, whether or not any such remnants are preserved in its immediate vicinity, probably filled sinkholes that formed while the old surface was still intact.

STRATIGRAPHY

All the known deposits of bauxite in Virginia occur in association with limestone and dolomite in strata of Cambrian and Ordovician age that crop out in areas well within the Appalachian Valley and in a belt along its southeast margin, adjacent to the west slope of the Blue Ridge Mountains. The sequence of stratigraphic units to which these strata belong is given in the generalized section. The carbonate minerals that compose limestone and dolomite are moderately soluble in water; formations in which these minerals predominate are therefore eroded more rapidly and become cavernous more readily than do various ridge-forming rock units that crop out in the valley and in adjoining higher areas. The rocks exposed in the Blue Ridge Mountains consist largely of quartzite and shale of Early Cambrian age and still older igneous rock, much of which is greatly metamorphosed. Post-Ordovician formations, such as the Tuscarora Quartzite of Silurian age, form prominent ridges in many parts of the valley.

BAUXITE DEPOSITS

COMPOSITION AND DESCRIPTION

The bauxite of the Virginia deposits, like that of deposits elsewhere in the United States, consists primarily of gibbsite, the hydrous aluminum oxide. The gibbsite is intermixed with impurities, chief among which is the clay mineral kaolinite, $Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$. No other clay mineral constituents were found by X-ray analyses in samples of the bauxite or in the enveloping deposits of white clay, nor do the samples contain any quartz sand. The iron content of the bauxite, especially from deposits which have been mined, is uniformly low, generally less than 1 percent.

The bauxite is generally pisolitic, and its color is almost uniformly very light gray to very light buff. In the bauxite of the Spottswood district, the diameter of the pisolites is generally less than 2 mm, though larger pisolites are not uncommon. Compound pisolites, composed of a cluster of small pisolites enclosed within a rind of fine-grained or cryptocrystalline gibbsite, are commonly as much as 40 mm in diameter.

The bauxite occurs as pockets within irregularly shaped bodies of white kaolin which, in turn, are enveloped by sandy yellow residual clay. The contact between the white and yellow materials is abrupt.

Generalized section of rocks exposed in the Spottswood district and adjacent areas

[Mines and prospects are those in which units are associated with occurrence of bauxite and white clay]

Age	Stratigraphic unit	Approximate thickness (feet)	Character	Mines and prospects
Middle Ordovician	Blount Group of former usage (lower part?)	?	Limestone and shale (exposed only in southeastern part of district; upper part is concealed beneath Pulaski thrust-fault block).	
Lower Ordovician	Stones River Group	300	Limestone, fossiliferous, topographically weak.	
	Beekmantown Dolomite	1,500	Mostly limestone, alternating and intergrading with dolomite. Reefs of chert characterize upper and lower parts of formation and form ridges. Exposures are poor and fossils scarce.	Allen mine; Yago farm; Harris mine.
	Stonehenge Limestone	500	Limestone, fossiliferous, rather pure, containing a few thin beds of dolomite; contains much chert in small masses. Surfaces of residuum is covered by quartz crystals, well formed, ranging to 2½ inches in diameter, which occur singly and as clusters, radiating outward from small pods of quartz. They probably formed in small cavities within masses of calcite, a fact suggested by impressions of calcite crystals on several faces of one of the larger quartz crystals.	Prospect southwest of Allen mine; Lightner mine.
Upper Cambrian	Conococheague Limestone	2,000	Limestone, thin-bedded in upper part of formation, dolomitic in lower part; rare interbeds of sandstone, most of which occur in uppermost part and seem to have been deposited in shallow water. Fossils scarce and fragmental throughout formation. Strata of upper part form ridges more commonly than any other rocks in Spottswood district.	Berry farm; prospect west of Allen mine.
Middle and Upper Cambrian	Elbrook Dolomite	2,000	Dolomite; upper part of formation is so argillaceous that leaching of carbonate during weathering leaves yellow shalelike residum. Contains much less chert than Conococheague Limestone.	Lott prospects.
Lower Cambrian	Waynesboro Formation	2,000	Limestone and dolomite, mostly dark and impure, and shale, gray, greenish-gray, and maroon; slaty cleavage commonly cuts across beds. Formation contains a few beds of sandstone and chert.	
	Tomstown Dolomite	400	Dolomite, finely crystalline, slightly argillaceous. Leaching leaves residuum containing lenses of silicified oolite, a few sandy strata in basal part. Karst topography characterizes much of area underlain by this formation.	Houston manganese mines; Cold Spring clay mine; Mine Bank manganese mine; Chalk Mine Run deposits.

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The authors believe the yellow residual clay to be the result of long-continued weathering of the carbonate rock of the formations of Cambrian and Ordovician age that are associated with all the Virginia bauxite deposits. X-ray analyses of residual material that mantles the surface in most parts of the Spottswood district indicate that about half its mineral content is kaolinite; the other constituents are generally quartz, mixed-layer clay, and illite in roughly equal amounts.

ORIGIN

The bauxite and the kaolin are believed by the authors to be residual materials that remained after leaching of rock debris that accumulated on the Harrisburg surface in early Tertiary time. The rock debris probably was derived from metamorphic rocks of the Blue Ridge province; probably little debris was derived from the formations listed in table 1. The authors do not believe that the bauxite and white kaolin were derived mainly from argillaceous residual material comparable to that of the sandy yellow clay by which the bauxite and kaolin are surrounded today.

The presence of bauxite deposits in the Appalachian Valley of Virginia suggests that the climate here was once wetter, warmer, and more equable than that of today. The present climate is of a modified continental type characterized by moderate average annual precipitation and a considerable, though not extreme, annual range of temperature. According to Cady (1936, p. 6–8), the average precipitaton at Staunton during a 42-year period was 37.73 inches, and the average annual temperature for that period was 58.8°F. Rainfall averages for the wettest and driest months, June and November, respectively, were 4.21 and 2.21 inches; temperature averages for the warmest and coldest months, July and January, respectively, were 74.3° and 35.4°F. Formation of bauxite by weathering is generally considered to require a climatic environment in which the temperature exceeds 77°F (25°C) most of the year and in which evaporation does not exceed rainfall for as much as one month a year (Mohr, 1933, p. 12–18; Gordon and Tracey, 1952, p. 23–24). On the basis of evidence presented by Bridge (1950, p. 196–197), the climate of the Appalachian Valley in Tertiary time probably conformed to these requirements.

The kaolin within which the pockets of bauxite are enclosed is believed by the authors to have accumulated in well-drained areas on the Harrisburg surface and to have subsided into sinkholes comparable to those which occur abundantly today in areas of karst topography on remnants of that surface along the east margin of the valley in Augusta County. The characteristic shapes and attitudes of the deposits and the disarrangement of materials within them tend to con-

firm this belief. The kaolin masses are highly irregular in shape but are generally in the form of either a downward-tapering cone or a downward-driven wedge elongate in the direction of regional strike. From some, one or more rootlike appendages extend downward. The kaolin bodies that have been observed are only the remnants of larger masses, for all were being eroded when discovered. The materials that were exposed in mining showed much disarrangement whereby small and large blocks of kaolin, some of them angular in form, were intermixed with the bauxite. The disarrangement suggests that the deposits of kaolin and bauxite, after having formed by weathering at or near the old Harrisburg surface, which was considerably higher than the present surface, may have subsided into sinkholes caused by collapse of roofs of underlying caverns. At a few places in the mines, bedding, though poor, suggests that the bauxite and kaolin, after falling into the sinkholes, were in part redeposited therein by running water. The present restriction of deposits of bauxite and kaolin to sites on or close to divides and spurs is probably fortuitous, inasmuch as such locations have merely undergone less erosion, and consequently less removal of such material, than have surrounding areas.

DISCOVERY, PRODUCTION, AND RESERVES

The history of bauxite mining in Virginia is short. Bauxite was first discovered and mined in 1915, when a few carloads were obtained from a small pocket overlying manganese ore in the west pit of the Houston mines near Roanoke (Stose and others, 1919, p. 121–123). No other deposits were reported anywhere in the State until 1930, when a specimen of white pisolitic rock, picked up by Charles Lightner on his farm near Spottswood and analyzed by the Virginia Department of Agriculture and Immigration, was identified as bauxite. Other deposits were discovered later in localities farther north, and bauxite was mined intermittently in the Spottswood district from 1940 to 1946.

The first bauxite produced from the Spottswood district came from a mine opened in 1940 on the Lightner property. In 1941 the Allen mine was opened, and the Harris mine was in operation early in the summer of 1942. Total production for the district was taken from these three mines and was about 30,000 long tons, dried basis, or about 0.2 percent of the bauxite produced in the United States during the period 1940–46. Peak production for the district was reported in 1942 and 1943, when more than half the total was mined. Mining thereafter became unprofitable and was suspended, owing to an improved outlook for imports of bauxite together with a sharp decline in demand for domestic high-silica bauxite. A small tonnage from stocks

that had accumulated at the mines was nevertheless shipped in 1944, and the greatly depleted reserves in the pits yielded small tonnages to cleanup operations that began in 1945 and continued intermittently until all these mines were finally shut down in December 1946. No bauxite has been mined in Virginia since that time.

MINES AND PROSPECTS

SPOTTSWOOD DISTRICT

LIGHTNER MINE

The Lightner mine is about 2½ miles west of Spottswood on the Charles Lightner farm (pl. 1). The mine is at an altitude of 1,910 feet at the foot of the southeast side of a long strike ridge underlain by the Conococheague Limestone and by the lower part of the Stonehenge Limestone. Bedrock is not exposed at the mine, but in an exposure a few hundred feet to the southeast, the strike is N. 20° W., and the dip is 40° NE.

The mine was operated under lease by the Republic Mining and Manufacturing Co. (now Alcoa) between 1940 and 1946. The workings in 1943 consisted of a pit about 200 feet long by 60 feet wide and from 10 to 40 feet deep. The long axis of the pit is parallel to the strike of the bedrock. The ore body was composite, made up of small bodies of bauxite separated by kaolin. One of the ore bodies is shown in figure 2. When visited in 1954, the pit was somewhat larger but otherwise virtually unchanged, although the walls were obscured by a thin coat of slope wash and the bottom was covered with kaolin which had been washed down. The bottom of the pit is usually dry. Nearly all the bauxite has been mined out, and the walls are formed of smooth kaolin.

The bauxite ore body, shaped like an irregular downward-tapering cone, was completely enveloped on the sides and bottom by a much larger mass of white kaolin containing no chert or grit. The contact between the kaolin and bauxite was sharp and dipped steeply toward the center of the pit. The ore body cropped out at the surface and may have been largely eroded when discovered.

The ore is white to light buff and rather earthy. Pisolitic structures are generally poor, but some ore consisted of pisolites 1 to 2 mm in diameter, cemented together but lacking any other matrix. The highest grade of ore contained 57.5 percent Al_2O_3; some of the material that was shipped contained only 49 percent Al_2O_3. All the bauxite was very low in iron.

A separate kaolin deposit lies about 200 yards north of the Lightner mine. Apparently most of the kaolin has been removed by erosion, but parts of this deposit are pisolitic, as indicated by float. No baux-

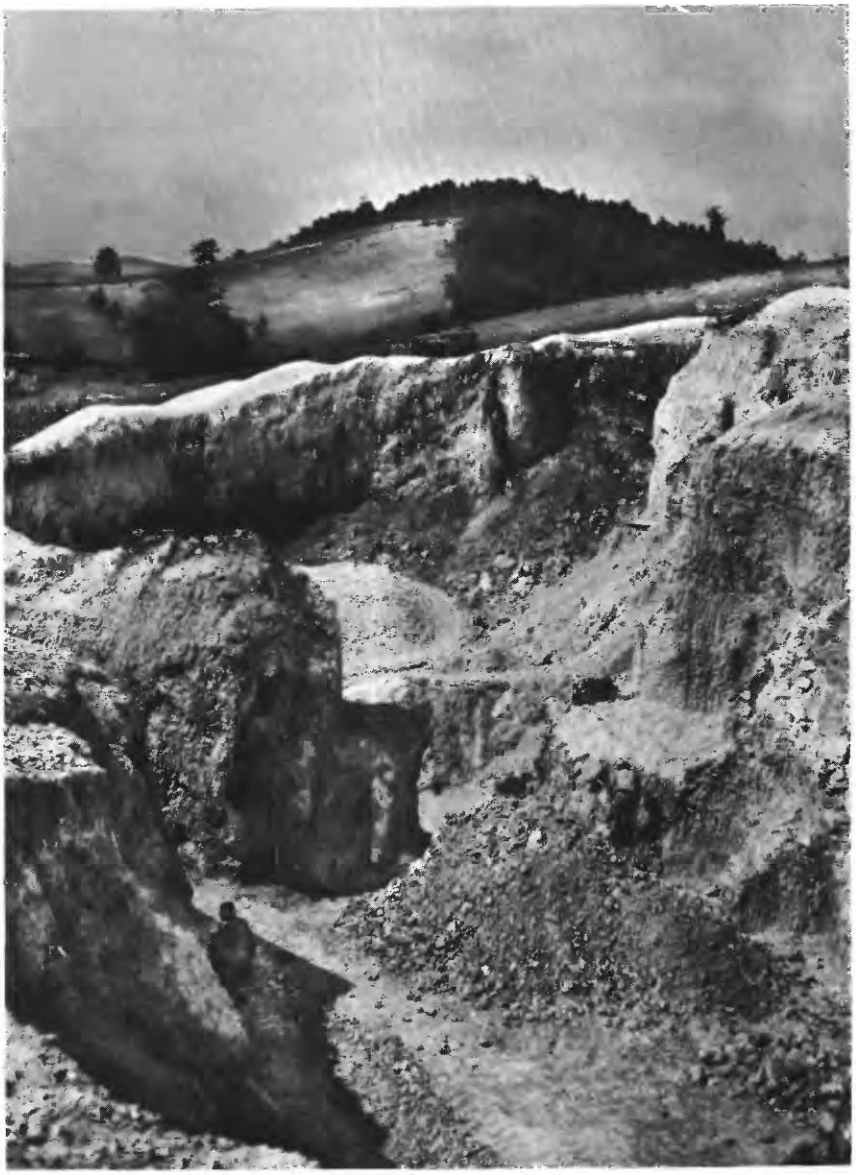

FIGURE 2.—The Lightner mine, Virginia. View to the south from north rim of pit. Photograph by J. Bridge, July 1942.

ite was found in this deposit in auger holes drilled 50 feet apart by the Republic Mining and Manufacturing Co.

ALLEN MINE

The Allen mine is on the G. F. Allen farm, about 4 miles, airline, north of Spottswood, just west of Augusta County road 670 (fig. 2), and about 4 miles northeast of the Lightner mine. The Allen mine was operated under lease by the Republic Mining and Manufacturing Co. (Alcoa). Mining began in the summer of 1941 and continued, except during the winter months, through 1943. A small amount of mining was also done during 1945 and 1946. At the end of 1942 the workings consisted of an open pit about 120 feet long, 90 feet wide, and about 50 feet in maximum depth. The mine was subsequently extended a short distance to the east and south and was deepened slightly. In 1954 the pit was full of water and was being used as a city dump.

The ore body cropped out at an altitude of 2,055 feet and had been partly eroded when discovered. Bedrock is not exposed in or adjacent to the mine, but nearby outcrops strike N. 40° E. and dip 35° SE. The deposit is near the foot of the northwest side of a long strike ridge formed by the lower part of the Beekmantown Dolomite and is immediately above the contact of that formation with the underlying Stonehenge Limestone.

The bauxite from the Allen mine is light gray to pale buff. It is characteristically very finely pisolitic, the pisolites being 1 to 2 mm in diameter. Some of the ore, however, consists of compound pisolites, 2 to 3 cm in diameter, which readily fall free from the matrix. Some finely pisolitic bauxite shows bedding in which layers of pisolites in a fine-grained matrix alternate with layers of closely packed pisolites. The appearance of the rock suggests a gradation upward from layers having no matrix to those having a matrix. A break in deposition occurs between each succeeding layer of pisolites. This bauxite indicates some redeposition by running water, as does also material in the south end of the mine where a peculiar type of bauxite was exposed for a depth of about 7 feet. Clay pellets as large as 3 inches in diameter and numerous enough to lower the grade of the ore were mixed with the bauxite in crude layers which seemingly strike N. 15° W. and dip 75° W. The mixing of bauxite and clay pellets may indicate subsidence into a shallow sinkhole and subsequent deposition, in part, by running water.

High-grade ore as shipped contained 59.2 percent Al_2O_3. Samples examined by X-ray analysis consisted of mixtures of gibbsite and kaolinite. All bauxite and kaolin were very low in iron.

Two small deposits have been reported near the Allen mine. One, about 600 feet southeast of the mine, showed abundant pisolitic float in earth removed from a cistern. Auger holes in the vicinity failed to penetrate either bauxite or kaolin, and the float probably came from the Allen deposit. The other showing, about 2,000 feet west of the Allen mine on the former Waugh farm, is a small pocket of kaolin which crops out on a hillside. It is exposed in the side of a gully across the creek from, and at about the same altitude as, the Allen mine. The pocket is about 20 feet in diameter but not very thick. Although a small amount of pisolitic float can be seen in the immediate vicinity, there is no evidence of a deposit large enough to be mined profitably.

HARRIS MINE

The Harris mine is 900 feet southeast of the Allen mine on the southeast side and near the crest of the same strike ridge as the Allen mine (pl. 1, section *A–A'*). The top of the deposit is at an altitude of 2,125 feet. The deposit probably was largely eroded when discovered.

The Harris mine was opened in 1942 by the Republic Mining and Manufacturing Co. which had purchased from the Harris farm the mineral rights to 2 acres of land containing the deposit. The workings consist of a small, roughly circular pit opening to the east. The mine was operated in 1942 and 1943, and a small additional tonnage was mined in 1945 and 1946. The pit was about 50 feet in diameter and 15 feet deep in early 1943 and was slightly enlarged to the north and deepened in subsequent operations. When seen in 1954, the deposit seemed to be entirely mined out. The walls and floor were covered by slope wash. The pit drains down hill to the east and holds no water.

Bauxite from the Harris deposit is characteristically earthy in appearance and light colored. In places dikes of brown clay cut the ore body and reduce the grade of ore. Analysis of average-grade ore shipped from this mine in 1943 showed 58.0 percent Al_2O_3, 6.2 percent SiO_2, 0.6 percent Fe_2O_3, 3.0 percent TiO_2, and 31.3 percent loss on ignition. Irregular compound pisolites or pebbles of pisolitic bauxite measured 1 to 4 cm in diameter, and pisolites in a matrix of buff earthy bauxite were from 1 to 5 mm in diameter. Many of the pisolites were hollow. X-ray analysis of a sample indicated that the material probably contains more than 80 percent gibbsite and less than 15 percent kaolinite, though it looks like low-grade bauxite.

LOTT PROPECTS

Three deposits on the Lott farm, about 2 miles northwest of Spottswood and 1½ miles northeast of the Lightner mine, are on the top

of a ridge at altitudes ranging from 2,100 to 2,140 feet. They overlie the Elbrook Dolomite but are almost on the trace of the steep-angle Staunton thrust fault that puts the dolomite against limestone of the Stones River Group (pl. 1).

These deposits were prospected by the Republic Mining and Manufacturing Co. in 1942. All three were found to be very small pockets of pisolitic bauxite. Their exact size is not known, and no chemical analyses of the bauxite are available.

OTHER BAUXITE DEPOSITS

Pisolitic bauxite and white kaolin have been reported from two areas in Virginia outside the Spottswood district. None contained more than a few carloads of bauxite when discovered. The more important of the two areas extends along the west slope of the Blue Ridge from the latitude of the Spottswood district southeast almost to Roanoke. The other is in the Shenandoah Valley northeast and northwest of the Spottswood district.

The deposits along the west slope of the Blue Ridge are, from northeast to southwest, as follows (fig. 1): At the Cold Spring clay mine; at the Mine Bank maganese mine; along Chalk Mine Run; and at the Houston manganese mines. Siliceous bauxite has been reported to occur on the Curry farm about 1½ miles northeast of the Houston mine on the top of a small knob on the northwest side of Grindstone Knob at an altitude of 1,540 feet, but no bauxite is present. A prospect tunnel which was caved when visited in 1943 was driven near the top of the knob, but there was no other prospecting. The so-called "bauxite" is an oolitic, irregular, light-colored, cherty float. A sample analyzed by the U.S. Bureau of Mines contained 95 percent SiO_2.

The area northeast and northwest of the Spottswood district includes only two deposits. One, on the Yago farm, is about 3 miles northwest of the district. The other, on the Berry farm, is about 18 miles northeast of the district, or about 6 miles northeast of Staunton.

COLD SPRING CLAY MINE

The Cold Spring clay mine, also known locally as the Chalk mine, consists of two large clay pits. The location is shown by mine symbol in the northern part of the published topographic map of the Vesuvius 15-minute quadrangle and on figure 1. The pits are on the steep west slope of the Blue Ridge at an altitude of about 2,200 feet, just above the dissected surface that forms the floor of the Appalachian Valley.

The deposits exposed in the pits are within the stratigraphic interval of the Tomstown Dolomite, although that formation does not crop out in the immediate vicinity. The Antietam Quartzite, which underlies the Tomstown, is exposed in a wall along the east sides of the

pits, where it dips 60° to 65° W. The upper part of the Antietam here consists of sandstone overlain by a few feet of sandy shale, which in turn underlies 10 to 15 feet of limonitic clay. A few feet of shaly beds may be present between the limonitic clay and the white clay deposit, but the beds are not well exposed.

White kaolin is exposed along the east edges of both pits. It is less pure than that elsewhere in the pits and contains a moderate amount of sand, probably due to contamination from the Antietam, and a number of rudely spherical masses of translucent chalcedony. Some of the chalcedony is oolitic and resembles chert, characteristic of the Tomstown, that has replaced calcareous oolite (Knechtel, 1943, p. 167). The average diameter of these masses is about 2 inches, but some masses exceed 12 inches in diameter.

Elsewhere in the deposit, most of the clay is free of grit. X-ray analysis of a sample of gray and lavender clay showed only kaolinite with well-formed prism reflections. No quartz was present. Throughout most of the deposit the clay is white to pale lavender, gray, or light buff. Along the west edge of the deposit yellow, buff, and red tones predominate. In places along the west wall the grit-free clay seems to rest on yellow impure clay which contains traces of bedding and which is probably decalcified argillaceous limestone. The overburden is a stony soil consisting of large and small boulders derived from the Antietam Quartzite.

Bauxite was found in the north clay pit about 1926 and was put on the dumps along the aerial tramway. Its presence was reported by Knechtel (1943, p. 167), and small pieces of pisolitic bauxite could still be found there in 1954. The bauxite deposit was reported by the operator to have been a downward-tapering cone surrounded by white or almost white clay. The total tonnage of bauxite was less than a carload. Bauxite on the dumps is white to very light gray, and the pisolites range from 3 to 6 mm in diameter. The pisolites on the surfaces of most pieces of the bauxite are hollow, and even those on freshly broken surfaces commonly are either hollow or only partly filled. Roughly equal amounts of gibbsite and kaolinite were present in a sample examined by X-ray analysis. No chemical analyses are available.

The mine was operated by the Cold Spring Mining Co. until the mid–1940's. High-grade clay was used as a filler for coated papers; lower grade material was used as a filler in the rubber industry. None of the bauxite was shipped.

MINE BANK MANGANESE MINE

A small deposit of refractory clay in which no pisolitic material was observed is reported to have overlain clay containing limonite and

manganese in the upper part of the Mine Bank manganese mine (fig. 1). The stratigraphic position of this deposit is virtually the same as that of deposits in the Cold Spring clay mine, but the altitude is about 50 feet higher. The mine, now abandoned, has been described by Knechtel (1943, p. 190–193). No samples or analyses of the refractory clay are available.

CHALK MINE RUN DEPOSITS

A very small amount of pisolitic clay, first noticed by R. O. Bloomer in 1942 (written commun., W. C. Warren to E. F. Burchard, Nov. 1942), occurs at two localities along Chalk Mine Run (fig. 3) about 6 miles east-southeast of Lexington. Both localities are in an area underlain by the Tomstown Dolomite. The topographic position of these deposits, between 1,200 and 1,300 feet in altitude, is very low compared with that of other deposits in the State.

Pisolitic material from the north deposit contained 35 percent Al_2O_3, according to a partial chemical analysis, and may best be designated as a pisolitic clay. Owing to the poor exposures and brief time spent at this locality, we could not determine whether the pisolitic clay was formed in place or find any information as to its origin.

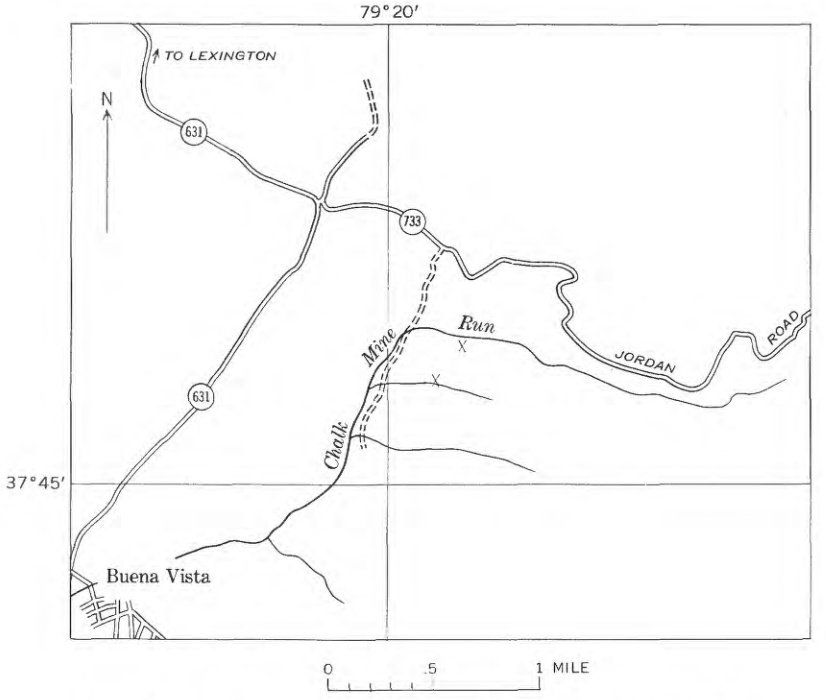

FIGURE 3.—Clay deposits on Chalk Mine Run, Rockbridge County, Va.

X-ray analysis of nonpisolitic white clay from the other deposit indicated that the clay consists largely of kaolinite and contains some hydrous mica and quartz, but no gibbsite. The nonpisolitic sample may represent residuum from the Tomstown, but the geologic relationships at this locality are not clear.

HOUSTON MANGANESE MINES

The Houston manganese mines are about 12 miles, airline, northeast of Roanoke. They are shown by symbols on the published Roanoke topographic 15-minute quadrangle map and on figure 1.

The mines are two large opencuts about 1,500 feet apart on the northwest slope of the Blue Ridge; one is at an altitude of about 1,800 feet, and another, farther west, is at 1,720 feet. In 1917 the mines were 100 feet deep (Stose and others, 1919, p. 121). They have been abandoned for many years.

The mines are underlain by the Tomstown Dolomite close to its contact with the Antietam Quartzite, but only a residuum of red, yellow, and white clays, which is characteristic of the lower part of the dolomite where it has undergone intensive weathering, was encountered in the pit walls and in the immediate vicinity. The quartzite is well exposed less than half a mile west of the pits on the west side of Shay Hollow, along a Forest Service road to the Blue Ridge Parkway. At one place it strikes N. 70° E., and dips 48° N.; at another it strikes N. 85° E. and dips 53° N. The upper 200 to 300 feet of the Antietam is clean sandstone; this grades down into shaly or tuffaceous mudstone that shows spheroidal weathering. The mudstone appears to be at least 1,000 feet thick.

The bauxite was found only in the upper part of the western manganese pit. According to Stose (1919, p. 121), eight carloads of bauxite were mined and shipped in 1915. He writes (1919, p. 122–123):

> The bauxite in the west bank is pisolitic, and although some of it is cream-colored, most of it is red from the presence of considerable iron oxide. Many of the larger pisolites have been removed through solution leaving spherical cavities partly or entirely filled with clay. Here and there fine crystals of gibbsite coat cavities in the bauxite * * *. At only one place was the bauxite observed in place; it there occurred as fragments up to 40 pounds in weight in red clay a few feet below the surface.

When the mines were visited in 1943, the walls had caved so badly that the relationship betwen the bauxite and manganese was very obscure. A sample from a pocket too small to mine contained 55.5 percent Al_2O_3, according to a partial chemical analysis by the U.S. Bureau of Mines (written commun., 1943).

YAGO AND BERRY FARMS

Low-grade bauxite has been reported on the farm of Mr. Robert Yago in the southeast corner of the Craigsville 15-minute quadrangle in Virginia. The farmhouse is on County Road 678 about 1½ miles north of its junction with Virginia Highway 252, and about 3½ miles, airline, northwest of the Allen mine. Mr. Yago states that auger holes were put down some years ago. The results of the drilling are unknown, and the location of the holes can no longer be determined. No surface indications of bauxite or kaolin could be found by the authors. This deposit is probably very small, and the highest-grade material may be pisolitic clay. The deposit is at an altitude of about 1,960 feet.

A kaolin pocket similar in appearance to those in the Spottswood district, though no material resembling bauxite was found, occurs on the farm of A. M. Berry about 6 miles north of Staunton, on County Road 613 at an altitude of about 1,500 feet. Possibly, this deposit represents the very bottom of a former sink.

As shown on the geologic map of the Appalachian Valley in Virginia (Butts, 1933), the deposits on the Yago and Berry farms are associated with formations which also crop out in the Spottswood district. The bauxite locality on the Yago farm is underlain by the Beekmantown Dolomite close to a thrust fault which brings the Waynesboro Formation (Lower Cambrian) to the surface. The clay on the Berry farm is probably associated with the Conococheague Limestone near the crest of a small anticline, in the center of which the underlying Elbrook Dolomite is exposed.

OUTLOOK FOR FURTHER DISCOVERIES

In view of the small size of known bauxite deposits in Virginia and their relatively high silica content, further exploration for commercial deposits in the State may not be warranted. If the search for them should nevertheless be resumed, six areas would seem to deserve study because of geologic and topographic conditions comparable to those associated with bauxite deposits already known in the State. Listed in order from north to south and described with reference to place names appearing on the Craigsville, Staunton, Millboro, Lexington, and Vesuvius topographic 15-minute quadrangle maps, the six areas are:

1. Between Staunton and Greenville, in the higher hills west of, and within 2 miles of, U.S. Highway 11.
2. In the hills east of Back Creek extending from Middlebrook as far north as the Chesapeake and Ohio Railroad.

3. In the group of hills that extends almost 4 miles north from Rockbridge Baths; north of these hills, along the Ridge called Big Hill, and east of Walker Creek; the entire area of hills eastward from Big Hill as far as the Lightner mine, northward as far as McKinley, and northeast to Summerdean.
4. On Mt. Atlas and Canaan Hill, about 6 miles north of Lexington and half a mile west of Timber Ridge.
5. In hills which reach altitudes of 1,800 to 1,900 feet about 2½ miles west of Lexington on Virginia Highway 251.
6. Along the belt of outcrop of the Tomstown Dolomite on the west side of the Blue Ridge, between the Cold Spring clay mine and the Houston manganese mine.

The areas just listed are forest covered to an extent that would make prospecting difficult, but this circumstance lends support to the idea that more ore bodies may be present. Each of the first five areas listed is underlain by three formations in which bauxite was found in the Spottswood district: the Conococheague Limestone (Upper Cambrian), Stonehenge Limestone (Lower Ordovician), and the Beekmantown Dolomite (Lower Ordovician). The sixth area, as noted, is underlain by the Tomstown Dolomite and accordingly is comparable, in its geologic environment, to the Cold Spring clay mine and the Houston manganese mine.

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