STATE OF ARKANSAS
ARKANSAS GEOLOGICAL SURVEY
GEORGE C. BRANNER
STATE GEOLOGIST

INFORMATION CIRCULAR 8

GEOLOGY OF THE ARKANSAS BAUXITE REGION

BY

M. N. BRAMLETTE

LITTLE ROCK
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LETTER OF TRANSMITTAL

ARKANSAS GEOLOGICAL SURVEY

Little Rock, Arkansas

November 23, 1936

Hon. J. M. Futrell,
Governor, State of Arkansas,
Little Rock, Arkansas.

Sir:

I hand you herewith Arkansas Geological Survey Information Circular 8, "Geology of the Arkansas Bauxite Region," by M. N. Bramlette, associate geologist of the United States Geological Survey.

The field work for this report was undertaken by the United States Geological Survey in the bauxite area of Pulaski and Saline counties in the summer of 1934,with funds provided by the Public Works Administration. The investigation differs materially from former studies made of the area in that 55 test holes,with an average depth of 167 feet,were drilled to obtain information bearing on the character and position of the subsurface formations. From the data secured it has been possible to determine the approximate time, and the conditions under which,the deposits were formed, and from this, to limit the depths below which bauxite will not be found over a considerable area. The horizontal limits of bauxite distribution have also been determined to the northwest of the now known bauxite area although not to the south or east. Following the guidance suggested economies in prospecting should result if testing is limited to the depths and areas in which it is indicated that commercial deposits are likely to occur.

It should be emphasized that the partial estimates of commercial ore made by Mr. Bramlette are intended to be approximations of a very rough character only and which future testing may radically increase or decrease. Much drilling must be done in both Saline and Pulaski counties before any reasonably accurate and final estimates of the reserves can be made.

The publication of the report is undertaken by the Arkansas Geological Survey as a cooperative undertaking with the federal survey as, in the normal course of events, publication would have been indefinitely delayed.

Yours very respectfully,

George C Branner

State Geologist.

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GEOLOGY OF THE ARKANSAS BAUXITE REGION

By M. N. Bramlette

ABSTRACT

Bauxite is at present the only commercial source of aluminum, and Arkansas supplies over 90 per cent of the total annual production of the United States. The reserves are clearly not inexhaustible, and a rough estimate indicates enough bauxite of present ore grade to last perhaps 40 years, at the average rate of production for the 10-year period 1924-34.

The commercial deposits are restricted to two areas, the larger one near the town of Bauxite, in Saline County, and the other southeast of Little Rock, in Pulaski County. The bauxite deposits of these areas are derived from the surficial alteration of a nepheline syenite, generally known in the region as "granite," and the economically important ore deposits are confined to areas near this rock.

The results obtained from this investigation, through the drilling of 55 test holes 167 feet in average depth and some surface mapping, show that large quantities of nonmerchantable bauxite occur between the two areas of syenite. These occurrences are relatively thin sheet deposits of bauxite high in silica and iron, which were not formed directly from an underlying syenite but occur at a definite stratigraphic horizon in the sedimentary formations. Evidence is presented that this easily recognizable horizon, at the contact of the Midway and Wilcox groups of the Eocene, represents the period during which all the bauxite was formed through profound weathering of an old land surface. The conclusion is reached that syenite projecting above this horizon may have a blanket of bauxite formed upon it, but that syenite occurring below this horizon is little altered and is not accompanied by bauxite. This conclusion eliminates the possibility of bauxite in the areas in which Midway rocks occur at the surface, even though they are underlain by syenite. Subsurface contours on the top of the limestone of Midway age are shown on the map, to indicate a limiting depth below which prospecting should not be carried. This critical depth also bears on the possibility of buried hills of syenite that may be capped with bauxite, as the number and extent of such undiscovered occurrences are limited by the vertical range of strata to which bauxite is confined. The widely scattered drilling obviously leaves large areas untested in the extensive region around and between the two known bauxite districts, but the results very much reduce the possible extent of undiscovered deposits. The report indicates certain areas where the results seem to suggest the most promise of encountering ore with more intensive drilling.

INTRODUCTION

Object of Investigation

In 1934 the Public Works Administration allotted funds for the United States Geological Survey to make an investigation of the bauxite deposits in Arkansas. The program of work was largely limited to prospecting with a light drilling rig, as the surface geology was well known through earlier work, and geophysical investigations of underground conditions would have required larger funds than were available and could not have established definite results unless accompanied by some drilling. The work was supplemented by some remapping of the surface geology of parts of Pulaski and Saline counties on the new topographic map of the Alexander and Sweet Home quadrangles being prepared by the United States Geological Survey and by an examination of the natural outcrops and mine exposures of bauxite.

The large amount of drilling exploration already done by various companies and individuals made it improbable that extensive new deposits of bauxite would be discovered. However, most of the earlier drilling was close to known deposits, and few of the more widely scattered tests of a "wildcat" nature had been carried to sufficient depth to indicate the possibilities fully. The program of prospecting by drilling here described was planned to gain some first-hand data on the underground conditions of occurrence of the bauxite and their bearing on the possibility of more extensive reserves in undiscovered deposits.

Acknowledgments

The project was directly in charge of M. N. Bramlette, under the supervision of E. F. Burchard, of the United States Geological Survey, who made two inspection visits to the area during the period of field work. C. J. Finger, Jr., was in charge of the drilling operations and sampling during much of the period, as a junior geologist temporarily appointed for this Public Works project, and H. S. Rankin, junior geologist, and Philip Dulin, Jr., were in charge of these operations at earlier periods of the work. George Key, William Cash, and John Stanley proved a capable drilling crew.

Special thanks are due to Mr. J. F. Gibbons, superintendent for the Norton Co., for the rental of the drilling rig at a nominal figure and for other courtesies and much information. Mr. L. R. Branting, superintendent for the Republic Mining & Manufacturing Co., was also helpful in many ways and granted free access to all the company's properties and mine workings. Other operators were very helpful, including Mr. G. R. Hall and Mr. C. E. Olson, of the Dixie Bauxite Co.; Mr. W. J. Crouch, of the William J. Crouch Mining Co.; Mr. W. L. Powers, of the American Cyanamid & Chemical Co.; and Mr. B. A. Fletcher, an independent operator. Mr. George C. Branner, State Geologist of Arkansas, showed helpful interest and cooperation throughout the progress of the work. Appreciation is expressed to the Director of the United States Geological Survey and the State Geologist of Arkansas for permission to submit this report, in essentially its present form, as a thesis for the degree of doctor of philosophy at Yale University.

Previous Investigations

The bauxite in Arkansas was first reported in 1891 by J. C. Branner 1/ and in 1897 he presented a more extended account of the deposits and included some discussion of their mode of origin 2/. Williams 3/ mentioned the bauxite deposits incidentally and presented a good map of the area south of Little Rock and a less detailed map of the area in Saline County. A fuller report on the deposits was made by Hayes 4/ in 1901, including a more detailed map of the area in Saline County, an estimate of tonnages of bauxite, and a discussion on the origin of the bauxite.

All these early reports recognized the close association of the bauxite deposits with the syenite but favored a view that the syenite was a source of hot waters charged with aluminum salts, which were precipitated as bauxite on the sea floor. Apparently this view resulted largely from the fact that most of the bauxite shows a pisolitic or oölitic structure, and at that time such structure was thought to develop only in a precipitate from hot waters. However, Hayes recognized the fact that part of the bauxite showed a granitic texture similar to that of the underlying syenite and considered this evidence that part of the bauxite was formed directly from an alteration of the syenite, but he suggested that the alteration was affected by hot waters from the sye-

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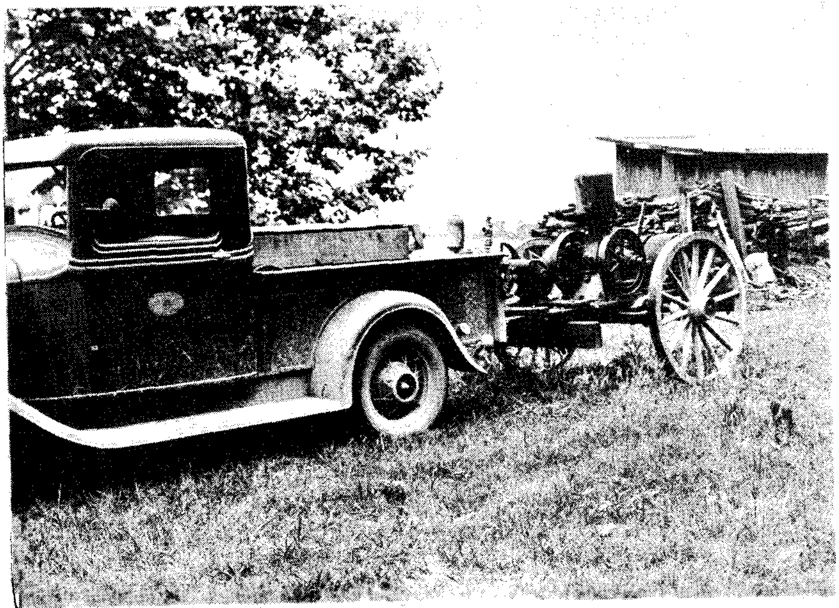
1/ Branner, J. C., Bauxite in Arkansas: Am. Geologist vol. 7, pp. 181-183, March, 1891.

2/ Branner, J. C., The bauxite deposits of Arkansas: Jour. Geology, vol. 5, no. 3, pp. 263-289, 1897.

3/ Williams, J. F., The igneous rocks of Arkansas: Arkansas Geol. Survey Ann. Rept. for 1890, vol. 2, 1891.

4/ Hayes, C. W., The Arkansas bauxite deposits: U. S. Geol. Survey 21st Ann. Rept. pt. 3, pp. 435-472, 1901.

A. Test drilling by the Dixie Bauxite Co., Sweet Home region, Pulaski County.



B. Drilling engine on wheels and attached to truck for moving during drilling operations by U. S. Geological Survey.

A crew of three men was used, one of them spending much of the time in hauling water for the drilling. The geologic assistant supervised the drilling and kept the logs of the test holes and samples. When bauxite was encountered, to obtain samples of any value for chemical analysis it was necessary to run casing (generally 2-inch pipe) down to the top of the bauxite bed. The hole was then carefully washed out by pumping through sufficient clean water to carry out all sand and mud. A special ore bit used in this sampling has a steel ball seated above an intake hole in the bit, and the sample of bauxite cuttings is thus caught in the bit and drill stem. The sample from about two feet of drilling is obtained by bringing out the drill stem and bit as no water is circulated by the pump during this sampling. With proper care this method of sampling gives fairly satisfactory results, as the analyses of samples thus collected have been shown to check reasonably near the analyses of subsequent samples taken in underground development.

In this project comparatively few of the test holes were cased and thus carefully sampled, even where bauxite was encountered. It seemed that in this wildcat type of prospecting the considerable extra time necessary for careful sampling would not be justified, for several reasons. In drilling unknown areas the bauxite is likely to be a thin bed, and after running casing and preparing to sample, the bauxite might prove to be only a foot or a few feet thick and thus be of no economic importance even if of good quality. Also the known conditions indicate that the ore is in pockets and so variable laterally that any results from widely scattered test holes would be of little significance as to the quality or quantity of ore on a particular property. More detailed drilling would be necessary in favorable localities to determine the true character of an ore body.

The chemical analyses of the bauxite, from the three test holes that were carefully sampled, were made by R. E. Stevens, of the United States Geological Survey, and, as is customary, only the essential constituents were determined.

The early mapping in Pulaski County by J. F. Williams and in Saline County by C. W. Hayes was checked and found to be fairly accurate, considering the meager exposures of bedrock near the contacts. Some remapping was done to adjust the earlier mapping to the new topographic base maps of parts of Pulaski and Saline counties. However, these new maps are not yet published, and the map accompanying this report (plate 9) presents the geology located with reference to the drainage and culture of the new base maps, without including the topographic contour lines. Because of its significance to the problem, the Midway-Wilcox contact was mapped, as it had not been shown on earlier maps. However, this contact as mapped is rather generalized and in part inferred from the topography, as the exposures are quite inadequate. In tracing this contact, a few outcrops of low-grade bauxite were added to those previously mapped. The mine pits and underground workings were all examined, and samples were taken from them for laboratory examination.

LOCATION AND GENERAL GEOLOGY

The bauxite deposits of Arkansas occur in Saline and Pulaski counties, near Little Rock, in the central part of the state. The commercially important deposits are found in two areas about 14 miles apart. The area in Saline County includes the mining town of Bauxite, which is about four miles east of Benton, and this area is the more productive. The area in Pulaski County, a few miles south and southeast of Little Rock, has produced less ore and appears to have much less extensive deposits.

Both of the bauxite areas are located on and around the two corresponding areas of syenite, shown on plate 9. The areas of syenite or "granite" hills occur a few miles southeast of the border of the comparatively flat Gulf Coastal Plain, which includes the southeastern half of the state. Northwest of the nearly flat-lying Tertiary beds of the Coastal Plain are hills of older rocks, of Paleozoic age, which are highly folded and form the east end of the Ouachita Mountain region.

Paleozoic and Igneous Rocks

The general distribution of the Paleozoic rocks is indicated on plate 9, though the contact with the Coastal Plain deposits is generalized because of the poor exposures, as in the southeastern part of T. 1 N., R. 13 W., where this contact occurs in the Fourche Creek Valley and is covered with alluvium. This valley is shown with Tertiary deposits, as the alluvium was not mapped, but in parts of the valley the bedrock under the alluvium may be Paleozoic rather than Tertiary. The early Paleozoic rocks are intensely folded and considerably metamorphosed and include some hard siliceous rocks, such as novaculite. The later Paleozoic rocks, probably Carboniferous, are less strongly folded and altered and consist more largely of coarser clastic shales and sandstones. Small areas of the Paleozoic rocks occur adjacent to the syenite south and southeast of Little Rock, and a few remnants, too small to map, occur in the syenite area of Saline County. At the contact with the syenite these rocks are usually baked and altered.

The syenite of the two areas is similar, and as this rock in Saline County is known, from the scattered outcrops and the drilling tests, to extend at comparatively shallow depths northeastward as far as Vimy Ridge, it seems probable that the two large areas of syenite represent stocklike masses projecting up from a single larger body of igneous rock beneath the surface. Most of this igneous rock is a nepheline syenite, but there are smaller masses and dikes of tinguaite and less common types of more mafic character, such as fourchite. These igneous rocks have been well described by Williams 10/ and will therefore not be considered in detail in this report.

Tertiary Deposits of Midway Age

The nearly flat-lying Coastal Plain deposits extend around and partly cover both of the large syenite masses. The lowest of these deposits appears to be of Midway (lower Eocene) age, though Cretaceous beds are known not far to the south and southwest. The Eocene thus seems to overlap the Cretaceous in this region and rests directly on the Paleozoic rocks and the syenite. The lower part of the Midway consists of limestone, which becomes thin-bedded and soft at the top and grades through a few feet of marly clay into the overlying unit of "blue" clay. Formation names have been applied to several units of the Midway group in Texas and Louisiana, but as exact correlations cannot be attempted here, these or other formation names will not be applied in this report. It is probable that at least part of the limestone of this region is correlative with part of the Kincaid of Texas 11/, and the overlying clay with the Wills Point of Texas 12/.

The limestone of Midway age is fossiliferous, with many shell fragments and micro-fossils present in the drill cuttings. The micro-fossils include Foraminifera, Bryozoa, and ostracodes. Some of the Foraminifera from the drill cuttings were examined by L. G. Henbest, of the United States Geological Survey, who states that they are typical Midway species. Fossils from an outcrop of this limestone in sec. 8, T. 1 S., R. 13 W., were determined by G. D. Harris 13/ in 1892 as of Midway age. Glauconite is common in some beds of this limestone and also small pellets of phosphate. Much of the limestone encountered in some of the test holes is rather pure, but more of it is sandy. Few data on the thickness of the limestone are available, as it was difficult to drill through this rock in most places, but test holes B2, in sec. 34,

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10/ Williams, J. F., op. cit., pp. 126-162.

11/ Gardner, Julia, Kincaid formation, name proposed for Lower Midway of Texas: Am. Assoc. Petroleum Geologists Bull., vol. 17, no. 6, p. 744, June, 1933.

12/ Alexander, C. I., Stratigraphy of the Midway group (Eocene) of southwest Arkansas and northwest Louisiana: Am. Assoc. Petroleum Geologists Bull., vol. 19, no. 5, pp. 696-699, May, 1935.

13/ Harris, G. D., The Tertiary geology of southern Arkansas: Arkansas Geol. Survey, Ann. Rept. for 1892, vol. 2, pp. 36-49, 1894.

T. 1 S., R. 14 W., and H2, in sec. 9, T. 2 S., R. 14 W., show that in these areas it is more than 50 feet thick. Water wells drilled at Bauxite are understood to have penetrated slightly over 100 feet of the limestone before reaching "granite." The water from these wells has a fluorine content that makes it unsuitable for drinking, because of its effect on the teeth, and this fluorine is perhaps derived from the fluorite present in the syenite. Water wells drilled at Mabelvale indicate that the limestone there is only 15 to 20 feet thick and rests on harder rocks that are probably Paleozoic, though samples of these rocks were not available for examination. Where the limestone was deposited over the syenite, there is in many places a coarse basal sand composed of hard, angular gray grains of comparatively fresh feldspar (largely orthoclase), clearly derived from the adjacent syenite. This fresh feldspar sand, resulting from the disintegration of the syenite without much chemical alteration or decomposition, was apparently the result of cutting and breaking down of the syenite by waves of the Midway sea. Similar fresh feldspar sand also occurs commonly as thin beds and as scattered grains within the limestone. This is a significant feature bearing on the formation of the bauxite (p. 25).

Overlying the limestone of Midway age and grading up from it through a few feet of marl, or calcareous clay, is the "blue" clay member. This clay is very dark gray when wet in the drill mud but lighter gray and with a bluish tone when dry. It is regularly encountered above the limestone, and though no fossils were found in it above the basal few feet of marl, it appears to be a marine formation. This clay is considered to be a part of the Midway, both because it seems to be a marine formation in gradational contact with the underlying limestone and because of its similarity in lithology and stratigraphic relations to the clay of Midway age in Louisiana and Texas 14/. It is also probably correlative with the Porters Creek clay, of Midway age, of Missouri, Illinois, Kentucky, Tennessee, and Mississippi. However, it does not appear to contain as much bentonitic clay as most of the Porters Creek, and a test of the bleaching property of the blue clay from an outcrop sample from Saline County, made by P. G. Nutting, of the United States Geological Survey, indicates that it is distinctly less efficient for oil bleaching than much of the Porters Creek clay 15/. Thin concretionary beds of siderite, six inches or less in thickness, occur at various horizons in the blue clay at some localities. The blue clay is generally about 40 to 60 feet thick, but in the area around test holes D1 and D2, in Pulaski County, and holes J3 and J4, in Saline County, it is about 100 feet thick. The variation in thickness is due, in part, to the unconformity at its top, representing erosion and deep weathering of the upper part of the blue clay on an old land surface formed by the southward withdrawal of the Midway sea. The blue clay grades up into buff clays and red and yellow mottled clays, which represent an altered and oxidized zone of varying thickness, about 20 feet at most, formed from the upper part of the blue clay.

Bauxite-Kaolin Zone

What is termed in this report the "bauxite-kaolin zone" overlies the blue clay of Midway age or its upper weathered part of buff and mottled clays. In attempting to map the poorly exposed contact of the Midway and the overlying Wilcox, this zone was found wherever the contact was seen, and the horizon is marked by numerous springs on hillsides, where water passing down through the sandy beds of the Wilcox encounters the impervious clays of the Midway. As the bauxite and kaolin of this zone were probably formed as residual deposits in early Wilcox time, the zone may be considered a part of the Wilcox, and it is thus shown on the map. Where the hills of syenite were high enough to escape burial by the Midway deposits of limestone and blue clay and thus formed a part of the old land surface after the withdrawal of the Midway sea, the

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14/ Alexander, C. I., op. cit.

15/ Lang, W. B., King, P. B., Bramlette, M. N., Bay, H. X., and Munyan, A. C., Clay investigations in the southern states, 1934-35--Reports on nine projects conducted by the U. S. Geological Survey under appropriations granted by the Federal Administration of Public Works, with an introductory chapter by G. R. Mansfield: U. S. Geol. Survey Bull.--(in preparation).

bauxite-kaolin zone extends up and over the syenite. In such places this zone is generally thicker and contains much more and better bauxite than in areas where the zone lies on the blue clay and consists more largely of kaolin and bauxitic clay.

Lignitic Deposits of Wilcox Age

The Wilcox consists of nonmarine beds of sand, clay, and lignite. Though lignite beds are common only in the lower part of the Wilcox, many of the clays and some of the sands are more or less lignitic. The assignment of Wilcox (lower Eocene) age to these beds is based on plant fossils from several localities examined by E. W. Berry 16/, who points out that these are middle Wilcox. Probably no lower Wilcox sediments were deposited in this region, and the bauxite and kaolin residual deposits were formed during early Wilcox time.

The Wilcox is several hundred feet thick and originally covered the bauxite zone completely, even where this zone extends up over the higher hills of syenite, as is shown by undisturbed remnants of the overlapping Wilcox beds on some of the highest hills. The beds of sand, clay, and lignite are extremely variable in thickness and in many places lens out within short distances. However, a dark-brown silty clay in the lower part of the Wilcox is thick and persistent over a large area south of Bryant, as shown by the test holes, and clays at about the same horizon toward the east, near Vimy Ridge, are generally light greenish gray. In some areas, as at the locality of test hole E1, in Sec. 9, T. 1 S., R. 12 W., the Wilcox includes some dark bluish-gray clay that resembles the blue clay of Midway age. Clay of this type in the Wilcox is not thick, however, and is generally interbedded with sands or lignite and thus not likely to be confused with the thick bed of blue clay of the Midway, which is underlain by limestone. Lenticular beds and concretions of siderite are common in the Wilcox as encountered at depth in drilling, and much of the ironstone occurring in the Wilcox at the surface is probably derived from the surface oxidation of the siderite.

The lignite and lignitic clay beds are thickest and most numerous in the basal part of the Wilcox. The usual condition is shown in most of the open-pit mines, where lignite or black lignitic clay rests directly on the bauxite. The lignite is usually thicker at lower levels and thinner or passing out completely on higher levels of the irregular bauxite surface, as illustrated in plate 2,A. At some places where the lignitic Wilcox beds were deposited on a slope of the bauxite surface there is one foot or more of basal conglomerate consisting of rounded pebbles and boulders of the underlying bauxite (plate 2,B).

The sand of the Wilcox, even in the basal part and directly above the bauxite, is composed largely of rounded quartz grains, with accessory heavy minerals consisting of zircon, rutile, tourmaline, kyanite, and some garnet. This composition suggests that the sand was derived from the old Paleozoic rocks, some of which are of similar mineral composition, and is in significant contrast to the feldspar sands, derived from fresh syenite, which occur in the Midway (p. 16).

Subsequent Geologic Events, with Summary of History

The geologic history, as interpreted from the foregoing descriptions, will be briefly summarized, along with the subsequent geologic changes that have resulted in the conditions now existing in the region. The syenite magma was intruded into the folded Paleozoic rocks at considerable depth beneath the surface, as the coarse crystallization of granitic texture indicates a slow cooling. The intrusion of the syenite obviously occurred after the Paleozoic and before early Eocene (Midway) time, perhaps during the Cretaceous period, as igneous rocks of similar types are known to have

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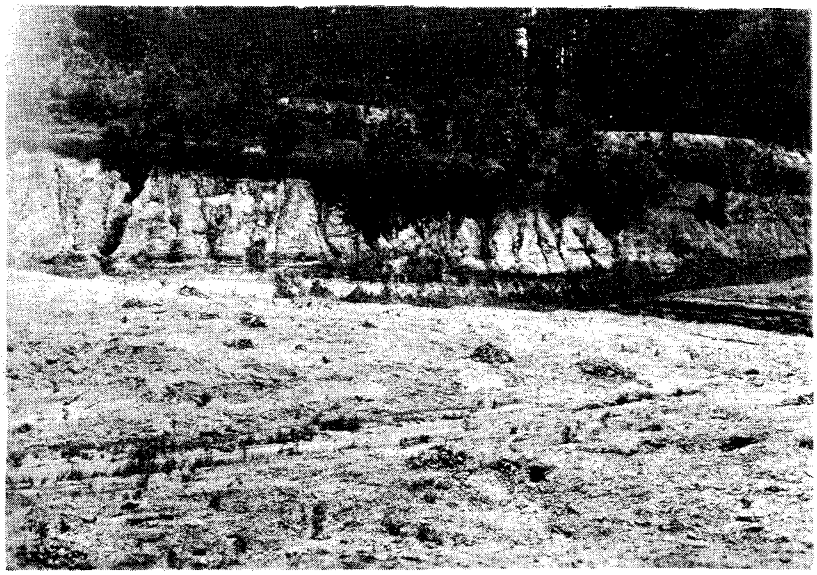
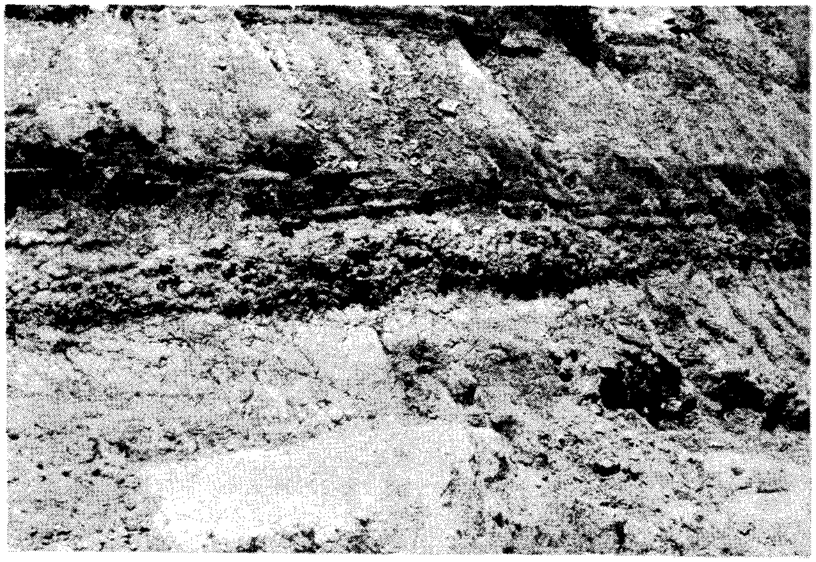
16/ Berry, E. W., The lower Eocene floras of southeastern North America: U. S. Geol. Survey Prof. Paper 91, p. 37, 1916.



A. Stripped bauxite (in foreground) and overlying Wilcox sedimentary rocks. At right is bed of lignite 10 to 15 ft. thick, immediately overlying the ore, with lignite wedging out against the topographic rise in ore body. West Maud mine of Republic Mining & Manufacturing Co., Saline County.



B. Contact of lignitic Wilcox sedimentary rocks with underlying bauxite, showing a basal conglomerate of bauxite at the contact, near center of photograph. Mine cut near center of sec. 15, T. 2 S., R. 14 W., Saline County.

been formed in Cretaceous time in other parts of Arkansas 17/ and in the Louisiana 18/. The cover of Paleozoic rock was in large part removed by erosion, exposing the syenite at the surface before Midway time. The Midway sea then covered much of the area with deposits of limestone, followed by blue clay, but the higher parts of the hills of syenite were islands and thus did not receive these deposits. After the Midway sea withdrew toward the present Gulf of Mexico, the land surface was deeply weathered to form the kaolin and bauxite, under the favorable climatic and other conditions that are discussed on page 27. A rising baselevel then permitted the accumulation of hundreds of feet of the Wilcox continental deposits of sand, clay, and lignite, which completely buried the old weathered surface, even the hills forming its higher parts. Subsequent changes in baselevel have resulted in more erosion, which has cut away much of the Wilcox and exposed some of the old surface on which bauxite occurs and also has cut away the bauxite-kaolin zone in large areas, exposing the underlying hard syenite. Probably in late Tertiary time several feet of gravel accumulated on a surface that now stands about 350 to 400 feet above sea level, but this gravel surface has been largely cut down and much of the gravel spread at lower levels. The later erosion has cut deeper and therefore more completely uncovered the hills of resistant syenite in the area south of Little Rock, in Pulaski County, than in the Saline County area, which is farther from the main drainage system of the Arkansas River.

HISTORY OF DEVELOPMENT AND PRODUCTION

Bauxite in Arkansas was first described in 1842 by Dr. W. Byrd Powell 19/, who noted the peculiar character of this rock in Fourche Cove but did not recognize its true nature. It seems to have been first recognized as bauxite by John C. Branner 20/ in 1887, when it was being used for surfacing the road from Sweet Home to Little Rock. Branner's first published report of the occurrence and recognition of bauxite appeared in 1891 21/. This was only a few years after the first discovery of bauxite in America, at Rome, Ga., and three years after the Pittsburgh Reduction Co. had been organized to commercialize the Hall process of aluminum production. There was little activity in the Arkansas bauxite region for several years after the first discovery, as the demand for such ore was very slight.

Active development began in 1895, with the purchase of land and mineral rights on large areas, and in 1896 the first shipment of 20 tons of ore was made. In 1898 about 633 tons of bauxite was mined for the production of alum. The Pittsburgh Reduction Co., now the Republic Mining & Manufacturing Co., a producing subsidiary of the Aluminum Co. of America, entered the Arkansas bauxite field in 1899 and produced in that year 1,720 tons of ore. In the same year the General Bauxite Co., which had made an experimental shipment of 20 tons in 1896, also shipped some ore. During the next three years the production continued small, but in 1903 it rose to more than 25,000 tons. The production has increased rapidly since that time and had reached nearly 200,000 tons in 1914. The World War resulted in a remarkable increase, and Arkansas reached its maximum production of more than 500,000 tons in 1918. After the war the production dropped and varied considerably from year to year, but in 1923 was back up to nearly 500,000 tons, which represented about one-half of the world production for that year. Since 1923 the increased production of foreign ore, particularly the high-grade ores from northern South America, has reduced the Arkansas production so that in 1929 it was only 351,054 tons, or about one-fifth of the world production for that

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17/ Ross, C. S., Miser, H. D., and Stephenson, L. W., Water-laid volcanic rocks of early Upper Cretaceous age in southwestern Arkansas, southeastern Oklahoma, and northeastern Texas: U. S. Geol. Survey Prof. Paper 154, pp. 175-202, 1929.

18/ Bramlette, M. N., Volcanic rocks in the Cretaceous of Louisiana: Am. Assoc. Petroleum Geologists Bull., vol. 8, no. 3, pp. 344-346, 1924.

19/ Powell, W. B., A geological report upon the Fourche Cove and its immediate vicinity, Little Rock, 1842.

20/ Branner, J. C., The bauxite deposits of Arkansas: Jour. Geology, vol. 5, no. 3, pp. 263,266, 1897.

21/ Branner, J. C., Bauxite in Arkansas: Am. Geologist, vol. 7, pp. 181-183, 1891.

year. Depressed economic conditions reduced the output further, and in 1932 it was only 89,779 tons, but it has since gradually increased again, and a total of 145,764 tons was produced in 1934.

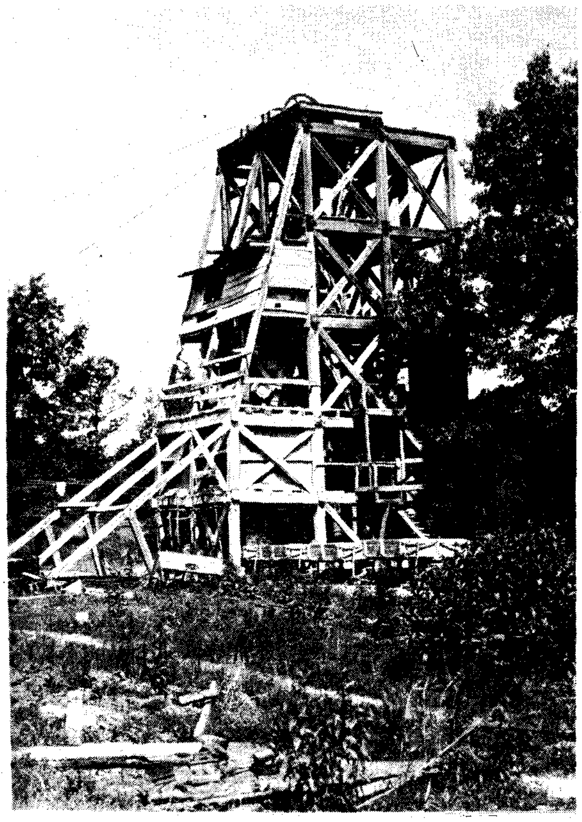
The American Bauxite Co. and its successor the Republic Mining & Manufacturing Co., both subsidiaries of the Aluminum Co. of America, have been the largest producers of bauxite in Arkansas. Most of this company's production has come from its properties near Bauxite, Saline County, and a much lesser amount from its Radcliffe mine, near Sweet Home, Pulaski County (plate 3,B). Most of the output has come from open-pit mines, but recently this company has been taking much of the ore from an underground mine, the tunnel entrance of which is near the north line of sec. 22, T. 2 S., R. 14 W.

Mining the ore underground by sinking a shaft is a comparatively recent development resulting from discovery by drilling of good ore at depths of 100 feet or more below the surface. The first shaft mine was put down by the Dixie Bauxite Co. on its property near Sweet Home (plate 3,A), and it has recently put down a second shaft on this property. The American Cyanamid & Chemical Co. has produced ore from an open pit and more recently from two shaft mines on its property near Mount Olive, in Saline County; and the company has a shaft mine that is not yet shipping ore in sec. 9, T. 1 S., R. 12 W., Pulaski County. The William J. Crouch Mining Co. is producing bauxite for the General Abrasive Co. from a shaft mine in the southwestern part of sec. 4, T. 1 S., R. 12 W. The Arkansas Bauxite Co. has recently been organized to mine bauxite for quick-hardening cement from a shaft mine in the northeast corner of sec. 17, T. 2 S., R. 14 W. Dr. S. R. Crawford was producing some ore from a shaft mine in sec. 24, T. 2 S., R. 14 W., Saline County, but his operations were discontinued by 1935.

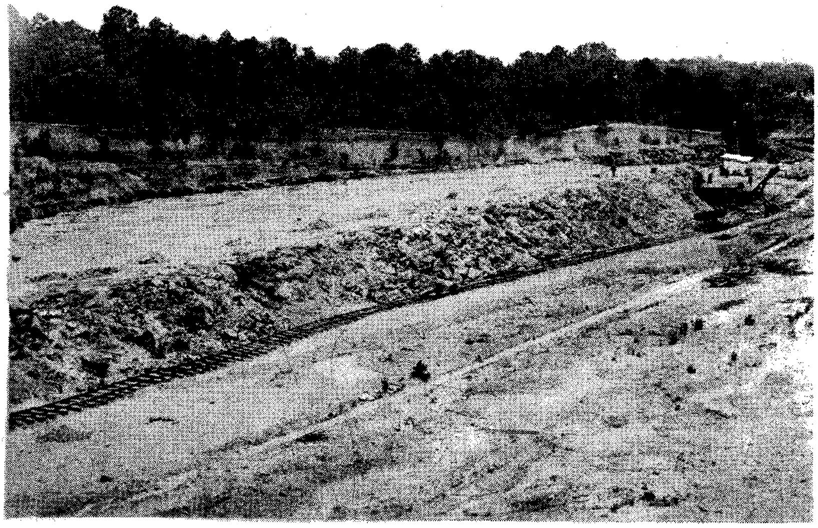
The ore is nearly all calcined at local mills before shipment to refineries outside the state, the water content being thus reduced from nearly 30 per cent of combined water to less than one per cent. The major part of the ore is shipped to the refineries and reduction plants for aluminum production, but much ore is also shipped for abrasive and chemical purposes. Additional discussion of the methods of mining and treating the ore has been presented in papers by George C. Branner 22/ and others 23/. (See production table, p. 10)

22/ Branner, G. C., The Arkansas bauxite deposits: XVI Internat. Geol. Cong. Guidebook 2, pp. 97-100, 1933. Current bauxite mining activities in Arkansas: Mining and Metallurgy March 1935, pp. 123-124.

23/ Cash, F. E., and Von Bernewitz, M. W., Methods, cost, and safety in stripping and mining coal, copper ore, iron ore, bauxite, and pebble phosphate: U. S. Bur. Mines Bull. 298, pp. 228-237, 1929.



A. Shaft mine of Dixie Bauxite Co., in Sweet Home area, Pulaski County.



B. Stripped bauxite being mined at Radcliffe mine of Republic Mining & Manufacturing Co., in Sweet Home area, Pulaski County.

Bauxite Produced in Arkansas and in the United States

1898-1934

(From U. S. Geological Survey and U. S. Bureau of Mines)

Year	Arkansas		United States	
	Long tons	Value	Long tons	Value
1898	633		25,149	$ 75,437
1899	5,045		35,280	125,598
1900	3,445		23,184	89,676
1901	867		18,905	79,914
1902	4,645		27,322	120,366
1903	25,713		48,087	171,306
1904	25,748		47,661	235,704
1905	32,956		48,129	240,292
1906	50,267		75,332	368,311
1907	a/ 60,000		97,776	480,330
1908	b/ 37,703		52,167	263,968
1909	b/ 106,874		129,101	679,447
1910	b/ 115,836		148,932	716,258
1911	b/ 125,448		155,618	750,649
1912	117,299		159,865	768,932
1913	169,871	$ 846,988	210,241	997,698
1914	195,247	976,686	219,318	1,069,194
1915	268,796	1,370,489	297,041	1,514,834
1916	375,910	2,011,590	425,100	2,296,400
1917	506,556	2,724,007	568,690	3,119,058
1918	562,892	3,133,880	605,721	3,447,992
1919	333,490	1,855,159	376,566	2,201,747
1920	481,279	2,897,892	521,308	3,247,345
1921	124,850	755,400	139,550	889,800
1922	266,790	1,682,890	309,600	2,012,330
1923	493,880	2,980,580	522,690	3,156,610
1924	327,630	1,981,000	347,570	2,137,990
1925	296,320	1,878,450	316,540	1,988,250
1926	371,570	2,298,550	392,250	2,415,200
1927	303,830	1,892,860	320,940	1,988,780
1928	361,236	2,193,230	375,426	2,273,898
1929	351,054	2,181,158	365,777	2,265,638
1930	315,273	1,823,389	330,612	1,928,297
1931	186,697	1,081,450	195,895	1,140,629
1932	89,779	507,697	96,349	548,168
1933	142,179	853,718	154,176	923,259
1934	145,764	1,057,062	157,838	1,129,053

a/ Approximate figure.
b/ Includes the production in Tennessee.

OCCURRENCE OF THE BAUXITE

The close association of the larger deposits of bauxite with the syenite was noted by the earliest investigators, and later work, particularly in test drilling, shows that this association is even more definite than was obvious from the surface examinations. However, there is also a very large amount of low-grade bauxite and bauxitic clay which occurs within the Eocene sedimentary beds of the Coastal Plain deposits.

Though the thickness and quality of the bauxite vary greatly, it generally forms blanketlike deposits that are underlain by kaolin. The rapid variations in thickness of the bauxite are largely due to the irregular lower surface, at the contact with kaolin. Lenses of bauxite 30 to 35 feet in maximum thickness form pockets extending down into the kaolin, or "horses" of the kaolin may extend up and reduce the thickness of bauxite to almost nothing. The upper surface of the bauxite is comparatively smooth or regular and sharply marked off from the overlying beds, but the contact with the kaolin is very irregular and gradational. It is therefore commonly impossible to determine without continued checks by chemical analysis just what portion to mine and what portion to exclude because of high silica content from admixed clay. The bauxite and kaolin together form a generally continuous blanket deposit - where not removed by erosion - with the bauxite in the upper part, locally thick, thin, or absent. Both were formed by the weathering of an old land surface and are grouped as a single "bauxite-kaolin zone" in some of the following discussion.

The thicker and better-quality bauxite occurs where the bauxite-kaolin zone overlies syenite. This bauxite grades down into a variable thickness of the underlying kaolin, which with depth shows increasingly well the original granitic texture in the residual feldspar forms preserved in the soft kaolin. This completely kaolinized syenite grades down into the "rotten granite," or partly kaolinized syenite, in which the feldspar grains are white or pale green through alteration but are increasingly hard with depth and with increasing amounts of other original minerals, such as biotite and amphibole, and this material grades down into the hard, unaltered syenite. This transition zone from the bauxite down to hard syenite measures as much as 50 feet in some of the test holes. Most of the bauxite of commercial grade is found in these residual deposits formed from the underlying syenite. Some reworked or sedimentary bauxite occurs immediately above these deposits in places, as boulders of bauxite forming a basal conglomerate in the Wilcox beds (plate 2,B). However, this bauxite conglomerate is too thin and impure to be of any commercial interest and is significant only in considering the origin of the bauxite.

The bauxite-kaolin zone where it overlies the syenite is generally very irregular in attitude, pitching at angles of as much as 20° and as much as 10° for a distance of more than 1,000 feet. These irregularities of dip reflect the irregular topography of the syenite hills at the old surface on which the bauxite was formed. Plate 4,A, shows a stripped ore surface with a dip of about 10°, which is underlain by syenite, and the relations are illustrated in the generalized cross section (plate 5,B).

The bauxite-kaolin zone extends out beyond the irregular surface on the higher areas of syenite to an even and nearly flat surface where the zone is underlain by the Midway blue clay and conforms to the gentle dip of about 1° SE. that is the regional dip of the Coastal Plain deposits. The results of this investigation indicate that these deposits of bauxite overlying the blue clay and thus interbedded in the Tertiary sedimentary formations are not reworked or sedimentary bauxite, and on page 26 evidence is presented that they were formed in place, and are confined to the stratigraphic horizon representing the unconformity between the Midway and Wilcox.

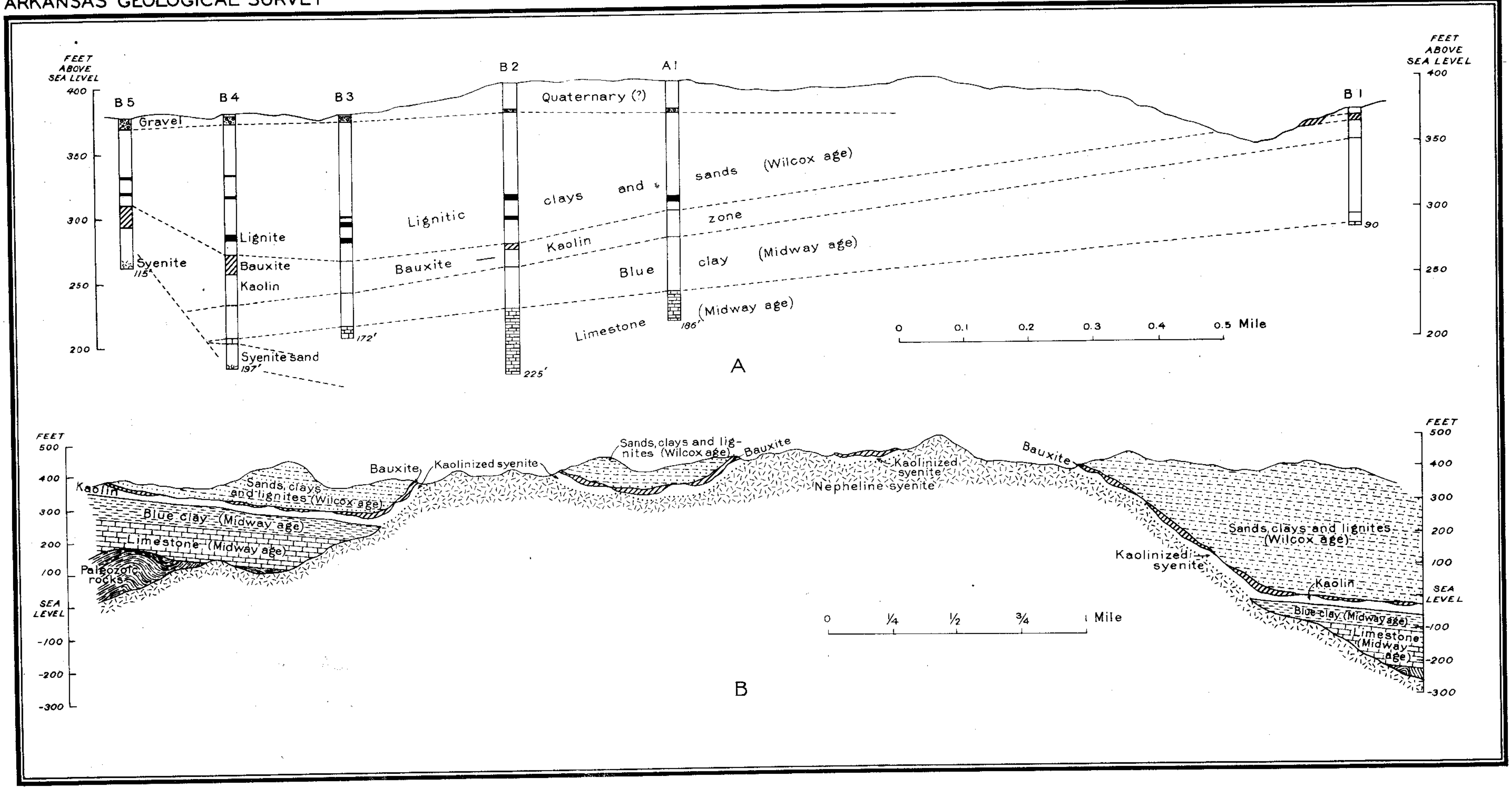
The bauxite deposits underlain by blue clay are generally thin and of poor quality because of the high percentage of iron or silica, or both, and consist largely of very ferruginous bauxite or laterite and bauxitic clay. However, in some places adjacent to the flanks of syenite hills that extend above the level of the Midway thicker deposits of bauxite of commercial grade overlie the blue clay. Such a relation is indicated in plate 5, and is discussed in considering the results of drilling (p.19).

GENERAL CHARACTER OF THE BAUXITE

The term "bauxite" is applied rather loosely in this report to rock high in aluminum hydroxide. A chemical analysis, showing the content of alumina and combined water to be higher than in kaolin, is commonly the only definite means of identification, but if no rigorous classification is used the physical characteristics of

A. Stripped bauxite showing dip of ore body, corresponding with dip of underlying syenite surface. Pruden mine of Republic Mining & Manufacturing Co., Saline County.

B. Large area where ore has been mined out. Hamp Smith mine of Republic Mining & Manufacturing Co., Saline County.


FEET ABOVE SEA LEVEL
400
350
300
250
200
B 5
B 4
B 3
B 2
A 1
B 1
Gravel
Quaternary (?)
Lignite
Bauxite
Kaolin
Syenite
115'
Syenite sand
197'
172'
225'
186'
90
Lignitic clays and sands (Wilcox age)
Bauxite — Kaolin zone
Blue clay (Midway age)
Limestone (Midway age)
0 0.1 0.2 0.3 0.4 0.5 Mile
A
FEET
500
400
300
200
100
SEA LEVEL
-100
-200
-300
Kaolin
Sands, clays and lignites (Wilcox age)
Blue clay (Midway age)
Limestone (Midway age)
Paleozoic rocks
Bauxite
Kaolinized syenite
Sands, clays and lignites (Wilcox age)
Bauxite
Kaolinized syenite
Nepheline syenite
Bauxite
Sands, clays and lignites (Wilcox age)
Kaolinized syenite
Kaolin
Blue clay (Midway age)
Limestone (Midway age)
0 1/4 1/2 3/4 1 Mile
B

bauxite are usually sufficient for its recognition. There is a complete gradation from bauxite to kaolin and from bauxite to iron oxide. Rock that has some of the characteristics of bauxite but obviously a high clay content is termed "bauxitic clay" in this report, and rock that is very high in iron oxide or hydroxide is termed "laterite." Only a small part of what is classed as bauxite is sufficiently pure aluminum hydroxide to be merchantable bauxite of present commercial grades.

These gradations are accompanied by much variation in physical characteristics, and even the bauxite of commercial grade shows a great variety of texture, color, and hardness; so that these features seldom serve as a guide to the grade of ore, or even as an indication that the bauxite is of commercial quality. However, one familiar with bauxite can usually distinguish it from bauxitic clay and laterite, and operators in a local deposit are often able to judge the approximate quality of the ore.

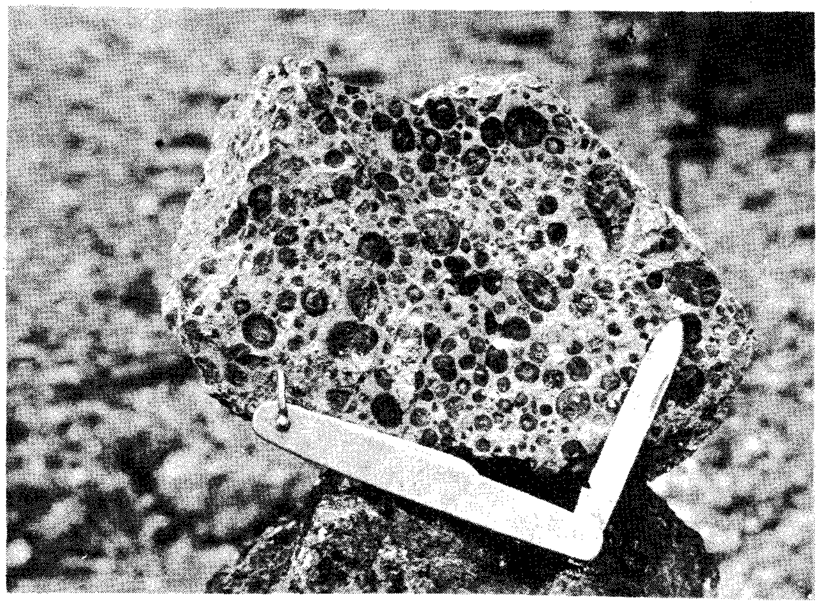
The color of bauxite varies from a grayish white through many tones of yellow, buff, and brown to nearly brick-red. The color alone is not a reliable criterion of the iron content, as some of the buff to reddish-brown ore contains less iron than other bauxite of grayish white color. The hardness varies greatly, though most of the bauxite is a coherent and fairly hard rock, especially near the upper surface. In specific gravity also the bauxite shows much variation, from a rather dense and heavy rock to a very light and porous one. Harder 24/ states that for conservative estimates of tonnage, one gross ton represents 23 cubic feet of low-iron bauxite or 19 cubic feet of dense, high-iron bauxite. These figures are due to the high porosity, as the specific gravity of bauxite would otherwise show about 14 cubic feet to the gross ton.

Pisolitic texture is common in the Arkansas bauxite, (plate 6,A) as it is in bauxite from most other regions, and is the most generally obvious feature in its recognition. However, much of the bauxitic clay and laterite also show this texture, and some of the best ore does not show it. The pisolites are roughly spherical and show more or less concentric banding of varying colors. They vary greatly in diameter, from less than 0.1 inch to more than one inch, and many of the larger ones are compound, enclosing several smaller pisolites. Some of the pisolitic bauxite shows a large amount of structureless matrix, with the spherules well separated, but in other portions the pisolites have very little matrix and break down into loose spherules on being mined.

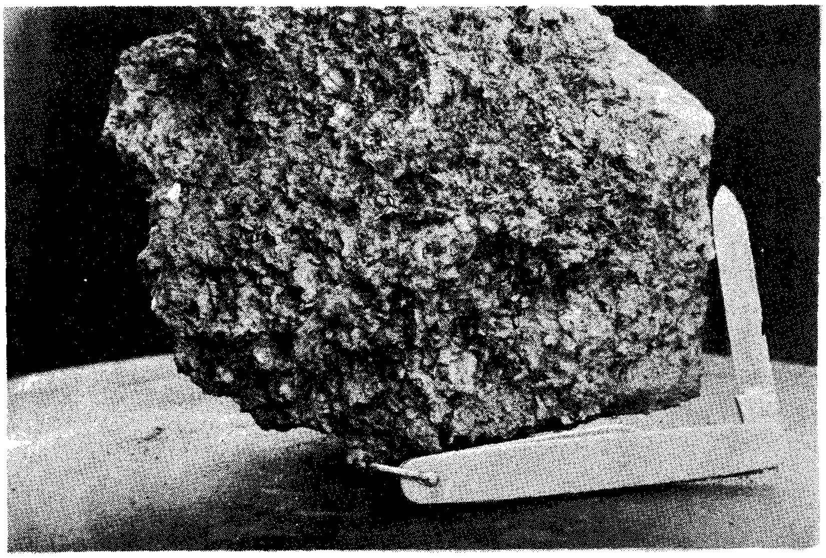
Granitic texture is common in the bauxite deposits of Saline County, particularly in the lower parts of the bauxite. This texture is shown in plate 6,B and is better seen in thin sections of this material. The original form of the feldspar crystals, and therefore the granitic texture inherited from the original syenite, is well preserved. Some of the other minerals from the syenite have been completely leached out, making the rock very porous, and the term "sponge ore" is often applied to this porous type. Locally the entire thickness of bauxite shows granitic texture. Elsewhere material of this type is overlain by the pisolitic bauxite, which may extend down as pockets into the underlying granitic bauxite, but no locality is known where the pisolitic bauxite occurs beneath the granitic type.

In places, as at mine 14 of the Republic Mining & Manufacturing Co., some bauxite of good quality is found that is very fine grained, massive or structureless, and in physical appearance almost indistinguishable from the underlying clay. Bauxite of this type occurs in the lower part of the ore deposit in horselike masses and was classed with the similar clay "horses" until chemical analyses showed it to be good ore. This claylike ore appears to be uncommon, but recognition of it depends on chemical analyses, and it might easily be overlooked.

24/ Harder, E. C., Edwards, J. D., Frary, F. C., Jeffries, Zay. The Aluminum industry - aluminum and its production, p. 66, New York, McGraw-Hill Book Co., 1930.



A. Hard, pisolitic bauxite from mine 14 of Republic Mining & Manufacturing Co., Saline County.



B. Bauxite of granitic texture from Church mine of Republic Mining & Manufacturing Co., Saline County.

CHEMICAL FEATURES

The purest Arkansas bauxite approaches the composition of the mineral gibbsite ($Al_2O_3.3H_2O$), which contains 65.4 per cent of alumina and 34.6 per cent of water. However, even the bauxite of highest quality always contains as impurities some silica, iron, and titanium. With increasing amounts of silica there are all gradations from the best-quality ores to bauxitic clays and to kaolin. With increasing amounts of iron there is a corresponding gradation from merchantable bauxite to laterite and to iron ore. The titanium, though regularly present, nowhere exceeds a few per cent and generally runs about 2 per cent.

The bauxite is not generally of present merchantable grade unless it contains about 55 or 56 per cent of alumina and little more than about 7 per cent each of silica and iron. A somewhat higher iron content is permissible in the ore for aluminum and for abrasives; on the other hand, ore for chemical purposes may contain over 7 per cent of silica without serious difficulties but should have an iron content of only 3 per cent or less. The content of combined water is generally 25 to 30 per cent before calcining.

Mead 25/ has presented chemical data (see analyses below) showing the complete gradation in chemical composition from the syenite through the decomposed and kaolinized syenite to the bauxite. This change involves the loss of alkalies, alkaline earths, and much silica, with the resulting concentration of alumina and a large increase in water and pore space. These chemical changes are characteristic of the decomposition of silicate rocks in ordinary weathering, though the final stage of the process that produces the bauxite from kaolin occurs only under particularly favorable conditions of climate, bed rock, and topography (p. 27).

Analyses of Samples Showing Gradation from Unaltered Syenite to Bauxite Ore 26/

	1	2	3	4
Silica (SiO_2)	58.00	52.64	39.80	10.64
Alumina (Al_2O_3)	27.10	29.56	37.74	57.48
Iron oxide (Fe_2O_3)	1.86	1.06	1.60	2.56
Iron oxide (black) (FeO)	3.30	.80	.10	.20
Magnesium oxide (MgO)	.25	.00	.00	----
Calcium oxide (CaO)	1.62	.00	.00	----
Sodium oxide (Na_2O)	6.70	4.46	----	----
Potassium oxide (K_2O)	.25	.44	----	----
Titanic oxide (TiO_2)	.40	1.20	3.30	1.20
H_2O	1.22	9.00	17.00	28.36

1, Unaltered syenite; 2, 3, intermediate stages; 4, bauxite ore

The following analyses of samples are discussed in considering the results of drilling tests (p. 14).

25/ Mead, W. J., op. cit., pp. 48-50.
26/ Mead, W. J., op. cit., pp. 48-50.

Chemical Analyses of Bauxite Samples

R. E. Stevens, U. S. Geological Survey, Analyst

	Alumina (Al_2O_3)	Silica (SiO_2)	Iron oxide (Fe_2O_3)	Titanic oxide (TiO_2)	Above 110° C. (H_2O+)	Below 110° C. (H_2O-)	Total
Bauxite of granitic texture from old Calumet pit, sec. 26, T. 2 S., R. 14 W.	56.58	10.35	2.23	1.79	29.03	0.22	100.20
Outcrop sample of low-grade bauxite at Midway-Wilcox contact, sec. 12, T. 1 S., R. 13 W.	47.68	22.48	2.47	2.55	22.27	.52	97.97
Samples from drill hole C1:							
141-143 feet	36.32	38.00	2.35	1.98	15.90	.75	95.30
143-145 feet	38.34	33.88	6.82	1.50	18.22	.69	99.45
145-147 feet	39.92	17.00	14.55	1.69	24.54	.89	98.59
147-149 feet	43.72	14.25	12.30	2.04	25.01	.76	98.08
149-151 feet	44.78	15.90	10.80	1.98	25.52	.68	99.66
151-153 feet	43.00	24.21	7.88	1.89	20.92	.85	98.75
153-155 feet	41.68	30.62	5.86	1.73	18.61	.73	99.23
155-157 feet	42.69	19.89	10.76	2.16	22.76	.91	99.17
157-159 feet	39.11	31.21	6.82	1.92	17.60	.95	97.61
159-161 feet	37.75	38.60	3.97	1.92	15.06	.74	98.04
Samples from drill hole C3:							
118-120 feet	42.40	14.35	13.61	1.40	26.09	1.24	99.09
120-122 feet	52.77	7.15	8.44	1.32	29.83	.62	100.13
122-124 feet	41.30	9.78	17.99	1.61	28.09	.82	99.59
124-127 feet	36.81	28.38	11.93	1.15	19.81	.70	98.78
127-130 feet	33.15	33.72	12.39	1.05	17.83	.82	98.96
Samples from drill hole B5:							
74-76 feet	51.00	15.72	2.73	2.25	26.35	1.44	99.49
76-78 feet	58.03	4.73	2.77	2.46	31.31	.63	99.93
78-80 feet	58.60	5.74	2.57	2.06	30.70	.15	99.82
80-83 feet	52.00	9.43	5.83	4.08	26.71	.42	98.47

MINERAL FEATURES

The chemical composition of the purer bauxite approaches that of the mineral gibbsite, and crystals of that mineral are obvious in the microscopic examination of most samples. The ore of granitic texture from the old Calumet pit, is nearly all gibbsite, and the granitic type of bauxite generally consists largely of crystalline gibbsite. The pisolitic ore seems similar to the gibbsitic ore, to judge by the chemical composition and dehydration curves (plate 7), but microscopic examination shows only a minor amount of recognizable crystals of gibbsite in the pisolitic type, which consists dominantly of an apparently amorphous form of the aluminum hydroxide. The relations suggest that the amorphous material has formed from the crystalline gibbsite through solution and redeposition that produced the pisolites, and a development of spherical forms is a common tendency in the growth of noncrystalline minerals. Lacroix 27/ and Mead 28/ have presented evidence that the pisolites represent a con-

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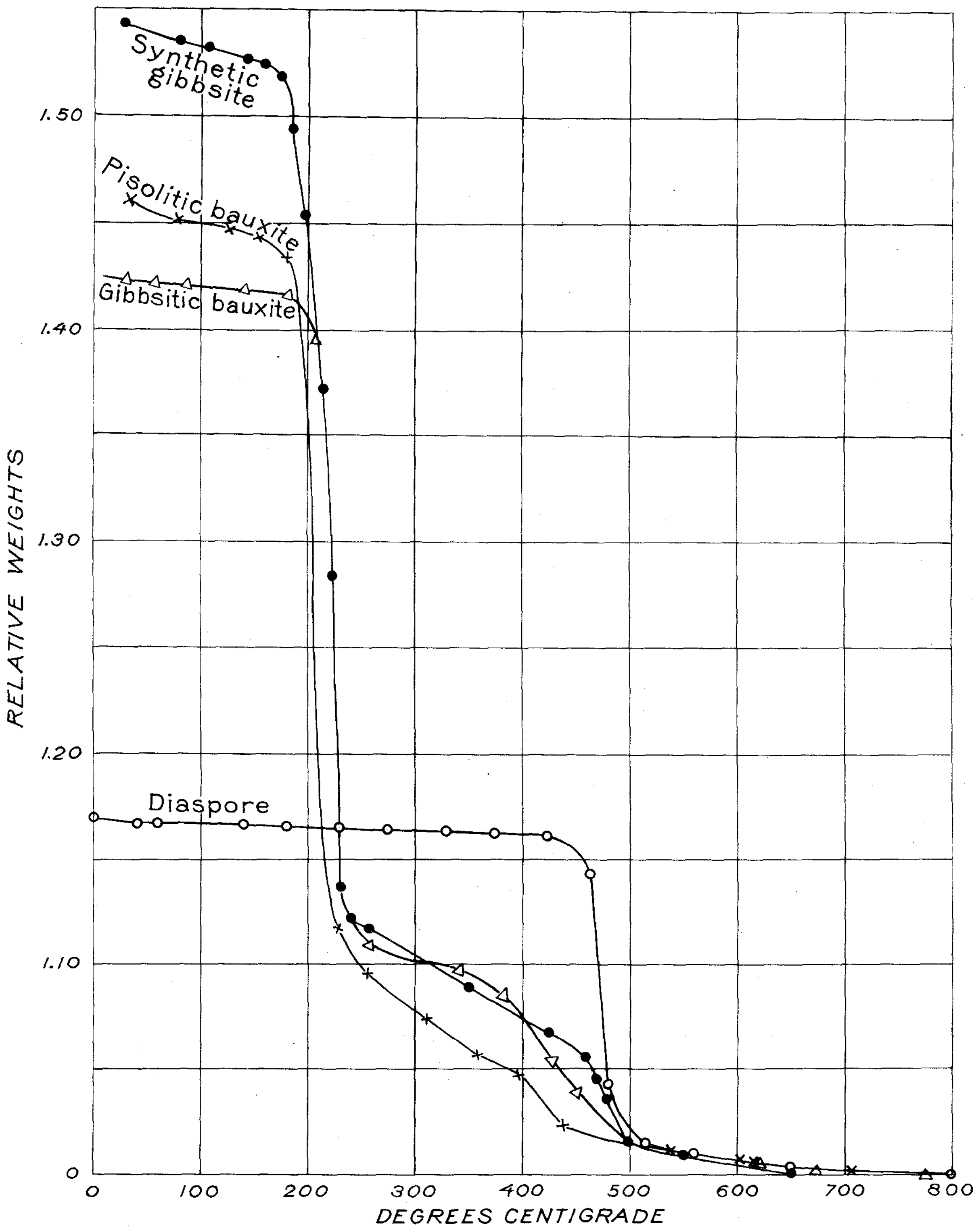
27/ Lacroix, A., Laterites de la Guinee: Mus. histoire nat. Nouv. arch. ser. 5, vol. 15, p. 341, Paris, 1913.

28/ Mead, W. J., op. cit., pp. 52-54.


Synthetic gibbsite
Pisolitic bauxite
Gibbsitic bauxite
Diaspore
RELATIVE WEIGHTS
1.50
1.40
1.30
1.20
1.10
0
DEGREES CENTIGRADE
0
100
200
300
400
500
600
700
800

cretionary form of development within the bauxite, and the conditions under which this occurred are considered in the discussion of origin of the bauxite (pp.25-31). In the abundance of the trihydrate of aluminum, shown by the chemical and mineral evidence, the Arkansas bauxite is in distinct contrast with the French bauxite, which contains about 12 to 15 per cent of combined water and thus approaches the monohydrate, diaspore. Some deposits of bauxite in the Ural region of Russia 29/ and in Kashmir, India 30/ are unusually low in water and contain recognizable diaspore. These deposits have been involved in strong folding of the strata and may thus have been converted into the monohydrate through metamorphism during the structural deformation. Dehydration curves (plate 7) suggest that the pisolitic and granitic ores of Arkansas contain no appreciable amount of the monohydrate, as there is no marked break in the curves between 450°-500°, such as is shown by diaspore, and no break in the curve occurs at a position to suggest a mineral of the composition $Al_2O_3.2H_2O$.

Clay minerals are generally present in variable amounts in the bauxite and account for the silica content, free quartz is not present in the bauxite, except as small amounts of sand in the upper part, where it has been introduced from the overlying Wilcox sediments. The upper one foot or more of the bauxite is commonly high in silica, owing largely to a high clay content. The base of the bauxite usually shows a gradational contact with increasing proportions of kaolin and other clay minerals. The kaolin underlying the bauxite is generally white, except where surface oxidation has affected it, and carries abundant scattered pellets of siderite. The kaolin may be nearly textureless or massive in the upper part but where it is underlain by syenite much of it shows the granitic texture and there is a gradual change from the kaolin to the "rotten granite" and finally to the hard syenite. The "rotten granite" is white to pale green and commonly carries abundant siderite spherules. Microscopic examination indicates the presence of several distinct types of clay minerals in this zone, with typical kaolinite developing last from earlier clay minerals. However, the difficulties in distinguishing definitely the various clay minerals, without x-ray diffraction work, prevented any attempt at a systematic study of them in this work. The term "kaolin" is therefore used loosely here for the white clays that are known to include at least some true kaolinite, and "kaolinized syenite" is used for the soft syenite that has been altered to white clay minerals, even though kaolinite is commonly a minor one of these clay minerals.

The iron present in the bauxite occurs as oxide and hydroxide, as the carbonate in siderite, and as the sulphide in pyrite. Siderite is commonly the chief iron mineral where the bauxite has not been subjected to present surface oxidation, and much of it is obviously later than the formation of the bauxite, for it occurs as well-developed crystals filling cavities and pore spaces within the bauxite. Some magnetite is present in the bauxite, and rusty-coated ilmenite is generally present in small amounts. Additional notes on the iron minerals are included in the section on the origin of the bauxite (pp. 25-31).

The chemical changes involved in the alteration of the syenite, through kaolin, to bauxite were well presented by Mead 31/ and therefore are only briefly mentioned in this report, but the mineral changes will be considered in more detail.

The syenite naturally varies in composition from place to place, so that each specimen shows a somewhat different proportion of mineral constituents. Also some minerals, such as diopside and albite-oligoclase, that are present in certain specimens are entirely lacking in others. These variations make it impossible to compare accurately in percentages, the individual samples of original syenite with those of the bauxite that would be derived from them, because the samples in any transitional sequence are necessarily separated by some feet or even scores of feet. An average com-

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29/ Arkhangelsky, A. D., On the origin of the bauxites of U.S.S.R.: Soc. nat. Moscou, Bull. nouv. ser., tome 40, Sec. geol., tome 11(4), pp. 434-436, 1933.

30/ Rao, T.V.M., On bauxite from Kashmir, India: Geol. Mag., vol. 55, no. 768, p. 288, 1928.

31/ Mead, W. J., op. cit., pp. 48-50.

position of each of the four types is therefore given in the following table, based on series of samples from five localities where the transitional change can be observed in mine openings. Examination of additional samples from localities where the entire transition is not exposed indicates that these averages are roughly representative. The figures in the table represent approximate percentages by volume of crushed rock and thus disregard porosity.

Average Mineral Composition of Rock Types Showing Transition from Syenite to Bauxite

	Fresh syenite	Crumbly syenite	Kaolinized syenite	Bauxite (granitic type)
Gibbsite and bauxite	--	--	--	85.0
Clay minerals	--	3.0	95.0	10.0
Orthoclase	50.0	54.0	--	--
Albite-oligoclase	12.0	14.0	--	--
Nephelite	10.0	--	--	--
Analcite	2.0	--	--	--
Aegirite	12.0	15.0	--	--
Diopside (salite?)	2.0	--	--	--
Amphibole	3.0	4.0	--	--
Biotite	4.0	5.0	--	--
Magnetite	2.0	2.0	--	--
Ilmenite	1.0	1.0	2.0	2.0
Titanite	2.0	2.0	--	--
Xanthitane	--	--	3.0	3.0
Apatite	.5	--	--	--
Fluorite	.1	(?)	--	--
	100.6	100.0	100.0	100.0

Several samples of the fresh syenite from the Fourche Mountain area, in Pulaski County, and the area near Bauxite, in Saline County, show the consistent presence of titanite, magnetite, ilmenite, and apatite, and usually some fluorite; and these are the only accessory heavy minerals present. Such common accessory minerals as zircon and rutile are in general completely absent but these and other minerals including garnet, tourmaline, and kyanite, are common in the adjacent Wilcox sedimentary rocks and are also found to some extent in the pisolitic upper part of the bauxite, but not in the underlying granitic bauxite that is shown in the table. This indicates a certain amount of reworking or mixing of the upper pisolitic bauxite with the overlying Eocene sediments.

Intermediate samples, between the types shown in the table, show the order of alterations about as follows: (1) Brown hornblende changes to green hornblende; (2) nephelite changes to analcite, and the feldspars become distinctly cloudy with clay minerals; (3) analcite and apatite disappear through leaching; (4) pyroxenes, amphiboles, and perhaps fluorite disappear; (5) biotite becomes bleached and then disappears, titanite alters to the hydrous mineral xanthitane, and the feldspars are completely altered to clay minerals; (6) magnetite disappears, ilmenite is partly altered to leucoxene, and the clay minerals alter to gibbsite.

These mineral changes would appear to represent a normal sequence in most respects for a complete weathering process, though the thoroughness of the chemical decomposition is remarkable. The total disappearance of magnetite is perhaps surprising, as it is a relatively stable mineral and might be expected to persist in the final product represented by the bauxite. In some samples even the ilmenite has been altered and apparently largely lost, and only the peculiar hydrous titanium mineral xanthitane remains as the heavy residue of the bauxite.

This titanium mineral generally occurs in appreciable amounts in the bauxite, and as the proportion present indicates that it is the source of most of the TiO_2 shown in the bauxite analyses, a particular effort was made to determine its true mineral character. It occurs in discrete grains 0.25 minimum or more in maximum size and as larger aggregates that show in thin sections the lozenge-shaped cross section of the original titanite grains. Evidence that it was derived from titanite is also found in some intermediate samples where the titanite grains are only partly altered to this mineral. The mineral is yellow to amber, is translucent, and has an index of refraction well above 2.1 (the highest index melt tested). It is nearly isotropic except for parts showing weak birefringence with waxy extinction that seems to be the strain birefringence shown by some amorphous substances, and it gives no definite optical figure. It is soluble in a hot, strong solution of sulphuric acid. A concentrate of the mineral that appeared to be about 95 per cent pure showed the following chemical composition:

Analysis of Titanium Mineral in Bauxite

Charles Milton, of the United States Geological Survey, Analyst

Titanium oxide (TiO_2)	77.24
Alumina (Al_2O_3)	6.73
Iron oxide (Fe_2O_3)	4.83
Phosphate (P_2O_5)	.93
Silica (SiO_2)	.84
H_2O below 110° C. (H_2O -)	2.07
H_2O above 110° C. (H_2O +)	7.57
	100.21

Mr. Milton also gave helpful suggestions about the character of the mineral. At least part of the Al_2O_3 and Fe_2O_3 is due to the impurities in the concentrated sample, as these consisted of some gibbsite and ilmenite, but it seems probable that part of these sesquioxides and the P_2O_5 are due to solid solution in the hydrous titanium oxide. The composition, appearance, and mode of origin resemble those of xanthitane, 32/ though none of this mineral was available for direct comparisons. Lacroix 33/ suggested the name "doelterite" for the titanium hydrate which from the chemical composition of bauxite he assumed to be present, but the titanium hydrate described here seems to represent the earlier-named mineral xanthitane. A study of some leucoxene by Coil 34/ indicates a rather similar chemical composition, and it appears possible that leucoxene is a finely divided form of xanthitane.

RESULTS OF DRILLING TESTS

Location of Test Holes

A total of 55 test holes were drilled, besides several holes that had to be abandoned, owing to drilling difficulties, before they had reached sufficient depth to yield significant information. The 55 holes represent a total of 9,171 feet of drill-

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32/ Shepard, C. U., Five new mineral species-1, Xanthitane: Am. Jour. Sci., 2d ser., vol. 22, p. 96, 1856. Eakins, L. G., Xanthitane from North Carolina: U. S. Geol. Survey Bull. 60, p. 135, 1890.

33/ Lacroix A., op. cit., p. 334.

34/ Coil, Fay, Chemical composition of leucoxene in the Permian of Oklahoma: Am. Mineralogist, vol. 18, no. 2, pp. 62-65, 1933.

ing and thus average 166.7 feet to the hole. The minimum depth was 27 feet in test hole F5, and the maximum 464 feet in hole J3. The locations of the test holes are indicated on plate 9, and more specific locations with reference to nearby landmarks are given with the individual logs, presented in the appendix.

A closely spaced drilling program was not possible with the time and funds available, and the locations were largely in the nature of "wildcat" tests, with intervals as great as half a mile or more between holes of a series. Such widely scattered drilling gave information on the general conditions of occurrence of the bauxite but could not prove much in regard to any particular deposit or the amount and quality of ore on any particular property. For such information, drilling and careful sampling of test holes spaced at 50-100-foot intervals is necessary, and the entire drilling program might thus have been required to test thoroughly a single small property.

The first series of test holes (A1 to A9) was drilled from Bryant northeastward through Alexander to Mabelvale. A shorter line of more closely spaced holes (B1 to B5) was drilled north and south from Bryant. A third line of test holes (C1 to C16) extended from Hurricane Creek northeastward through Vimy Ridge to a point near the border of Pulaski County, with a side line of three holes (CC1 to CC3) drilled north toward Alexander. Two holes (H1 and H2) were drilled northwest of Bauxite, and four holes (J1 to J4) southwest of the Saline County bauxite area. In Pulaski County two test holes (D1 and D2) were drilled west of Arch Street Pike along the Base Line road, and two more (E1 and E2) west of Arch Street Pike 1½ miles south of the Base Line road. Four scattered test holes (G1 to G4) were put down in an area southeast of Mabelvale, and five other scattered holes (F1 to F5) were drilled south of the Fourche Mountain region. Three test holes (M1 to M3) were drilled in the Fourche Bayou flats, east of the syenite outcrops of the Fourche Mountain region.

The purpose of this selection of test-hole locations will appear in the following discussion.

Interpretation of Logs

The cross section in plate 5,A presents the correlations and underground relations indicated by the line of holes (B1 to B5) extending north and south from hole A1 at Bryant; and the logs and interpretations of these holes will be considered first and in some detail, as they show certain conditions that were found to be general.

Test hole B1 was drilled near an outcrop of bauxite and penetrated this bauxite bed from the depth of 5 feet to 10 feet. Underground, as in the outcrop, this bauxite appeared to be high in iron and silica and was obviously of poor grade. Beneath the bauxite there is 14 feet of mottled clays and white kaolin, which represent the weathered upper part of the blue clay of Midway age. The blue clay was penetrated from 24 to 80 feet and at that depth grades into a gray calcareous clay containing many Foraminifera and other micro-fossils. Beneath 8 feet of this calcareous clay is limestone which was penetrated for only 2 feet in this hole, to a total depth of 90 feet. The limestone, also of Midway age, showed many micro-fossils and fragments of larger fossils in the drill cuttings.

The cross section (plate 5,A) shows the southward dip of the beds from hole B1, indicated from the depths at which they were encountered in holes A1, B2, B3, and B4. This south dip, exaggerated in the cross section by the difference in horizontal and vertical scale, is the resultant of the regional dip of about 1° SE. that is general in these Coastal Plain deposits. The Midway blue clay and limestone continue with the southward dip to the point where they thin out against the flank of the buried hill of syenite, near test hole B4. In this hole only the upper few feet of the limestone is present, as it is thinning out against the syenite, and the limestone is underlain by a coarse sand of hard, angular gray feldspar grains, like the feldspar of the fresh syenite and apparently derived from the adjacent syenite through disintegration without much chemical decomposition. The softer clayey partings in the limestone in test holes B3, B2, and A1 also contain sand that consists dominantly of similar fresh feldspar grains derived from unaltered syenite.

In significant contrast, in hole B5, where the syenite extends above the horizon of the top of the blue clay and was thus never covered with the Midway deposits, the syenite is greatly altered, through chemical decomposition, for about 30 feet down from its top. In this hole the under clay at two feet beneath the bauxite gave evidence of the granitic texture, in that the white clay particles in the drill-mud returns and in samples collected showed many clay particles with the flat cleavage faces and rectangular shapes of the original feldspar crystals, though they were soft and completely kaolinized. The change was gradational from this completely kaolinized syenite, which drilled as a soft clay, to the so-called "rotten granite," in which the feldspar grains are more obvious and harder, though still white and altered to such an extent as to be drilled easily. This hole was ended at 115 feet, where the drilling became slow, as the rock was hard enough to bounce the drill stem. At this depth, however, the syenite was not entirely fresh, as the feldspar, though hard, was grayish white from some alteration, as compared with the darker bluish-gray feldspar of the fresh syenite. Casing was set on encountering the bauxite in this hole, and the analyses of four samples (p. 14) indicate that at least four feet of this bauxite is of high quality.

The bauxite-kaolin zone contains no bauxite and consists only of a white kaolin in test hole A1 and only of bauxitic clay in hole B3. However, it forms a distinctive zone occurring between the sandy and lignitic beds of the Wilcox and the dark-blue clay of the Midway. Where the Midway thins out against the flank of the syenite mass, between holes B4 and B5, the bauxite-kaolin zone extends up and over the syenite. In hole B4 this zone is thicker than in holes to the north and includes 39 feet of beds between the depths of 108 and 147 feet, though only the upper 16 feet contains much bauxite. The increased thickness here and at some other localities where this zone overlies blue clay but is near a comparatively steep slope of a syenite mass may be accounted for as the thicker deposit of wash that would accumulate at the base of the slope. In hole B4 there is some suggestion that such slope debris was deposited as a feldspar sand, like that occurring below the Midway at the bottom of the hole, and that the feldspar sand was then altered to bauxite. This is indicated by the fact that less completely weathered material containing grains of kaolinized feldspar is increasingly abundant lower in the bauxite-kaolin zone, which is the reverse order of what would be expected if the debris were accumulated down the slope through erosion after the period of bauxite formation had blanketed the syenite.

The series of test holes A1 to A9, between Bryant and Mabelvale, constituted the first line of drilling, and the locations are in part near outcrops of bauxite. These locations were selected to test the possibility that the isolated bauxite outcrops might represent small exposures of larger bodies of ore overlying syenite at depth, and at the time of this drilling the Midway-Wilcox contact had not been mapped nor its significance realized. Test hole A1 encountered no bauxite but struck a white clay or kaolin beneath lignite and overlying the blue clay and limestone of Midway age. Similar conditions are indicated in the logs of test holes A2 and A3. In hole A4 the Midway was encountered immediately below the surface zone of soil, sand, and gravel, and the subsequent mapping showed that the Midway-Wilcox contact passes along the hill about 300 feet south of the hole, with some kaolin and mottled clay at the top of the blue clay. Test hole A5 was drilled in a stream-valley flat and encountered only sands, probably alluvium, until very hard rock at 43 feet stopped the drilling. This rock was so hard that no determinable cuttings of it were brought up with the drill mud, but it was thought to be a siliceous rock, perhaps the Paleozoic novaculite. Test hole A6 entered the Midway immediately beneath surface gravel and encountered the limestone at 13 feet. The clay overlying the limestone is sticky and yellow to buff, the blue clay also has this characteristic in many places where weathered near the present surface. Hole A7, at Alexander, started just below the Midway-Wilcox contact, in the weathered upper part of the blue clay, and was drilled through 23 feet of the underlying limestone. Hole A8 was also started below the Midway-Wilcox contact, and a bed of low-grade bauxite occurs at this contact only a few hundred feet to the southwest. Hole A9, at Mabelvale, was drilled near an outcrop of bauxite, which proved to be a bed only a few feet thick at the Midway-Wilcox contact, and the hole started below this horizon and encountered the Midway blue clay and limestone. The distance of more than two miles between test holes 8 and 9 is greater than the intervals between other holes of this series, but information on two water wells that encountered blue clay and limestone indicated that similar conditions occur in this interval.

The series of test holes C1 to C16, from Hurricane Creek northeastward through Vimy Ridge, was drilled to test the possible extension of the syenite and associated bauxite of the Saline County district and their continuation underground to the Pulaski County bauxite district. Hole C1 encountered bauxite at 140 to 157 feet. Casing was set at 141 feet and samples taken from 141 to 161 feet. Although some of this bauxite appeared of possible commercial grade, the chemical analyses presented on page 14 show that it is all much too high in silica or iron, or both. The bauxite is underlain by kaolin and kaolinized syenite, the syenite occurring well above the level at which Midway beds would have been deposited in this area. Test hole C1A was drilled east of C1, and shows the syenite mass at a depth sufficient to be overlain by the Midway. In this hole the bauxite-kaolin zone consists largely of kaolin and bauxitic clay, but the zone is comparatively thick and seems to represent conditions similar to the occurrence in hole B4, described above and shown in plate 5,A. Test hole C2 encountered a thin bed of bauxite overlying the kaolinized syenite, which is at less depth than in hole C1 and is nearer the outcrop of syenite to the west. Test hole C3 also encountered bauxite overlying altered syenite, at a depth well above that at which the syenite would be covered by Midway deposits, as indicated for this area by the subsurface contours on the limestone (plate 9). Casing was set on top of the bauxite in this hole, and the chemical analyses of the samples presented on page 14 show that only one sample (120-122 feet) approaches merchantable grade. Test hole C4 encountered only kaolin and bauxitic clay in the bauxite-kaolin zone, which here overlies the blue clay and limestone of Midway age. In test hole C5 about five feet of bauxite overlies kaolin and blue clay. Feldspar sand derived from disintegrated syenite was encountered beneath the blue clay at about 300 feet, a depth at which limestone would occur here is not thinned out against the syenite. This indicates the considerable local relief of the syenite. There is an outcrop of syenite a quarter of a mile to the north, at about the same surface altitude as the test hole. In test hole C6 a 6-foot bed of bauxite was found overlying the blue clay, but syenite sand and hard syenite were encountered above the level at which limestone would have been deposited. Test hole C7 encountered only a bauxitic clay overlying kaolinized syenite, which occurs here at about the depth that would represent the Midway-Wilcox contact as calculated from the subsurface contours on limestone in this area. Test hole C8 encountered only white clay in the bauxite-kaolin zone at 202-208 feet, underlain by some blue clay; and feldspar sand and hard syenite occur here beneath the top of the Midway. Hole C9 was nearer an outcrop of syenite and thus encountered the syenite well above the level of the Midway-Wilcox contact in this area, but though the syenite is kaolinized there is no bauxite over it. In test hole C10 the syenite was encountered about 20 feet above the depth at which Midway deposits would have been overlying it, but in this hole also the kaolinized syenite is not overlain by bauxite, though there is some bauxitic clay. Test hole C11 encountered no bauxite above the kaolinized syenite, which occurs at about the depth that would be expected for the Midway-Wilcox contact at this location. Test hole C12 encountered no bauxite, and the syenite here is unaltered and underlies the blue clay and the uppermost part of the limestone. In test hole C13 no bauxite was found, and fresh feldspar sand and hard unaltered syenite were encountered at depths below that calculated for the top of the Midway at this point. However, no blue clay was encountered in this hole, and it appears that the blue-clay horizon is here represented by greensand, though this is the only example found of any such lateral change in the Midway deposits. Test hole

C15 did not reach sufficient depth to encounter the bauxite-kaolin zone, because of hard rock that seems to represent an increased development of siderite beds in the Wilcox. The location for hole C14 was not drilled, because of the slow drilling progress and lack of promising results in the other tests of this region. Test hole C16 encountered bauxitic clay and kaolin overlying the Midway blue clay, and the drilling was ended in the limestone.

Three test holes (CC1 to CC3) were drilled along the road north to Alexander from a point near hole C10. Test hole CC1 encountered the kaolinized syenite well above the depth at which Midway deposits would overlap it in this area, but kaolin with no bauxite occurs above the kaolinized syenite here. Hole CC2 shows similar conditions. Test hole CC3 penetrated no bauxite, though between 81 and 121 feet it encountered some kaolin or white clay, which would appear to represent the bauxite-kaolin zone, as the regional dip would indicate that the Midway-Wilcox contact should be expected here at about 100 feet below the surface. No Midway was encountered beneath this zone, and the drill cuttings of sand, sandstone, and hard carbonaceous shale appeared to represent more probably Paleozoic rocks that are underlain by syenite. The Midway may thus thin out against a buried hill of Paleozoic rock here, and similar conditions were suggested for test hole A5, which is less than one mile to the northwest.

Test holes H1 and H2 give some data on the area to the northwest of the Saline County bauxite district. Hole H1 was drilled near an outcrop of bauxite and penetrated a thickness of about 23 feet of bauxite and bauxitic clay. The whole bauxite-kaolin zone is almost 50 feet thick here, though it overlies the Midway blue clay and limestone. The unusual thickness of this zone overlying blue clay would make the casing and careful sampling of this bauxite advisable; but the conditions were not anticipated, and so the thickness, if any, of merchantable bauxite was not ascertained. However, most of the material appeared to be low-grade bauxite and bauxitic clay. Test hole H2 encountered no bauxite and only kaolin overlying the blue clay. A 3-foot bed of sand occurring just above the limestone consists of hard, fresh feldspar grains, obviously derived from the unaltered syenite.

The series of test holes J1 to J4 was intended to obtain a subsurface profile on the southwest side of the Saline County bauxite area and to test the area of strong magnetic intensity indicated on the map by Stearn [35] in the vicinity of holes J3 and J4. However, the profile is incomplete because two intermediate locations for test holes between J2 and J3 were abandoned before reaching the base of the Wilcox, owing to difficulty with caving sands. Test hole J1 is only 1,000 feet southwest of the syenite outcrops and encountered kaolinized syenite or "rotten granite" at a depth of 64 feet. The altered syenite is here far above the depth at which it would have been covered by Midway deposits, but there is no bauxite overlying it. Test hole J2 encountered similar conditions except that the kaolinized syenite is here at a lower level. Test hole J3 was the deepest hole drilled and was ended at 464 feet, after reaching the limestone. White clay with no bauxite occurs above the blue clay. The probable mass of igneous rock that causes the local strong magnetic attraction is at greater depth and is overlain by the Midway and probably Paleozoic rocks. Test hole J4 was drilled at a lower topographic position in the intense magnetic area, but blue clay and limestone were again encountered, and the limestone was hard and presumably about 100 feet thick, so an attempt to drill through it was abandoned. Some bauxite and bauxitic clay were encountered overlying the blue clay in this hole.

Test holes G1 to G4, southeast of Mabelvale, in Pulaski County, all encountered the blue clay and limestone, and in this region syenite, if present, would appear to occur generally beneath the Midway. Holes G1 and G4 were drilled near outcrops of bauxite and encountered thin beds of low-grade bauxite and associated kaolin overlying the blue clay. Hole G3 was drilled in an area with Midway at the surface, except for

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[35] Stearn, N. H., A geomagnetic survey of the bauxite region in central Arkansas: Arkansas Geol. Survey Bull. 5, pl. 1, 1930.

a thin cover of soil and gravel. At this locality the upper part of the blue clay is sticky and yellow to buff as a result of surface weathering, but the bauxite-kaolin zone has been eroded. Some sand with the limestone in the lower part of this test hole consists of fresh feldspar grains, like that elsewhere derived from the unaltered syenite, and here, as in some other occurrences, some feldspar sand may have been washed out several miles from the source and not indicate syenite immediately adjacent. Test hole G2 encountered white clay with abundant siderite pellets overlying the blue clay and limestone, and these Midway deposits occur at a greater depth than would be expected from a normal regional dip, as is indicated by the sub-surface contours on plate 9.

Test holes D1 and D2 entered the blue clay of the Midway immediately below the surface soil and alluvium. No bauxite nor kaolin was encountered, as the tests were started at a lower horizon than the bauxite-kaolin zone, which has been eroded in this area. Thin beds of siderite are more common in the blue clay than is usual in most other areas. The syenite and overlying feldspar sand, encountered beneath the Midway deposits in hole D1, are hard and unaltered.

Test hole E1 was started in the Wilcox, only about 1,000 feet west of the outcrop of syenite. The syenite, encountered above the depth at which the Midway-Wilcox contact would have been expected, is kaolinized or altered to considerable depth. Only one foot of bauxite was encountered above the kaolin, though a thicker deposit of bauxite occurs under similar conditions in the shaft mine only 750 feet to the southeast. Test hole E2 penetrated the blue clay at 150 feet, with white clay but no bauxite overlying it. In this hole only the upper part of the limestone is present, as it thins out against the syenite, which is here fresh and hard. The dip of the syenite mass from the outcrop through holes E1 and E2 is between 6° and 7° and is thus comparable to many of the surface slopes on the adjacent hills of syenite.

Test holes F1 to F5 all encountered syenite at comparatively shallow depths, well above that at which the top of the Midway would otherwise occur in these localities. The syenite is deeply altered or kaolinized in each of these holes, but only in hole F4 is there a deposit of bauxite overlying it.

Test hole M1 encountered "rotten granite" immediately underlying a thick deposit of river alluvium, and the zone of bauxite and kaolin may have been developed here but cut away by the stream that deposited the alluvium. Test hole M2 encountered bauxite with a thin bed of lignite occurring within the bauxite zone, as in part of the bauxite deposit to the west that is being mined underground by the Dixie Bauxite Co. The quality of the bauxite in this hole is not known, as samples suitable for chemical analyses were not obtained, and the thickness of the deposit is questionable, as the hard rock on which drilling was stopped proved not to be syenite. Test hole M3 also encountered some bauxite and was ended on similar hard rock, without having reached syenite or Midway, and therefore there may be an additional thickness of bauxite here that was not tested.

Interpretation of Results

The interpretation of the line of test wells B1 to B5 was studied in some detail, and the results of these and the other test wells indicate that the relations set forth below are general. The syenite where it extends above the top of the Midway is regularly much altered and kaolinized and may have deposits of bauxite developed on it, except where more recent erosion has removed these alteration products and the comparatively fresh syenite is exposed at the surface. The syenite and feldspar sand derived from it occurring beneath deposits of Midway age show little of this alteration through chemical decomposition and no formation of kaolinized syenite and bauxite. A general zone of kaolin with some bauxite and bauxitic clay occurs at the contact of the Wilcox and Midway, but this bauxite is rarely thick and is of low quality.

Subsurface contours on the top of the limestone of Midway age are shown on plate 9, based on the meager data from the scattered test holes. The data available would have been ample for this purpose if the limestone had the regular regional dip that might be expected, but the drilling indicates a considerable variation in dip in some areas, and the contouring is therefore generalized. However, by superposing these subsurface contour lines upon the new topographic map, which will soon be available, the approximate depth at which limestone may be expected at any location can be determined. The top of the limestone is contoured rather than the top of the blue clay because the clay, though it forms the top of the Midway, affords a less definite and regular stratigraphic horizon, owing to the unconformity. And though the top of the blue clay represents the critical horizon below which bauxite is not to be expected, the clay is generally only 40 to 60 feet thick and it is seldom difficult to carry the drilling on down to the limestone, which forms a more easily recognized lower limit for drilling.

The bauxite encountered above kaolinized syenite in hole B5 is in part of very good quality. Though not a thick bed here, more ore is known to occur under similar conditions to the south. Drilling by the General Foods Co. is understood to have outlined about 125,000 tons of ore on 5 acres of the nearby Kelley and Greene properties. The conditions in this area, as indicated by the drilling and surface geology, suggest that commercial deposits are not likely to occur in sec. 34 or the N. ½ sec. 35, T. 1 S., R. 14 W., as any bauxite encountered in those tracts will probably be a thin bed of low grade overlying the blue clay. The S. ½ sec. 35 would seem to offer better prospects, as suggested by the conditions indicated in hole B4; and more favorable conditions are indicated for much of sec. 2, T. 2 S., R. 14 W.

Much bauxite of low grade, generally high in iron, is understood to have been encountered by drilling in the Hurricane Creek bottom land of secs. 3, 11, and 12, T. 2 S., R. 14 W., and bauxite of this type was penetrated in test hole C3. Some bauxite of perhaps better quality has been encountered in the southern part of sec. 11.

The bauxite encountered in test hole C1 is shown by the analysis on page 14 to be of poor quality. However, the bed is here about 17 feet thick, and the conditions of occurrence, together with those found in holes C3 and C1A, suggest the possibility of finding some good ore in parts of sec. 18, T. 2 S., R. 13 W., and in sec. 13, T. 2 S., R. 14 W. A deposit of ore is known to occur in the northern part of sec. 24, T. 2 S., R. 14 W., and a shaft mine operated by Dr. Crawford has produced some ore intermittently. A shaft mine of the American Cyanamid & Chemical Co. in the southwest corner of this same section has also been producing recently.

No drilling was attempted on the south side of the Saline County bauxite district, but ore is known to occur at the surface (plate 8,A) and at shallow depths in the northwestern part of sec. 26, T. 2 S., R. 14 W., and the conditions appear favorable for parts of sec. 27. The 30-acre tract controlled by the Southern Acid & Chemical Co. in the NW. ¼ SW. ¼ sec. 27 is understood to have a deposit of about 500,000 tons of good ore, as indicated by the drilling done by this company, and the deposit overlies kaolinized syenite.

The results from the drilling of test holes J1 to J4 are not encouraging, but these holes are too widely spaced to give much information on conditions in this area. Though no bauxite was encountered over the kaolinized syenite in holes J1 and J2, the conditions indicated permit the possible occurrence of ore deposits nearby. The probable occurrence of igneous rock beneath the area around holes J3 and J4 was suggested by Stearn [36], and he considered it probable, from the intense magnetic anomaly, that this rock is a pluglike mass of peridotite and estimated its depth beneath the surface at 1,600 feet. The test holes drilled here show that the probable igneous rock is at least below the horizon of the Midway-Wilcox contact and thus offers no possibility of associated bauxite. Conditions favorable for the possible occurrence of some deposits of ore in secs. 28, 21, and 20, T. 2 S., R. 14 W., are suggested.

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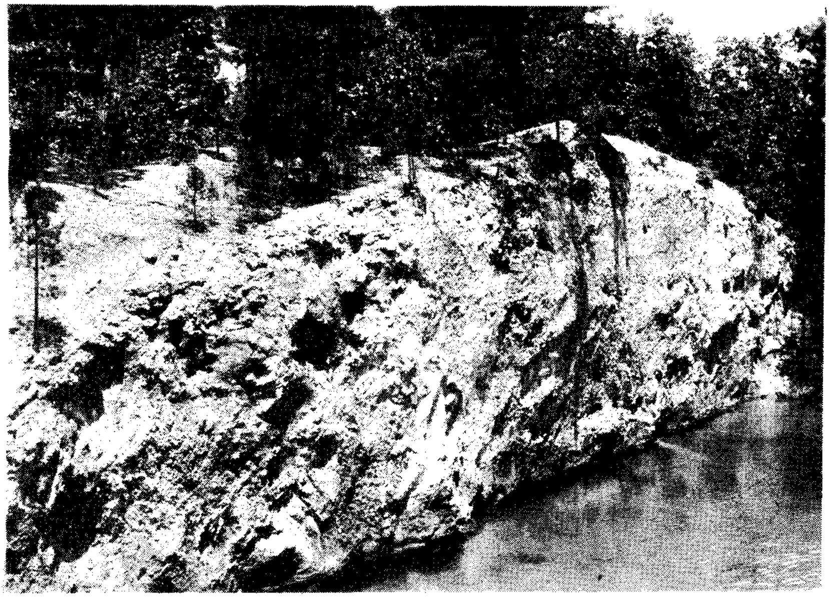
[36] Stearn, N. H., op. cit., pp. 12-13.



A. Old Calumet pit, showing about 35-foot face of ore of granitic texture, sec. 26, T. 2 S., R. 14 W., Saline County.

B. Surface of stripped ore at mine 14 of Republic Mining & Manufacturing Co., Saline County.

A deposit of ore is being mined by shaft in the NW. $\frac{1}{4}$ sec. 17, T. 2 S., R. 14 W. This bauxite overlies the blue clay but is probably not far out from the flank of the syenite mass and thus occurs in relations similar to those discussed for test hole B4. Areas in secs. 17 and 8, adjacent to this shaft mine, would appear to offer possibilities of additional ore.

Test hole H2 indicates that the syenite drops off rapidly in this direction and is overlapped by Midway deposits. However, about half a mile to the east, on the Stuckey property, a good deposit of ore is understood to have been proved. Whether or not this deposit immediately overlies kaolinized syenite was not ascertained. The unusually thick zone of bauxite and kaolin, for an occurrence overlying the blue clay, encountered in test hole H1 is of interest, but this deposit was not properly sampled for chemical analyses, and the amount, if any, of commercial grade was not determined.

Both sec. 1, T. 2 S., R. 14 W., and sec. 36, T. 1 S., R. 14 W., would seem to offer some possibilities of ore underground, from the conditions encountered in test holes C5 and C9 and from the presence of syenite at the surface in these sections, though the scattered test holes encountered no bauxite deposit of commercial interest.

The results obtained from the drilling of test holes C5 to C13 and CC1 to CC3 show that a large area south of Alexander and west and southwest of Vimy Ridge has syenite relatively near the surface, in part covered by Midway deposits, in part near the depth of the Midway-Wilcox contact, and in large part above depths that would be covered by Midway deposits. The syenite encountered in the last-named relation is thoroughly kaolinized and would seem to offer possibilities of having some good bauxite deposits associated with it in places. However, none of the scattered test holes encountered any bauxite overlying the kaolinized syenite, and though these holes were quite inadequate to test this large area properly they indicate less promise for the area than might be expected under the conditions. The reason why bauxite was not found at any of the several localities in this area where kaolinized syenite had developed is not obvious; it may be a consequence of one or more of the several factors that are unfavorable for the development or accumulation and preservation of bauxite. However, the small number of test holes may give an erroneous impression of the conditions, and the presence of kaolinized syenite under large parts of the area indicates that much additional drilling is necessary to prove definitely the presence or absence of associated ore deposits.

Test holes C16, A9, and G1 to G4 indicate that in this large area the syenite, if present at depth, is generally overlain by the blue clay and limestone of Midway age, and that the low-grade bauxite and bauxitic clay encountered is that occurring generally at the Midway-Wilcox contact. However, the drilling in this area is obviously too scattered to eliminate the possible occurrence of a syenite mass beneath some part of the area at a depth shallow enough to be covered by Wilcox deposits but not by the Midway. Geophysical methods for testing such a possibility might prove preferable to the large amount of drilling that would be necessary to test this otherwise unpromising area.

Test holes A4 to A9, G3, D1, and D2, with the results of field examinations and mapping, indicate that the large area with Midway at the surface, as shown on plate 9, cannot be considered prospective bauxite land; as neither the low-grade bauxite of the Midway-Wilcox contact will be encountered, nor is there any prospect of bauxite associated with syenite at depth, because the syenite would be covered by Midway deposits and thus unaltered. On the north and west sides of the syenite area of Pulaski County the syenite is in contact with Midway deposits, as shown on plate 9, and is comparatively fresh rock with no kaolinized syenite and bauxite, such as are exposed at many places on the south and east borders of the syenite area, where the syenite is in contact with Wilcox deposits.

Test holes E1 and E2 encountered no bauxite except for a 1-foot bed overlying the kaolinized syenite in E1, though this hole is only 750 feet from the shaft mine that shows 20 to 30 feet of bauxite in similar relations to the syenite. Another shaft mine operated by the William J. Crouch Mining Co. half a mile north of these test holes is working a deposit understood to contain about 100,000 tons of ore. This indicates the local,pockety character of the ore bodies, which, however, all occur in the more continuous bauxite-kaolin zone, and there would seem to be a possibility of other small ore bodies in the W. ½ sec. 9 and the northeastern part of sec. 8, T. 1 S., R. 12 W.

The widely scattered test holes F1 to F5 show that southeast of the Fourche Mountain region of Pulaski County the syenite is near the surface over a large area and well above the depths at which the Midway deposits would have covered it in this region. The syenite encountered in these test holes is kaolinized through as much as 50 feet of its upper part, but only in hole F4 was bauxite encountered above this "rotten granite." The large area underlain by kaolinized syenite is favorable for the occurrence of some deposits of merchantable bauxite, and additional drilling may encounter something of more importance than has yet been found, though the considerable amount of drilling by commercial interests has apparently not been promising.

Test holes M1 to M3 indicate some possibility of a commercial deposit of bauxite in sec. 20 and perhaps additional ore in sec. 19, T. 1 N., R. 11 W. Hole M1 encountered no bauxite but found kaolinized syenite immediately overlain by recent river alluvium, and bauxite if originally present here would have been eroded and may occur to the east, down the flank of the syenite mass, where it was not reached by the river cutting. Hole M2 encountered bauxite, but the quality was not determined, and the thickness may be greater than that penetrated, as the hard rock on which the drilling was stopped proved not to be syenite and may therefore have additional bauxite beneath it. Hole M3 likewise encountered some bauxite, the thickness of which was not definitely determined, as drilling was stopped on hard rock that may occur within the bauxite deposit. These three drilling tests, combined with the occurrence of good deposits of ore at the Radcliffe mine and on the Dixie Bauxite Co.'s property, make additional testing in secs. 19 and 20, T. 1 N., R. 11 W. appear promising. Drilling exploration on the Dixie Bauxite Co.'s property, in sec. 19, T. 1 N., R. 11 W., is understood to have shown that the ore body being mined grades over into low-quality bauxite and bauxitic clay to the east, though isolated pockets of good ore are encountered in this direction. A larger body of ore may therefore occur farther east, in the region of test holes M1 to M3.

A comparison of the depths at which syenite was encountered in various holes with the map by Stearn 37/ indicates that the relative depth to syenite does not correspond closely with the lines of magnetic intensity, as only the most marked magnetic areas reflect proximity to syenite, and most of these areas are on outcrops of the igneous rock. One example of this lack of correlation is seen in the area south of Alexander and west of Vimy Ridge, where syenite was encountered at relatively shallow depths, though the magnetic lines would not suggest this for the particular area. However, the general conclusion from this magnetic survey that the two large areas of syenite are probably connected at depth remains probable and was partly substantiated by the present investigation.

ORIGIN OF THE BAUXITE

The results set forth above indicate that much of the bauxite is a product of the surficial alteration of syenite, the most conclusive evidence being the complete gradation, found in test holes and surface exposures, from the fresh syenite, through kaolinized syenite, to bauxite that preserves the original texture of the syenite. Some facts have been presented which suggest that the bauxite not thus formed from an underlying syenite represents a similar product of alteration of other surface rocks. Additional discussion of this type will indicate the basis for the conclusion that all

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37/ Stearn, N. H., op. cit., pls. 1 and 3.

the bauxite was formed through the alteration of surface rocks, and that this alteration occurred at a particular time in the Eocene epoch. As the alteration was the result of weathering and as this normal process has produced no comparable results before or since that time in the region, there must have been especially favorable conditions at that particular time.

The facts which indicate that the bauxite was all formed during a single period in early Wilcox time and is thus confined to the basal part of the Wilcox are summarized below, and the relations are illustrated in the cross section (plate 5,B).

1. The syenite at the surface or encountered in test holes is deeply weathered and altered to kaolin and bauxite only where it formed a part of the old surface on which continental sediments of the Wilcox were deposited, and the syenite is comparatively fresh, with no development of bauxite, where it was protected from this surface alteration by the cover of Midway deposits.

2. The bauxite that does not overlie syenite occurs at a definite stratigraphic position at the base of the Wilcox and above the blue clay of Midway age.

A small amount of reworked bauxite occurs in some places as a basal conglomerate in the Wilcox, where a higher part of the Wilcox overlaps upon hills of syenite that are blanketed with bauxite, and under these conditions a very minor amount of sedimentary bauxite mixed with much sand occurs locally interbedded in the Wilcox. An unusual occurrence of lignite within the bauxite is known in the deposit being mined by the Dixie Bauxite Co. and also a mile to the east, in test hole M2. In the Dixie mine the ore pitches steeply southward, down the flank of the syenite mass that crops out not far to the north. The bauxite is of the pisolitic type and, particularly in the upper part, has comparatively little matrix, so that much of it breaks down into individual pisolites in mining. Where the bed of lignite and black lignitic clay occurs most of the ore is beneath it, and the few feet of bauxite overlying the lignite is generally softer and has a higher clay content. It appears probable that this bauxite overlying the lignite is a reworked or sedimentary bed that has been carried down as pisolitic bauxite from higher slopes to the north, after the accumulation of the lignite over the main body of ore.

However, that nearly all the bauxite occurring interbedded in the sedimentary formations appears to have developed in place, rather than as transported or sedimentary bauxite, is indicated by the following facts:

1. This bauxite is confined to a single stratigraphic position and does not occur interbedded in the Wilcox at various horizons above its base, except for the very minor amounts of transported material mentioned above.

2. The bauxite of this type is regularly underlain by kaolin with scattered pellets of siderite, like the bauxite formed in place from syenite, and the zone of kaolin grades down into the blue clay of Midway age. No such consistent presence of an underlying transition zone of kaolin would be expected if this bauxite were transported material.

3. The bauxite occurs as lenticular deposits at the one horizon and grades laterally into bauxitic clays or kaolin, with no regard to the direction from which it would have been derived and transported, as is illustrated in the cross sections (plates 5,A and 5,B).

4. The beds are massive, with no evidence of pebbles or boulders and no admixed sand except for a very small amount of sand in the upper part of the beds that has been carried down from the overlying Wilcox. The pisolitic texture is not evidence of transportation but has been shown to be a concretionary form of development which occurs also in the bauxite that was obviously formed in place.

Though bauxite of this type thus appears to have been formed in place above the blue clay, the evidence available does not show what proportion of it may have been formed directly from the alteration of the blue clay, and what proportion may have been formed from the alteration of feldspar sand washed out over the surface of the blue clay from adjacent syenite hills, at the end of Midway time.

The relations pointed out in the interpretation of the logs of the test holes, such as hole B4, and illustrated in plate 5,A suggest that this bauxite was largely derived from the alteration of feldspar sand that had been washed out over the surface of the blue clay from adjacent syenite. That such feldspar sand may occur in comparatively pure beds is shown by its presence in the Midway some miles from any probable source. That such feldspar sand may be the major source of the bauxite occurring above blue clay is suggested by the occurrence of this bauxite only in a region within a few miles of the syenite and the apparent absence of bauxite at the Midway-Wilcox contact elsewhere in the state.

A thin bed of very poor bauxite at the Midway-Wilcox contact occurs in the southwestern part of sec. 31, T. 2 S., R. 15 W., beyond the area shown on the map, and is the only occurrence known at so great a distance (about 9 miles) from a syenite area. The bauxite at such distance would seem more probably to have been formed directly from the underlying blue clay. The bauxite occurring above blue clay in areas nearer the syenite is underlain by kaolin and mottled clays that form a weathered zone at the top of the blue clay, and at least part of this bauxite may therefore be derived from the weathering of the blue clay. The chemical composition of this clay is probably not very dissimilar to that of the syenite, and the chemical changes involved in the alteration through weathering would be similar. Bauxite is known to have been formed from underlying clay in some other regions, and that from Mississippi described by Burchard 38/ would appear to be one of these occurrences. It is perhaps a significant point that this Mississippi bauxite occurs also at the base of the Wilcox, and similar occurrences at the Midway-Wilcox contact in Alabama have been described by Adams 39/.

Consideration of the mode of formation of the Arkansas bauxite and the discussion of other deposits occurring in many parts of the world, for which an extensive bibliography is included in a book by Fox 40/, suggest that weathering of surface rocks has produced most if not all bauxite deposits. However, for a normal weathering process to form commercially important deposits, it seems necessary to have had particularly favorable conditions lasting for a long period of time. The more influential conditions of climate, topography, and bedrock are discussed below. The modern studies of soils have given most of the definite data on the influence of these conditions.

Climatic Conditions

A review of the large literature on bauxite and laterite deposits of other regions would be too long for this paper, but the view seems general that a warm and humid climate is an important factor in their development, and that such deposits of recent formation are confined to tropical regions. The study of the fossil plants of the Wilcox by Berry 41/ indicated that this flora was subtropical.

Modern studies of soils indicate that climate is probably even more important than character of bedrock in determining the weathering products that compose a mature soil. An excellent discussion of the character and origin of soil types has recently

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38/ Burchard, E. F., Bauxite in northeastern Mississippi: U. S. Geol. Survey Bull. 750A, pp. 101-146, 1925.

39/ Adams, G. I., Bauxite deposits of the southern states: Econ. Geology vol. 22, no. 6, pp. 615-620, 1927.

40/ Fox, C. S., Bauxite and aluminous laterite, London, Technical Press, 1932.

41/ Berry, E. W., The lower Eocene floras of southeastern North America: U. S. Geol. Survey Prof. Paper 91, p. 135, 1916.

been published in a book by Robinson 42/. He reviews the evidence that the degree of weathering in soils is indicated by the silica-alumina ratios, and that soils with a high content of the oxides of alumina and iron are most weathered, and are found in tropical or subtropical regions.

In the chemical decomposition of silicate minerals, through oxidation, hydration, and more largely hydrolysis, the importance of abundant water in the processes is obvious. Nutting 43/ has shown the effectiveness of pure water in removing the silica from a clay complex, and the rapid saturation with the dissolved silica, so that the bound or slowly circulating water in clays is commonly nearly saturated with silica, and abundant waters of freer circulation are needed for the thorough leaching of silica. The importance of temperature is indicated by the statement of Robinson 44/ that "chemical changes increase in velocity with rise of temperature, a rise of 10° centigrade approximately corresponding with a doubling of velocity." Under tropical conditions of high humidity and high temperature chemical decomposition is therefore at a maximum, particularly for the desilicification of silicate minerals to concentrate a residuum of the less soluble hydroxides of aluminum and iron.

In tropical regions it is common to have marked seasons of heavy rainfall alternating with comparatively dry seasons, and the view is general that this alternation is an important factor in the process of laterite formation. The typical laterite appears from published descriptions not only to consist of a surface deposit enriched in the sesquioxides through leaching out the more soluble constituents, but to include a hard surface incrustation of these sesquioxides, particularly that of iron. This incrustation is interpreted as an enrichment of the surface residuum through a cementation by these sesquioxides, which are slightly soluble but tend to be reprecipitated during the surface evaporation of soil moisture in the drier season. The Arkansas bauxite does not seem to have much of the lateritic crust formed through such a process and is more strictly a residual deposit. However, the development of the pisolitic texture may be connected with some such process as that suggested for these lateritic crusts.

Character of Bedrock

Bauxite and laterite are known to have been formed through the alteration of a variety of rocks, and deposits have been described that were derived from such widely different types as basalt, syenite, gneiss, limestone, and clay shale. These deposits usually reflect the source rock to some extent, as in the ferruginous laterites developed from rocks originally high in iron, such as basalt. Syenite is one of the most favorable rock types to produce bauxite, because of its large content of feldspar, which alters to aluminum silicates and finally to bauxite, and the absence of free silica as the more stable mineral quartz. The considerable content of nephelite in Arkansas syenite is also favorable, as this is an easily altered aluminous silicate.

Topographic and Ground-water Conditions

The importance of topographic and ground-water conditions is suggested in the following statement by Sir John Harrison on the bauxite deposits of British Guiana, quoted by Hardy and Follett-Smith 45/: "The primary process of formation of laterite is the same on high or on low levels. The after-processes differ materially. On well-drained mountain plateaux, where the rainfall is very high (i.e. about 150

42/ Robinson, G. W., Soils, their origin, constitution, and classification, London, 1932.

43/ Nutting, P. G., The solution and colloidal dispersion of minerals in water: Washington Acad., Sci., Jour., vol. 22, no. 10, pp. 261-267, May 19, 1932.

44/ Robinson, G. W., op. cit., p. 266.

45/ Hardy, F., and Follett-Smith, R.R., Studies in tropical soils: Jour. Agr. Sci., vol. 21, p. 750, 1931.

inches), and more or less continuous throughout the year, primary laterite appears to be permanent as such, and where not exposed to washing, accumulates in considerable thickness." Woolnough 46/, describing the deposits of Australia, and several other writers consider a nearly flat and low level surface, or peneplain, essential to the formation of laterites.

The data presented in this report show that the surface on which the bauxite occurs in Arkansas could hardly be classed as a peneplain, as there were hills with a relief of 200 to 300 feet within short distances, indicated by slopes of 10° to 15° on the undeformed bauxite surface for distances of at least 1,000 feet. This topographic relief would result in a better subsurface drainage of descending ground water and thus in more thorough leaching and deeper alteration of the syenite bedrock. Such conditions are important for bauxite formation, as contrasted with swampy conditions due to a ground-water table near or at the surface (p. 30).

The hilly topography on which this bauxite was formed presents difficulties in understanding how the bauxite accumulated near the surface over a long period of time without being continually eroded or washed away. That the bedrock was thus thoroughly decomposed and altered and yet remained in place on these slopes may perhaps be due to an effective cover of vegetation at all times, resulting from a continuously wet climate, without marked torrential rains. However, the lack of surface erosion, though general, may have been less complete than is apparent from the inadequate exposures.

Process of Bauxite Formation

With the continuation of favorable conditions for a long period in early Wilcox time--perhaps for as much as 1,000,000 years or more, as the entire Eocene is estimated at about 13,000,000 years 47/--the process of bauxite formation through the alteration of syenite could be effected by a normal weathering of the surface rocks.

This weathering by chemical decomposition produced a comparatively porous kaolinized syenite, through the leaching of the less stable minerals, as indicated in the discussion on mineral features, and a gradual deepening of the zone of decomposition. The more complete alteration near the surface, under more oxidizing conditions, converted the upper part into the bauxite that is relatively stable under these conditions. Much of the silica of the clay minerals would be carried away in solution or colloidal suspension during the process. Probably a part of the more finely divided clay would be carried downward in suspension, as is indicated in many soil profiles 48/, thus increasing the porosity of the upper zone and on deposition at lower levels of less free circulation further decreasing the permeability below and limiting the depth of more thorough alteration to bauxite. The variations in mineral composition and texture of the altered syenite and other factors influencing the downward movement of water would probably result in a very uneven surface of this less permeable underclay and account for the many "horses" of clay and deeper pockets of bauxite. Local slumping and settling as a result of varying conditions during the process of alteration may have been a factor in varying the permeability and depth of alteration, as was suggested by Mead 49/.

The dominance of alumina over iron in the original composition of the syenite bedrock resulted in an aluminous laterite or bauxite. However, evidence presented in discussing the chemical and mineral features of the deposits indicates that the physico-chemical conditions were such as to concentrate the alumina more largely at the

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46/ Woolnough, W. G., Laterite in western Australia: Geol. Mag., vol. 5, no. 6, 385-393, 1918.
47/ Knopf, Adolph, and others, Physics of the earth, IV- The age of the earth; Nat. Research Council Bull. 80, p. 49, 1931.
48/ Robinson, G. W., op. cit., p. 53.
49/ Mead, W. J., op. cit., pp. 51-52.

surface, the iron being leached out along with the more soluble constituents. This is in contrast with the usual process that forms typical laterites, in which both iron and alumina are concentrated as a residue of least soluble constituents; but, as has been pointed out, the typical laterites are considered to be in part a caliche-like incrustation deposited at the surface through surface evaporation in the drier season, and it appears possible that iron is more largely concentrated in this manner, and that the aluminum forms the more characteristically residual sesquioxide.

Perhaps owing to a more continuously humid climate and more vegetation, the original iron of the Arkansas syenite was leached largely in the ferrous state and carried down and precipitated as the carbonate, in the zone of abundant spherules of siderite, which is generally present in the kaolinized syenite. This is shown by the fact that the transition zone of kaolin or kaolinized syenite directly underlying the bauxite has been largely leached of the original iron and is now white, and the little remaining iron is unoxidized, except where exposed by erosion to recent surface oxidation. The more intensive weathering nearer the surface that produced the bauxite occurred under more oxidizing conditions but was acting on the kaolinized rock, from which most of the iron had been leached. The iron now present in the bauxite varies greatly in amount and is very abundant in many places, but this iron is largely secondary, as indicated by its occurrence in vugs and veins, lining or filling cavities and pores in the bauxite. The ferrous state of the iron as siderite and pyrite, except where exposed to recent surface oxidation, also suggests secondary development of iron, as the compound to be expected in connection with the aluminum hydroxide as bauxite would be iron hydroxide. This secondary iron in the bauxite would seem to have been introduced from above, because most of the original iron was leached, as indicated by the underlying kaolinized syenite.

The introduction of secondary iron and some other changes in the bauxite appear to have resulted from different conditions, which followed the period of bauxite formation. The gradually rising baselevel that initiated the deposition of the continental Wilcox beds first produced swampy conditions, with the accumulation of lignites in many places. These swampy conditions signify a water table at or very near the surface, following the rising baselevel. Swampy conditions, with lack of oxidation and circulation in the water-logged bedrock, are not favorable for bauxite formation, and as pointed out by Robinson 50/ there is rather a reverse tendency, in the development of material of a siliceous type through weathering. Evidence that the bauxite was formed before the overlying lignites accumulated is seen in some facts already presented, particularly in the occurrence of the conglomerate of bauxite at the contact with the lignite on some slopes of the bauxite surface. The boulders and pebbles in this bauxite conglomerate are rounded, and that they were formed from the underlying bauxite, rather than through later alteration of syenite boulders, is indicated by their lack of any concentric zones of alteration such as might be expected if they were derived from boulders of syenite. Moreover, these boulders and pebbles are of granitic texture where the adjacent bauxite is of granitic type and of pisolitic texture where the adjacent bauxite is of pisolitic type.

Additional evidence of the different process under the swampy conditions of lignite accumulation is seen in the upper part of the bauxite, immediately adjacent to the overlying lignite. The upper few feet of the bauxite is generally high in silica, owing to a larger proportion of clay minerals in this zone. This upper zone is very distinct in many of the exposures and is well seen in the Radcliffe mine. Here the upper two to three feet of the bauxite deposit is soft and claylike and is gray owing to the ferrous state of the iron, which occurs largely as pyrite. Pisolites are less numerous, and those present are largely leached, so that spherical cavities remain. It thus appears that reducing conditions with waters charged with organic acids from the lignitic deposits had reversed the process that forms bauxite and had leached aluminum hydroxide from this upper zone and perhaps also even resulted in some resilicification of the aluminous material, such as has been described from some laterites

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50/ Robinson, G. W., op. cit., pp. 72-94.

soil profiles in British Guiana 51/.

Any aluminum hydroxide leached from this upper zone would probably be redeposited as it was carried downward into the bauxite and might thus be a factor in the development of the bauxite of the more dense and pisolitic type. This is suggested by the facts that the bauxite is more largely of granitic texture in some topographically high areas of the bauxite surface which are overlain by less lignite, and that the bauxite is all pisolitic at lower levels of the surface which are generally covered by more lignite. However, the pisolitic texture was probably more largely developed before the lignites were deposited, as this texture is present to some extent in the upper zone that is high in clay content, and the reworked bauxite in the conglomerate underlying the lignite shows in some places boulders of pisolitic texture and in others boulders of granitic texture. If the pisolitic bauxite had been developed in the late stages of the period of bauxite formation through a process of solution and redeposition by surface evaporation in the drier seasons, like some of the typical lateritic rocks, it might also show the relation to topography pointed out above, as such a process would be more active at lower levels, nearer the ground-water table.

Swamp conditions frequently involve a high iron content of the waters carried in from adjacent areas, and it is probable that swamp waters introduced and precipitated the secondary iron carbonate and pyrite in the bauxite of this region. Iron carbonate concretions occur beneath many lignite and coal deposits.

The formation of some of the bauxite through alteration of the former surface beds of Midway blue clay has been suggested. The bauxite overlying this blue clay is generally in comparatively thin beds and is of poor quality owing to the high iron and silica content. Under the conditions considered favorable for bauxite formation only a relatively thin bed of bauxite would be expected to develop from the weathering of the blue clay. The chemical composition of this clay, though no analysis is available, is perhaps not very different from that of the syenite; but certain constituents of the syenite, such as the nephelite, would be more readily altered than the blue clay, and the resulting porous texture of the syenite would be more favorable for a deep and thorough decomposition than the uniform texture of the fine-grained blue clay. The fact that the surface underlain by blue clay was topographically low and flat would also make this clay surface less favorably situated for the downward movement of ground waters and the resulting leaching and alteration. The high iron and silica content may be due in part to the composition of the blue clay, and in part to the introduction of secondary iron and some silica into these relatively thin beds of bauxite, under the succeeding swampy conditions of lignite deposition, as was suggested for an upper zone of the thicker bauxite deposits that overlie syenite.

GENERAL CONCLUSIONS AND ESTIMATE OF RESERVES

The evidence presented above showing that the bauxite was formed during a single period and is confined to the old land surface of this period has a significant bearing on the bauxite prospects of the region. Likewise bearing on the potential reserves is the conclusion that of the bauxite occurring at this old surface only the part which is closely associated with the syenite is likely to include merchantable ore. The large amounts of bauxite occurring at the Midway-Wilcox contact and thus underlain by the blue clay are generally too high in silica and iron to be of any present commercial interest except possibly for cements. The areas shown on the map with Midway beds at the surface hold no promise of bauxite, regardless of the presence or absence of syenite underground.

These conclusions indicate that the more promising prospects for future discoveries of bauxite [illegible]ited to the area within a mile or little more of the syenite. Much of this area [illegible] been tested to [illegible] extent and either taken by commercial inter-

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51/ Hardy, F., [illegible]-Smith, R. [illegible] pp. 749-[illegible] ests or proved unpromising. However, a large area south of Alexander and west of Vimy Ridge, though in part two miles or more from surface areas of syenite, has been shown to have syenite sufficiently near the surface not to be covered with Midway deposits. Such an area would thus seem promising for some discovery of ore, but the few tests made in this investigation encountered only kaolinized syenite. Areas in which the relations of the syenite to the Midway-Wilcox contact are similar and which thus offer possibilities of associated bauxite might be found by geophysical methods or by additional drilling, but the limiting conditions presented make such new areas less probable and restrict greatly their possible extent.

These conclusions thus have an important bearing on any attempt to estimate reserves of ore. The marked variation in thickness and lateral extent of the bauxite, and particularly that of commercial grade, makes any estimate of reserves little better than a guess. Obviously only after detailed drilling and sampling of all prospective territory has been done can any close estimate be made. The extensive test drilling carried on for many years by the Republic Mining & Manufacturing Co. has probably given only rough estimates on its own reserves, and though these reserves constitute a major part of the probable total, comparatively little is established otherwise.

The following very rough estimate of merchantable bauxite is presented only as an attempted approximation, which should be at least closer than the only other published estimate, made in the early days by Hayes 52/. However, his estimate of 50,000,000 tons included all bauxite, and he did not predict how much of it would prove to be of commercial grade. Subsequent work indicates that his estimate of the total is probably low, but the amount of bauxite of present commercial grade would appear to be less than 50,000,000 tons.

The following estimate of tonnages by townships is based only on some approximations from the very meager data from surface exposures of thickness and extent of ore observed on some of the properties of the Republic Mining & Manufacturing Co., from verbal information by the drillers who tested some of the smaller properties of other operators, and finally on the assumption that underground conditions will roughly average those of areas where some detailed information is available. The inadequacy of these data as a basis for any close estimate of reserves is obvious, and though the figures presented are not intended to represent a known minimum, they may prove to be nearer a minimum than a maximum total, as is suggested by the discussion on results of drilling. For example the reserve estimates list T. 2 S., R. 13 W., T. 1 S., R. 14 W., T. 1 S., R. 13 W., without including any reserve tonnage for these townships because the available information indicates conditions which give little basis for expecting considerable bauxite deposits, but only with additional drilling can their potentialities be finally established. The very few test holes drilled in these townships would be of almost no significance as to possible ore in the large areas, except for the indication these limited data give on the geologic conditions, and the known relations of such conditions to the bauxite occurrences.

The tabulation presents totals by townships, based on rough estimates of each section from assumed acreage and average thickness of ore. Though the estimates for some sections may well have been too large, these will perhaps be compensated by others that are probably low.

The tonnages are calculated at 2,000 tons per acre per foot of thickness, which represents 21.78 cubic feet per ton of ore. Harder 53/ suggests between 19 and 23 cubic feet per gross ton for estimates. (See p. 33 for tabulation)

52/ Hayes, C. W., op. cit., p. 469.

53/ Harder, E. C., Edwards, J. D., Frary, F. C., and Jeffries, Zay. The aluminum industry- aluminum and its production, p. 66, McGraw-Hill Book Co., New York, 1930.

	Tons
T. 2 S., R. 13 W., Saline County. Probably contains little bauxite of commercial grade except perhaps some in west line of sections, particularly sec. 18.	
T. 1 S., R. 14 W., Saline County. Southeastern part contains much low-grade bauxite at the Midway-Wilcox contact but probably little of commercial grade except perhaps small amounts in secs. 35 and 36.	
T. 2 S., R. 14 W., Saline County. Largely in central and east-central part of township. , ...	10,000,000
T. 1 S., R. 13 W., Saline and Pulaski counties. Large tonnages of low-grade bauxite at Midway-Wilcox contact, but probably little of commercial grade.	
T. 1 S., R. 12 W., Pulaski County. Largely in north-central part of township	600,000
T. 1 N., R. 12 W., Pulaski County. Largely in Sweet Home area	500,000
T. 1 N., R. 11 W., Pulaski County. Largely in Sweet Home-College Station area	500,000
Total . . .	11,600,000

APPENDIX

LOGS OF TEST HOLES

DRILL HOLE A1

Missouri Pacific Railway property.

Sec. 34, T. 1 S., R. 14 W., about 600 ft. east and 100 ft. south from railroad crossing at Bryant. Elevation 402 ft.

Total depth	186 ft.	Depth to top of blue clay (Midway)	120 ft.
Depth to top of bauxite-kaolin zone (kaolin with no bauxite)	99 ft.	Depth to top of limestone	162 ft.

	Thickness (feet)	Depth (feet)
Surface soil and brown sandy clay	10	10
Clay, sandy, gray	12	22
Gravel and coarse sand	3	25
Clay, sandy, dark	1	26
Gravel and coarse white sand	4	30
Clay, silty, dark brown, and thin sands, some lignite	50	80
Clay, sticky, gray	10	90
Lignite, firm	4	94
Clay, soft, gray	5	99
Siderite, hard	-1/4	99-1/4
Kaolin or white clay with small siderite pellets	20-3/4	120
Clay, dark bluish gray	42	162
Clay, calcareous, gray, with thin limestone beds and some sand of hard, fresh feldspar grains	23	185
Limestone, hard, with micro-fossils and glauconite	1	186

DRILL HOLE A2

Louis Carger property.

Sec. 35, T. 1 S., R. 14 W., south side of road about 90 ft. north of Carger house. Elevation 395 ft.

Total depth	177 ft.	Depth to top of blue clay (Midway)	126 ft.
Depth to top of bauxite-kaolin zone (grayish-white clay with no bauxite)	106 ft.	Depth to top of limestone	171 ft.

	Thickness (feet)	Depth (feet)
Surface soil and brown sandy clay	8	8
Gravel, white	-1/2	8-1/2
Clay, sandy, gray	9-1/2	18
Clay, silty, dark brown, with thin sands	64	82
Clay, sticky, greenish gray	18	100
Clay, greenish gray, with thin layers of hard siderite	6	106
Clay, light gray, with siderite pellets	20	126
Clay, dark bluish gray	45	171
Clay, dark gray, with thin limestone beds	5	176
Limestone, hard, with micro-fossils and glauconite	1	177

DRILL HOLE A3

C. P. Walden property.

Sec. 26, T. 1 S., R. 14 W., on east side of road about 550 ft. south of point where power line crosses road. Elevation 435 ft.

Total depth	225 ft.	Depth to top of blue clay (Midway)	176 ft.
Depth to top of bauxite-kaolin zone (clay with no bauxite)	150 ft.	Depth to top of limestone	196 ft.

	Thickness (feet)	Depth (feet)
Sand, red, and red sandy clay	8	8
Sandstone, hard, ferruginous	-1/2	8-1/2
Sand, red, and sandy clay	9-1/2	18
Clay, silty, dark brown	52	70
Clay, silty, brown, with streaks of lignite	14	84
Clay, white	22	106
Lignite, soft, and lignitic clay	16	122
Clay, sticky, gray	13	135
Clay, gray, with thin beds of hard siderite	4	139
Clay, silty, gray	11	150
Clay, grayish white	21	171
Siderite, hard	-1/2	171-1/2
Clay, sticky, pink	4-1/2	176
Clay, dark bluish gray	20	196
Clay, gray, with thin limestone beds	4	200
Limestone, with thin layers of calcareous clay	23	223
Limestone, hard, with micro-fossils and glauconite	2	225

DRILL HOLE A4

Republic Mining & Manufacturing Co. property.

Sec. 26, T. 1 S., R. 14 W., on north side of road about 900 ft. west of bridge crossing creek. Elevation 340 ft.

Total depth	115 ft.
Depth to top of bauxite-kaolin zone	Hole started below this horizon.
Depth to top of blue clay (Midway)	15 ft.
Depth to top of limestone	85 ft.

	Thickness (feet)	Depth (feet)
Surface sand	10	10
Gravel and coarse sand	2	12
Clay, sandy, red	3	15
Clay, dark bluish gray	70	85
Clay, gray, with thin limestone beds	20	105
Limestone, with thin clay beds, becoming harder and thicker bedded with depth	10	115

DRILL HOLE A5

J. W. Shipp property.

Sec. 24, T. 1 S., R. 14 W., between road and railroad where road turns north from paralleling railroad. Elevation 335 ft.

Total depth	43 ft.
Depth to top of bauxite-kaolin zone	Hole started below this horizon
Depth to top of blue clay (Midway)	Hole started below this horizon
Depth to top of limestone	(?)

	Thickness (feet)	Depth (feet)
Loam, sandy	2	2
Gravel	1	3
Clay, sandy	3	6
Gravel	-1/4	6-1/4
Clay, sandy, brown	6-3/4	13
Sand and sandy clay, gray	30	43
Rock, very hard; perhaps quartzose rock of Paleozoic age.	-1/4	43-1/4

DRILL HOLE A6

C. G. Thomas property.

Sec. 13, T. 1 S., R. 14 W., west of road about 400 ft. southwest of road culvert. Elevation 330 ft.

Total depth	29 ft.
Depth to top of bauxite-kaolin zone	Hole started below this horizon
Depth to top of blue clay (Midway)	Hole started below this horizon
Depth to top of limestone	13 ft.

	Thickness (feet)	Depth (feet)
Loam, sandy	2	2
Gravel	4	6
Clay, sandy, yellow (weathered blue clay)	3	9
Clay, sandy, buff (weathered blue clay)	4	13
Limestone, with soft clay seams	10	23
Limestone, thicker beds and harder; some sand and glauconite	6	29

DRILL HOLE A7

Dr. J. D. M. Powell property.

Sec. 18, T. 1 S., R. 13 W., on vacant lot at west side of Alexander about 250 ft. west of church. Elevation 340 ft.

Total depth	70 ft.
Depth to top of bauxite-kaolin zone	about at surface level
Depth to top of blue clay (Midway)	21 ft.
Depth to top of limestone	47 ft.

	Thickness (feet)	Depth (feet)
Sand and soil	1	1
Clay, sandy, mottled red	13	14
Clay, sticky, grayish white	3	17
Clay, yellow	4	21
Clay, dark bluish gray	23	44
Siderite, hard	-1/2	44-1/2
Clay, calcareous, greenish gray, with micro-fossils	2-1/2	47
Limestone, with thin beds of calcareous clay	15	62
Limestone, hard, some glauconite and micro-fossils	8	70

DRILL HOLE A8

F. R. Woolford property.

Sec. 17, T. 1 S., R. 13 W., about 150 ft. north of road, across from former house location. Elevation 330 ft.

Total depth	34 ft.
Depth to top of bauxite-kaolin zone	Hole started below this horizon
Depth to top of blue clay (Midway)	19 ft.
Depth to top of limestone	32 ft.

	Thickness (feet)	Depth (feet)
Loam and surface gravel	1	1
Clay, sandy, mottled red and yellow	5	6
Clay, sticky, yellow	5	11
Sandstone, hard, ferruginous	-1/4	11-1/4
Clay, yellow (probably weathered blue clay)	7-3/4	19
Clay, dark bluish gray	11	30
Clay, calcareous, greenish gray, with micro-fossils	2	32
Limestone, with micro-fossils	2	34

DRILL HOLE A9

Republic Mining & Manufacturing Co. property.

Sec. 10, T. 1 S., R. 13 W., about 40 ft. east and 100 ft. north from point where power line crosses road. Elevation 325 ft.

Total depth	77 ft.
Depth to top of bauxite-kaolin zone	Hole started just below this horizon
Depth to top of blue clay (Midway)	17 ft.
Depth to top of limestone	75 ft.

	Thickness (feet)	Depth (feet)
Loam, sand, and gravel	1	1
Clay, sandy, mottled red and yellow	12	13
Clay, sticky, yellow	4	17
Clay, dark gray	10	27
Clay, dark bluish gray	48	75
Limestone, hard, with micro-fossils	2	77

DRILL HOLE B1

Republic Mining & Manufacturing Co. property.

Sec. 26, T. 1 S., R. 14 W., about 600 ft. south and 500 ft. east from northwest corner of section. Elevation 375 ft.

Total depth	90 ft.	Depth to top of blue clay (Midway)	24 ft.
Depth to top of bauxite-kaolin zone	5 ft.	Depth to top of limestone	88 ft.

	Thickness (feet)	Depth (feet)
Surface sand and sandy clay	5	5
Bauxite, hard, reddish brown	2	7
Bauxite, soft, yellow	3	10
Clay, mottled, red and white	4	14
Clay, yellow, with hard streaks of iron oxide	3	17
Kaolin or white clay	4	21
Clay, sticky, pink	3	24
Clay, dark bluish gray	56	80
Clay, calcareous, gray, with many micro-fossils	8	88
Limestone, hard, with thin clay partings; micro-fossils and glauconite	2	90

DRILL HOLE B2

Dulin & Olson property.

Sec. 34, T. 1 S., R. 14 W., about 150 ft. northwest of east quarter corner of section. Elevation 402 ft.

Total depth	225 ft.	Depth to top of blue clay (Midway)	142 ft.
Depth to top of bauxite-kaolin zone	124 ft.	Depth to top of limestone	174 ft.

	Thickness (feet)	Depth (feet)
Surface loam and yellow sandy clay	5	5
Clay, sandy, with thin beds of sand	16	21
Gravel	2	23
Clay, sticky, red	-1/2	23-1/2
Clay, silty, dark brown	26-1/2	50
Clay, silty, brown, with thin beds of sand	33	83
Clay, gray	4	87
Lignite, soft	4	91
Clay, gray	11-1/2	102-1/2
Siderite, hard	-1/2	103
Lignite, firm	2	105
Clay, light gray	12	117
Siderite, hard	-1/4	117-1/4
Clay, light gray	6-3/4	124
Bauxite, hard.	4	128
Clay, white and bauxitic	6	134
Clay, sticky, light gray, with siderite pellets	8	142
Clay, dark bluish gray	32	174
Limestone, with soft clay seams and micro-fossils	50	224
Limestone, hard, with some grains of hard, fresh feldspar.	1	225

DRILL HOLE B3

E. Baird property.

Sec. 35, T. 1 S., R. 14 W., just east of road at southwest corner of property. Elevation 378 ft.

Total depth	172 ft.	Depth to top of blue clay (Midway)	136 ft.
Depth to top of bauxite-kaolin zone (clay with no bauxite)	112 ft.	Depth to top of limestone	163 ft.

	Thickness (feet)	Depth (feet)
Loam, sandy	1	1
Gravel and sand	5	6
Clay, red	2	8
Clay, silty, dark brown	64	72
Clay, light gray	6	78
Lignite, soft	1	79
Clay, light gray	3	82
Lignite	3	85
Clay, sticky, light gray	7	92
Siderite, hard	-1/2	92-1/2

DRILL HOLE B3 (Cont.)

	Thickness (feet)	Depth (feet)
Clay, light gray	2-1/2	95
Lignite, firm	2	97
Clay, tough, light gray	15	112
Clay, grayish white, bauxitic (?), with siderite pellets	8	120
Clay, light greenish gray	4	124
Clay, light gray	12	136
Clay, dark bluish gray	5	141
Clay, greenish gray	4	145
Clay, dark bluish gray	2	147
Clay, brownish gray	5	152
Clay, dark bluish gray	11	163
Clay, calcareous, gray, and thin limestone beds	8	171
Limestone, hard, with some coarse hard fresh feldspar sand	1	172

DRILL HOLE B4

J. W. Rogers property.

Sec. 35, T. 1 S., R. 14 W., 50 ft. north of Rogers' house. Elevation 380 ft.

Total depth	197 ft.	Depth to top of blue clay (Midway)	147 ft.
Depth to top of bauxite-kaolin zone	108 ft.	Depth to top of limestone	173 ft.

	Thickness (feet)	Depth (feet)
Loam, sandy	1	1
Gravel	7	8
Sand and sandy clay	2	10
Clay, silty, dark brown	10	20
Clay, silty, dark brown, and thin sand beds	28	48
Lignite, soft	1	49
Clay, silty, dark brown, and thin sand beds	3	52
Clay, sandy, light greenish gray	12	64
Lignite, soft	2	66
Clay, sandy, light greenish gray	27	93
Lignite, soft	3	96
Clay, sandy, light greenish gray	7	103
Clay, grayish white	5	108
Bauxite, firm, gray	1	109
Clay, white, bauxitic	5	114
Bauxite, soft	5	119
Bauxite, firm, with some softer streaks	5	124
Siderite and bauxitic clay	2	126
Clay, bauxitic, and many clusters of siderite pellets	16	142
Kaolin	5	147
Clay, dark bluish gray	21	168
Clay, greenish gray and bluish gray	5	173
Limestone, with thin partings of calcareous clay	4	177
Clay, calcareous and sandy, with sand all hard, angular feldspar grains	5	182

DRILL HOLE B4 (Cont.)

	Thickness (feet)	Depth (feet)
Sand, coarse, consisting of hard angular fresh feldspar grains (caving)	15	197
Syenite, hard		

DRILL HOLE B5

Elrod heirs property.

Sec. 2, T. 2 S., R. 14 W., just east of road and about 300 ft. south of northwest corner of section. Elevation 377 ft.

Total depth	115 ft.
Depth to top of bauxite-kaolin zone	67 ft.
Depth to top of blue clay (Midway)	Thinned out on syenite
Depth to top of limestone	Thinned out on syenite

	Thickness (feet)	Depth (feet)
Sand and gravel	10	10
Clay, sandy, gray	1	11
Clay, silty, dark brown, with some lignite	8	19
Clay, firm, white	4	23
Clay, sticky, dark gray	10	33
Clay, dark brown	1	34
Clay, light greenish gray	9	43
Clay, dark brown, lignitic	3	46
Lignite	1	47
Clay, sticky, gray	5	52
Clay, soft, white	6	58
Lignite	1	59
Clay, pink, grading down into white clay	8	67
Bauxite, hard	1	68
Clay, soft, white	2	70
Bauxite, firm, brown (4 samples)	13	83
Clay, sticky, white	2	85
Clay, soft, white, with soft, kaolinized feldspar grains .	20	105
Syenite, kaolinized (rotten granite)	7	112
Syenite, kaolinized but getting hard	3	115

DRILL HOLE C1A

Republic Mining & Manufacturing Co. property.

Sec. 18, T. 2 S., R. 13 W., on north side of Sardis road about 600 ft. west of nearest house. Elevation 305 ft.

Total depth	310 ft.
Depth to top of bauxite-kaolin zone	222 ft.
Depth to top of blue clay (Midway)	245 ft.
Limestone not found	Syenite encountered at 310 ft.

	Thickness (feet)	Depth (feet)
Clay, sandy, mottled red and gray	7	7
Gravel	4	11
Clay, dark brown, and lignite	3	14
Sand, fine, with some brown clay	8	22
Sand, fine, and sandy clay with some lignite	8	30
Sand, fine, with some brown clay	101	131
Clay, dark brown, lignitic	2	133
Sand, fine, with some brown lignitic clay	26	159
Clay, dark brown, with some lignite	11	170
Sand, fine, with some brown lignitic clay	16	186
Lignite	1	187
Sand, fine, with some brown lignitic clay	12	199
Sand, mixed with bauxitic clay	11	210
Clay, soft, white	9	219
Clay, white, with some bauxite	3	222
Bauxite, firm, crumbly, with siderite pellets	8	230
Clay, white, bauxitic, with many siderite pellets	15	245
Clay, dark bluish gray	45	290
Clay, dark, with much sand consisting of feldspar	5	295
Sand, granitic, consisting of hard feldspar grains	15	310

DRILL HOLE C1

J. W. Northern property.

Sec. 18, T. 2 S., R. 13 W., about 40 ft. southwest of Hurricane Creek bridge. Elevation 303 ft.

Total depth	228 ft.	Blue clay (Midway) thinned out on syenite
Depth to top of bauxite-kaolin zone	140 ft.	Limestone thinned out on syenite

	Thickness (feet)	Depth (feet)
Gravel	10	10
Clay, sandy, dark brown	6	16
Sand, brown	3	19
Clay, brown, and sand	11	30
Clay, dark brown	29	59
Clay, brown, with thin beds of sand	21	80
Clay, dark brown, lignitic	8	88
Clay, sandy, brown, with thin beds of sand	7	95

DRILL HOLE C1 (Cont.)

	Thickness (feet)	Depth (feet)
Sand, fine, and sandy clay	3	98
Clay, sandy, dark brown, with thin beds of sand	39	137
Clay, brown, with some lignite	3	140
Bauxite, firm, gray to yellow (8 samples)	17	157
Clay, white, or kaolin, and some bauxite (2 samples)	3	160
Clay, white, kaolinitic, with siderite pellets	18	178
Clay, pale green	3	181
Clay, pale green and white, with grains of soft kaolinized feldspar	29	210
Syenite, kaolinized and soft (rotten granite)	15	225
Syenite, kaolinized but becoming hard	3	228

DRILL HOLE C2

J. W. Northern property.

Sec. 13, T. 2 S., R. 14 W., on north side of road just across from Northern house. Elevation 325 ft.

Total depth	75-1/4 ft.	Blue clay (Midway) thinned out on syenite
Depth to top of bauxite-kaolin zone	55 ft.	Limestone thinned out on syenite

	Thickness (feet)	Depth (feet)
Clay, sandy, red	8	8
Gravel	2	10
Clay, silty, gray	6	16
Gravel and coarse sand	8	24
Clay, sandy, dark brown	25	49
Clay, sandy, gray	2	51
Sand, gray, with some clay	4	55
Bauxite, firm, gray to buff	4	59
Clay, white, bauxitic	6	65
Clay, grayish white, with siderite pellets	5	70
Clay, white, with grains of kaolinized feldspar	2	72
Syenite, kaolinized and soft (rotten granite)	3	75
Syenite, hard	-1/4	75-1/4

DRILL HOLE C3

Whitley property.

Sec. 12, T. 2 S., R. 14 W., at west side of road 400 ft. north of bridge of north branch of Hurricane Creek. Elevation 307 ft.

Total depth	172 ft.	Blue clay (Midway) thinned out on syenite
Depth to top of bauxite-kaolin zone	117 ft.	Limestone thinned out on syenite

	Thickness (feet)	Depth (feet)
Clay, sandy, sand, and gravel	8	8
Gravel and sand	1-1/2	9-1/2
Clay, silty, dark brown	12-1/2	22
Clay, silty, brown, and thin sands	34	56
Sand, fine, hard	5	61
Clay, silty, brown, and thin sands	46	107
Clay, dark gray	7	114
Lignite, firm	2	116
Clay, light gray	1	117
Bauxite, firm, reddish brown (3 samples)	7	124
Clay, white, bauxitic (2 samples)	6	130
Clay, grayish white to bluish white, with siderite pellets.	30	160
Clay, pale greenish gray, with grains of kaolinized feldspar	8	168
Syenite, kaolinized (rotten granite), getting hard at bottom	4	172

DRILL HOLE C4

Chicago, Rock Island & Pacific Railway property.

Sec. 12, T. 2 S., R. 14 W., at east side of road about 680 ft. north of railroad crossing. Elevation 346 ft.

Total depth	272 ft.	Depth to top of blue clay (Midway)	240 ft.
Depth to top of bauxite-kaolin zone (bauxitic clay)	222 ft.	Depth to top of limestone	265 ft.

	Thickness (feet)	Depth (feet)
Gravel	12	12
Sand, red	3	15
Clay, silty, dark brown	30	45
Sand, firm, gray	14	59
Sand, firm, with streaks of brown clay	7	66
Clay, silty, dark brown; some lignite	14	80
Clay, silty, dark brown, with thin beds of sand	36	116
Clay, dark, lignitic	2	118
Lignite	14	132
Sand, hard	18	150
Sand, soft, greenish gray, with some green clay	28	178
Siderite	1	179
Sand, greenish gray	24	203

DRILL HOLE C4 (Cont.)

	Thickness (feet)	Depth (feet)
Lignite, firm	19	222
Clay, light gray, bauxitic, with small siderite pellets . .	18	240
Clay, dark bluish gray	25	265
Limestone, with calcareous clay seams in upper part with micro-fossils; hard in lower part.	7	272

DRILL HOLE C5

J. J. Schichtel property.

Sec. 1, T. 2 S., R. 14 W., on west side of road at north side of sharp sag or valley. Elevation 420 ft.

Total depth	304 ft.
Depth to top of bauxite-kaolin zone	226 ft.
Depth to top of blue clay (Midway)	238 ft.
Limestone not found	Syenite at 304 ft.

	Thickness (feet)	Depth (feet)
Clay, sandy, red	4	4
Sand, firm, with some brown clay	56	60
Clay, silty, dark brown, with thin beds of sand	42	102
Sand, firm to hard	16	118
Clay, silty, dark brown, with thin beds of sand	28	146
Sand, firm to hard	27	173
Clay, sandy, greenish gray	39	212
Clay, dark, lignitic	2	214
Lignite	4	218
Clay, light gray to grayish white	8	226
Bauxite, hard, gray to brown	5	231
Clay, white, or kaolin	7	238
Clay, dark bluish gray (poor returns in sample)	51	289
Clay, and feldspar sand of syenite (poor returns)	15	304

DRILL HOLE C6

P. Bohn property.

Sec. 6, T. 1 S., R. 13 W., 60 ft. northwest of road corner in southeast corner of property. Elevation 330 ft.

Total depth	265 ft.
Depth to top of bauxite-kaolin zone	202 ft.
Depth to top of blue clay (Midway)	226 ft.
Limestone not found	Syenite encountered at 265 ft.

	Thickness (feet)	Depth (feet)
Clay, sandy, yellowish gray	8	8
Gravel and sand	3	11
Sand and dark sandy clay	2	13
Clay, sandy, dark brown	33	46
Sand, fine, soft	9	55
Clay, sandy, dark brown, with thin beds of sand	31	86
Lignite, soft	5	91
Clay, gray	6	97
Lignite	3	100
Clay, sticky, grayish white	5	105
Clay, sticky, light greenish gray	27	132
Clay, sandy, gray	5	137
Siderite, hard	-1/4	137-1/4
Clay, silty, gray	20-3/4	158
Clay, lignitic	3	161
Lignite, firm	11	172
Clay, sticky, dark gray	18	190
Lignite and lignitic clay	5	195
Clay, light gray	7	202
Bauxite, hard, light gray	3	205
Bauxite, hard, reddish brown	3	208
Clay, light gray, with siderite pellets	15	223
Siderite, hard thin beds	2	225
Clay, pink	1	226
Clay, dark bluish gray	14	240
Syenitic sand, with some clay; sand consisting of hard feldspar	10	250
Syenitic sand, consisting of hard angular feldspar	15	265
Syenite, hard and fresh		

DRILL HOLE C7

P. Bohn property.

Sec. 6, T. 1 S., R. 13 W., on east side of road 280 ft. north of road culvert. Elevation 338 ft.

Total depth 225 ft.
Depth to top of bauxite-kaolin zone (only bauxitic clay) 179 ft.
Blue clay (Midway) thinned out on syenite
Limestone thinned out on syenite

	Thickness (feet)	Depth (feet)
Clay, sandy, yellow	12	12
Gravel	1	13
Clay, silty, dark brown	59	72
Lignite	7	79
Clay, silty, gray	9	88
Clay, green gray, with small siderite pellets	37	125
Lignite	3	128
Clay, greenish gray	21	149
Siderite, hard	1	150
Clay, dark brown, with some lignite	10	160
Clay, dark gray	8	168
Lignite	8	176
Siderite, hard	1	177
Clay, light gray	3	179
Clay, bauxitic, with small siderite pellets	6	185
Clay, bauxitic, yellowish gray	6	191
Clay, pinkish gray, with kaolinized feldspar grains (kaolinized syenite)	24	215
Syenite, kaolinized (rotten granite), becoming hard at bottom	10	225

DRILL HOLE C8

Mrs. Mildred McMurray property.

Sec. 31, T. 1 S., R. 13 W., 90 ft. west of road and 280 ft. north of fence forming south line of property and section. Elevation 385 ft.

Total depth 264 ft.
Depth to top of bauxite-kaolin zone (no bauxite, only white clay) 202 ft.
Depth to top of blue clay (Midway) 208 ft.
Limestone not found
Syenite encountered at 264 ft.

	Thickness (feet)	Depth (feet)
Loam, sandy, yellow	3	3
Gravel	2	5
Clay, sandy, reddish yellow	5	10
Clay, silty, dark brown, with thin beds of sand	80	90
Sand, with thin layers of brown sandy clay	39	129
Clay, gray, with thin beds of lignite	43	172
Siderite, hard	1	173

DRILL HOLE C8 (Cont.)

	Thickness (feet)	Depth (feet)
Clay, gray	1	174
Siderite, hard	-1/2	174-1/2
Clay, sandy, gray	27-1/2	202
Clay, white	6	208
Clay, dark bluish gray	17	225
Clay, with some feldspar sand	12	237
Syenitic sand, composed of hard, angular feldspar grains . .	27	264
Syenite, hard		

DRILL HOLE C9

H. G. Chalkley property.

Sec. 31, T. 1 S., R. 13 W., about on line between secs. 31 and 36, 800 ft. west of house. Elevation 433 ft.

Total depth	147 ft.	Blue clay (Midway) thinned out on syenite
Depth to top of bauxite-kaolin zone (no bauxite)	136 ft.	Limestone thinned out on syenite

	Thickness (feet)	Depth (feet)
Soil, sand, and gravel	9	9
Sand, white	38	47
Clay, silty, brown, with thin sand beds	15	62
Clay, sandy, brown	23	85
Lignite	9	94
Sand, firm, with thin beds of clay	32	126
Clay, sandy, brown	10	136
Clay, grayish white, with kaolinized feldspar grains (kaolinized syenite)	10	146
Syenite, partly kaolinized, but hard	1	147

DRILL HOLE C10

R. W. Lasater property.

Sec. 31, T. 1 S., R. 13 W., about 300 ft. south and 60 ft. east from road junction. Elevation 375 ft.

Total depth	221 ft.	Blue clay (Midway) thinned out on syenite
Depth to top of bauxite-kaolin zone (clay)	163 ft.	Limestone thinned out on syenite

	Thickness (feet)	Depth (feet)
Sand and red clay	9	9
Clay, silty, brown	26	35
Clay, sandy, brown, with thin beds of sand	10	45
Sand, firm, with thin beds of brown clay	70	115
Clay, greenish gray, with few thin lignite beds	11	126
Siderite, hard	-1/2	126-1/2
Clay, light greenish gray	30-1/2	157
Siderite, hard	1	158
Clay, light greenish gray	5	163
Clay, white, and bauxitic clay	2	165
Siderite, hard	2	167
Clay, white, or kaolin	2	169
Siderite, thin crusts with clay	3	172
Clay, grayish white, with some kaolinized feldspar grains (kaolinized syenite)	10	182
Clay, pinkish gray, with some kaolinized feldspar grains (kaolinized syenite)	4	186
Clay, greenish gray, with some kaolinized feldspar grains (kaolinized syenite)	13	199
Clay, white, with feldspar grains (kaolinized syenite)	12	211
Syenite, kaolinized, with siderite pellets, getting hard	10	221

DRILL HOLE C11

Otto Winkler property.

Sec. 32, T. 1 S., R. 13 W., in field about 30 ft. south of road, opposite Winkler house. Elevation 390 ft.

Total depth	286 ft.	Blue clay (Midway) thinned out on syenite
Depth to top of bauxite-kaolin zone (no bauxite)	222 ft.	Limestone thinned out on syenite

	Thickness (feet)	Depth (feet)
Sand and sandy clay, red to gray	20	20
Clay, silty, brown	46	66
Clay, sandy, brown, with thin layers of sand	4	70
Sand, firm, with few thin beds of brown clay	45	115
Clay, sandy, brown, and thin sand beds	14	129
Lignite	11	140
Clay, silty, greenish gray	32	172
Siderite, hard	-1/2	172-1/2
Clay, light greenish gray	9-1/2	182

DRILL HOLE C11 (Cont.)

	Thickness (feet)	Depth (feet)
Siderite	2	184
Clay, sandy, light gray	36	220
Siderite, hard	2	222
Clay, grayish white, grading down into kaolinized syenite	62	284
Syenite, partly kaolinized but hard	2	286

DRILL HOLE C12

Mrs. Marie Kerr property.

Sec. 29, T. 1 S., R. 13 W., about 150 ft. west of road corner. Elevation 330 ft.

Total depth	272 ft.	Depth to top of blue clay (Midway)	196-1/2 ft.
Depth to top of bauxite-kaolin zone (no bauxite)	195 ft.(?)	Depth to top of limestone	270 ft.

	Thickness (feet)	Depth (feet)
Clay and sand, red and yellow	11	11
Clay, sandy, brown	29	40
Clay, sandy, brown, with thin sand beds	75	115
Lignite	3	118
Clay, gray	12	130
Lignite	2	132
Clay, sandy, brown	4	136
Clay, light green	21	157
Clay, dark gray	8	165
Clay, light green	30	195
Siderite, hard	1-1/2	196-1/2
Clay, dark bluish gray	54-1/2	251
Siderite, hard	-1/2	251-1/2
Clay, sandy, with grains of feldspar	18-1/2	270
Feldspar sand, hard, and some limestone with micro-fossils.	1	271
Syenite, hard	1	272

DRILL HOLE C13

Gus Butler property.

Sec. 28, T. 1 S., R. 13 W., on north side of road about 420 ft. west of railroad crossing. Elevation 336 ft.

Total depth	227 ft.	Depth to top of blue clay (Midway) (green sand)	(?)
Depth to top of bauxite-kaolin zone (no bauxite)	(?)	Limestone not found	
		Syenite encountered at	227 ft.

	Thickness (feet)	Depth (feet)
Clay, sandy, yellow	6	6
Gravel	-1/4	6-1/4
Clay, sandy, dark brown, with thin beds of sand	54-3/4	61
Clay, sandy, light gray	13	74
Lignite, firm	3	77
Clay, sandy, dark and lignitic	7	84
Clay, light gray	14	98
Clay, sandy, dark gray, with some lignite	52	150
Sand, greenish gray, with some gray clay	11	161
Siderite, very hard	-1/2	161-1/2
Sand, green, soft to firm	48-1/2	210
Siderite, hard	1-1/2	211-1/2
Syenite sand, composed of hard, angular feldspar grains	13-1/2	225
Syenite, hard and fresh	2	227

DRILL HOLE C15

John Spann property.

Sec. 27, T. 1 S., R. 13 W., about 110 ft. south and 800 ft. west from road corner. Elevation 357 ft.

Total depth	161 ft.	Blue clay (Midway) not reached
Bauxite-kaolin zone not reached		Limestone not reached

	Thickness (feet)	Depth (feet)
Clay, sandy, yellow	11	11
Sand, coarse, red	2	13
Clay, sandy, dark brown	7	20
Clay, sandy, brown, with some lignite	16	36
Clay, sandy, brown	36	72
Clay, silty, brown, with thin beds of hard sand	52	124
Clay, greenish gray	23	147
Clay, light gray	13	160
Siderite, very hard (too hard to drill with light rig)	1	161

DRILL HOLE C16

W. M. Gilzow property.

Sec. 22, T. 1 S., R. 13 W., about 60 ft. northwest of gate into field from main road and 420 ft. north of railroad crossing. Elevation 327 ft..

Total depth	202 ft.	Depth to top of blue clay (Midway)	152 ft.
Depth to top of bauxite-kaolin zone (bauxitic clay)	126 ft.	Depth to top of limestone	195 ft.

	Thickness (feet)	Depth (feet)
Soil and sand	8	8
Clay, sandy, red	2	10
Clay, silty, dark brown	16	26
Clay, silty, dark brown, with a little lignite	3	29
Lignite and lignitic clay	1	30
Clay, gray to greenish gray	10	40
Lignite	2	42
Clay, sandy, greenish gray	15	57
Lignite	1	58
Clay, gray to greenish gray	10	68
Lignite and lignitic clay	6	74
Clay, light gray	12	86
Lignite	1	87
Clay, light gray to white	13	100
Clay, silty, light gray	7	107
Lignite	3	110
Clay, light gray, with some siderite pellets	7	117
Clay, dark brown, with some lignite	3	120
Clay, sandy, gray	5	125
Siderite, hard	1	126
Bauxite, soft, white, or bauxitic clay	2	128
Clay, white, bauxitic	6	134
Clay, white, with many siderite pellets	14	148
Clay, light green	4	152
Clay, dark bluish gray	6-1/2	158-1/2
Siderite, hard	-1/2	159
Clay, dark bluish gray	19	178
Siderite, hard	-1/2	178-1/2
Clay, dark bluish gray	16-1/2	195
Limestone, thin beds, with partings of calcareous clay . .	6	201
Limestone, hard, with micro-fossils	1	202

DRILL HOLE CC1

D. Ashcraft property.

Sec. 30, T. 1 S., R. 13 W., on east side of road just south of small stream. Elevation 420 ft.

Total depth	145 ft.	Blue clay (Midway) thinned out on syenite
Depth to top of bauxite-kaolin zone (no bauxite)	102 ft.	Limestone thinned out on syenite

	Thickness (feet)	Depth (feet)
Sand and buff sandy clay	8	8
Clay, sandy, yellow	2	10
Clay, sandy, mottled red and gray	1	11
Clay, sandy, dark brown, with a little lignite	4	15
Clay, sandy, dark brown, with thin sand beds	7	22
Sand, with thin beds of brown sandy clay	16	38
Clay, sandy, dark brown, and thin beds of sand	33	71
Lignite and dark lignitic clay	1	72
Clay, greenish gray	12	84
Clay, greenish gray, with few thin beds of lignite	18	102
Clay, white, or kaolin	8	110
Clay, white, with some kaolinized feldspar grains	5	115
Syenite, kaolinized and soft	15	130
Syenite, kaolinized (rotten granite) getting hard at bottom	15	145

DRILL HOLE CC2

G. Myers property.

Sec. 30, T. 1 S., R. 13 W., at east side of road at foot of hill. Elevation 389 ft.

Total depth	131 ft.	Blue clay (Midway) thinned out on syenite
Bauxite-kaolin zone (no bauxite)		Limestone thinned out on syenite

	Thickness (feet)	Depth (feet)
Soil and sand	2	2
Clay, sandy, red	2	4
Clay, sandy, mottled red and gray	3	7
Clay, sandy, light gray	2	9
Clay, sandy, dark brown, with a little lignite	4	13
Lignite, soft	1	14
Clay, sandy, dark brown, with a little lignite	5	19
Lignite	3	22
Sand, firm, with a little light gray clay	24	46
Lignite	5	51
Clay, light gray, with few thin streaks of lignite	14	65
Clay, dark gray to greenish gray	22	87
Clay, grayish white	2	89
Clay, dark gray to greenish gray	14	103
Sand	2	105
Siderite, very hard	-1/2	105-1/2

DRILL HOLE CC2 (Cont.)

	Thickness (feet)	Depth (feet)
Feldspar sand, soft (kaolinized syenite)	19-1/2	125
Syenite, kaolinized (rotten granite)	5	130
Syenite, hard	1	131

DRILL HOLE CC3

State Sanitarium property.

Sec. 24, T. 1 S., R. 14 W., just northwest of junction of road with trail off to west. Elevation 380 ft.

Total depth	173 ft.		
Bauxite-kaolin zone (no bauxite)	(?)	(about 100 ft.)	
Blue clay (Midway) zone	(?)	Paleozoic rocks	(?)
Limestone zone	(?)	Paleozoic rocks	(?)

	Thickness (feet)	Depth (feet)
Clay, very sandy, red	6	6
Clay, sandy, mottled red and gray	4	10
Sand, with some yellow clay	19	29
Lignite	1	30
Clay, sandy, light greenish gray	5	35
Clay, dark brown, and lignite	3	38
Clay, sandy, greenish gray, with some lignite	8	46
Clay, sandy, grayish white	5	51
Clay, sandy, greenish gray	7	58
Sand, with thin beds of greenish-gray clay	8	66
Siderite, hard	-1/2	66-1/2
Sand and greenish-gray clay	2-1/2	69
Siderite, hard	-1/2	69-1/2
Sand and greenish-gray clay	10-1/2	80
Siderite, hard	1	81
Sand and white clay	40	121
Siderite, hard	-1/2	121-1/2
Sand	12-1/2	134
Sand and soft red sandstone	25	159
Lignite (?), hard	-1/2	159-1/2
Rock (?), hard	3-1/2	163
Lignite (?), hard	1	164
Sand, hard	5	169
Sand (?) with some calcareous shale	2	171
Syenite, hard; feldspar somewhat kaolinized but hard . . .	2	173

DRILL HOLE D1

Lee Jarrett, agent for property.

Sec. 5, T. 1 S., R. 12 W., about 110 ft. south and 300 ft. south and 300 ft. west from bridge. Elevation 243 ft.

Total depth	149 ft.
Depth to top of bauxite-kaolin zone	Hole started below this zone
Depth to top of blue clay (Midway)	15 ft.
Depth to top of limestone	115 ft.

	Thickness (feet)	Depth (feet)
Clay, sandy, light gray	13	13
Gravel and sand	2	15
Clay, dark bluish gray	12-3/4	27-3/4
Siderite, thin beds in clay	1-1/4	29
Clay, dark bluish gray	13	42
Siderite	-1/4	42-1/4
Clay, dark bluish gray	19	61-1/4
Siderite	-3/4	62
Clay, dark bluish gray	41	103
Sand, granitic, consisting of hard angular feldspar grains.	12	115
Limestone, soft, with thin beds of feldspar sand	22	137
Sand, granitic, consisting of hard angular feldspar grains.	11	148
Syenite, hard	1	149

DRILL HOLE D2

Fred Christian property.

Sec. 32, T. 1 N., R. 12 W., about 50 ft. west and 150 ft. north from road corner. Elevation 260 ft.

Total depth	122 ft.
Depth to top of bauxite-kaolin zone	Hole started below this zone
Depth to top of blue clay (Midway)	15 ft.
Depth to top of limestone	110 ft.

	Thickness (feet)	Depth (feet)
Clay, sandy, red	6	6
Gravel	1	7
Clay, red	1	8
Clay, reddish brown	7	15
Clay, dark bluish gray	13	28
Clay, gray, with some red clay	6	34
Clay, dark bluish gray, with few thin seams of siderite	26	60
Siderite, hard	-1/2	60-1/2
Clay, dark bluish gray, with few thin seams of siderite	49-1/2	110
Limestone, with micro-fossils, and few thin beds of sandy clay	11	121
Limestone, hard	1	122

DRILL HOLE E1

American Cyanamid Co. property.

Sec. 9, T. 1 S., R. 12 W., about 40 ft. south of road, near northwest corner of property. Elevation 280 ft.

Total depth	161 ft.	Blue clay (Midway) thinned out on syenite
Depth to top of bauxite-kaolin zone	87 ft.	Limestone thinned out on syenite

	Thickness (feet)	Depth (feet)
Soil, sandy	1	1
Clay, sandy, yellow	15	16
Clay, sandy, gray	12	28
Clay, silty, dark bluish gray, with few thin beds of lignite	22	50
Clay, dark greenish gray	7	57
Lignite	18	75
Clay, silty, greenish gray	5	80
Lignite	5	85
Clay, gray, lignitic	2	87
Bauxite, firm, gray	1	88
Clay, white, bauxitic, and kaolin, with many siderite pellets	11	99
Clay, soft, white, with many siderite pellets	11	110
Siderite	1	111
Clay, white, with some soft kaolinized feldspar grains, becoming firmer with depth and increasing amount of feldspar	39	150
Syenite, kaolinized (rotten granite)	6	156
Syenite, partly kaolinized, but getting hard	5	161

DRILL HOLE E2

W. Rauch property.

Sec. 9, T. 1 S., R. 12 W., about 40 ft. south of road and 20 ft. east of small stream. Elevation 265 ft.

Total depth	228 ft.	Depth to top of blue clay (Midway)	150 ft.
Depth to top of bauxite-kaolin zone (no bauxite)	(?) about 132 ft.	Depth to top of limestone	220 ft.

	Thickness (feet)	Depth (feet)
Sand and sandy clay	8	8
Clay, sandy, yellow	7	15
Clay, sandy, yellowish brown, and sand	18	33
Clay, sandy, yellow, and coarse sand	17	50
"Ironstone," hard	-1/2	50-1/2
Clay, sandy, yellow	2-1/2	53
"Ironstone," hard	-1/2	53-1/2
Sand, fine, and sandy clay	6-1/2	60
Siderite, hard	-1/2	60-1/2

DRILL HOLE E2 (Cont.)

	Thickness (feet)	Depth (feet)
Clay, sandy, gray, and sand (poor returns for sample) . . .	55-1/2	116
Lignite	5	121
Clay, sandy, lignitic	9	130
Lignite	2	132
Clay, grayish white (poor returns for sample)	18	150
Clay, dark bluish gray	18	168
Siderite, hard	-1/2	168-1/2
Clay, dark bluish gray	11-1/2	180
Siderite, hard	-1/2	180-1/2
Clay, dark bluish gray	21-1/2	202
Clay, dark bluish gray, with thin beds of siderite	4	206
Clay, dark bluish gray to greenish gray	14	220
Limestone, with micro-fossils; thin beds of granitic sand consisting of hard angular feldspar grains	5	225
Limestone	2	227
Syenite, hard	1	228

DRILL HOLE F1

Mrs. Ward property.

Sec. 16, T. 1 S., R. 12 W., about 70 ft. east of road and 120 ft. north of house. Elevation 295 ft.

Total depth	145 ft.	Blue clay (Midway) thinned out on syenite
Depth to top of bauxite-kaolin zone (no bauxite)	115 ft.	Limestone thinned out on syenite

	Thickness (feet)	Depth (feet)
Sand and sandy clay	3	3
Clay, silty, brown, with streaks of lignite	7	10
Clay, silty, dark brown	24	34
Clay, greenish brown	3	37
Clay, yellow, "soapy" (possible bentonite bed)	2	39
Clay, sandy, brown	9	48
Clay, sandy, brown, with few thin beds of lignite	4	52
Clay, sandy, brown	2	54
Sand, firm, with few thin beds of lignitic clay	6	60
Clay, sandy, lignitic	13	73
Clay, sandy, yellow, with thin beds of sand	5	78
Sand, with thin beds of brown sandy clay	37	115
Syenite, kaolinized (rotten granite), consisting of kaolinized feldspar, gradually becoming fresher and harder to bottom	30	145

DRILL HOLE F2

C. Russenberger property.

Sec. 10, T. 1 S., R. 12 W., 60 ft. west of road and about 300 ft. south of house. Elevation 287 ft.

Total depth	137 ft.	Blue clay (Midway) thinned out on syenite
Depth to top of bauxite-kaolin zone (no bauxite)	90 ft.	Limestone thinned out on syenite

	Thickness (feet)	Depth (feet)
Sand and sandy clay	3	3
Clay, sandy, yellow	6	9
Sand, orange, with some clay	3	12
Clay, sandy, brown, with some lignite	6	18
Sand, with little clay	7	25
Sand, and sandy clay, with some lignite	10	35
Lignite	1	36
Sand, with thin beds of lignitic clay	19	55
Sand, with little gray clay	17	72
Lignite	16	88
Clay, sandy, gray	2	90
Clay, white, or kaolin	15	105
Syenite, kaolinized, with white to greenish-gray kaolinized feldspars, getting gradually harder	30	135
Syenite, partly kaolinized but hard	2	137

DRILL HOLE F3

Mrs. A. P. Raines property.

Sec. 2, T. 1 S., R. 12 W., about 550 ft. south of Raines' house and across road from Richard's house. Elevation 280 ft.

Total depth	99 ft.	Blue clay (Midway) thinned out on syenite
Depth to top of bauxite-kaolin zone (no bauxite)	38 ft.	Limestone thinned out on syenite

	Thickness (feet)	Depth (feet)
Soil and sand	2	2
Clay, sandy, mottled red and yellow	5	7
Clay, sandy, yellow	5	12
Clay, very sandy, yellow to white	3	15
Clay, sandy, white	3	18
Clay, mottled yellow and brown	8	26
Clay, dark brown, with thin beds of lignite	9	35
Clay, light bluish gray	3	38
Clay, white, or kaolin, with siderite pellets	9	47
Clay, white, with some soft kaolinized feldspars	13	60
Syenite, kaolinized, soft, white to pale green	11	71
Syenite, kaolinized, but getting firmer	12	83
Syenite, kaolinized, pale green, and many siderite pellets.	8	91

DRILL HOLE F3 (Cont.)

	Thickness (feet)	Depth (feet)
Syenite, kaolinized, but getting harder, and many siderite pellets	8	99
Syenite, hard		

DRILL HOLE F4

Sec. 2, T. 1 S., R. 12 W., about 30 ft. west of road and 60 ft. south of Fish Creek. Elevation 265 ft.

Total depth	138 ft.	Blue clay (Midway) thinned out on syenite
Depth to top of bauxite-kaolin zone	100 ft.	Limestone thinned out on syenite

	Thickness (feet)	Depth (feet)
Sand	3	3
Clay, sandy, mottled yellow and brown	20	23
Gravel	1	24
Sand, gray, and sandy clay	40	64
Lignite	8	72
Clay, sandy, gray	6	78
Lignite	3	81
Clay, sandy, and sand, with some lignite	9	90
Clay, sandy, light gray	8	98
Clay, light gray	2	100
Bauxite, hard, yellow, with some siderite pellets	10	110
Clay, white, or kaolin, with some kaolinized feldspar	13	123
Clay, white, with kaolinized feldspars	7	130
Syenite, kaolinized, soft	3	133
Syenite, kaolinized, but getting firm	4	137
Syenite, partly kaolinized, hard	1	138

DRILL HOLE F5

Mrs. Wm. Sayles property.

Sec. 31, T. 1 N., R. 11 W., about 450 ft. west along lane from highway. Elevation 267 ft.

Total depth	27 ft.	Blue clay (Midway) thinned out on syenite
Depth to top of bauxite-kaolin zone (no bauxite)	20 ft. (?)	Limestone thinned out on syenite

	Thickness (feet)	Depth (feet)
Soil and sandy clay	6	6
Clay, sandy, pink	14	20
Sand, coarse, consisting of kaolinized feldspar(rotten granite)	5	25
Syenite, partly kaolinized, but fairly hard and in boulders	2	27

DRILL HOLE G1

E. L. Davis property.

Sec. 12, T. 1 S., R. 13 W., about 50 ft. west of big red barn. Elevation 320 ft.

Total depth	121 ft.	Depth to top of blue clay (Midway)	65 ft.
Depth to top of bauxite-kaolin zone	45 ft.	Depth to top of limestone	116 ft.

	Thickness (feet)	Depth (feet)
Soil and sand	3	3
Clay, sandy, mottled brown and yellow	4	7
Clay, sandy, mottled yellow and white	13	20
Clay, gray	4	24
Clay, sandy, dark brown, with some lignite	6	30
Clay, light bluish gray	1	31
Clay, white	3	34
Clay, grayish white, with siderite pellets	5	39
Clay, sandy, lignitic	3	42
Lignite	3	45
Bauxite, soft, or bauxitic clay	3	48
Clay, grayish white	4	52
Clay, light gray	6	58
Clay, mottled pink and white	7	65
Clay, dark bluish gray	11	76
Clay, dark bluish gray, with some thin hard siderite beds	3	79
Clay, dark bluish gray	37	116
Limestone, with thin beds of calcareous clay, with microfossils, and phosphate pellets	5	121

DRILL HOLE G2

H. Boecher property.

Sec. 13, T. 1 S., R. 13 W., about 100 ft. east of road corner. Elevation 283 ft.

Total depth	166 ft.	Depth to top of blue clay (Midway)	107 ft.
Depth to top of bauxite-kaolin zone (no bauxite)	87 ft.	Depth to top of limestone	164 ft.

	Thickness (feet)	Depth (feet)
Sand	8	8
Clay, sandy, mottled yellow and brown	7	15
Clay, sandy, gray, with some thin sand beds	24	39
Lignite and lignitic clay	6	45
Clay, very sandy, green	6	51
Clay, sandy, gray	3	54
Clay, sandy, brown	3	57
Clay, light greenish gray	6	63
Siderite, hard	1	64
Clay, light greenish gray, with siderite pellets	3	67
Clay, sandy, light greenish gray	4	71
Lignite	2	73
Clay, gray	13	86

DRILL HOLE G2 (Cont.)

	Thickness (feet)	Depth (feet)
Lignite	1	87
Clay, grayish white	4	91
Siderite, hard	-1/2	91-1/2
Clay, white, with siderite pellets and thin crusts	15-1/2	107
Clay, dark bluish gray	57	164
Limestone, with micro-fossils	2	166

DRILL HOLE G3

A. J. Rinke property.

Sec. 12, T. 1 S., R. 13 W., about 60 ft. south and 350 ft. west from road corner. Elevation 282 ft.

Total depth	63 ft.
Depth to top of bauxite-kaolin zone	Hole started below this horizon
Depth to top of blue clay (Midway)	6 ft.
Depth to top of limestone	48 ft.

	Thickness (feet)	Depth (feet)
Soil and sand	4	4
Clay, sandy, mottled red and brown	2	6
Clay, buff (surface weathered blue clay)	9	15
Clay, dark bluish gray	33	48
Limestone, thin beds, with beds of calcareous clay	9	57
Limestone, with few thin beds of calcareous clay, with micro-fossils, phosphate pellets, and some hard angular fresh feldspar grains	6	63

DRILL HOLE G4

Amos Morehart property.

Sec. 10, T. 1 S., R. 13 W., about 150 ft. north and 25 ft. west from road corner. Elevation 380 ft.

Total depth	126 ft.	Depth to top of blue clay (Midway)	64 ft.
Depth to top of bauxite-kaolin zone	41 ft.	Depth to top of limestone	124 ft.

	Thickness (feet)	Depth (feet)
Clay, sandy, mottled red and yellow	10	10
Clay, mottled red and white	6	16
Lignite and dark lignitic clay	4	20
Clay, white	2	22
Clay, light gray	4	26
Siderite, hard	1	27

DRILL HOLE G4 (Cont.)

	Thickness (feet)	Depth (feet)
Clay, gray	6	33
Lignite and lignitic clay	2	35
Clay, gray	6	41
Bauxite, soft, white, or bauxitic clay	7	48
Clay, soft, white, with many siderite pellets	6	54
Clay, light gray	10	64
Clay, dark bluish gray	18	82
Siderite, hard	1	83
Clay, dark bluish gray	13	96
Siderite, hard	-1/2	96-1/2
Clay, dark bluish gray	27-1/2	124
Limestone, hard, with micro-fossils	2	126

DRILL HOLE H1

Republic Mining & Manufacturing Co. property.

Sec. 5, T. 2 S., R. 14 W., on south side of road about 50 ft. west of crossing power line. Elevation 368 ft.

Total depth	144 ft.	Depth to top of blue clay (Midway)	68 ft.
Depth to top of bauxite-kaolin zone	24 ft.	Depth to top of limestone	136 ft.

	Thickness (feet)	Depth (feet)
Clay, sandy, red	4	4
Clay, sandy, yellow and gray	9-1/2	13-1/2
Lignite	-1/2	14
Clay, white	1	15
Sand, fine	4	19
Clay, white	5	24
Clay, white, bauxitic	3	27
Bauxite, soft, gray to yellow, or bauxitic clay	12	39
Clay, white	9	48
Bauxite, soft, or bauxitic clay	8	56
Clay, white, or kaolin, with many siderite pellets	12	68
Clay, dark bluish gray, sticky	28	96
Clay, dark bluish gray, crumbly	40	136
Limestone, thin beds, with partings of calcareous clay, and some sand consisting of hard, angular feldspar grains.	7	143
Limestone, hard	1	144

DRILL HOLE H2

Republic Mining & Manufacturing Co. property.

Sec. 9, T. 2 S., R. 14 W., at northwest edge of town of Bauxite, about 150 ft. north of nearest house. Elevation 390 ft.

Total depth	220 ft.	Depth to top of blue clay (Midway)	136 ft.
Depth to top of bauxite-kaolin zone (no bauxite)	120 ft.	Depth to top of limestone	171 ft.

	Thickness (feet)	Depth (feet)
Sand, yellow	9	9
Sand, yellow, with some clay	4	13
Sand, soft	2	15
Clay, silty, brown, with a little lignite	34	49
Lignite	2	51
Clay, dark brown, with some lignite	9	60
Clay, sandy, brown, and thin sand beds, with some lignite	60	120
Clay, white	16	136
Clay, dark bluish gray	32	168
Sand, granitic, consisting of hard angular feldspar grains	3	171
Limestone, with micro-fossils, and thin beds of calcareous clay	49	220

DRILL HOLE J1

Republic Mining & Manufacturing Co. property.

Sec. 28, T. 2 S., R. 14 W., on power line trail, about 40 ft. southwest of crossing with road. Elevation 400 ft.

Total depth	75 ft.	Blue clay (Midway) thinned out on syenite
Depth to top of bauxite-kaolin zone (no bauxite)	64 ft.	Limestone thinned out on syenite

	Thickness (feet)	Depth (feet)
Sand, red, with some clay	11	11
Sand, yellow	2	13
Clay, white	1	14
Sand, fine, yellow	18	32
Sand, and lignitic clay	8	40
Clay, sandy, brown, and lignite	22	62
Lignite	1	63
Clay, dark, lignitic	1	64
Syenite, kaolinized (rotten granite)	6	70
Syenite, partly kaolinized but getting harder	5	75

DRILL HOLE J2

Republic Mining & Manufacturing Co. property.

Sec. 28, T. 2 S., R. 14 W., along power line, about 50 ft. southwest from road along ridge. Elevation 468 ft.

Total depth	204 ft.	Blue clay (Midway) thinned out on syenite
Depth to top of bauxite-kaolin zone (no bauxite)	166 ft.	Limestone thinned out on syenite

	Thickness (feet)	Depth (feet)
Clay, sandy, red, with some gravel	4	4
Clay, sandy, red	3	7
Clay, sandy, mottled red and yellow	5	12
Sand, hard, red, and "ironstone"	3	15
Sand, fine, yellow, and some sandy clay	15	30
Sand, firm	24	54
Clay, sandy, dark brown	10	64
Sand, firm	56	120
Sand, with some dark brown clay and lignite	31	151
Clay, sandy, red and white	2	153
Sand, with some lignitic clay	13	166
Clay, white, with some soft kaolinized feldspar grains	9	175
Syenite, kaolinized (rotten granite)	15	190
Syenite, kaolinized but getting harder with depth	14	204

DRILL HOLE J3

Kidd property.

Sec. 29, T. 2 S., R. 14 W., in narrow lane about 450 ft. west of junction with road. Elevation 465 ft.

Total depth	464 ft.	Depth to top of blue clay (Midway)	365 ft.
Depth to top of bauxite-kaolin zone (no bauxite)	344 ft.	Depth to top of limestone	460 ft.

	Thickness (feet)	Depth (feet)
Sand, red, with some gravel	3	3
Clay, sandy, mottled red and gray	7	10
Clay, sandy, mottled yellow and white	6	16
Clay, dark brown	5	21
Clay, sandy, yellow and white	11	32
Clay, sandy, dark brown	8	40
Sand, fine	24	64
Lignite	1	65
Sand and some clay	17	82
Siderite, hard	1	83
Sand and brown clay	12	95
Siderite, hard	-1/4	95-1/4
Sand and some white clay	13-3/4	109
Siderite, hard	-1/2	109-1/2
Sand, firm	16	125-1/2

DRILL HOLE J3 (Cont.)

	Thickness (feet)	Depth (feet)
Siderite, hard	-1/2	126
Sand, with some clay and lignite and hard siderite beds	59	185
Clay, light gray (?) (poor returns)	17	202
Sand, firm, with some lignite	85	287
Clay, sandy, white, with thin sand beds	16	303
Siderite, hard	-1/2	303-1/2
Sand, and white clay (poor returns)	38-1/2	342
Siderite, hard	2	344
Clay, white, with siderite pellets	21	365
Clay, dark bluish gray	95	460
Limestone, with some thin beds of calcareous clay	4	464

DRILL HOLE J4

Davenport heirs property.

Sec. 30, T. 2 S., R. 14 W., on southwest side of road just west of small stream. Elevation 345 ft.

Total depth	310 ft.	Depth to top of blue clay (Midway)	205 ft.
Depth to top of bauxite-kaolin zone	172 ft.	Depth to top of limestone	300 ft.

	Thickness (feet)	Depth (feet)
Sand, with some yellow clay	13	13
Gravel	1	14
Sand and dark-brown silty clay, with some lignite	17	31
Lignite	1	32
Clay, dark brown, lignitic	3	35
Sand, firm, with some dark-brown clay	75	110
Sand, with dark-brown lignitic clay	15	125
Sand, coarse, with some clay	17	142
Lignite	1	143
Clay, sticky, grayish white.	9	152
Siderite, hard	1	153
Sand, coarse, with some gray clay	15	168
Clay, soft, white	4	172
Bauxite, firm, and bauxitic clay	8	180
Clay, white, with many siderite pellets	25	205
Clay, dark gray	3	208
Clay, dark bluish gray	92	300
Limestone, with micro-fossils, and thin beds of calcareous clay	10	310

DRILL HOLE M1

John Fletcher property.

Sec. 20, T. 1 N., R. 11 W., between road and Fourche Creek, about 650 ft. southwest of bridge. Elevation 245 ft.

Total depth	65 ft.	Blue clay (Midway) thinned out on syenite
Depth to top of bauxite-kaolin zone (no bauxite)	55 ft.	Limestone thinned out on syenite

	Thickness (feet)	Depth (feet)
Soil and sand	6	6
Clay, sandy, brown	27	33
Clay, sandy, gray	7	40
Sand, coarse	10	50
Gravel and coarse sand (base of alluvium)	5	55
Syenite, kaolinized (rotten granite)	5	60
Syenite, partly kaolinized, greenish gray, getting hard	5	65

DRILL HOLE M2

F. L. French property.

Sec. 20, T. 1 N., R. 11 W., between road and Fourche Creek, about 600 ft. east of west line of section. Elevation 245 ft.

Total depth	83 ft.	Blue clay (Midway) probably thinned out on syenite
Depth to top of bauxite-kaolin zone	68 ft.	Limestone probably thinned out on syenite

	Thickness (feet)	Depth (feet)
Soil and fine sand	4	4
Clay, fine, sandy, brown	35	39
Sand, coarse	10	49
Gravel and coarse sand (base of alluvium)	2	51
Lignite and lignitic clay	2	53
Clay, light gray to greenish gray	6	59
Siderite, hard	1	60
Clay, white	1	61
Lignite and dark lignitic clay	4	65
Clay, white	1	66
Clay, white, bauxitic	2	68
Bauxite, hard, white to yellow	2	70
Bauxite, firm, gray	6	76
Lignite	1	77
Bauxite, firm	5	82
Rock (?), hard	1	83

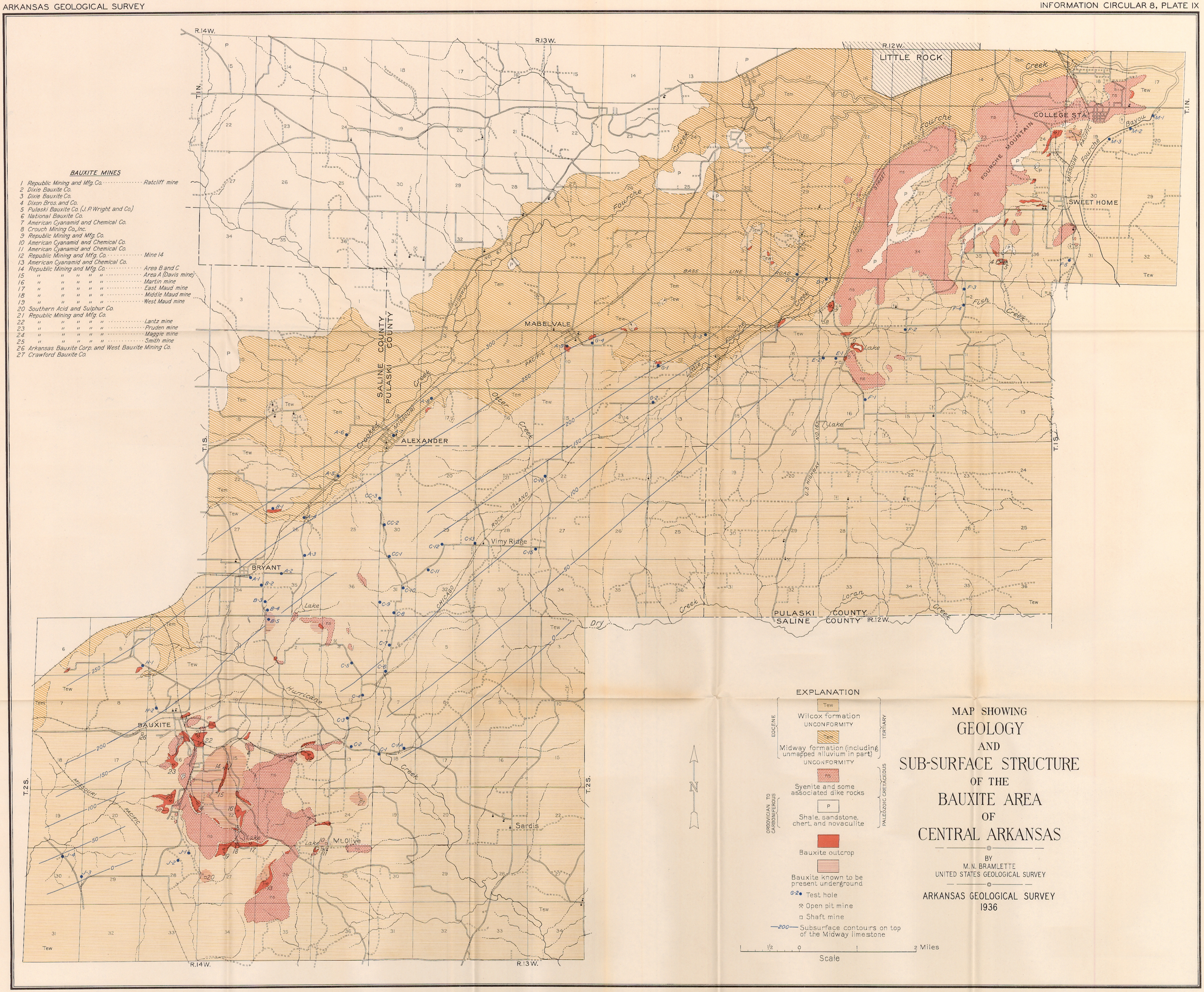
DRILL HOLE M3

M. Hall property.

Sec. 19, T. 1 N., R. 11 W., between road and Fourche Creek, about 210 ft. west of cabin. Elevation 245 ft.

Total depth	89 ft.	Blue clay (Midway) probably thinned out on syenite
Depth to top of bauxite-kaolin zone	80 ft.	Limestone probably thinned out on syenite

	Thickness (feet)	Depth (feet)
Soil	2	2
Clay, sandy, brown	20	22
Clay, fine, and clay	16	38
Sand, coarse	10	48
Gravel and coarse sand (base of alluvium)	4	52
Sand, with thin beds of red and gray clay	11	63
Lignite and lignitic clay	7	70
Clay, light gray to greenish gray	8	78
Lignite	2	80
Bauxite, soft, gray and brown	7	87
Rock (?), hard	2	89



BAUXITE MINES

1	Republic Mining and Mfg. Co.	Ratcliff mine
2	Dixie Bauxite Co.	
3	Dixie Bauxite Co.	
4	Dixon Bros. and Co.	
5	Pulaski Bauxite Co. (J. P. Wright and Co.)	
6	National Bauxite Co.	
7	American Cyanamid and Chemical Co.	
8	Crouch Mining Co., Inc.	
9	Republic Mining and Mfg. Co.	
10	American Cyanamid and Chemical Co.	
11	American Cyanamid and Chemical Co.	
12	Republic Mining and Mfg. Co.	Mine 14
13	American Cyanamid and Chemical Co.	
14	Republic Mining and Mfg. Co.	Area B and C
15	" " " " "	Area A (Davis mine)
16	" " " " "	Martin mine
17	" " " " "	East Maud mine
18	" " " " "	Middle Maud mine
19	" " " " "	West Maud mine
20	Southern Acid and Sulphur Co.	
21	Republic Mining and Mfg. Co.	
22	" " " " "	Lantz mine
23	" " " " "	Pruden mine
24	" " " " "	Maggie mine
25	" " " " "	Smith mine
26	Arkansas Bauxite Corp. and West Bauxite Mining Co.	
27	Crawford Bauxite Co.	

EXPLANATION

TERTIARY

EOCENE

Tew — Wilcox formation

UNCONFORMITY

Tem — Midway formation (including unmapped alluvium in part)

UNCONFORMITY

PALEOZOIC CRETACEOUS

ns — Syenite and some associated dike rocks

ORDOVICIAN TO CARBONIFEROUS

P — Shale, sandstone, chert, and novaculite

🟥 Bauxite outcrop

▤ Bauxite known to be present underground

G-2 ● Test hole

⚒ Open pit mine

□ Shaft mine

—200— Subsurface contours on top of the Midway limestone

1 ½ 0 1 2 Miles

Scale

MAP SHOWING
GEOLOGY
AND
SUB-SURFACE STRUCTURE
OF THE
BAUXITE AREA
OF
CENTRAL ARKANSAS

BY
M. N. BRAMLETTE
UNITED STATES GEOLOGICAL SURVEY

ARKANSAS GEOLOGICAL SURVEY
1936