Geology of the Arkansas Bauxite Region

GEOLOGICAL SURVEY PROFESSIONAL PAPER 299

U.S. DEPARTMENT OF THE INTERIOR

March 3, 1849

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By MACKENZIE GORDON, JR., JOSHUA I. TRACEY, JR., *and* MILLER W. ELLIS

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Description, classification, and origin of the bauxite deposits, and their geologic setting relative to an early Eocene land surface

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GEOLOGY OF THE ARKANSAS BAUXITE REGION

By Mackenzie Gordon, Jr., Joshua I. Tracey, Jr. and Miller W. Ellis

ABSTRACT

The Arkansas bauxite region lies near the center of the State in Pulaski and Saline Counties. It is irregular in outline, covering about 275 square miles and is elongate in a northeasterly direction. Bauxite deposits in the region can be grouped into two principal districts, one in Pulaski County about 5 miles south of Little Rock, and the other, more important commercially, about 25 miles southwest in Saline County.

The bauxite deposits lie entirely within the Gulf Coastal Plain province a short distance southeast of its boundary with the Interior Highlands province. The surface rocks in this part of the Gulf Coastal Plain are early Tertiary sand and clay. The topography consists of gently rolling hills that are less than 200 feet above the valleys. The maximum relief is about 340 feet. The lowest point, on Fourche Creek, is about 240 feet above sea level, and the highest altitude, on Alexander Mountain 15 miles to the southwest, is 580 feet.

The rocks underlying the Interior Highlands province at the northeast edge of the bauxite region are folded sandstone and shale beds of Paleozoic age. North and northeast of Little Rock the topography consists of flat to rounded ridges and broad to narrow valleys. This area merges southwestward into a region consisting of prominent straight ridges and narrow valleys, generally trending northwestward. The Paleozoic rocks generally are increasingly old and more tightly folded to the southwest. The line of demarcation between the Interior Highlands and Gulf Coastal Plain physiographic provinces is the contact between the hard rocks of Paleozoic age and the soft beds of Tertiary age to the southeast.

The Coastal Plain includes marine and nonmarine strata of Paleocene and Eocene age, gravel of late Tertiary and Quaternary age, and terrace deposits and alluvium of Quaternary age. The Tertiary sediments rest unconformably on rocks of Paleozoic age and on intrusive masses of nepheline syenite of probable Late Cretaceous age. These strata lap over and around the resistant masses, particularly the nepheline syenite, parts of which remained exposed as hills throughout much of their history. The Tertiary strata generally strike northeastward and dip gently southeastward, although this has been modified locally by compaction.

The Midway group, which is divided into two formations, consists of dominantly marine sediments of Paleocene age. The lower one, of interbedded gray marly clay and sandy limestone containing local conglomerate, is the Kincaid formation. The upper one, consisting essentially of blue-black or dark-gray clay, somewhat calcareous at the base, is the Wills Point formation.

The sediments of Eocene age are dominantly nonmarine and overlie unconformably those of the Midway group. Most of these continental beds have been referred to the Wilcox group, which in this area is divided into three formations. The lowest is the Berger, which consists mainly of interbedded gray silty clay, greenish-gray sand, and lignite. Fringing the buried nepheline syenite hills, a facies of weathered detrital kaolinitic clay that contains many bauxite bodies is included in the Berger. The overlying Saline formation includes a lower member of chocolate-brown silty to sandy clay and an upper member of red ferruginous sand. Along the upland of Paleozoic rocks a gravel and sand facies is present in the Saline. The uppermost of the Wilcox formations is the Detonti sand, a gray to tan sand containing scattered clay beds. In the southwestern part of the bauxite region an extensive bed of lignite occurs at the base of the sand.

Later Eocene strata are represented locally by nonmarine and marine beds, mostly sand, clay, and some lignite, of the Claiborne and Jackson groups. It is possible that regional studies will later prove that the Wilcox in the Arkansas bauxite region should be restricted to the Berger formation and that the Saline formation and Detonti sand should be transferred to the Claiborne group. The writers are following usage in the present classification of the rocks.

The outcrops of the nepheline syenite and related igneous rocks associated with the bauxite in this region are the more elevated parts of cupolas of a batholith of feldspathoidal igneous rock. These igneous rocks were intruded into sediments of Paleozoic age, the youngest of which are probably Pennsylvanian. Subsequent erosion exposed parts of the igneous mass, some to prolonged weathering, and some to be buried by sediments of Paleocene and Eocene time. Two coarse-grained varieties of the nepheline syenite are the principal source rocks of most of the bauxite. These are the nepheline syenite that is locally known as "gray granite;" and pulaskite, the so-called blue granite.

Bauxite in the region occurs as discontinuous blanketlike deposits over the weathered surface of the nepheline syenite hills and as lenticular deposits resting unconformably on the gently sloping surface of the Wills Point formation near the break in slope where it comes in contact with the igneous rock. Secondary deposits similarly tongue into stratigraphically higher units. Bauxite formed almost entirely from the nepheline syenite rocks in place or from detritus derived from these rocks. The deposits may be classified into four types.

Type 1. Residual deposits on the upper slopes of partly buried nepheline syenite hills. These deposits have a lower zone preserving the granitic texture of the original rock, and an upper concretionary zone.

Type 2. Deposits in the bauxite-kaolin facies of the Berger formation. This facies lies on lower slopes which are cut into the Wills Point formation (Paleocene) and forms part of the edge of the Berger formation (lower Eocene). The deposits have

a lower zone locally preserving fragmental clay textures, a thick concretionary zone above, and commonly a siliceous "hardcap" upslope. They grade into kaolin laterally and vertically.

Type 3. Bedded deposits of the Berger formation. These alluvial deposits are composed of stratified, sorted, or crossbedded pebbles, pisolites, and grains of bauxite. They characteristically truncate, overlie, and fill channels in type 2 deposits.

Type 4. Conglomerate deposits at or near the base of the Saline formation. They consist of rubble deposits of large and small fragments of bauxite and clay largely derived from type 1 deposits and generally lie a short distance downslope from the type 1 deposits.

Types 1 and 2 deposits are the most extensive and are almost equally important commercially. Types 3 and 4 have provided ore in a number of mines, but neither is of primary commercial importance.

In Arkansas the type 1 bauxite originated directly from the nepheline syenite by subaerial weathering under certain restricted physical-chemical conditions. The lower part called granitic bauxite or "sponge ore" shows a striking similarity in texture to the nepheline syenite. Pseudomorphs of microcrystalline gibbsite after feldspar are common and are characterized by large relict crystals marked by groups of parallel linear cavities. The upper part has acquired a pisolitic texture through redistribution of gibbsite. The kaolin between the bauxite and the nepheline syenite did not form as an intermediate stage in this process but was derived from the igneous rock by later weathering when conditions favored the formation of kaolin.

Downslope, the type 2 deposits formed in place by the subaerial weathering of a colluvial detritus washed down from the nepheline syenite. The type 3 and 4 deposits originated from the other two largely by mechanical erosion and deposition somewhat down the slope.

The primary mineral in Arkansas bauxite is gibbsite, aluminum trihydrate. The chief impurities are silica in the form of kaolinite and sand, and iron in the form of siderite, hematite, goethite, magnetite, and pyrite. Boehmite occurs rarely. The titanium minerals, ilmenite, sphene, anatase, and rutile, occur in minor amounts.

Spectrographic study indicated a significant concentration of gallium and niobium in the bauxite compared with the nepheline syenite. This concentration is in accordance with the ionic potential of these elements. It also showed a concentration of chromium, copper, molybdenum, zirconium, titanium, scandium, vanadium, beryllium, manganese, yttrium, and lead; and a depletion of strontium, lanthanum, barium, calcium, and magnesium.

Bauxite was first identified in Arkansas in 1887 by J. C. Branner, then State geologist. In order to stimulate production of the ore, a description of the rock was published in 1891. However, bauxite mining was still in its infancy in the United States and remained centered in Georgia and Alabama until 1898 when commercial production in Arkansas began. By 1903, however, Arkansas had become the leading producer in the United States, a position never since relinquished. The largest annual production from the region was 7,053,028 long tons in 1943. Total estimated production of crude bauxite from 1896 through 1949 is about 32 million long tons.

Open-pit mining is the preferred method in the region and, until the late twenties, was the only one used. Before 1927, the greatest amount of overburden stripped to reach ore was 80 feet. Owing to exhaustion of most of the shallow ore and costs of stripping the deeper deposits, several underground-mining methods were introduced. In the late twenties and early thirties about 60 percent of the bauxite production came from underground mines. More recent improvement of earth-moving equipment and the necessity during World War II for exposing the largest volume of ore in the shortest possible time led to a renewal of strip-mining on a large scale. During the forties, by far the greater proportion of bauxite came from open-pit mines.

Reserves in the region in 1950 are estimated at about 70.7 million long tons averaging 50 percent alumina and 9 percent silica, but assuming no cutoff on iron. Of this total, about 62.6 million tons occurs in Saline County, and 8.1 million tons in Pulaski County. Most of the ore remaining in Pulaski County occurs in deposits containing less than 500,000 tons. In Saline County, however, a major part of the reserves is in deposits that contain more than a million tons in place.

INTRODUCTION

Investigation of the Arkansas bauxite region was undertaken primarily as part of a cooperative exploration program of the U. S. Geological Survey and the U. S. Bureau of Mines during World War II to add to the bauxite reserves of the United States. The U. S. Bureau of Mines has released data derived from the drill holes, their location and brief logs and analyses of the bauxitic and kaolinitic rocks (Malamphy and others, 1948).

This report offers a more complete geologic interpretation of drill-hole data as well as of other information assembled in the course of field investigations by members of the Geological Survey field party. It is concerned principally with the program of exploration, the stratigraphic occurrence and geologic relationship of the bauxite deposits, and with the reserves discovered.

LOCATION OF AREA

The Arkansas bauxite region lies in Pulaski and Saline Counties near the center of the State (fig. 1). The area that was mapped in connection with the study of the bauxite deposits is irregular and is elongate northeastward. It extends from longitude 92°37′30″ W. to 92°12′30″ W. and from latitude 34°45′ N. to 34°28′ N. The total area is about 275 square miles.

The bauxite mines in this region can be grouped into two principal mining districts, one in Pulaski County and the other in Saline County. The Pulaski mining district is about 5 miles south of the city of Little Rock and consists of bauxite deposits that lie a short distance southwest, south, and east of the nepheline syenite outcrop of Granite Mountain (sometimes called Fourche Mountain), between Berger and College Station in Pulaski County. The Saline mining district includes the bauxite mines and deposits associated with two separate partly-buried hills of nepheline syenite in Saline County. The smaller and more northerly of the two, the Alexander Mountain nepheline syenite hill east of the town of Bryant, has bauxite deposits on the west, south, and east sides. About 2 miles to the southwest is the larger Saline County nephe-

line syenite hill that crops out in the vicinity of the town of Bauxite, where the largest ore bodies and mines in the bauxite region are found.

CULTURE

Little Rock, largest city and capital of Arkansas, with a population of about 100,000, lies in the northeast corner of the region. It is the business and industrial center for most of the state. Industry in the rest of the region, except for the bauxite mining activity, is chiefly agriculture and, to a lesser extent, lumbering. East and southeast of Little Rock are the flat flood plains of the Arkansas River, fertile farmland where cotton, corn, and rice are the principal crops. Southwest of the city along the belt where the lower part of the Tertiary formations crops out, about 15 to 20 percent of the land is in cultivation. In the area south of this belt, not more than 5 percent is farmed. Much of the land is held by lumber companies for a future timber and paper-pulp supply.

Of the smaller towns, the two principal ones are located in the western part of the area. They are Benton, a town with a fairly large lumber industry and extensive gravel pits, and Bauxite, a mining town. During the war the largest alumina plant in the world was built at Hurricane Creek by the Defense Plant Corp.

The principal lines of communication follow the

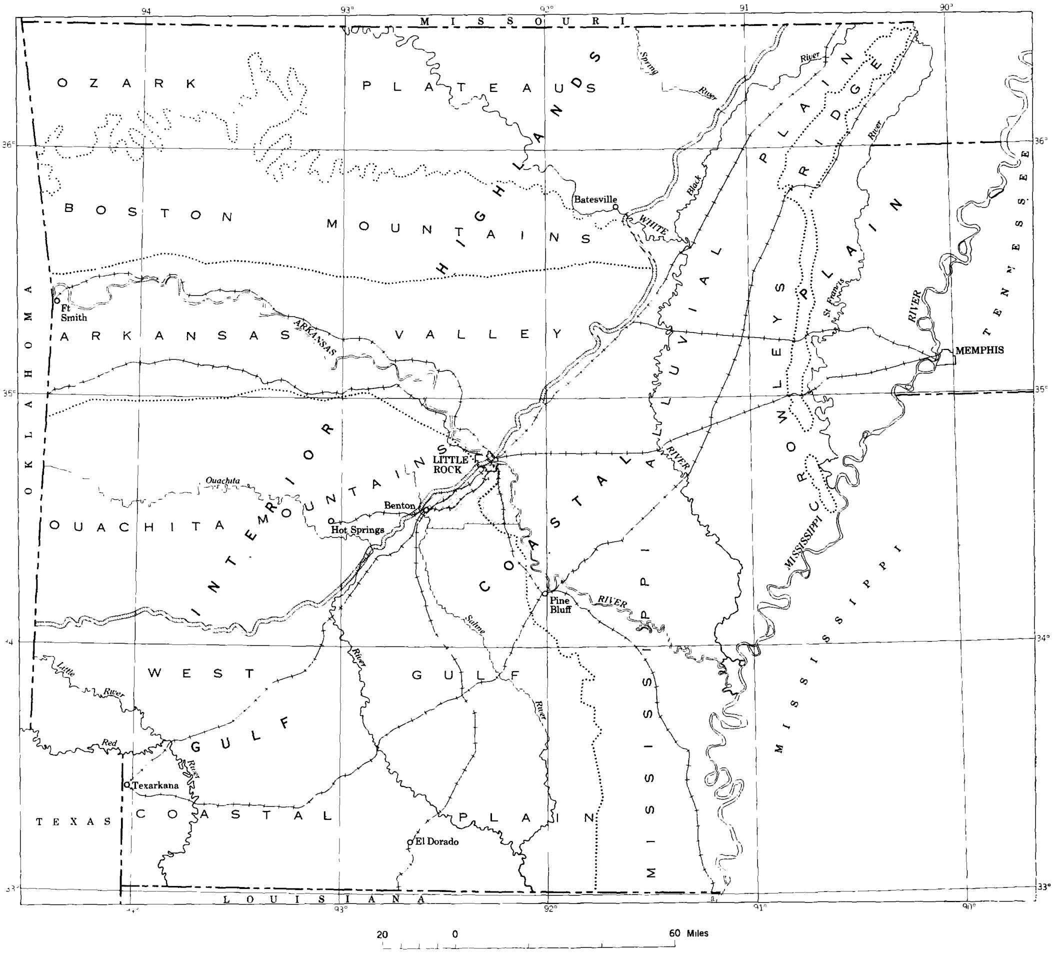

FIGURE 1.—Index map showing the location of the bauxite region and physiographic provinces of Arkansas.

region's general southwesterly trend. These include the main trunk lines of the Missouri Pacific and the Chicago, Rock Island, and Pacific Railroads which pass through or near the principal mining districts. Spur lines and one spur railroad, the Bauxite and Northern which joins the Missouri Pacific Railroad, lead to the bauxite drying plants and the alumina plant, and also to the timberland south of the bauxite region.

Paved roads connect the principal towns and the mining centers in the area. A network of improved gravel roads also serves most of the bauxite region. In the Saline mining district some roads are maintained by the mining companies. Unimproved county roads, many along section or quarter section lines, give access to nearly all parts of the region except in periods of heavy continuous rainfall.

PHYSIOGRAPHIC SUBDIVISIONS AND TOPOGRAPHY

Little Rock is situated on the boundary between two major physiographic provinces, the Gulf Coastal Plain and the Interior Highlands (fig. 1). This boundary trends northeastward through Arkansas and is a relatively abrupt break in the general surface conformation of the land. The bauxite deposits are southeast of the boundary and entirely within the Coastal Plain.

The Interior Highlands province has two major subdivisions within the area covered in this report, the Arkansas Valley and Ouachita Mountains provinces. North and northeast of Little Rock, including much of the area upon which the city is built, is the Arkansas Valley that extends from the edge of the Coastal Plain westward into eastern Oklahoma. The valley is characterized by somewhat flat to broadly rounded ridges and broad to narrow valleys with bluffs cut in the sandstone and shale of late Paleozoic age that flank the Arkansas River. In the environs of Little Rock the maximum relief is about 300 feet, the low point is 225 feet above sea level on the bank of the Arkansas River at the northeast edge of the city, and the high point about 525 feet above sea level about 2 miles northwest of Douglasville.

The boundary between the Arkansas Valley and the Ouachita Mountains is placed slightly west of Douglasville, along Brodie Creek and its tributary, Panther Branch (pl. 1). The boundary between these two subprovinces is not sharp and the different types of topography merge somewhat. The Ouachita Mountains province extends westward across Arkansas into Oklahoma. Along the north edge of the bauxite region the Ouachita Mountains province consists of prominent straight ridges and generally narrow valleys, most of which have marked northwesterly trends. This topography, developed on the older tightly folded rocks of Paleozoic age, reflects in general the vagaries of the structure of these rocks. The maximum relief is about 450 feet. The lowest point, 250 feet above sea level on Fourche Creek, is just south of Douglasville, and the highest, slightly more than 700 feet, is near Twin Spring in sec. 10, T. 1 N., R. 14 W., several miles outside the mapped area.

The Coastal Plain likewise has two principal subdivisions in the area studied, the West Gulf Coastal Plain and the Mississippi Alluvial Plain (fig. 1). The West Gulf Coastal Plain is the most important region of the physiographic subdivisions for within its limits are the bauxite deposits of Arkansas. The surface rocks are early Tertiary sand and clay, and the topography is fairly gentle. Most of the low rolling hills stand less than 200 feet above the nearby valleys, and the maximum relief is about 340 feet. The lowest point is about 240 feet above sea level, on the western arm of Fourche Creek, at the southeast corner of Little Rock, and the highest one is slightly more than 580 feet at the north end of Alexander Mountain, about 12 miles to the southwest. Granite Mountain, a prominent bifurcate northeasterly-elongate hill of nepheline syenite rocks, about 2 miles south of Little Rock, reaches a maximum altitude of 536 feet. The nepheline syenite outcrop just south of Bauxite reaches an altitude of slightly more than 500 feet. Most of the bauxite deposits are in the areas immediately surrounding these crystalline masses.

The Mississippi Alluvial Plain extends eastward from the west edge of the flood plain of the Arkansas River, which also is the east boundary of the bauxite region. On this alluvial plain are deposited the most recent of the Coastal Plain sediments, consisting entirely of Quaternary and Recent clay, sand, and gravel. The maximum relief is less than 50 feet.

DRAINAGE

The Arkansas River skirts the northeast corner and the east edge of the bauxite region. At Little Rock the river leaves the sandstone and slaty shale of Paleozoic age in the upland and enters a broad flood plain on the Coastal Plain, flowing due south. At the west edge of the bauxite region the smaller Saline River flows southward to southeastward beyond the mapped area; then curves southwestward and joins the Ouachita River near the Arkansas–Louisiana border.

Between the two major streams at each side of the bauxite region there are two lesser but still important drainage systems. Hurricane Creek crosses the region in a southeasterly direction, flowing between the high ground at Bauxite and Alexander Mountain. It turns southward and enters the Saline River a considerable distance south of the mapped area. Fourche Creek,

also known as Fourche Bayou, empties into the Arkansas River at the east edge of Little Rock. It has two main tributaries: a southern one situated at the west edge of the Mississippi Alluvial Plain; and a western one at the north edge of the West Gulf Coastal Plain. Left bank tributaries of the western arm of Fourche Creek drain the Ouachita Mountains province and adjacent parts of the Arkansas Valley province between the Arkansas River and Hurricane Creek. From east to west the principal northwestward-trending streams are: Rock, Brodie, and McHenry Creeks; Haw and Callaghan Branches; the main extension of Fourche Creek, and its right-bank tributary, Owen Creek. West of Hurricane Creek, two small streams, Salt and McNeil Creeks, drain the area of rocks of Paleozoic age north of Benton and flow southwestward into the Saline River.

Although a seemingly intricate stream system exists in the Coastal Plain, large parts of the region are poorly drained.

CLIMATE AND VEGETATION

The climate of central Arkansas is marked by warm, fairly humid summers and moderate winters. For 65 years, from 1880 to 1944, the average monthly temperature at Little Rock, according to data of the U. S. Weather Bureau and charts assembled by the Arkansas State Planning Board, ranged from 42°F in January to 81°F in July, and the yearly temperature averaged 62°F. Extremes of temperature depart widely from these means. The frost-free growing season ranges from 6 to 9½ months and averages 8 months, from mid-March to mid-November. The annual precipitation for the same 65-year period mentioned above averaged 47.3 inches at Little Rock and ranged from 31.6 to 66.4 inches. Summer and early fall are the driest seasons. Snow rarely falls.

The uplands underlain by rocks of Paleozoic age northwest of Little Rock are covered mostly with second-growth timber. Except for the bottom lands, little of this land is suited to cultivation, though much of it has been cleared. Southeast of Little Rock the flat flood plain of the Arkansas River is the most fertile farm district.

Shortleaf pine predominates in most of the region, particularly on the uplands. Loblolly and slash pine are abundant on the sandy Coastal Plain soils. Thick stands of hardwood occur only where the pines have been cut. Post oak and hickory are abundant on shallow soils, whereas the willow oak, hickory, ash, and sweet gum and black gum grow in poorly drained areas.

Among the more restricted floral assemblages are the cypress swamps. Majestic stands of cypress tower above the bayou and swamp water that surrounds their roots, and the bodies of water are generally fringed with cottonwood trees. Another restricted assemblage is on nepheline syenite outcrops and consists mainly of cedar, dogwood, and a variety of flowering shrubs.

PREVIOUS WORK

J. C. Branner (1891) first reported bauxite in Arkansas. Six years after his first report he published a more detailed description of the deposits and discussed their mode of origin (Branner, 1897, p. 263–289). J. F. Williams (1891, p. 22, 29, 31, 124, 125, 162, and maps 2 and 3) mapped in detail the Pulaski County outcrops of nepheline syenite rocks, south of Little Rock, and their associated bauxite deposits. He also mapped the Saline County nepheline syenite outcrops, but in less detail. Penrose (1892, p. 107, 109) made incidental reference to the pisolitic bauxite in his work on the Tertiary iron ores. A more complete description of the deposits was published by Hayes (1901, p. 435–472), including a very good map of the deposits in Saline County.

W. J. Mead (1915, p. 28–54) investigated the deposits for the Alcoa Mining Co., then known as the American Bauxite Co. His work included exploration by many test pits and drill holes, and he presented evidence for the derivation of the bauxite from nepheline syenite by the chemical alteration in a normal weathering process. This important work was followed by a short paper by Wysor (1916, p. 42–50) calling attention to the presence of aluminum hydrates with less combined water than gibbsite in some of the pisolites.

Geophysical field methods were first used in the study of the bauxite region by Stearn (1930) who published the results of a geomagnetic survey. He suggested that this region was a province of nepheline syenite rocks mostly buried by later sediments, and that the area between the two producing districts might therefore contain extensive deposits of bauxite.

The most comprehensive geologic report on the Arkansas bauxite region before the present investigation was that of M. N. Bramlette (1936). It summarized the results of a field program of the U. S. Geological Survey and Arkansas Geological Survey that included mapping of the Midway and Wilcox formations throughout the region, investigation of the pits and shaft mines, and drilling of 55 wildcat holes outside the known producing districts.

In addition to the geologic reports cited above, many others have been published on the production of bauxite and mining methods.

PRESENT INVESTIGATION

The joint bauxite program of the Geological Survey and the Bureau of Mines began in April 1941, when the

directors of the two agencies were asked by the Secretary of the Interior to begin the preparation of a complete and independent inventory of the bauxite deposits in the United States. The preliminary work was done by J. R. Thoenen for the Bureau of Mines and E. F. Burchard for the Geological Survey. In November 1941 they published an estimate, as of September 1, 1941, of the bauxite reserves of the United States based on the following grades:

Grade and alumina content of bauxite reserves according to Thoenen and Burchard

Grade	Alumina (percent)	Silica (percent)
A	+55	<7
B	50–55	<15
C	45–50	<30
D	30–45	(1)

[1] High content of silica and iron.

The reserves of the known deposits in other states were given in long tons calculated on a "mined and dried" basis and probably representing 65–70 percent of the actual raw bauxite in the ground.

Estimated bauxite reserves of the United States, in long tons, grade, and alumina content, percent; according to Thoenen and Burchard, 1941

State	Estimated bauxite reserves, in long tons				
	Grade and alumina content, in percent indicated—				
	A (+55)	B (50–55)	C (45–50)	D (30–45)	Total
Arkansas	9,090,000	8,443,000	7,803,000	1,918,000	27,254,000
Alabama	16,000	79,000	33,000	230,000	358,000
Georgia	237,000	311,000	481,000		1,029,000
Mississippi		23,000	100,000	200,000	323,000
Tennessee		36,000	22,000		58,000
Virginia		6,000			6,000
Total	9,343,000	8,898,000	8,439,000	2,348,000	29,028,000

Although the bauxite industry at the time limited its specifications for ore largely to grade *A*, Thoenen and Burchard regarded the *A* and *B* grades as potential ore, because laboratory experiments had shown that the silica content of 12 to 15 percent in some bauxite ores can be lowered materially by flotation. Reference to the table above shows that of the bauxite that Thoenen and Burchard considered minable potential ore, an estimated 18,241,000 long tons in the United States, 17,533,000 or about 96 percent was in Arkansas.

Acting on the information contained in the Thoenen-Burchard report, Congress in the Second Supplemental National Defense Act, 1941, approved on October 28, 1941, authorized and provided appropriations for exploratory investigations that might lead to the discovery of additional domestic bauxite reserves.

In the 4 years that followed, during which time the United States was engaged in World War II, a total of 12,102,225 long dry tons of bauxite was mined and shipped in the Arkansas bauxite region.

Field work was begun by the Geological Survey and the Bureau of Mines in three separate physiographic provinces: the Appalachian Valley region, a belt that extends southwestward through the States of Virginia and eastern Tennessee, to Georgia and Alabama; the East Gulf Coastal Plain, in Georgia, Alabama, Mississippi, and Tennessee; and the West Gulf Coastal Plain, where the work was largely centered in the Arkansas bauxite region (fig. 2). Potential sources of alumina such as alunite, high-alumina clay, and even anorthosite were also investigated. However, by the end of the war no adequate commercial process for the extraction of alumina from any of these substances was in operation; and bauxite remains the sole commercial source of metallic aluminum.

In December 1941 field work began in Arkansas. Its purpose as originally conceived was to supplement the geophysical work of Stearn by more detailed geophysical surveys to chart the distribution and configuration of the igneous basement rocks, to check this work by drilling deep holes with a rotary rig, and to make this information available to the bauxite industry and the public as an aid to further exploration.

Before the attack on Pearl Harbor, however, it became evident that because of a threatened aluminum shortage, actual drilling in search of new reserves would have to be undertaken by the Government. The first drill started work in Pulaski County on May 1, 1942, and 4 months later 6 drills were operating. The construction of new drills through allocations made by the War Production Board brought the operation to a peak during the latter part of 1943, when 20 drills were operating in Pulaski and Saline Counties. After the aluminum crisis passed the number of rigs in operation decreased from 19 to 12 in 1944, and to 8 in May 1945 when drilling was terminated. The statistics of this work and of the 6,932 drill holes actually completed have been summarized by Malamphy and others (1948, p. 57–62).

GEOPHYSICAL PROGRAM

A discussion of the geophysical work and its results has been written by Malamphy and Vallely (1944, p. 324–366) and by Thoenen, Malamphy, and Vallely (1945). To test the results of the geophysical surveys, a rotary drill capable of drilling to depths of 2,000 feet was used. The anomalies interpreted as indicating the presence of highs on the upper surface of the igneous mass were checked by drilling. Between September 1, 1942 and July 10, 1943, 58 holes were completed in the

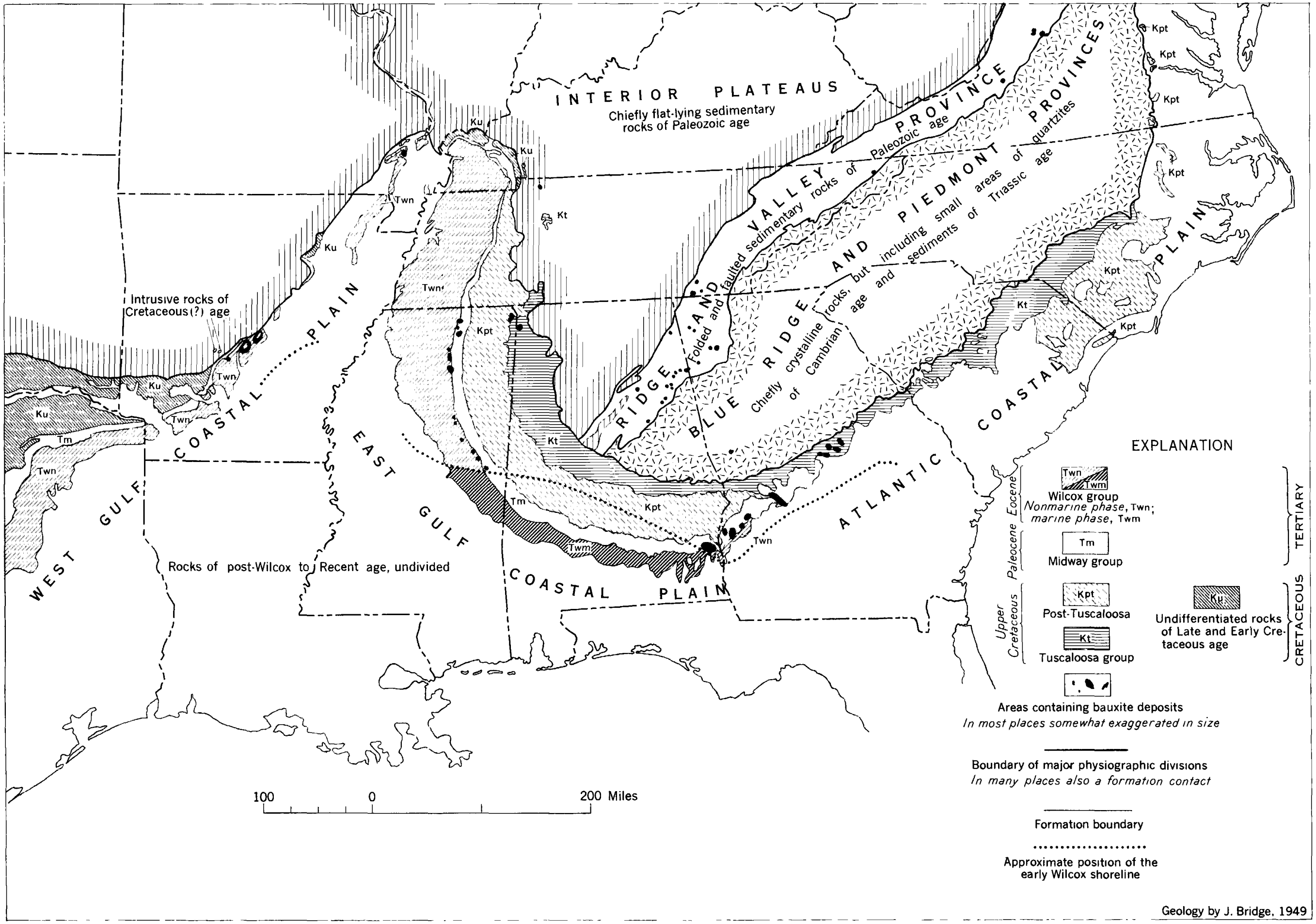

FIGURE 2.—Bauxite-bearing areas of the southeastern United States, showing their relation to geologic formations and to major physiographic divisions.

south-central and southeastern parts of the region. These holes ranged in depth from 427 feet to the maximum contracted depth of 1,500 feet, and averaged 1,090 feet. Much geologic information was obtained from the data accumulated as a result of this program, particularly concerning the stratigraphy of the Midway and Wilcox sediments and of the nature of the unconformity between the two groups. The procedure was to drill through the Wilcox with a dragbit, changing to a core barrel a short distance above the expected Wilcox-Midway contact, and to core through the contact taking samples of the rocks above and below it. Drilling by dragbit was then resumed through the Midway section until the basement rock was reached and a core was taken. Additional cores were taken at intervals to determine lateral and vertical variations in the Tertiary rock types.

Of the 10 major anomalies tested, all were caused by local hills or bosses of nepheline syenite, as had been anticipated. Holes drilled away from the centers of these anomalies and between them cut nepheline syenite rocks or metamorphic rocks of Paleozoic age at lower elevations than those drilled above these anomalies. Only 2 of the 10 local highs project above the surface of the Midway and were therefore possible areas of bauxite formation. These two, the Sardis high in secs. 9, 10, 15, and 16 of T. 2 S., R. 13 W., Saline County, and the Ledbetter high in secs. 29, 30, and 31, T. 1 S., R. 12 W., mostly in Pulaski County (pl. 2), already had been located by seismic surveys done for the mining companies and were partly explored by company drill holes. A little bauxite of very low grade had been found and further drilling was necessary later to prove that geologic conditions in these two areas were unfavorable for the accumulation and preservation of any significant deposits of bauxite. Thus the results of the geophysical program indicated that the large region between the two producing districts was unfavorable for the accumulation of bauxite even above the more elevated parts of the igneous complex. The prospecting work, therefore, was restricted to areas where extensive erosion of the bauxite was not indicated.

BAUXITE DRILLING PROGRAM

The principal function of the geologic program was to search for new reserves of bauxite, and more than 20,000,000 tons of ore in place were delimited by the drilling program.

When a new area was to be explored the geologic staff would first compile on a map information from nearby surface outcrops and from records of government and company drill holes, to show the configuration of the post-Midway surface upon which the bauxite deposits rest (pl. 2). Trends of subsurface valleys that head on buried nepheline syenite hills, and trends or groups of bauxite deposits in areas already closely drilled, with reference to the buried edge of the rocks of Midway age, were projected into the area under study. The intersections of such trends were regarded as favorable sites for drilling.

To explore such an area wildcat holes were drilled at points about 1,000 feet apart on a triangular grid, so that the holes were at the apices of equilateral triangles 1,000 feet on a side. The triangular pattern was considered more efficient than a rectangular grid, and the 1,000-foot spacing was taken as the largest practicable to cover the area quickly without missing significant bauxite deposits (fig. 3). A deposit of more than 50,000 tons generally should be detected by this spacing of the drill holes, even though no hole reached the commercial parts of the deposit. For this reason it was helpful to core all of the "bauxite-kaolin zone" in all preliminary holes. Secondary wildcat holes were sometimes drilled between the preliminary ones, usually after the ones containing bauxite had been offset and the bauxite deposits delimited. Several additional small deposits were discovered in this manner.

After an area was tested by the preliminary wildcat holes, the deposits of bauxite indicated by the drilling were delimited by drill holes spaced 200 feet apart on a triangular grid. This grid was considered sufficient for determining within reasonable limits the overall tonnage. Where several nearly linear bodies were found, it was necessary to space the drill holes 100 feet apart. Where a spacing larger than 200 feet was used, such as an ore body drilled early in the project employing a 300-foot grid, lateral variations in grade and thickness caused inaccurate results. In the close drilling a uniform triangular grid again proved more useful than a rectangular one. The 200-foot spacing, however, is not sufficiently close to give accurate information on the grades of ore in different parts of the deposit. Before mining, it is usually necessary to drill holes 100, 50, or even 25 feet apart to secure this information.

All wildcat holes were drilled until the basement rock was reached. Likewise, the drill holes 400 feet apart on the blocking-out grids usually were driven to basement rock. The information thus gained revealed the structural features of the ancient land surface upon which the bauxite was formed (pl. 2), and made it possible to present the detailed geologic information contained in this report.

Most of the bauxite deposits are lenticular and finger laterally into the surrounding kaolinitic clay, and show an accompanying appreciable decrease in grade. Some limitation on minimum minable thickness and minimum grade therefore had to be set to delimit a deposit. Most of the mining companies regarded an 8-foot thickness

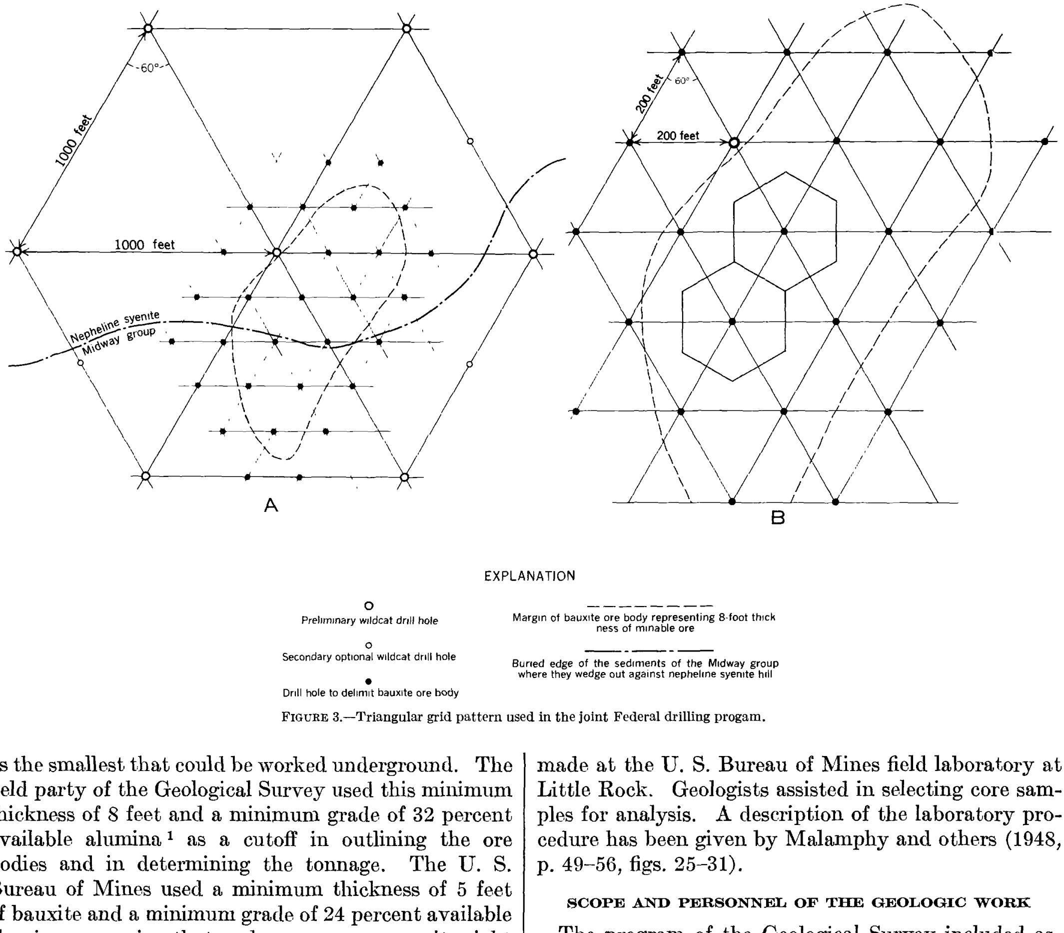

FIGURE 3.—Triangular grid pattern used in the joint Federal drilling progam.

as the smallest that could be worked underground. The field party of the Geological Survey used this minimum thickness of 8 feet and a minimum grade of 32 percent available alumina[1] as a cutoff in outlining the ore bodies and in determining the tonnage. The U. S. Bureau of Mines used a minimum thickness of 5 feet of bauxite and a minimum grade of 24 percent available alumina, reasoning that under a war economy it might be possible or even necessary to process material of such a grade. A deposit was considered delimited when it was surrounded by holes containing less than the minimum thickness or grade of bauxite.

The geologists made drilling logs of the overburden from cuttings carried to the surface by the drilling mud, assigned depths at which to start and stop coring through the bauxite or the "bauxite-kaolin zone," and made detailed lithologic descriptions of the cores. They also recorded the amount of core lost in the process of drilling and, where possible, specifically assigned its position. It generally was possible to determine with reasonable accuracy where the loss came in a core run.

Chemical analyses of bauxite and clay samples were made at the U. S. Bureau of Mines field laboratory at Little Rock. Geologists assisted in selecting core samples for analysis. A description of the laboratory procedure has been given by Malamphy and others (1948, p. 49–56, figs. 25–31).

SCOPE AND PERSONNEL OF THE GEOLOGIC WORK

The program of the Geological Survey included assembling drilling data from the operating companies' thousands of drill holes, logging the drill cores, making topographic and geologic surface and subsurface maps to interpret the geology, recommending coring depths, drilling sites, and cored intervals to be sampled, as well as partial supervision of the wildcat drilling programs. In order to keep pace with the drilling program, to record the information from the drill holes and to predict favorable areas for prospecting, it was necessary to utilize the services of 36 geologists at the peak of operations in 1943. As the need for bauxite lessened, this number was gradually reduced.

R. P. Bryson was in charge of the Arkansas field party, assisted by Mackenzie Gordon, Jr., who supervised the field work, and in 1943 by S. S. Goldich. The following men, attached to the bauxite field party during

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[1] Available alumina percent is an empirical figure amounting to the percent of alumina less 1.1 times the percent of silica. For a further discussion see page 95.

the years indicated, assembled geologic data and drew up drilling recommendations in the five principal drilling areas: W. E. Benson (1942–44), M. W. Ellis (1942–45), Mackenzie Gordon, Jr. (1942–45), T. A. Steven (1942–44), and J. I. Tracey, Jr. (1942–45). Men in charge of work on specific ore bodies and the years of their association with the field party are as follows: W. B. Allen (1944–45), C. N. Bozion (1943–45), E. A. Brown (1943–45), J. A. Cathcart (1943–45), J. B. Collins (1943–44), Hanford Drummond (1943–44), R. A. Harris (1943–44), F. A. Hewitt (1943–45), J. A. Jackson (1943–44), A. L. Jenke (1943–45), E. P. Kneedler (1942–45), W. N. Laval (1943–45), H. W. McGee (1942–45), E. B. Parmalee (1942–45), W. J. Powell (1943–45), W. M. Quackenbush (1943–44), F. M. Sanford (1943–44), Robert Schneider (1943–44), R. C. Shelton (1942–44), G. E. Siple (1943–45), P. D. Snavely, Jr. (1942–43), and H. G. Stephens (1942–45). They were assisted by J. W. Adams (1943), Brewster Baldwin (1942), L. D. Clark (1942), S. H. Daviess (1942), N. M. Denson (1943), W. W. Doyle (1944–45), H. B. Foxhall (1942–44), W. R. Griffitts (1942–43), L. S. Gurney (1943–44), R. L. Heller (1943), F. A. Hildebrand (1943–45), R. B. Johnson (1942–43), C. R. Kirschner (1943–45), J. H. Morris (1942–43), G. L. Quick (1942), G. J. Tassi (1943–44), and R. M. Thompson (1942–43).

Bryson was responsible for much of the preliminary organization of this report and for planning the format of the ore body and subsurface maps. The field geologists listed above, whose unpublished ore body reports were drawn upon in preparing the descriptions of many of the bauxite deposits, are credited where possible in the text. Their descriptions have been shortened considerably and some interpretations based on subsequent information have been added by the authors.

Petrographic studies of the bauxite and associated rocks were made in 1943–44 by M. I. Goldman (1949; Goldman and Tracey, 1946). Special studies, which have contributed to this report, were made on theoretical chemical composition of bauxite by Bryson; on kaolinitic clay associated with the bauxite by Quick and by Tracey (1944); on sampling methods by Foxhall; on a map showing location of bauxite mines and deposits by Parmalee; on nepheline syenite outcrops by Hildebrand (1949); and on the lithology of the Wills Point formation by Stephens. Surface mapping and stratigraphic investigations were made by Gordon, Ellis, Steven, Benson, Hildebrand, and Tracey. Compilation of the large subsurface map (pl. 2) was done by Tracey, Steven, Shelton, Gordon, and Benson, with assistance from Parmalee, Jenke, Ellis, and Cathcart. A preliminary version of this map was published by the Geological Survey (Bryson, Gordon, and others, 1944). Preparation of the ore-body maps and sections was supervised by R. Bruce Parmalee.

In addition to studies by regular members of the Arkansas field party, special field work was undertaken by W. H. Monroe in 1942 on a reconnaissance of the geology of the Cretaceous, Midway, and Wilcox rocks of Clark, Hot Springs, and western Saline Counties; by L. W. Stephenson in 1943 on a reconnaissance of possible bauxite deposits between Gurdon, Ark. and the Texas State line; by J. A. Gardner in 1944 on the macrofauna of the Midway group in Pulaski and Saline Counties, assisted by R. A. M. Schmidt who made a preliminary study of the microfauna; by R. W. Brown in 1944 on the fossil plants of the Wilcox group in Pulaski and Saline Counties; and by E. C. Fischer in 1944 on bauxite reserves.

Macrofossils in the marine Tertiary sediments were identified by Miss Gardner, foraminifers by J. A. Cushman and M. R. Todd, ostracodes by F. M. Swain, and fossil plants by R. W. Brown. Rock analyses by C. M. Warshaw and W. W. Brannock, mineralogic studies by Charles Milton and M. L. Lindeberg, X-ray determinations by J. M. Axelrod, and spectroscopic work by K. J. Murata have contributed to this report. Photographs of bauxite specimens were taken by N. L. Shupe.

ACKNOWLEDGMENTS

The writers wish to express their gratitude to the mine operators and owners for many courtesies extended and for generous cooperation with the geologic field work. Twenty-nine of the bauxite companies that operated in Arkansas during World War II gave the Geological Survey access to their files of drilling data and thereby enabled the government drilling program to supplement what was accomplished by company effort. Particular thanks are due the officials of the Alcoa Mining Co., especially Messrs. Lawrence Litchfield, Jr., L. R. Branting, C. Jessup, and J. W. Lewellen; to Carl Schmedeman of Reynolds Mining Corp.; to Philip Dulin, Jr., of the Dulin Bauxite Co.; and to the officers of the American Cyanamid and Chemical Corp., Crouch Mining Co., and the Norton Co.

We are grateful for permission to use a series of chemical analyses of bauxitized boulders made by R. C. Cross, chief chemist of the Alcoa Mining Co. The Arkansas Geological Survey provided subsurface information from deep drill holes which has been used in preparing the stratigraphic section of the report.

Particular mention must be made of the contribution of the personnel of the field party of the U. S. Bureau of Mines under the direction of M. C. Malamphy and of J. R. Thoenen, district engineer. The Bureau of Mines supervised the drilling operations, geophysical

surveys, and chemical analyses of the bauxite samples. The close cooperation and many individual contributions and courtesies of Malamphy and his staff of engineers, especially G. K. Dale, J. L. Vallely, H. M. Pigman, V. Cox, T. A. Jones, A. H. Reed, Jr., A. Ollar, and M. Woodle, is deeply appreciated.

The manuscript for this report has benefited from helpful comments and suggestions made by S. S. Goldich, V. T. Allen, Josiah Bridge, W. R. Griffitts, and E. C. Fischer. To all who contributed time and effort to the task of reviewing and criticizing the report, we offer our sincere thanks.

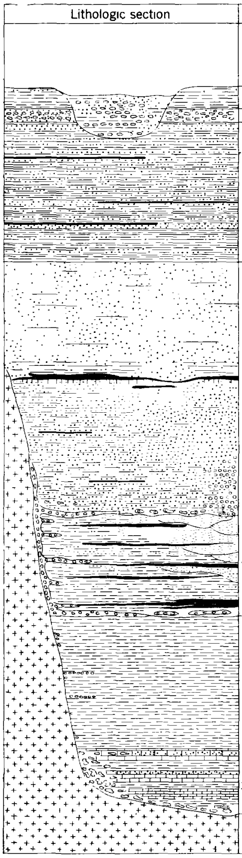
DESCRIPTIVE GEOLOGY

GEOLOGIC SETTING

The bauxite region of central Arkansas contains bedded rocks of three ages: a thick sequence of steeply dipping strata of Paleozoic age, another sequence of gently dipping strata of early Tertiary age, and upper Tertiary and Quaternary alluvial deposits that locally cover both sequences. A complex group of alkalic igneous rocks has been intruded into the sedimentary rock sequence of Paleozoic age and is overlain unconformably by the rocks of Tertiary and Quaternary age (fig. 4). Weathering of these igneous rocks mostly in early Eocene time provided the material for the bauxite deposits.

The rocks of Paleozoic age are undifferentiated in this report but include beds of probable Ordovician to Pennsylvanian age. They are tightly folded in places, and have a marked northwest strike.

The igneous rocks include stocks and other bodies of nepheline syenite and porphyritic alkalic syenite, as well as dikes and border phases of related rocks. These



	Formation	Thickness (feet)	Character	Age
	Terrace deposits and alluvium	0–120	Terrace deposits up to 60 feet thick fringe the Arkansas River floodplain and Fourche Bayou. They consist of dark-red sticky clay containing irregular calcareous nodules and fine silt grading locally into white or cream sand in the upper part. River valleys at lower elevations contain alluvium consisting of gravel, sand, silt, and clay to depths of 120 feet	Quaternary
	UNCONFORMITY			
	Terrace gravels	0–30	Terrace gravels on benches at elevations from 300 to 520 feet above sea level consist of poorly sorted, loosely consolidated pebbles and cobbles interbedded with reddish-brown coarse sand	Quaternary and (or) Tertiary
	UNCONFORMITY			
	Undifferentiated Jackson and Claiborne groups	350±	Gray, green, bluish, cream, and ocher silty clay, locally interbedded with brown carbonaceous clay and thin lignite beds; these alternate with medium- to coarse-grained sand. A red to brown sandstone with fossils of Jackson age is in the upper part. Workable beds of bentonitic clay are near the base	Early Eocene
Wilcox group	Detonti sand	207–412	Continental homogeneous tan or gray fine- to medium-grained sand that contains layers and lenses of gray silty clay; a bed of dark-brown woody lignite at the base locally	Early Eocene
	LOCAL UNCONFORMITY			
	Saline formation	0–450	Dark-chocolate-brown silty to sandy carbonaceous clay interlaminated with white micaceous sand, with scattered lignite and sideritic layers; grades into dark-brown medium-grained to coarse sand. A large deposit of gravel and coarse sand in the lower part fringes the Paleozoic upland; a prominent red to brown coarse sand in the upper part wedges westward from the Arkansas River area. Reworked bauxite beds in the lower part fringe nepheline syenite hills. Plants of Wilcox age are found at many localities	Early Eocene
	UNCONFORMITY			
	Berger formation	0–347	Greenish- to bluish-gray silty clay and grayish-green fine sand alternate with lignite, black lignitic and brown carbonaceous clay, and hard layers of impure crystalline siderite. An apron of gray kaolinitic fragmental clay containing bodies of tan bauxite fringes nepheline syenite hills. Beds are sandier basinward	Early Eocene
	UNCONFORMITY			
Midway group	Wills Point formation	0–450	Dark-bluish-gray to black silty clay with sideritic layers; a dark-gray calcareous mudstone containing marine microfossils locally at the base. Varicolored clay constituting an ancient weathering profile occurs in places at the top	Paleocene
	Kincaid formation	0–185	Greenish-gray and dark-gray clay, sandy in places, interbedded with fossiliferous marl, sandy glauconitic limestone, and calcareous sandstone; the beds are more calcareous in the upper part. Marine megafossils and microfossils are common	Paleocene
	UNCONFORMITY			
	Nepheline syenite		Light-gray or bluish feldspathic and feldspathoidal igneous rocks in a batholith containing pendants of altered rocks of Paleozoic age. Weathered locally to kaolin or bauxite	Late Cretaceous

FIGURE 4.—Diagrammatic sketch illustrating the sedimentary rocks that flank and overlie nepheline syenite in the Arkansas bauxite region.

rocks have a northeasterly trend and contain roof pendants of rocks of Paleozoic age that likewise have a northeasterly trend.

Extensive erosion truncated the rocks of Paleozoic age and exposed the igneous complex in a series of low hills. The lower Tertiary sedimentary rocks which contain many of the bauxite deposits lie unconformably on the resistant rocks of Paleozoic age, and are draped over the nepheline syenite hills. They strike generally northeast and dip gently southeast, although locally the strike is modified by compaction. The rocks dip gently upslope, or northwest, of the igneous hills, and more steeply downslope. The surface contact between the fairly hard rocks of Paleozoic age and the soft Tertiary sedimentary rocks is the physiographic line of demarcation between the Ouachita Mountain province and the Gulf Coastal Plain.

The Paleocene sediments, almost entirely marine, consist of the Midway group subdivided into the Kincaid formation at the base and the Wills Point formation above. These are overlain unconformably by lower Eocene nonmarine beds of the Wilcox group subdivided into the Berger formation, which contains many bauxite deposits at its upslope edge, the Saline formation resting unconformably upon the Berger, and the Detonti sand. Later Eocene strata are represented by locally little known nonmarine and marine beds of the Claiborne and Jackson groups. The more recent sediments of the bauxite region include gravels of undifferentiated late Tertiary and Quaternary age, sand and clay terrace deposits of Quaternary age, and Quaternary alluvium.

SEDIMENTARY ROCKS

UNDIFFERENTIATED METAMORPHIC ROCKS OF PALEOZOIC AGE

The somewhat altered bedded rocks of Paleozoic age crop out at the north edge of the area between the flood plains of the Saline River and the Arkansas River, beginning about a mile northwest of Benton and extending northeastward to Little Rock. They include gray, green, brown, and black altered shale, black slate, gray to brown quartzite and sandstone, chert, and siliceous shale. In the bauxite region the formations cannot be differentiated with certainty. For the formations of Paleozoic age recognized in the Ouachita Mountain province the reader is referred to Croneis (1930, p. 91–148), and to Purdue and Miser (1923, p. 122–179) for the formations of Paleozoic age exposed in Garland, Hot Springs, and Montgomery Counties.

The rock pendants of Paleozoic age in the nepheline syenite intrusive masses of the Coastal Plain province are more difficult to differentiate because they have been somewhat altered by contact metamorphism. Most of the pendants occur in the Pulaski nepheline syenite mass and consist of gray quartzite and gray and green altered shale. At the north end of the nepheline syenite mass of Alexander Mountain a fairly large area is underlain by black slate. The most interesting feature of these rocks associated with the nepheline syenite is the large amount of feldspar in many of them, in Pulaski and Saline Counties. Some of these rocks, though retaining a well-marked bedding that appears to be sedimentary, are seen in thin section under the polarizing microscope to consist almost wholly of feldspar crystals. Many of the contacts between this rock and the nepheline syenite are sharp, but locally in Pulaski County this type of rock also appears to grade through the tinguaitic border phase to pulaskite as described by Williams (1891, p. 99–106, 149, 150). Whether the feldspar was an original detrital constituent of the rock, as for example in the tuff lentils that have been described in the Stanley shale, or was introduced at the time of the intrusion of the alkalic rocks is not known. Evidence that this rock was at least a minor contributor to the bauxite deposits is indicated by several bauxite pebbles discovered at the Section 15 mine in Saline County. These pebbles displayed lithologic structures characteristic of the metamorphosed sedimentary rocks but upon analysis were found to consist almost entirely of gibbsite.

TERTIARY SYSTEM

PALEOCENE SERIES—MIDWAY GROUP

GENERAL FEATURES

A marine sequence of foraminiferal calcareous shale, arenaceous limestone, calcareous glauconitic sandstone, conglomerate, and light to very dark bluish-gray clay shale forms the lowest division of the Tertiary system in central Arkansas. The major subdivisions of this group are remarkably uniform laterally throughout the Gulf Coastal Plain. They include a lower, highly calcareous, moderately resistant formation containing some sand and clay beds and an upper clay shale formation not commonly exposed at the surface but represented in some of the drill holes by more than a hundred feet of sedimentary rocks. These rocks are important to the history of bauxite because of their stratigraphic position immediately underlying many of the bauxite deposits. A study of this group thus furnishes a clue to some of the physiographic conditions leading to the formation of the bauxite.

These sediments are equivalent to the shaly limestone, calcareous sandstone, and overlying black clay exposed at Midway Landing and at Pine Barren Creek in Wilcox County, Ala., that were first designated as the "Midway

series" by Smith and Johnson (1887, p. 62–67, 70). It is of historic interest to recall that the earliest described outcrops of the Midway group were the calcareous beds containing marine fossils noted by Featherstonhaugh (1835, p. 60, 62) on the bank of the Arkansas River at Little Rock, also 3 miles west of Little Rock where they were quarried for making lime at that time, and in the bed of the Saline River 28 miles west of the town. Featherstonhaugh said they contained *Ostrea, Turritella, Calyptrea, Cerithium,* and other fossils and were Tertiary beds "of the Eocene period of Mr. Lyell."

The first thorough study of these rocks was made by Harris (1894, p. 8, 9, 22–54, 184, 185) who applied the name "Midway stage" to the early Tertiary marine sediments of central Arkansas that underlie the terrestrial sediments of the so-called Lignitic stage. He described in some detail the known outcrops, their lithology and paleontology, and particularly noted the fossiliferous limestone beds in the lower part of the section. Harris (1896, p. 41, 42) correlated the *Enclimatoceras* (*Hercoglossa*) and *Turritella*-bearing limestone beds of the Little Rock area with other similar calcareous beds at Tehuacana in Limestone County, Tex., at Midway Landing, Ala., and the oyster-bearing beds south and southwest of Clayton, Ala.

Geologists who have studied the Midway sediments in Arkansas, such as Stephenson and Crider (1916, p. 44–54), Dane (1929, p. 152–160, pl. 1), Bramlette (1936, pl. 9), and Corbin and Heyl (1941), have continued to map and describe them as a single stratigraphic unit. In other states the Midway group has been subdivided into several formations. In Texas the Midway has been the subject of paleontologic work by Plummer (1926) and by Gardner (1928, 1933, and 1935), who have demonstrated the feasibility of dividing the Midway into two lithologically and faunally distinct mappable units, the Kincaid and Wills Point formations. Bramlette (1936, p. 5) has suggested that these two units are each represented, at least in part, by the deposits of Midway age in the Arkansas bauxite region. On the geologic map (pl. 1) that accompanies this report the Kincaid and Wills Point formations have been differentiated in the bauxite region at the suggestion of Julia Gardner, who spent several weeks making a paleontologic study of the outcrops of the Midway of the area in the fall of 1944.

KINCAID FORMATION

Definition.—The Kincaid formation received its name from Kincaid Ranch in Uvalde County, Tex. The name was proposed by Gardner (1933, p. 744) to designate the lower part of the Midway group, easily distinguishable lithologically and faunally from the upper part. An earlier name proposed by Harris (1896, p. 129, 155), the Tehuacana limestone, was used for a while in a broad sense for the entire formation. However, most geologists felt that this name was too firmly restricted to the limestone beds at the top of the lower Midway section, and its usage for the greater interval was dropped. The Kincaid formation in Texas has been subdivided into three units in ascending order: the Littig glauconite member, a thin basal yellowish-gray glauconitic sand containing phosphatic nodules; the Pisgah member, a section of yellow, gray, green, and buff clay and glauconitic sand containing several limestone beds; and the Tehuacana member, a slightly thinner section of grayish-white fossiliferous limestone and greenish-gray calcareous sandstone.

Distribution and surface outcrop.—In southwestern Arkansas beds of highly glauconitic and phosphatic sand, probably representing the Littig glauconite member, crop out at a few localities in eastern Hempstead and western Nevada Counties where they disconformably overlie the Arkadelphia marl of Late Cretaceous age (Dane, 1929, p. 152–160). The basal member has not yet been identified east of these localities and may be absent in central Arkansas, where the Kincaid formation rests directly upon rocks of Paleozoic age. More likely the basal member was overlapped by succeeding members of the Kincaid. Light to dark-gray calcareous clay and thin scattered yellow earthy limestone beds equivalent to the Pisgah member crop out at many localities in southwestern Arkansas and extend northeastward at the surface into central Arkansas, as far as the east-central part of Saline County. Light-gray fossiliferous limestone, buff to bluish-gray marl, and greenish-gray glauconitic sandstone beds that constitute the lateral equivalent of the Tehuacana member have a wider distribution in Arkansas than beds of the other two members. These beds extend northeastward across the State in a narrow discontinuous belt from the Texas border to Little Rock and in more scattered outcrops to the southeast corner of Independence County.

In the Arkansas bauxite region the Kincaid formation lies at or near the north edge of the Gulf Coastal Plain in a long narrow northeastward-trending discontinuous band of outcrop that reaches 2 miles in width in several places, but generally is much narrower. Locally there are many scattered inliers, particularly near the town of Benton. These outcrops are exposed where streams have cut through the gravel deposits of the Saline formation. The formation at Benton is composed largely of calcareous clay, sand, marl, and a few scattered limestone beds. Outcrops are poor and are limited mainly to the banks of streams and to road cuts. In the area surrounding the town of Alexander several fairly persistent limestone beds in the

upper part of the formation are expressed topographically in a poorly defined terrace or cuesta, but good exposures are few. Near Mabelvale and Geyer Springs in Pulaski County the formation is buried mostly beneath the alluvium of Fourche Bayou. Along the south edge of the city of Little Rock several good exposures of the sand and limestone make up the upper part of the Kincaid where it abuts the upland rocks of Paleozoic age. Between Little Rock and Cabot, Lonoke County, there are no outcrops, but limestone of the Midway has been questionably identified in an 82-foot well drilled at Jacksonville, Pulaski County (Stephenson and Crider, 1916, p. 259).

In the bauxite region, drill holes show that the Kincaid formation is present at depth beneath the Wills Point formation at most localities. Locally along the flanks of nepheline syenite hills the Kincaid thins out and is overlapped by the Wills Point. At many localities, particularly where the limestone and calcareous shale finger shoreward into tongues of conglomeratic nepheline syenite debris, the Kincaid extends somewhat farther upslope than the Wills Point. In some places, beneath subsurface Eocene drainage, green nonglauconitic sand of the Eocene Berger formation rests directly upon the Kincaid formation.

Thickness.—At the surface in the bauxite region, the measured thickness of the Kincaid formation ranges from 7½ to nearly 60 feet. Where the equivalents of both the Pisgah and Tehuacana members are present the thickness commonly ranges from 35 to 60 feet. Where only the equivalent of the Tehuacana is present the thickness rarely exceeds 15 feet.

At depth the formation is thin or absent locally along the flanks of buried nepheline syenite hills but thickens rapidly basinward. Under some of the bauxite ore bodies, particularly in Pulaski County, nepheline syenite debris and sand as much as 69 feet thick have been recorded in drill holes within a few hundred feet of the edge of the formation. Where limestone is present, the thickness usually is greater. The thickest Kincaid section in the vicinity of the bauxite ore bodies was recorded in USBM (U. S. Bureau of Mines) drill hole 2–111, in the NW¼NE¼ sec. 11, T. 1 S., R. 12 W., downslope from the Birnbach bauxite deposit. The formation measured 154 feet thick, 2,600 feet east-southeast of the buried contact of the nepheline syenite and the Midway.

Farther out in the basin some of the deeper drill holes have cut as much as 185 feet of limy beds that apparently represent the Kincaid formation. Excessively thick deposits of limestone that constitute a large part of the total thickness of the Midway group were cut by drill holes upslope from nepheline syenite hills wholly or partly buried by the Paleocene sedimentary rocks.

Data supplied by the Arkansas Geological Survey indicate that in the Youngblood No. 1 well of the Shaffer Oil and Refining Co., drilled 600 feet south and 575 feet west of the northeast corner of the NW¼NW¼ sec. 34, T. 4 S., R. 13 W., about 1½ miles north-northwest of Sheridan, Grant County, and 10 miles south of the south edge of the bauxite region, the thickness of the Kincaid formation is 95 feet (a depth of 1,966 to 2,061 feet) as evidenced by a study of the foraminiferal content of the cores by H. J. Plummer. In this well the Kincaid rests upon 193 feet of Upper Cretaceous sedimentary rocks that in turn lie upon igneous rock identified as pyroxenite. In the Long Bell No. 1 well, of the Shaffer Oil and Refining Co., drilled 330 feet south and 330 feet east of the northwest corner of the NW¼NE¼ sec. 36, T. 5 S., R. 12 W., in Grant County, Mrs. Plummer's foraminiferal identifications indicate that the Kincaid is 136 feet thick (a depth of 2,620 to 2,756 feet).

Lithologic description.—The Kincaid formation is composed mainly of intergrading and interfingering beds of soft claystone, calcareous sandstone, sandy limestone, marl, and conglomerate, in that order of abundance, and includes minor beds or layers of conglomerate, arkose, kaolin, lignite, and a coquina of calcareous tests of marine organisms. Most of the sand has glauconite disseminated through it in rough to smooth rich green grains ranging in size from tiny specks to nearly a millimeter across. The quartz sand grains are essentially fine grained to medium grained, are angular or moderately well rounded, and have a glassy surface. Rarely some of the grains are frosted. The sand generally is well packed and the amount of calcium carbonate varies in the interspaces between the grains grading into limestone where an excess of this material is present. Most of the limestone beds are sandy or marly and lenticular. They contain abundant fossils, principally mollusks and foraminifers. Normally the quantity of fossils in a single bed varies generally with the amount of limestone and inversely with the amount of quartz sand. A few of the limestone beds contain small phosphatic pebbles. Much of the calcium carbonate has been leached; hence, preservation of the fossils generally is poor.

Most of the clay in the Kincaid formation is medium gray to buff or tan. Locally it is dark gray and resembles clay of the Wills Point formation. In contrast to the bluish-black clay of the Wills Point, however, most of the Kincaid clay is calcareous and grades locally into marl. Calcareous tests of foraminifers, ostracodes, and pelecypods are widely distributed in these beds. A small sample of the gray to yellowish

clay from fossil collection no. 17138, submitted to J. M. Axelrod for X-ray examination, consisted principally of montmorillonite, some quartz, and a trace of unidentified matter.

The arkose and conglomerate beds of the Kincaid are mostly limited to the subsurface. They consist of partly weathered detritus from the nepheline syenite and, to a lesser extent, from the rocks of Paleozoic age. Arkose and conglomerate are gradational one with the other as their source is the same, and grain size is the differentiating feature. The finer grain sizes are carried farther from the source. These rocks are best developed near the upslope lip of the formation, particularly along slopes of nepheline syenite hills where they form a series of coalescing alluvial fans that interfinger with limestone and clay downslope. They have been found in nearly all the holes drilled through the formation, downdip from nepheline syenite masses that were exposed in Midway time, and as far out in the present basin as the area surrounding the nepheline syenite high near Woodson. The coarser detritus consists of pebbles, cobbles, and boulders. Pebbles and cobbles as much as 4 inches across frequently were recovered in the cores, and larger fragments and blocks exceeding 3 feet in diameter probably were drilled through (see basal bed in the section on page 16). The pebbles are subangular to rounded, and nearly all have worn and smoothed surfaces. Some of them, particularly those derived from the bedded rocks of Paleozoic age, are flat or angular and have smoothed faces, edges, and corners. The larger fragments are generally set in a matrix of fine sandy material of similar composition which is partly decomposed or disintegrated. Where the nepheline syenite debris is calcareous, fossil remains particularly of echinoderms and bryozoa are common. Downdip the rock fragments generally are embedded in limestone. Conglomeratic beds occur at different levels in the formation but are widespread in the lower few feet.

Sand and granule gravel beds composed largely of feldspar occur in the formation at widespread localities, most commonly near the upslope edge. The grains and granules are angular to subangular and unweathered to slightly decomposed. The nepheline syenitic detritus of all sizes usually is unweathered or only slightly decomposed except at localities along the upslope edge of the formation where it was exposed to post-Midway weathering.

The following typical subsurface section logged in an exploratory drill hole at the western slope of the Pulaski nepheline syenite hill presents a fairly complete description of the Kincaid formation beneath the bauxite deposits.

Section of the Kincaid formation cored in USBM drill hole 20–049 drilled 670 feet west and 270 feet south of the northeast corner of the NE¼SE¼ sec. 8, T. 1 S., R. 12 W., about three-fourths of a mile south of Berger, Pulaski County

[Description by J. A. Gardner and M. I. Goldman]

	Thickness (feet)	*Depth (feet)*
Kincaid formation:		
Clay, gray thickly speckled with white, probably products of partly disintegrated feldspar crystals; no reaction to HCl	1.7	227.9–229.6
Clay debris, similar to the interval above except for increasingly prominent feldspar crystals; base of the interval a mass of light-gray partly disintegrated feldspar crystals with a few ferromagnesian minerals, mainly biotite	.9	229.6–230.5
Limestone, very light gray, and nepheline syenite debris; much of the limestone is calcite and shows cleavage faces; a large siderite cobble at 240 feet	9.6	230.5–240.1
Limestone and nepheline syenite debris, greenish-gray, containing some biotite and green alteration minerals concentrated in narrow nearly horizontal bands as much as 2 inches thick	14.9	240.1–265.0
Limestone and nepheline syenite debris, an intimate mixture of green clay, feldspar crystals and limestone, the clay and feldspar are products of the disintegration of the nepheline syenite; contains pockets of clear crystalline calcite; fossiliferous along several breakage planes, fragmental fossils include an echinoid spine at 266 feet and probably oyster shells and possibly crab claws at 272 and 273 feet	8.0	265.0–273.0
Nepheline syenite debris with limestone, pale green to green, like the interval above but less limy	2.6	273.0–275.6
Limestone, pale greenish-gray, sandy, glauconitic, coarsely fossiliferous, slightly argillaceous; contains some small fragments of soapy translucent montmorillonitic clay; the sand is fine (grains 0.10–0.15 mm), and corroded at the top of the interval; coarser, more abundant, and somewhat rounded downwards; the glauconite is a rich green, the grains small (0.1–0.05 mm), fractured and worn; fossils principally *Ostrea* fragments and crab claws, *Calyptraea* sp. at 279 feet	4.6	275.6–280.2
Sand, medium-grained, angular, in dark-gray clay matrix, calcareous with scattered fossil shell fragments in upper part; lower part broken up and probably partly lost in coring	2.1	280.2–282.3
Lignite, dark-brown, firm	.2	282.3–282.5

Section of the Kincaid formation cored in USBM drill hole 20–049 drilled 670 feet west and 270 feet south of the northeast corner of the NE¼SE¼ sec. 8, T. 1 S., R. 12 W., about three-fourths of a mile south of Berger, Pulaski County—Continued

	Thickness (feet)	*Depth (feet)*
Kincaid formation—Continued		
Lignitic clay, very fine grained, micaceous with very little other silt, passing again into lignite and with white clay pebbles, a quarter of an inch in diameter, in the lower part	0. 8	282. 5–283. 3
Clay pebble rock, white or whitish kaolinitic clay pebbles of different tones in a light-gray matrix are surrounded by films and stringers of black carbonaceous material impregnated with sulfides; also many angular feldspar grains	. 8	283. 3–284. 1
Lignitic clay, silty, containing an interbedded white clay pebble layer near the top, grading downward to coarse dark-gray argillaceous noncalcareous sand	2. 4	284. 1–286. 5
Sand, gray to green, carbonaceous micaceous noncalcareous, contains some disintegrated feldspar crystals and abundant disseminated sulfide flakes. Part lost in coring	5. 0	286. 5–291. 5
Nepheline syenite, probably a boulder, hard, gray, containing unweathered solid feldspar crystals	3. 4	291. 5–294. 9
Total thickness of the Kincaid formation	67. 0	
Residual nepheline syenite(?):		
Kaolinized nepheline syenite, grayish-green matrix with abundant angular disintegrated feldspar crystals	3. 0	294. 9–297. 9
Decomposed nepheline syenite, the upper part clayey but with hard feldspar crystals and dark ferromagnesian minerals, also some disseminated sulfide resembling pyrite; the matrix becomes harder at depth	6. 4	297. 9–304. 3

The section given above is one of a few that showed lignite, carbonaceous clay, noncalcareous sand, and kaolinitic clay associated with more typical beds of this formation. These may represent continental deposits of Kincaid age that were later covered, as the sea encroached, by marine sediments of the formation.

Lignite is rare but fragments were found in clastic sediments near the base of the formation in several other drill holes near the edge of the formation. In USBM drill hole 12–156 under the Thomas-Williams bauxite deposit in the NW¼NW¼ sec. 36, T. 1 S., R. 14 W., on the west flank of Alexander Mountain, Saline County, there were lignite fragments in 2½ feet of light-green calcareous clay at the base of the Kincaid which is 12.8 feet thick and directly underlies the Berger formation. In USBM drill hole 8077, under the Fuller School bauxite deposit in the NE¼SW¼ sec. 25, T. 1 N., R. 12 W., near Sweet Home, Pulaski County, the basal 5–6 feet of the formation, a dark silty sand and conglomerate, contains abundant lignite fragments and shreds. In this hole the conglomeratic unit, probably of Kincaid age, is 14 feet thick and is overlain by about 21 feet of clay of the Wills Point formation.

Kaolinitic clay has been recognized in the formation in the pebbly clay in USBM drill hole 20–049 on the west slope of the Pulaski nepheline syenite hill at a depth of 283 feet, described in the section on this page. An analysis of this clay can be found in table 3 as well as an analysis of what is probably a lateral continuation of the same zone at a depth of 266 feet in USBM drill hole 20–048, which is 800 feet east-northeast of USBM drill hole 20–049.

Local sections.—Ten sections of the Kincaid formation are shown on plate 3, including those at four localities west of the mapped area. Fossils from these sections are listed in tables 1 and 2. Most of the fossiliferous outcrops of the lower Midway lie near Highway 67, which crosses the outcrop area of the Kincaid formation not far downdip from its irregular contact with the rocks of Paleozoic age.

Winters Cemetery section:

The westernmost section is exposed on the northeast slope of the hill below Winters Cemetery in the SE¼SW¼SE¼ sec. 35, T. 2 S., R. 16 W. Sediments of Midway age nearly 35 feet thick consist principally of gray clay but contain some marl in the upper part near the 400-foot contour. They crop out discontinuously from a small stream valley southwest to the top of the hill, where they are overlain by several feet of fine gravel of probable Wilcox age. Oysters and other mollusks are weathered from calcareous shale just below the marl about 250 feet southwest of the stream (coll. no. 17145).

Trace Creek section:

Beds apparently representing the Tehuacana member of the Kincaid formation crop out along an 11-foot cliff on the west bank of Trace Creek on the property of the State mental hospital and of W. J. Carradine. The following section is exposed:

Section of the Kincaid formation in SE¼SW¼ sec. 30 and the NE¼NW¼ sec. 31, T. 2 S., R. 15 W., Haskell Township, Saline County

	Feet
Limestone, light-gray weathering to grayish black or brown, hard, with disseminated grains of clear quartz sand, glauconite, and dark minerals. Contains dark stained fossil molds and a layer of *Ostrea pulaskensis* at base (loc. 17141)	2–2. 5
Sandstone, light brownish-gray weathering to brown, fine- to medium-grained, with angular quartz grains, glauconitic, calcareous (loc. 17279)	8. 5–9
Limestone, medium to dark gray, fine-grained, glauconitic, with fragmentary imprints of macrofossils. Exposed in creek bottom	1+

Dark-blue clay of the Wills Point formation is exposed west of this locality in a small eastward-flowing branch, 40 to 50 feet higher than the limestone.

State mental hospital outcrop:

Limestone of Midway age crops out also on the State mental hospital grounds in the SW¼NE¼ sec. 30, in the same township. The outcrop is at an altitude of about 340 feet on the hillside between the powerhouse and water tank, about 300 feet southwest of the powerhouse. Nearby limestone blocks from the same bed, thrown out during the construction of a tunnel not more than 13 feet deep, are exceedingly fossiliferous (loc. 17140).

Salt Creek section:

The lower part of the formation is exposed about 1 mile east of the last locality in roadside ditches and along a large ravine and adjacent hillside south of Highway 67, not far from Salt Creek, in the SE¼NW¼ sec. 20, T. 2 S., R. 15 W., Newcomb Township. Near the top of the hill some loose blocks of brick-red ferruginous sandstone come probably from the upper part of the formation. On the lower slopes of the hill a fairly complete section to the base of the formation is exposed, as follows:

Section of the Kincaid formation in the SE¼NW¼ sec. 20, T. 2 S., R. 15 W., Newcomb Township

	Feet
Clay, gray mottled with brown, locally stained black along small joint planes, containing scattered pockets of light-gray fine sand. Contains scattered macrofossils including nuculanid valves near base (loc. 17138). Covered above	10+
Marl, light-gray, indurated, conglomeratic, containing scattered pebbles of clay, black chert of probable Paleozoic age, phosphatic nodules, and disseminated glauconite grains; poorly fossiliferous (loc. 17139)	3
Clay, gray to yellow, slick, blocky, poorly exposed. Microfossils in upper part (loc. 17278)	13
Clay, as above, but filled with subangular blocks, as much as 1 foot long, of siliceous shale, novaculite, and other rocks derived from the underlying sequence of Paleozoic age	2

The contact with the rocks of Paleozoic age is exposed in the ravine about 100 feet north of the highway.

McNeil Creek section:

The greater part of the formation, including the lateral equivalents of the Pisgah and Tehuacana members, is best exposed near the town of Benton. A basal limestone bed, 1 to 2 feet thick, is exposed in the lower part of McNeil Creek (pl. 1) and in two small creeks 1 to 1¼ miles to the north, that drain the ridge between McNeil and Salt Creeks. This bed rests nearly horizontally upon steeply dipping altered shale of Paleozoic age. The limestone is light gray and contains pebbles as much as 3 inches across of dark-greenish-gray altered shale from the underlying rocks of Paleozoic age. It looks like concrete. The fossils are chiefly mollusks of which the most conspicuous genera include *Nuculana*, *Ostrea*, *Venericardia*, *Turritella*, and *Calyptraphorus*.

Overlying this limestone bed the clay beds equivalent to the Pisgah member are exposed at intervals along the bottom and lower banks of the creek as far as a point about 1,000 feet upstream from where McNeil Creek is crossed by Highway 70. For nearly a mile along the creek probably not more than 20 feet and certainly not more than 30 feet of section is exposed. Most of the clay is dark gray and some of it resembles the clay of the Wills Point formation. Interbedded with it are tiny white lenses of broken, weathered shell fragments and calcareous tests of microfossils, including, particularly in the upper part, layers of poorly preserved nuculanid valves (loc. 17144). Some shark teeth and other hard parts of fish are present.

Above the clay beds are fossiliferous sandy marls of the Tehuacana member equivalent, poorly exposed east of Highway 70 for 1,500 feet upstream where the Midway is covered by gravel of the Saline formation.

Benton lumberyard section:

The limestone beds normally present at the top of the formation appear to be lacking in McNeil Creek. These are, however, exposed farther south in the town of Benton, near the lumberyard in the SW¼SE¼SW¼ sec. 11, T. 2 S., R. 15 W. in a small stream about 50 feet north of State Highway 35.

The outcrop consists of two calcareous beds with an aggregate thickness of slightly more than 4 feet. The upper is a ferruginous, concretionary, somewhat cavernous limestone, locally silicified, mottled light to dark gray but more commonly weathered to dark red and in places blackish brown or yellow and earthy. Cavities are lined with small crystals of drusy quartz. Glauconite is disseminated through the rock. Macrofossils are poorly preserved (loc. 17136).

The lower bed consists of poorly indurated limestone, mottled light gray and yellowish brown, in places

splotched with black. Associated with it is a coarse-grained quartz sand containing glauconite. The nautiloid *Hercoglossa* was found in the limestone (loc. 17137).

Pine Crest outlier:

The two members of the Kincaid formation are exposed as far northeast as the S½SE¼ sec. 9, 1 S., R. 14 W. where the upper one is represented by brick-red highly ferruginous indurated sandstone containing imprints of *Ostrea*, *Venericardia*, and *Turritella*. The sandstone caps the hill above the 520-foot contour. Greenish-yellow clay beds of the lower part of the formation crop out along the north side of the road between the 480- and 500-foot contours.

Limerock Dairy section:

East of Collegeville the lower clay beds have not been identified. Outcrops of these beds equivalent to the Tehuacana member of the formation are rare. The best exposure is on the property of the Limerock Dairy in Pulaski County and has been described or cited by Harris (1894, p. 28–30; and 1896, p. 17), Stephenson and Crider (1916, p. 48–49), Spooner (1935, p. 113–115), and Corbin and Heyl (1941, p. 3, pl. 6).

Section at cliff on east bank of valley of Fourche Creek, at Limerock Dairy, about three-eighths mile southeast of Camp Marion, near center SW¼NE¼ sec. 8, T. 1. S., R. 13 W., Pulaski County

[Measured by J. A. Gardner and R. A. Schmidt]

Bed	Description	Feet
	Kincaid formation (Tehuacana member equivalent):	
a	Quartz sandstone, highly calcareous and glauconitic, light to medium gray where fresh, weathering brownish and locally deeply iron stained. Glauconite in coarse or medium grains, dull or polished (loc. 17133a)	1. 8
b	Limestone, partly weathered, rich in bivalves, sandy and highly glauconitic; light-gray groundmass splotched with yellow calcite; glauconite in large and small grains, segregated in pockets and disseminated through the rock (loc. 17133)	1. 7
c	Limestone, glauconitic but grains not so coarse nor so variable in size as in the bed above; limestone less yellowish than in bed *b*, though weathered specimens are yellowish brown. Contains structureless calcite and clear quartz sand; some iron staining (loc. 17134)	1. 7
d	Limestone, light-gray, dense; groundmass similar to that of bed *c;* abundant disseminated clear quartz grains, a few small scattered grains of glauconite. No shells except oyster fragments remaining; rock riddled by brown-stained cavities formed by solution of the shells (loc. 17135)	7. 3
	Kincaid formation—Continued	
e	Quartz sand, light- to medium-gray, slightly calcareous and glauconitic, composed of angular medium-sized grains; no identifiable fossils	4. 7+
	Total thickness exposed	17. 2+
	Rock of Paleozoic age:	
f	Black shale reported exposed only at times of very low water; not seen in 1944	(?)

The glauconitic sand and sandy limestone beds equivalent to the Techuacana member are exposed at many localities in the southwestern part of Little Rock. Most of these localities have been described or mentioned by Harris (1894, p. 12–15 and 26–28) either as Midway limestone localities or as outcrops of supposed Cretaceous age. L. W. Stephenson visited Harris' supposed Cretaceous localities in Little Rock in the fall of 1942, and J. A. Gardner visited them in the fall of 1944. Both found fossils in the beds in question and concluded that they are of Midway age.

Roselawn Cemetery section:

Harris (1894, p. 13, 14, fig. 1) described a section in the southwestern part of Little Rock that he thought might contain beds of Cretaceous age. This locality is at the intersection of 19th Street, or the "Old Hot Springs road," and a valley now occupied by the tracks of the Missouri Pacific Railroad and of the Chicago Rock Island, and Pacific Railroad. Harris' section, from top to bottom, follows:

Bed	Description	Feet
a	Midway limestone	2
b	Massive white and yellow sands	20
c	Impure bog iron ore: locally represented by a 2-foot layer of ferruginous sand and gravel, underlain by white clay, sand, or gravel; with some scattered fossil casts of mollusks and crustaceans	10
d	Upturned Paleozoic slates	(?)

Harris believed that the fossils of bed *c* might be of Cretaceous age. The section is no longer exposed. Part of bed *c* crops out in railroad cuts at the west side of the valley. Gardner and Schmidt collected several fossiliferous float blocks of highly ferruginous concretionary sandstone that contained a little clay in the matrix (loc. 17146) 600 to 800 feet south of the 19th Street overpass at the base of the hill below the Roselawn Cemetery. These represent bed *c* of Harris section. Blocks from bed *a* of the section also were collected (loc. no. 17132) at the Roselawn Cemetery

on the hill at the west side of the valley, where they had been thrown out from excavations. The fossils of both beds are of Midway age and are shown on table 1.

Gully section in southwest Little Rock:

Fairly continuous exposure of Kincaid limestone and calcareous sand containing beautifully preserved microfossils at the base of the overlying Wills Point formation is on the east slope of the same prominent valleys mentioned above. This probably is the exposure mentioned by Harris (1894, p. 27) as "a compact bed of limestone east of the railway, opposite the (county) hospital in the bed of a small stream."

Section in east-west gully about 1,000 feet south of Roosevelt Road and about 250 feet east of the Chicago, Rock Island, and Pacific Railroad tracks, in the NE¼NW¼ sec. 16, T. 1 N., R. 12 W., in Little Rock, Pulaski County

[Measured by J. A. Gardner and R. A. Schmidt]

		Feet
Kincaid formation (Tehuacana member equivalent):		
a	Indurated sandy limestone packed with *Turritella*, light gray on freshly exposed surfaces, weathering to yellow; forms prominent ledge above lower beds downstream; near and under small bridge it floors the stream bed (loc. 17130)	3. 0
b	Quartz sand, closely packed but not indurated, with small disseminated grains of glauconite; few fossils (loc. 17130*a*)	2. 3
c	Sand, similar to that of bed *b* but firmly cemented by calcite possibly leached from the included shells (loc. 17131)	1. 0
d	Quartz sand, closely packed, uncemented, glauconitic; similar to that of bed *b* but apparently without fossils	1. 3
	Total thickness exposed	7. 6

Other outcrops in Little Rock:

At the foot of High Street on the south edge of the city along the north side of the Chicago, Rock Island, and Pacific Railroad tracks, rocks of Paleozoic age crop out at the base of a 50-foot cliff. Here the Kincaid formation, resting unconformably on the older rocks, is represented by 8 feet of nonfossiliferous gray medium-grained quartz sand that is conformably overlain by several feet of light-gray sand mottled and irregularly streaked and banded with rusty brown and speckled with small pellets possibly of kaolinite. Some greenish grains, probably of glauconite, are disseminated through the sand. The mottled sand is overlain by gray clay flecked with pink, which completes the sequence in the bluff; Gardner believed it was of Wilcox age or younger. The sedimentary rocks are barren except for poorly preserved *Halymenites* burrows in the mottled sand. Similarly filled tubes, about 5 millimeters across, occur in the same bed several hundred yards to the northwest where the sand has a reddish color.

Limestone of the Kincaid formation crops out sporadically at the foot of Main Street on the south edge of Little Rock, and fossiliferous fragments taken from excavations are piled near the street corners within a block or two of the railroad tracks. This is the easternmost outcrop now known in Pulaski County.

Relation to underlying rocks.—The Kincaid formation overlies the rocks of Paleozoic age with profound angular unconformity. The interval represented by this unconformity in the outcrop area extends from early Pennsylvanian to early Paleocene time. In places the Kincaid formation lies unconformably on the nepheline syenite rocks and their included pendants of altered rock of Paleozoic age.

Near the southeast edge of the bauxite region, deep drill holes show that the formation rests on Late Cretaceous sedimentary rocks of Arkadelphia age. A study by Spooner (1935, p. 63–108, 334–339, 436, figs. 60, 85) of the oil and gas wells of the Gulf Coastal Plain in Arkansas indicates that the buried edge of the Upper Cretaceous rocks extends in a northeasterly direction through the northwestern part of Grant County and the southeastern tip of Pulaski County. It is likely that several of the southeasternmost of the deep holes drilled by the U. S. Bureau of Mines to check the results of the geophysical surveys, had they been drilled deeper than the 1,500-foot maximum for these drill holes, would have cut strata of Cretaceous age beneath the Kincaid formation.

Fossils and correlation.—The Kincaid formation is generally fossiliferous, and some beds, particularly the sandy limestone, are highly fossiliferous. Pelecypods and gastropods are the most abundant macrofossils, especially in the sandy limestone. Foraminifers and, to a lesser extent, ostracodes are the common microfossils. They are found in nearly all the marine sediments but appear to be more widely distributed in the calcareous clay. Bryozoa, brachiopods, worms, echinoids, crabs, and fish are less common. Corals are rare.

A list of the localities from which collections were made is given with their numbers and descriptions. The numbers are also shown on the stratigraphic sections in plate 3, in table 1, and also in the text.

Fossil-collecting localities in the Kincaid formation in Pulaski and Saline Counties, Ark.

USGS locality	*Location*
17130	East-west gully about 1,000 feet south of the Roosevelt Road viaduct and 250 feet east of the Chicago, Rock Island, and Pacific Railroad tracks, in southwest Little Rock, NE¼NW¼ sec. 16, T. 1 N., R. 12 W., Pulaski County. Fossils from bed *a*, sandy gray limestone, 3 feet. Collectors: J. A. Gardner, R. A. M. Schmidt, and M. W. Ellis.

Fossil-collecting localities in the Kincaid formation in Pulaski and Saline Counties, Ark.—Continued

USGS locality	*Location*
17130*a*	Same locality as 17130. Bed *b*, quartz sand containing disseminated glauconite, 2.3 feet.
17131	Same locality as 17130. Bed *c*, quartz sand, 1 ft.
17132	Roselawn Cemetery, north of Roosevelt Road and directly west of Missouri Pacific Railroad tracks; limestone thrown out in digging graves; SW¼ sec. 9, T. 1 N., R. 12 W., Little Rock, Pulaski County. Collectors: J. A. Gardner and R. A. M. Schmidt.
17133	Cliff on east bank of valley of Fourche Creek at Limerock Dairy, about three-eighths of a mile southeast of Camp Marion, in the SW¼NE¼ sec. 8, T. 1 S., R. 13 W., Pulaski County. Bed *b*, glauconitic limestone, 1.7 ft. Collectors: J. A. Gardner and R. A. M. Schmidt.
17133*a*	Same locality as 17133. Bed *a*, calcareous glauconitic sandstone, 1.8 feet.
17134	Same locality as 17133. Bed *c*, glauconitic limestone 1.7 ft.
17135	Same locality as 17133. Bed *d*, glauconitic limestone 7.3 ft.
17136	Stream bed just north of bridge on State Highway 35; alongside lumberyard in the town of Benton, SW¼SE¼SW¼ sec. 11, T. 2 S., R. 15 W., Saline County. Concretionary limestone, highly silicified locally, weathering brick red, fossiliferous. Collectors: J. A. Gardner, R. A. M. Schmidt, M. W. Ellis, M. Gordon, Jr.
17137	Same locality as 17136. Compact to loosely indurated limestone and some coarse-grained quartz sand, immediately beneath bed of 17136.
17138	Ravine and ditches on south side of Highway 67, about 2½ miles by road southwest of bridge across Saline River, SE¼NW¼ sec. 20, T. 2 S., R. 15 W., Newcomb Township, Saline County. Gray to yellow blocky clay with sand pockets, just above limestone and marl bed of 17139. Collectors: J. A. Gardner, R. A. M. Schmidt, M. W. Ellis, and M. Gordon, Jr.
17139	Same locality as 17138. A 3-foot limestone and marl bed about 15 feet above base of formation.
17140	State mental hospital property. Limestone cropping out at about 340 feet altitude on hillside between powerhouse and water tank, about 300 feet southwest of powerhouse; similar rock thrown out in construction of tunnel from depth of not more than 13 feet, SW¼NE¼ sec. 20, T. 2 S., R. 15 W., Saline County. Collectors: J. A. Gardner, R. A. M. Schmidt, M. Gordon, Jr., M. W. Ellis, and R. P. Bryson.
17141	A cliff on west bank of Trace Creek, on the property of W. J. Carradine and of the State mental hospital, SE¼SW¼ sec. 30, and NE¼NW¼ sec. 31, T. 2 S., R. 15 W., Haskell Township, Saline County. Fossils from upper of two limestone ledges. Collectors: J. A. Gardner and R. A. M. Schmidt.
17142	Outlier of Kincaid formation lapping across the south edge of the E½ sec. 9, T. 1 S., R. 14 W., Owen Township, Saline County. Fossils from highly ferruginous resistant sandstone hill above the 520-foot contour. Collectors: J. A. Gardner and R. A. M. Schmidt.
17143	Same general locality as 17142, but several hundred feet farther east, in gully along north side of road, on the south line of the SE¼SE¼ sec. 9, T. 1 S., R. 14 W. From greenish-yellow clays at an altitude between 480 and 500 feet.
17144	Bed of McNeil Creek about 50–75 yards upstream from Highway 70, SE¼SE¼ sec. 3, T. 2 S., R. 15 W., near the north edge of Benton. From 2 feet of clay of Midway age locally grading laterally into dark-green silty sand; underlies alluvial sand and gravel. Collectors: R. P. Bryson, M. Gordon, Jr., and J. I. Tracey, Jr.
17145	Roadside ditch outcrop on north side of Highway 67, a short distance downslope from Winters Cemetery, 2½ miles southwest of State mental hospital in the SE¼SW¼SE¼ sec. 35, T. 2 S., R. 16 W., Saline County. Oysters weather from calcareous shale below limy marl about 250 feet southwest of stream valley. Collectors: W. E. Benson, M. Gordon, Jr., and J. I. Tracey, Jr.
17146	Missouri Pacific Railroad tracks below Roselawn Cemetery and about 600–800 feet south of the 19th Street overpass, Little Rock. Float of highly ferruginous and concretionary sandstone containing a little clay in the matrix. Collectors: J. A. Gardner and R. A. M. Schmidt.
17278	Same locality as 17138. Microfossils from yellow to gray blocky clay dug from gully on south side of highway, immediately below limestone ledge of 17139. Collector: R. A. M. Schmidt.
17279	Same locality as 17141. Microfossils from sandy bed between two limestone ledges. Collectors: R. A. M. Schmidt, M. W. Ellis, and M. Gordon, Jr.
17280	North bank of McNeil Creek, west of Highway 70, about 600 feet downstream from the bridge, NW¼NE¼NE¼ sec. 10, T. 2 S., R. 15 W., near the north edge of Benton. Dark-gray clay dug from bank. Collectors: M. Gordon, Jr., R. P. Bryson, and J. I. Tracey, Jr.
17281	North bank of McNeil Creek, near the north boundary of Benton, SW¼NW¼NE¼ sec. 10, T. 2 S., R. 15 W., Saline County. Microfossils from pockets of shells in dark-gray clay. Collector: M. Gordon, Jr.

The macrofossils collected at these localities have been studied in the field and in the laboratory, by Julia A. Gardner. Her specific identifications and notes as to the relative abundance of the fossils of the Kincaid formation appear on table 1. In an unpublished report prepared in December 1944 for the Arkansas bauxite field party, Miss Gardner makes the following comments concerning the collecting localities and their macrofaunas:

> The scattered outcrops of lower Midway sediments directly overlying the Paleozoic rocks are probably not synchronous. At two localities on the west margin of the Midway belt, (locs. 17144 and 17145) the fauna seems distinct and more closely allied to the

TABLE 1.—*Distribution of the faunas of early Midway age of Pulaski and Saline Counties, Ark.*

[By J. A. Gardner. Letters refer to abundance; r, rare, 3 or less; p, present; c, common; a, abundant]

	Locality																			Remarks
	17130	17130a	17131	17132	17133a	17133	17134	17135	17136	17137	17138	17139	17140	17141	17142	17143	17144	17145	17146	
Foraminifera					p	r				r							p			
Solitary coral						r			r	r			r							
Serpula? sp						r														
Echinoid remains					?p	r				r		r	r							
Small undetermined echinoids									p											
Conopeum damicornis Canu and Bassler?			p							p										Common in the Tehuacana member of the Kincaid formation.
?sp						r							p							
Bryozoa similar in shape to *Lunulites* but larger.							r													
Bryozoa										p				r						
Ostracodes					p											?c	c			
Nucula sp										r	r		r	?r						
Calorhadia? sp. cf. *Leda eoa* Gardner.											c						c			
?sp																	c			Relatively large; surface smooth or feebly striate.
cf. *C. saffordana* (Gabb)																	c			
?sp. A																?r	p			
Nuculanids; gen. and sp. indet						r					p	r				c		r		
Ledina? sp. cf. *L. smirna* Dall											c					r				
Orthoyoldia kindlei (Harris)?																	p			Described from the basal Midway of Tennessee.
Cucullaea macrodonta Whitfield			r			a	r		c	?r			p							Widespread in the Midway of the Gulf province.
sp								r					?r	r				r	r	
Breviarca? sp													r							
Glycymeris sp., probably n. sp						c				?r										
?sp							p													Shell thick, no trace of radial sculpture.
sp							p	r					?p	?r						
Brachidontes saffordi (Gabb)						p							p				r		?c	Lower Midway of Tennessee and Texas.
cf. *B. saffordi* (Gabb)																c				
?sp																			p	Relatively large; ribbing coarse
Pteria cf. *P. deusseni* Gardner.									r											
Pseudamusium? sp						r														
Plicatula n. sp									r	c										
Ostrea pulaskensis Harris	p	p	p	p		r	a	r		p		p	c	p						Widespread in the lower Midway of the Gulf province.
cf. *O. crenulimarginata* Gabb.																		c		
cf. *O. compressirostra* Say													p	r						
sp							r	p		p					p	r	c		c	
Crassatellites cf. *C. gabbi* (Safford).						p			r				p	r						
sp																r				
Venericardia (*Venericor*), n. sp																	p			Rib count very low, only 16 to 18.
smithii Aldrich								c	c	?c										Most common in the Kincaid formation of Texas.
cf. *V.* (*V.*) *smithii* Aldrich									p	p			p							
sp				p		p	c													
sp											r		p	r	p				r	
Kelliella? sp											r									
Diplodonta? sp										r			r							
Phacoides? (*Luciniscа?*) cf. *Lucina fortidentalis* Harris, 1896.																	p			
?sp									r											Shell small, moderately compressed, concentrically threaded.
(*Parvilucina?*) sp										?r										
Lucinoid; medium size													p							
"*Cardium*" sp. A,																				Shell large, the ribs narrow and numerous.
sp. B,																				Possibly *Cardium* sp. Harris, 1894.
sp						r	p						r	r						
Nemocardium sp							r	?r	p	?r			p	r						
Callocardia kempae Gardner						c							c							
cf. *C. kempae* Gardner									p					p						Described from the Kincaid formation of Texas.
sp								p						?r						
cf. *C. ripleyana* (Gabb)									c	c			p							

TABLE 1.—*Distribution of the faunas of early Midway age of Pulaski and Saline Counties, Ark.*—Continued

	Locality																			Remarks
	17130	17130a	17131	17132	17133a	17133	17134	17135	17136	17137	17138	17139	17140	17141	17142	17143	17144	17145	17146	
Venerid; cf. *Cytherea* (*Dosiniopsis*?) sp. Harris, 1892.						p	p	p					c							
Venerids							r													Shell medium size, transversely cordate, slightly inflated.
Venerids																				Shell small size, transversely cordate, strongly threaded.
Venerids; gen. and sp. indet									p	p				?r						
Tellina? sp. cf. *T.* sp. Harris, 1892.																	c	r		
Tellinid													r							
Corbula (*Caryocorbula*) sp. A						r														cf. *Corbula* (*Carycorbula*) sp. from 5 miles northeast of Kemp and Kaufman Counties, Tex.
sp									r		r		p			r	r			
Kuphus sp						r														
Tubes of unknown origin, possibly molluscan.								r			r							r		
Dentalium sp				r						?r			?r							
Mesalia n. sp. aff. *M. pumila* Gabb.													r							
sp	p		?r					?r												
Turritella n. sp.; group of *T. mortoni* Conrad.	c		p																	
cf. *T. mortoni mediaria* Bowles.																	c			
sp		p	c			p			r				r	c	c	r		p		
alabamiensis Whitfield	c		?p					a					?c	c	?c					Widespread in the lower Midway of the Gulf province.
cf. *T. alabamiensis* Whitfield.						p				c				p						
cf. *T. saffordi* Gabb																	r			
sp. A																	r			
sp. B; group of *T. humerosa* Conrad.																	r			
sp.; group of *T. humerosa* Conrad.	p												r				p			
cf. *T. humerosa* Conrad s. l.								p						r						
Lemintina? *gonioides* Gardner						r		p												Locally common in the Tehuacana member of Kincaid formation.
"*Cerithium*" sp								r												
Cerithiid; gen. and sp. indet																p				
Epitonium n. sp										?r			r							
Calyptrea sp						r		r						r						
Calyptraphorus n. sp																	p			Ribs shorter and more oblique than in *Calyptraphorus aldrichi* Gardner.
aldrichi Gardner						?p				?p										Common in the Kincaid formation of Texas.
sp						r	?r	r	r											
sp																	p			
Gyrodes? sp						r														
Polynices harrisi Gardner						?r														Present in the Kincaid formation of Texas.
Natica sp. cf. N. *perspecta* Whitfield.										p										
Natica? sp								r												
Naticoid; gen. and sp. indet																	r			A shouldered form.
Naticoids; gen. and sp. indet						p							r							
"*Pyrula*" sp. cf. *Pyrula* sp. Harris, 1892.														r						
sp									r											
Indet. gastropod			r																	Multiwhorled; numerous blunt ribs and a few strong spirals.
Volutes; gen. and sp. indet										r			?r							
Latirus? sp.; cf. *Fusus hubbardanus* Harris.																	r			
Orthosurcula sp								r												
Turrid; gen. and sp. indet						r			?r								r			
Cylichnina? sp						r		r	r				r				r			
Tornatellaea cf. *T. texana* Gardner.																	r			
sp							r		r											
Actaeonids						?r							r							
Hercoglossa ulrichi (White)							p			r										Widespread in the lower Midway of the Gulf province.
sp			r										r							
Callianassa ulrichi White	?p									c										
Crab fingers						r	p	r					r				r			
Shark teeth					p	r				r	r		r				p			
Otolith			r																	
Vertebrate remains					r						p						p			

lower Kincaid (lower Midway) of Texas than any of the other faunas in Pulaski or Saline Counties. The matrix does not present the highly glauconitic and phosphatic character of the Littig glauconite, the basal member of the Kincaid, but more closely resembles the Pisgah clay which overlies the Littig and underlies the Tehuacana limestone. The lower contact cannot be deeply buried, but is not exposed at either locality.

The blocky clays at localities 17138 and 17143 contain a meager assemblage characteristic of shallow water and a muddy bottom. They are distinct from other faunas within the area and to a lesser degree from one another. At 17138 the fauna is limited largely to taxodonts of the Nuculanid groups; a *Brachidontes* is the most common species in the clays at locality 17143. The stratigraphic position of no. 17143 may be a little lower than that of no. 17138 and more nearly comparable to that of the barren clays overlying the Paleozoic rocks and underlying the calcareous ledge at locality 17139. Probably one or both localities should be included in the equivalent of the Pisgah clay rather than in the "Midway lime." The ledge at locality 17139 is formed by an indurated limy rock on which *Ostrea pulaskensis* is the most common fossil. The base is a true conglomerate which includes shell fragments, a few molds of *Turritella* and small bivalves and other organic remains . . . *Brachidontes* and a small undetermined oyster are the common fossils in the ferruginous sandstone boulders scattered along the embankment at locality 17146, only 2 or 3 feet above the Paleozoic shales. Neither the fauna nor the lithology are closely related to that of any other outcrop although the boulders are not more than 10 or 15 feet below the float material of locality 17132 which contains *Hercoglossa*, a zone marker of the upper part of the lower Midway. A fine-grained compacted quartz sand specked with glauconite and apparently non-fossiliferous overlies the Paleozoic shale at Limerock Dairy. It seems to be a part of the "Midway lime" sequence and may be synchronous with the lower sandstone at the Roosevelt Road viaduct section. The ratio of the sand and lime varies widely within that series.

Several subdivisions of the main limestone bed are possible within limited outcrops, but they probably do not carry over any considerable distance. *Hercoglossa* is, perhaps, the most usable zone marker for it is readily recognized and, within the area under discussion, it seems to be restricted to a vertical range of about 5 feet near but not at the extreme top of the "Midway lime." Several species of *Turritella*, among them *T. alabamiensis* Whitfield, are characteristic of a slightly lower horizon. The distribution of *Ostrea pulaskensis*, crab fingers, and bryozoa may be controlled by ecologic conditions. The larger *Venericardia* of the *V. smithii* type are most common in the upper part of the fossiliferous section.

The lower and middle sections of the main limestone bed are probably represented in the section at localities 17130 to 17131; in the limestone thrown out in digging the graves in the Roselawn Cemetery at locality 17132; at locality 17135 on Fourche Creek; in the float limestone at locality 17140; in the upper limestone ledge at locality 17141 on Trace Creek; and probably in the ferruginous boulders scattered along the hillside terrace above locality 17138 and capping the hilltop at locality 17142.

The *Hercoglossa* zone is indicated in some of the float at locality 17132; in the upper part of the main limestone bed at locality 17134; on the southwestern edge of Benton at the top of 17137; and the species was found, probably in place, on the higher ground at locality 17140.

Lower Midway deposits younger than those of the *Hercoglossa* zone have been recognized at only a few localities. The limestone overlying the *Hercoglossa* bed at the Limerock Dairy carries an abundance of *Callocardia kempae* Gardner, apparently a marker of the upper beds; the same species was found at locality 17140 and may be present at localities 17136 and 17141. Most of the loose boulders at locality 17140 were thrown out from a lower level; those on the higher ground are probably in place, and a section of 15 to 20 feet may be represented. No higher beds of lower Midway age have been recognized.

Microfossils from this formation, including foraminifers identified by J. A. Cushman and ostracodes, by F. M. Swain, are listed on table 2. The microfossils of the Kincaid formation in central Arkansas are, like the macrofossils, typical species of early Midway age. Many have been recorded previously from the Kincaid formation in Texas and from the Clayton formation that represents the same lower calcareous phase of Midway deposition on the east flank of the Mississippi embayment in Georgia, Alabama, Mississippi, Tennessee, and southeast Missouri. A more detailed analysis and correlation of the Midway foraminiferal and ostracod faunas will be found in the discussion of fossils and correlation of the Wills Point formation, starting on page 33. A tentative correlation of the Kincaid and Wills Point formations of Texas with Paleocene formations in other parts of the world has been made by Gardner (1935, p. 88–99).

A small collection of vertebrate remains, mostly teeth, was made at the microfossil locality 17144, on McNeil Creek, at the north edge of Benton, Saline County. The fossils were identified by C. W. Gilmore, U. S. National Museum (written communication, 1944) who identified the following species:

- Reptilia:
  - Crocodilia:
    - *Thecachampsa* tooth
- Pisces:
  - *Odontaspis acutissima* Agassiz—shark teeth
    - sp.
  - *Myledaphus* sp.—ray
  - Fish vertebrae, not determinable
  - Otoliths (fish ear bones)
  - Fish teeth, not determinable
  - Fragments of fin spines and other undeterminable fragments, probably mostly of fish.

Conditions of deposition.—Nearly all the sediments of the Kincaid formation are marine. They were laid down in shallow water in a transgressing sea. Locally, several patches of terrestrial sediments, including kaolinitic clay, carbonaceous clay, and some lignite, occur underneath the marine sediments. These probably represent small coastal swampy areas that were covered by the encroaching sea. Where the sea lapped against the nepheline syenite that protruded as islands above its surface, a large amount of coarse feldspathic detritus was incorporated in the sediments. These are in the form of coalescing alluvial fans that fringe the rocky slopes. In Kincaid time the shoreline surrounding

Table 2.—*Foraminifera and Ostracoda of Kincaid age from localities in Pulaski and Saline Counties, Ark.*

	Locality No.						
	Collections from the Kincaid formation						
	[1] 17133a	[1] 17137	[1] 17144	17278	17279	17280	17281
Foraminifera (identified by J. A. Cushman):							
Spiroplectammina cretosa Cushman	------	------	------	------	×	------	------
wilcoxensis Cushman and Ponton	------	------	------	×	------	------	------
Textularia midwayana Lalicker	------	------	------	×	------	------	------
plummerae arkansasana Cushman	------	------	------	×	×	------	------
Robulus degolyeri (Plummer)	------	×	------	------	------	------	------
midwayensis (Plummer)	------	×	×	------	×	------	------
Dentalina colei Cushman and Dusenbury	------	------	×	------	------	------	------
gardnerae (Plummer)	------	×	------	------	×	------	------
naheolensis Cushman and Todd	------	------	------	×	------	------	------
pseudo-obliquistriata (Plummer)	------	------	×	------	------	------	------
Nodosaria affinis Reuss	------	------	------	------	×	------	×
Vaginulina longiforma (Plummer)	------	------	×	------	------	------	------
midwayana Fox and Ross	------	------	------	------	×	------	------
Lagena cf. *L. acuticostata* Reuss	------	------	×	------	------	------	------
Guttulina problema d'Orbigny	------	×	×	------	------	------	------
Globulina gibba d'Orbigny	×	------	×	×	×	------	------
Sigmomorphina terquemiana (Fornasini)	------	------	×	------	------	------	------
Polymorphina cushmani Plummer	------	×	------	------	------	------	------
Guembelina midwayensis Cushman	------	------	------	------	×	------	------
Nonionella insecta (Schwager)	------	------	×	------	------	------	------
soldadoensis Cushman and Renz	×	------	------	------	------	------	------
Eouvigerina excavata Cushman	------	------	×	×	×	------	------
Pseudouvigerina naheolensis Cushman and Todd	------	------	×	×	------	------	------
Siphogenerinoides eleganta (Plummer)	------	×	×	------	------	------	------
Buliminella elegantissima (d'Orbigny)	------	------	------	------	------	×	×
Bulimina cacumenata Cushman and Parker	×	------	×	×	×	×	------
Virgulina wilcoxensis Cushman and Ponton	×	------	------	------	------	×	×
Valvulineria wilcoxensis Cushman and Ponton	------	------	×	------	------	------	------
Gyroidina aequilateralis (Plummer)	------	------	------	×	------	------	------
subangulata (Plummer)	------	------	------	×	------	×	------
Eponides elevata (Plummer)	------	------	×	------	------	------	------
lotus (Schwager)	------	------	------	------	------	×	×
Siphonina prima Plummer	×	------	×	------	×	×	------
Alabamina wilcoxensis Toulmin	------	------	------	×	------	------	------
Globigerina pseudobulloides Plummer	×	×	×	×	×	------	×
triloculinoides Plummer	------	×	------	×	------	------	------
Anomalina acuta Plummer	×	------	------	------	×	------	------
Cibicides browni Kline?	------	------	------	×	------	------	×
howelli Toulmin	------	------	------	×	------	------	------
newmanae (Plummer)	------	------	------	------	------	------	×
praecursorius (Schwager)	×	×	×	×	×	------	×
Ostracoda (identified by F. M. Swain):							
Cytherella tumidosa Alexander	------	------	------	------	×	------	------
Cytherelloidea howei Swain	------	------	------	------	×	------	------
Bairdia magna Alexander	------	×	------	------	------	------	------
suborbiculata Alexander	------	------	------	------	×	------	------
Brachycythere plena Alexander	------	------	------	------	×	------	------
Cythereidis sp. aff. *Bythocypris? mcguirti* Howe and Garrett	------	------	------	------	×	------	------
Cythereis midwayensis Alexander	------	×	------	------	×	------	------
prestwichiana Jones and Sherborn	------	------	------	------	------	------	------
spiniferrima Jones and Sherborn	------	cf	------	------	×	------	------
Loxoconcha cf. *L. perdecora* Alexander	------	×	------	------	------	------	------
Orthonotocythere cristata Alexander	------	------	------	------	×	------	------
Orthonotocythere? n. sp. aff. *Loxoconcha mississippiensis* Kline	------	------	------	------	×	------	------
Cytheridea everetti Berry	------	------	------	------	×	------	------
n. sp. aff. *C. everetti* Berry	------	------	------	------	×	------	------

---

[1] See table 1 for macrofossils from same locality.

these islands was marked by many extensive rocky beaches.

The shoreline along the upland composed of rocks of Paleozoic age at the northern and northwestern fringe of the bauxite region probably was marked by the deposition of fine sediments such as sand and mud. The quartz sand now contained in the formation probably was derived largely from this upland area of rocks of Paleozoic age, but some of the sand and much of the clay may have been brought from considerably farther inland.

The climate in the bauxite region during Kincaid time probably was warm temperate to subtropical, to judge from the composition of the marine fauna. Gardner (1935, p. 99) has described the Midway fauna as "a homogeneous biota which lived on the warm and warm temperate shores of the Gulf of Mexico and as far south as Brazil * * *" That it was not actually tropical in Arkansas is indicated by the absence of orbitoid foraminifers, which are common in beds of the same age in the island of Trinidad, and by the absence of exclusively tropical mollusks and other macrofossils.

The comparative freshness of the feldspathic and nepheline syenite detritus in the formation indicates that the rate of erosion, transportation, and deposition may have been appreciably rapid, certainly more than it was subsequently in Wills Point or Berger time. Similar material transported probably no farther during late Wills Point time is largely kaolinitic.

Thus it appears that in the bauxite region at the time the Kincaid sediments were deposited, a shallow transgressing sea was encroaching on an upland area of rocks of Paleozoic age. A short distance from shore rugged island masses of nepheline syenite including some remnants of rocks of Paleozoic age were being actively eroded. The climate probably was warm temperate to subtropical with torrential rains.

[WILLS POINT FORMATION]

Definition.—The "Basal or Wills Point clays" was the name given by Penrose (1890, p. 19) to the lower Tertiary clay beds exposed in the vicinity of Wills Point, Van Zandt County, Tex. Under this designation Penrose included all the beds above the unconformity at the top of the Upper Cretaceous and below the base of the partly continental Sabine River strata (Wilcox). Harris (1896, p. 15, 41) pointed out that the laminated blue and yellow clay beds exposed for several miles west of Wills Point are equivalent only to the upper part of the section that in Alabama was designated as the Midway series by Smith and Johnson (1887, p. 62–67), emended somewhat by Harris. Nevertheless, the name Wills Point was dropped for some time because it was considered to be synonymous with the earlier name Midway.

In the early 1930's the name Wills Point was revived and redefined to apply only to the upper part of the Midway group that lies above the top of the Tehuacana member or its lateral equivalents in south-central to northeast Texas. In this part of Texas the Wills Point formation is subdivided into two members as follows:

Mexia member, a lower member of dark thinly laminated or compact fossiliferous clay of a fairly deep water marine facies; about one-third of the formation.

Kerens member, an upper member of dark-gray silty or sandy clay down to and including a thin aragonite bed, the Wortham aragonite lentil; about two-thirds of the formation.

The Wills Point formation has been mapped separately in the Arkansas bauxite region at the suggestion of Miss Gardner, who noted the similarity of the dark-gray and poorly fossiliferous silty clay that underlies most of the bauxite and kaolin deposits to the clay of the Kerens member in Texas, and who suggested also that yellowish-gray foraminiferal clay beds exposed above the limestone of the Kincaid formation within the city limits of Little Rock might represent the Mexia member. Clay beds of the Mexia member type were not recognized in other parts of the area, nor were they identified in drill holes, hence no attempt at subdivision of the Wills Point was made during mapping.

Distribution and surface outcrop.—The formation is exposed in a northeastward-trending discontinuous band southeast of and almost parallel to the area of outcrop of the Kincaid formation. Like that of the Kincaid, the Wills Point outcrop area is patchy in the vicinity of Benton where both formations are overlapped by gravel of the Saline formation. About a mile southwest of Alexander the Wills Point formation is absent across an area a little less than a mile wide because of channeling before or during the deposition of the thick sands of the Berger formation. The most extensive exposure of the Wills Point is between Mabelvale and Geyer Springs. Here it reaches a width of nearly 3 miles at right angles to the strike of the formation. Outcrops near Little Rock are confined to the lower part of the formation, and they are patchy like those at Benton because the formation is overlapped to the north and northwest by gravel of the Saline formation.

The uniformly soft clayey sedimentary rocks of the Wills Point formation are expressed in a flat featureless topography that is poorly drained. Outcrops are few and are limited to the beds of several of the smaller streams and to roadside ditches and cuts. Much of the surface is covered by a thin layer of sand or of gravel

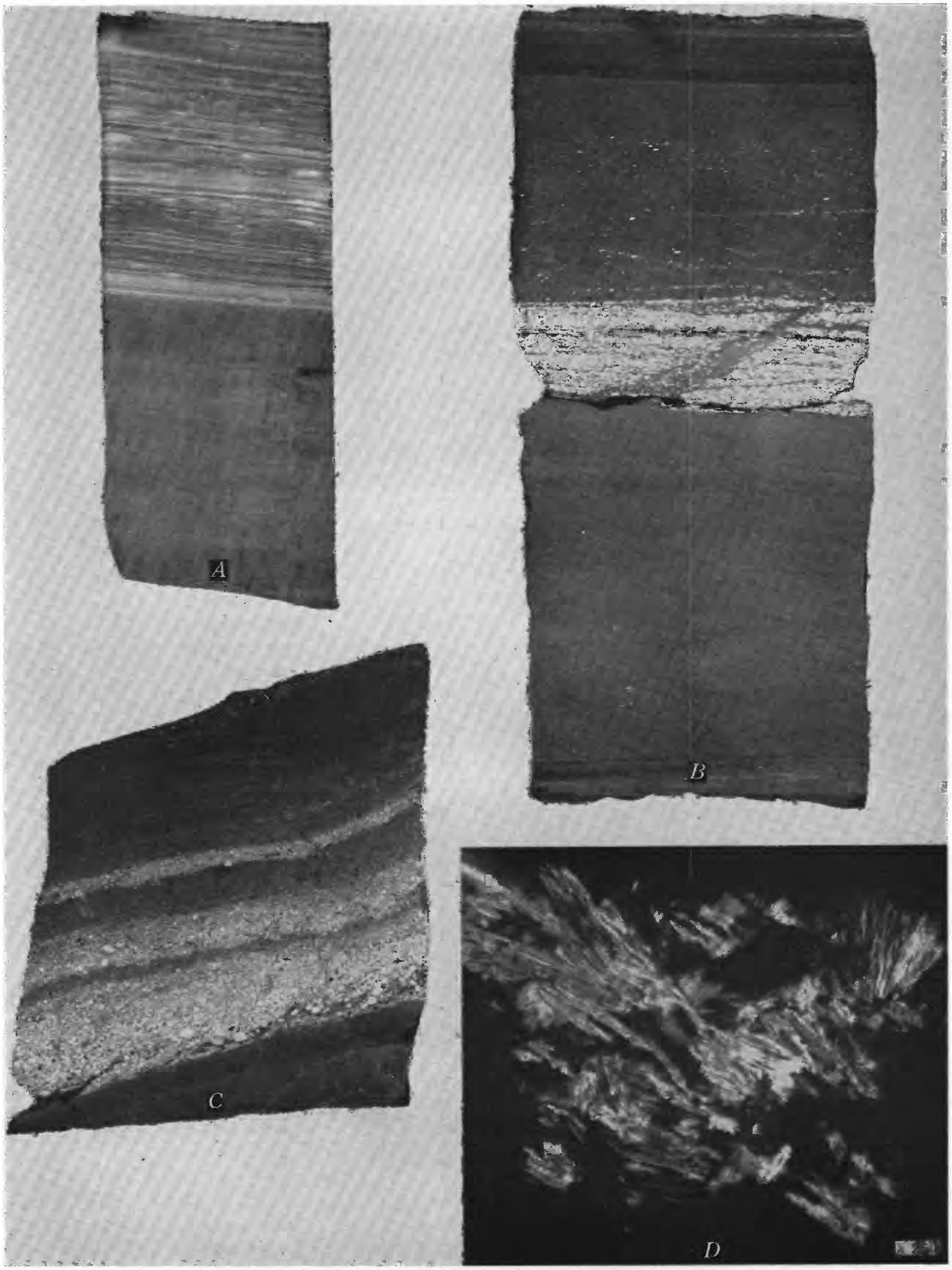


FIGURE 5.

washed down from younger beds. The topography of the formation is similar to that of the overlying Berger formation, and were it not for the more resistant deposits of siliceous and ferruginous bauxite and bauxitic clay at the base of the Berger that are expressed as topographic rises, or for the abundant drill-hole data, it would be difficult to map the contact between the two formations.

Thickness.—Where it is overlain by beds of the bauxitic and lignitic facies of the Berger formation, the Wills Point formation has a fairly uniform thickness ranging from 50 to 70 feet. Where the formation is overlain by green sand of the Berger or by gravel of the Saline formation, the exposed thickness may be much less or the formation may be entirely absent. The yellowish-gray foraminiferal clay near Little Rock does not exceed 30 feet in thickness.

The Wills Point formation thickens gradually basinward, as recorded in the deep drill holes. It thins over buried hills of nepheline syenite such as the one near Woodson, where the clay is only 20 feet thick, and is absent over larger buried hills such as the Ledbetter high where it was removed by erosion during Berger time. In valleys between the subsurface hills the thickness locally exceeds 300 feet. Records supplied by the Arkansas Geological Survey for two oil wells of the Shaffer Oil and Refining Co., indicate the thickness for the Upper Midway (Wills Point) of 306 feet (between depths of 1,660 and 1,966 feet) in the Youngblood No. 1 well in Grant County, and 450 feet (between depths of 2,166 and 2,620 feet) in the Long Bell No. 1 well in the same county.

Lithologic character.—In most of the bauxite region the Wills Point formation is a homogeneous fine silty clay. The unweathered clay cored in the drill holes is dark-bluish gray to black or blue black. It has a waxy appearance, particularly when cut with a knife. Most of the wet clay is sticky. The silt content varies, but a noticeable amount is always present and locally it predominates. Generally an excess of clay is in the formation near its upslope edge, where drilling was concentrated. Farther out in the basin in the deep drill holes, the formation has a high percentage of silt particles, and the sediment locally is a micaceous silt or fine sand.

Much of the dark silty clay shows graded bedding (fig. 5*A*) The silt, and particularly the micaceous material, is alined along horizontal partings. The laminae are formed by coarser particles directly overlying finer ones that have a sharp break in size along a single plane. Above this the particles grade to finer size upward to the next break where they are overlain by another layer of coarse particles. The laminae thus formed range from one-half to 5 millimeters in thickness, but generally are 2 to 3 millimeters. The sequence is repeated many times and indicates a cyclic or seasonal variation. The lamination is easily discerned where the clay has been weathered, but some cores of unweathered clay with no visible lamination break evenly along horizontal silty partings. Some laminae coalesce laterally and in many areas the clay is distinctly crossbedded. This is present in a few of the drill holes upslope along the nepheline syenite hill and in most of the drill holes in the deep parts of the basin where the clay is silty. The crossbedding is always on a miniature scale, never more than a few centimeters from topset to bottomset. At the few places where the clay crops out it appears massive. It weathers locally to a yellowish-gray clay with a hackly fracture.

Some of the clay at the top of the formation is bleached white to light gray or stained different colors (fig. 5*A*). This represents ancient weathering and is discussed on page 32. Siderite is common in the weathered part of the formation principally in small pinkish- to brownish-gray granular or oolitic pellets and aggregates. It also occurs at several horizons in the unweathered clay, in impure hard concretionary beds generally less than 6 inches thick, or disseminated in very fine grains. Pyrite is finely disseminated through most of the dark-gray clay and also occurs in gray to brassy rosettes and as fillings of small cavities.

EXPLANATION FOR FIGURE 5

Core specimens of sediments from the Wills Point formation. *A*, Khaki-colored and gray banding in weathered upper half of core; dark-gray silty clay in lower half. Sawed face of 2-inch core specimen from USBM drill hole 12–141, depth 205 feet, NE¼NE¼ sec. 35, T. 1 S., R. 14 W., Saline County. Natural size. *B*, Soft whitish grains and granules of kaolinitic clay and decomposed feldspar in dark-gray silty clay. Note lamination of sediments. Sawed face of 3-inch core specimen from USBM drill hole 15–119, depth 514 feet, SE¼NW¼ sec. 31 T. 2 S., R. 13 W., Saline County. Natural size. *C*, Kaolinitic and feldspathic debris in dark-gray silty clay. Sawed face of drill core specimen (AB–733–2), slightly distorted during coring. From Alcoa drill hole F–733B, depth 446 feet, Baxley property, SE¼NE¼ sec. 36, T. 2 S., R. 14 W., Saline County. Natural size. *D*, Photomicrograph of hydrous mica that has replaced kaolinite (dark field). This is a fairly common mineral in clay that was deposited in the Wills Point sea. Thin section (AB–262–1) from fragmental underclay beneath the Grubbs-Hawkins bauxite deposit, in Alcoa drill hole X–262, depth 412 feet, NW¼SE¼ sec. 36, T. 2 S., R. 14 W., Saline County. Crossed nicols. Photomicrograph by C. S. Ross. × 260.

Many cores of the clay on drying acquire a papillose surface, apparently caused by the partial decomposition of the pyrite.

Lignite is rare in the formation and has been found only near the upslope edge, apparently always as a detrital substance. A foot of hard black lignite was recorded in USBM drill hole 7–010 underlying the Birnbach bauxite deposit in the NW¼NW¼ sec. 11, T. 1 S., R. 12 W., on the south slope of the Pulaski nepheline syenite hill. It was cut by a drag bit in dark bluish-gray clay 12 feet below the top of the formation, which is 26 feet thick at this locality. None was found in adjacent holes, so this may have been a log or block of lignite. A similar occurrence was recorded in USBM drill hole 5–213 between the Vinson and Dixon bauxite deposits in the SW¼NW¼ sec. 1, T. 1 S., R. 12 W., where a large lignite block was cut below the base of the weathered interval, about 7 feet below the top of the formation which is probably not more than 20 feet thick at this locality.

Lignite fragments in dark-gray clay were found in USBM drill hole 9–026 in the SW¼NW¼ sec. 36, T. 1 S., R. 14 W., beneath the Thomas-Williams bauxite deposit on the west slope of the Alexander Mountain nepheline syenite hill. They were in the basal foot of the formation where it is only 2.2 feet thick. Small rectangular lignite fragments 2 to 3 millimeters long were found lying along bedding planes in dark-gray silty clay about 4 feet below the top of the formation, beneath the East Bauxite deposit, in USBM drill hole 15–142 in the NW¼NE¼ sec. 31, T. 2 S., R. 14 W., on the south slope of the Saline County nepheline syenite high. Small wispy carbonaceous fragments were recognized in a thin section of clay from the Wills Point, 8 feet below the top of the formation underlying the same deposit in USBM drill hole 15–119, in the SE¼NW¼ sec. 31.

In some of the deep parts of the depositional basin the lower part of the Wills Point section contains beds of soft gray limestone generally not more than 2 feet thick. Thick limestone sections in these deep areas have been assigned arbitrarily to the Kincaid formation but, as pointed out in the discussion of that unit, microfaunal studies have not been made to check the validity of this procedure.

Along the upslope lip of the formation, layers of kaolinitic clay several inches thick interfinger with the clay of the Wills Point formation (fig. 5*C*). These exhibit residual textures of pebbles and grains of the nepheline syenite from which they were derived. Similar layers of white clayey sand containing quartz sand grains occur at a few localities. Other macroscopically identifiable substances scattered through the clay include fragments and grains of feldspar, some of them partly decomposed (fig. 5*B*), a few phosphatic scales and other remains of fish, pyritized invertebrate tests and shells, and rarely pyritized leaves.

Under the microscope it can be seen that the larger silt particles in the average unweathered clay of the Wills Point formation include quartz, kaolinite, siderite, pyrite, carbonaceous material, probably feldspar and ilmenite, and possibly magnetite, according to a brief study of many samples made by H. G. Stephens. Quartz particles are angular to subangular, with wedgelike edges, and range from 0.02 to 0.04 millimeter in diameter. They are common in some parts of the clay where they have a random distribution and orientation. They make up more than 40 percent of the rock in some places but are rare in others. Kaolinite particles are flat or bent cleavage flakes with ragged edges. They reach a maximum of 0.07 millimeter in length and 0.015 millimeter in width throughout most of the clay but rarely are 0.4 millimeter long. They are light gray and have a pearly or silky luster. Their distribution appears to be more uniform than that of the quartz but they commonly lie parallel to the bedding along silty partings. Siderite where present occurs in clear crystalline fragments about 0.1 to 0.3 millimeter in diameter, or as light-tan to pinkish-brown pellets and aggregates. Some large aggregates are seen under the microscope to constitute one single crystal. The distribution of the siderite is spotty and much of it appears to occur in the upper parts of the clay that have been partly weathered. Pyrite is abundant in dark-gray clay and is disseminated evenly through it or concentrated along silty partings. In almost 50 clay samples examined by Stephens the pyrite was seen to occur in tiny brassy yellow octahedral crystals ranging in size from minute specks 0.02 to 0.04 millimeter. Although many of the crystals appear to have slightly rounded edges, rounded shapeless particles are rare. Pyrite is less common and more difficult to identify in the weathered light-gray clay. Carbonaceous material is intimately mixed with the dark-gray clay in extremely fine particles and tiny lignitic shreds. Feldspar particles are generally small and much less abundant than quartz particles. Small metallic grains and opaque specks are scattered sparsely in the clay. These may be small crystals and fragments of ilmenite, which is indicated by a fairly constant content of titanium oxide (1–2 percent) in chemical analyses of the clay.

Three samples of clay from the Wills Point formation from drill holes in Saline County were submitted to the Geological Survey for X-ray examination. The minerals determined by this method are listed in the table which follows.

Minerals identified by X-ray examination in clays from the Wills Point formation

[Analyst, J. M. Axelrod]

Mineral	Sample		
	1	2	3
Quartz	X	------	X
Kaolinite	X	X	X
Muscovite	------	X	Tr.
Feldspar	X	------	------
Unidentified	X	------	------

1. Fragmental clay detritus or granule conglomerate in dark-gray silty clay (specimen AB-733-2; see fig. 5*C*) from Alcoa drill hole F-733B, depth 446 feet, Baxley property, SE¼NW¼ sec. 36, T. 2 S., R. 14 W., Saline County.
2. Dark-gray silty laminated clay (specimen AB-12141-1; see fig. 5*A*) from USBM drill hole 12-141, depth 205 feet, NE¼NE¼ sec. 35, T. 1 S., R. 14 W., Saline County.
3. Fragmental clay detritus in a dark gray silty clay (specimen AB-15119-1; see fig. 5*B*) from USBM drill hole 15-119, depth 514 feet, SE¼NW¼ sec. 31, T. 2 S., R. 13 W., Saline County.

Additional clay from the same three specimens was tested by means of a portable thermal analysis machine, by E. C. Fischer. These samples gave typical reactions for kaolinite and quartz.

Kaolinite appears to be the principal clay mineral in the Wills Point, at least in the bauxite region. No montmorillonite was identified in any of the samples studied either by optical or by X-ray methods. These samples, however, came from near the nepheline syenite masses from the weathering of which large quantities of kaolinite were derived.

Hydrous mica was identified by C. S. Ross (oral communication, 1950) replacing kaolinized nepheline syenite directly beneath a few feet of weathered clay of the Wills Point. According to Ross the hydrous mica was formed by the fixation of potassium in sea water. Hydrous mica also has been identified in kaolinitic clay fragments near the base of the underclay beneath bauxite deposits (fig. 5*D*) in at least two localities.

The persistent dark-gray to bluish-black color of the fresh clay is caused mostly by extremely fine carbonaceous particles and in part to finely disseminated pyrite.

Chemical analyses have been made of the fresh clay of the Wills Point formation from many drill holes and in four of them, drilled in secs. 8 and 9, T. 1 S., R. 12 W., on the west slope of the Pulaski nepheline syenite hill, the entire thickness of the formation has been cored and analyzed. The sampled intervals in these four drill holes, their brief lithologic descriptions, and their chemical analyses are given in table 3, together with analyses of underlying and overlying rocks.

TABLE 3.—*Chemical analyses by the triacid method of clay of the Midway group and of the lower part of the Wilcox group*

[Analyses by U. S. Bureau of Mines]

Depth (feet)	Lithologic description	Analyses in percent						
		Al_2O_3	SiO_2	Fe as Fe_2O_3	TiO_2	Ignition loss	Insoluble	FeO
	USBM drill hole 1-305. NW¼SW¼ sec. 9, T. 1 S., R. 12 W. E. H. Ford property							
	Berger formation:							
157.2–158.2	Bauxitic clay, tan to cream with crude pisolites, and carbonaceous fragments.	46.1	31.2	1.2	2.6	18.2	0.7	0.2
158.2–161.7	Bauxitic clay, as above	48.6	25.2	.8	3.0	21.8	.6	.4
161.7–164.5	Bauxitic clay, as above, but grading to clay below; sideritic bed from 163.1 to 164.1.	27.3	27.7	22.6	2.4	19.5	.5	18.0
164.5–170.5	Kaolinitic clay, gray, sideritic	33.6	38.4	11.2	1.8	14.0	1.0	7.2
170.5–174.5	Kaolinitic clay, gray highly sideritic	28.0	33.9	19.0	1.4	15.7	2.0	14.4
	Wills Point formation:							
174.5–181.5	Clay, gray above, khaki below transversely laminated sideritic bed from 175.9 to 176.4.	20.3	51.4	12.5	1.4	10.8	3.6	9.2
181.5–184.9	Clay, dark bluish-gray, silty and finely micaceous, transversely laminated.	20.9	65.9	3.1	.8	6.7	2.6	.7
184.9–194.9	Clay, as above; sideritic layer from 191.1 to 191.4	16.0	56.4	11.4	1.2	9.8	5.2	6.5
194.9–206.5	Clay, as above	21.1	62.9	5.6	.5	6.4	3.5	3.0
206.5–217.2	Clay, as above; sideritic layer from 206.8 to 207.3; greenish material, feldspar grains from 210.0 to 210.5.	18.1	46.1	19.2	.8	13.4	2.4	11.9
217.2–227.6	Clay as above	22.3	62.5	5.5	.4	6.9	2.4	3.1
227.6–238.0	do	25.7	56.9	6.4	.9	7.6	2.5	2.6
238.0–247.8	Clay, as above; with sideritic layers	6.4	51.4	24.3	1.0	15.3	1.6	18.0
247.8–252.9	do	21.9	49.4	5.6	1.5	7.9	13.7	.9
	Kincaid formation:							
252.9–258.4	Conglomerate, white to greenish-gray loosely consolidated debris of decomposed nepheline syenite pebbles in a calcareous matrix.[1]	------	------	------	------	------	------	------
258.4–277.8	Limestone with nepheline syenite pebbles; conglomerate, as above, but matrix harder.[1]	------	------	------	------	------	------	------

See footnote at end of table.

TABLE 3.—*Chemical analyses by the triacid method of clay of the Midway group and of the lower part of the Wilcox group*—Continued

Depth (feet)	Lithologic description	Analyses in percent						
		Al_2O_3	SiO_2	Fe as Fe_2O_3	TiO_2	Ignition loss	Insoluble	FeO
	USBM drill hole 18-073. SE¼NE¼ sec. 8, T. 1 S., R. 12 W. Lewis Treadway property							
	Berger formation:							
160. 7–164. 7	Bauxitic clay, cream to gray with tan fragments, sideritic.	36. 6	30. 0	11. 0	3. 1	18. 4	0. 9	8. 5
164. 7–167. 9	Bauxitic clay, as above	37. 6	30. 2	9. 6	3. 0	18. 4	1. 2	6. 9
167. 9–168. 7	Kaolinitic clay, light gray, sideritic	35. 3	38. 0	7. 9	2. 8	15. 4	. 6	6. 6
168. 7–169. 3	do	34. 8	36. 5	9. 5	2. 6	15. 4	1. 2	7. 4
169. 3–171. 0	Kaolinitic clay, fragmental gray, sideritic	34. 0	36. 3	10. 0	2. 8	15. 8	1. 1	8. 3
171. 0–171. 7	do	30. 7	34. 1	14. 8	2. 8	16. 9	. 7	13. 1
171. 7–177. 8	do	29. 7	31. 6	17. 1	2. 8	17. 0	1. 8	13. 2
177. 8–179. 8	Clay, mottled red, gray and brown, pebbly, containing siderite aggregates.	21. 0	28. 2	27. 2	2. 8	19. 3	1. 5	21. 4
	Wills Point formation:							
179. 8–180. 8	Silty clay, dark bluish-gray, laminated with light gray silt and kaolinitic stringers.	17. 6	61. 0	2. 4	1. 0	6. 2	11. 8	. 6
180. 8–191. 0	do	16. 2	67. 6	2. 0	. 9	6. 3	7. 0	1. 1
191. 0–201. 0	Silty clay, dark bluish gray, horizontally laminated with paler sandier clay.	19. 6	65. 8	3. 1	1. 2	7. 0	3. 3	. 7
201. 0–211. 3	do	19. 9	62. 00	6. 2	1. 2	7. 6	3. 1	2. 0
211. 3–221. 5	Silty clay, as above: 6-inch siderite layer at 216.8 ft	19. 8	62. 8	5. 1	1. 0	7. 8	3. 5	2. 2
221. 5–231. 5	Silty clay, as above; 6-inch siderite layer at 223.5 ft	18. 5	51. 6	13. 4	1. 5	11. 6	3. 4	9. 4
231. 5–240. 4	Silty clay, as above	21. 8	62. 4	4. 4	1. 0	7. 3	3. 1	. 9
240. 4–241. 2	Clay, light gray, sideritic	16. 4	32. 5	28. 2	2. 0	19. 4	1. 5	24. 6
241. 2–251. 2	Silty clay, dark bluish, with light gray clay fragments	20. 6	61. 1	6. 7	1. 4	7. 9	2. 3	3. 4
251. 2–261. 0	Silty clay, as above; 6-inch siderite layer at 253.0 ft	20. 8	62. 8	5. 3	1. 5	7. 1	2. 5	1. 5
261. 0–267. 1	do	22. 4	60. 4	4. 5	1. 2	6. 6	4. 9	1. 1
267. 1–268. 2	Silty clay, dark gray, mixed with weathered nepheline syenite debris.	30. 6	35. 4	18. 6	2. 0	5. 6	7. 8	15. 8
	Kincaid formation:							
268. 2–271. 0	Feldspathic sand, light gray to white	19. 7	41. 6	2. 8	2. 6	7. 1	26. 2	0. 5
271. 0–277. 6	Nepheline syenite debris gray	24. 2	41. 8	1. 7	2. 4	8. 1	21. 8	. 3
277. 6–281. 0	Fragmental clay, gray, derived from kaolinized nepheline syenite; fragments as much as one-half inch.	26. 4	41. 5	1. 9	2. 0	9. 2	19. 0	. 1
281. 0–284. 6	Nepheline syenite debris, white	26. 3	44. 2	1. 6	2. 2	9. 5	16. 2	. 2
284. 6–291. 8	Nepheline syenite debris, green	17. 5	40. 3	2. 6	1. 6	7. 1	30. 9	. 2
	USBM drill hole 20-048. SW¼NW¼ sec. 9, T. 1 S., 12 W. C. R. Winn property							
	Berger formation:							
138. 1–142. 3	Kaolinitic clay, carbonaceous, dark gray to gray at top; contains pisolitelike clay fragments	40. 8	38. 5	1. 3	4. 3	14. 4	0. 7	0. 1
142. 3–147. 3	Kaolinitic clay, light gray, less silty with depth	38. 6	41. 0	1. 4	4. 7	13. 3	1. 0	. 1
147. 3–153. 1	Kaolinitic clay, as above, but contains white to dark gray clay fragments	35. 0	38. 0	6. 2	5. 4	14. 8	. 6	4. 4
	Wills point formation:							
153. 1–155. 1	Clay, cream to white, laminated, slightly silty; considerable granular siderite in upper 2.5 feet	24. 5	49. 8	7. 2	3. 6	10. 5	4. 4	5. 6
155. 1–157. 1	Clay, as above, but with light lavender cast	21. 3	52. 7	2. 6	1. 6	7. 0	14. 8	1. 2
157. 1–163. 7	Clay, dark bluish-gray, laminated, finely micaceous	21. 3	61. 6	1. 8	2. 0	7. 2	6. 6	. 1
163. 7–171. 7	do	20. 8	57. 9	2. 6	2. 6	7. 2	8. 9	. 4
171. 7–172. 7	Sideritic rock, hard	12. 7	18. 6	41. 0	2. 8	24. 8	. 1	32. 0
172. 7–174. 3	Clay, dark bluish-gray, laminated, silty, finely micaceous	21. 1	61. 8	5. 4	1. 4	6. 9	3. 4	1. 4
174. 3–184. 6	do	21. 0	61. 4	5. 8	2. 0	7. 2	2. 6	1. 7
184. 6–195. 4	do	22. 4	62. 4	4. 8	1. 6	6. 9	1. 9	1. 2
195. 4–206. 3	do	24. 5	34. 1	4. 0	1. 4	6. 8	29. 2	. 7
206. 3–217. 1	do	23. 3	56. 2	4. 3	1. 8	6. 8	7. 6	. 9
217. 1–218. 4	do	22. 6	58. 1	6. 0	1. 0	7. 7	4. 6	1. 4
	Kincaid formation:							
218. 4–221. 4	Clayey feldspathic debris; upper 0.7 foot mixed with dark blue-gray silty clay and probably is basal Wills Point	19. 1	29. 8	12. 7	2. 0	11. 4	25. 0	10. 2
221. 4–239. 1	Limestone and nepheline syenite rubble	(1)		------	------	------	------	------
239. 1–248. 7	Calcareous nepheline syenite debris; weathered grayish-green, with less calcareous layers	1. 2	12. 2	2. 9	. 8	34. 0	48. 9	1. 2
248. 7–259. 6	Limestone with nepheline syenite rubble	(1)		------	------	------	------	------
259. 6–265. 1	Nepheline syenite debris, dark green, clayey near base	19. 3	33. 1	3. 6	1. 8	6. 3	35. 9	1. 3

See footnote at end of table.

TABLE 3.—*Chemical analyses by the triacid method of clay of the Midway group and of the lower part of the Wilcox group*—Continued

Depth (feet)	Lithologic description	Analyses in percent						
		Al_2O_3	SiO_2	Fe as Fe_2O_3	TiO_2	Ignition loss	Insoluble	FeO
	USBM drill hole 20–048. SW¼NW¼ sec. 9, T 1 S., .2 W. C. R. Winn property—Continued							
	Kincaid formation—Continued							
265. 1–266. 0	Kaolinitic clay, varicolored, fragmental, abundant dark mica flakes	31. 9	39. 9	10. 0	3. 0	12. 2	3. 0	2. 3
266. 0–271. 3	Clay, white and green, fragmental	27. 5	37. 2	6. 4	2. 6	11. 5	14. 8	3. 0
	Basement rock:							
271. 3–281. 9	Decomposed nepheline syenite, white and light green, kaolinitic	15. 9	41. 9	5. 4	3. 0	8. 0	25. 8	3. 3
281. 9–285. 9	Nepheline syenite, weathered as above, clayey in uppermost, 0.1 foot	12. 8	41. 0	4. 2	2. 0	6. 7	33. 3	1. 9
285. 9–292. 3	Nepheline syenite, less weathered than above	12. 1	34. 8	4. 9	1. 6	6. 0	40. 6	2. 6
	USBM drill hole 20–049. NE¼SE¼ sec. 8, T. 1 S., R. 12 W. T. R. Vinson property							
	Berger formation:							
149. 5–151. 0	Bauxitic clay, light tan, soft; a few oolites or pisolites	31. 5	30. 3	16. 3	2. 8	18. 2	0. 9	12. 2
151. 0–154. 8	Kaolinitic clay, cream to gray, with a few tan clay fragments	26. 6	28. 5	22. 8	2. 8	18. 6	. 7	17. 2
154. 8–161. 3	Kaolinitic clay, light gray, sideritic in bands and patches	27. 1	28. 8	22. 4	2. 4	18. 4	. 9	18. 9
	Wills Point formation:							
161. 3–165. 5	Clay, gray to light tan, sideritic plastic	25. 4	46. 6	11. 7	2. 0	12. 5	1. 8	9. 9
165. 5–167. 0	Silty clay, banded khaki	18. 9	51. 8	14. 5	1. 5	9. 7	3. 6	6. 2
167. 0–176. 0	Silty clay, blue-black, laminated, finely micaceous, plastic; with disseminated pyrite grains and clusters	21. 5	64. 7	1. 9	. 9	7. 5	3. 5	. 3
176. 0–186. 7	Silty clay, as above	24. 4	61. 3	3. 7	1. 0	7. 8	1. 8	. 6
186. 7–197. 2	do	21. 9	62. 2	4. 9	1. 0	7. 4	2. 6	1. 1
197. 2–198. 0	Sideritic rock, hard	9. 3	8. 9	50. 5	2. 2	28. 6	. 5	44. 8
198. 0–208. 6	Silty clay, blue-black, laminated, finely micaceous, plastic, with disseminated pyrite	22. 9	57. 8	5. 7	. 9	7. 5	5. 2	2. 2
208. 6–219. 3	do	22. 5	56. 6	7. 0	1. 0	8. 0	4. 9	3. 3
219. 3–228. 3	Silty clay, as above; the basal foot or two mixed with feldspathic fragments	22. 6	55. 7	8. 3	1. 0	8. 8	3. 6	4. 3
	Kincaid formation:							
228. 3–230. 5	Nepheline syenite debris; gray to green subangular fragments in a calcareous matrix	19. 8	33. 3	16. 6	2. 2	14. 4	14. 0	13. 3
230. 5–273. 0	Limestone and nepheline syenite rubble; bands of green minerals ¼ to 2 inches thick [1]	(1)	----	----	----	----	----	----
273. 0–282. 3	Nepheline syenite debris, calcareous to clayey, interbedded with limestone [1]	(1)	----	----	----	----	----	----
282. 3–283. 3	Lignite and carbonaceous clay [1]	(1)	----	----	----	----	----	----
283. 3–284. 1	Kaolinitic clay, pebbly; clay fragments about one-half inch in diameter	32. 3	44. 1	1. 4	1. 9	12. 2	8. 1	. 3
284. 1–286. 5	Carbonaceous sandy clay, gray to green micaceous, feldspathic [1]	(1)	----	----	----	----	----	----
286. 5–290. 2	No recovery	----	----	----	----	----	----	----
	Basement rock:							
290. 2–297. 9	Decomposed nepheline syenite	9. 2	46. 9	1. 8	1. 1	3. 9	37. 1	. 7
297. 9–304. 3	Decomposed nepheline syenite; harder with depth	15. 0	44. 9	3. 9	1. 2	6. 6	28. 4	2. 2

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[1] Not analyzed.

The triacid analyses used for analyzing bauxite samples are not precise for silty clay of the Wills Point formation but give the approximate proportions of the principal constituents, and supply chemical data that can be used along with the physical properties as a means of identifying the fresh clay. As may be seen by studying table 3, the distinguishing chemical characteristics of most of the clay of the Wills Point formation are (1) a silica content higher than 50 percent, (2) an alumina content lower than 25 percent, and (3) an insoluble residue notably greater than that of the bauxite-kaolin zone but considerably less than that of the upslope sedimentary rocks of the Kincaid formation.

At the top of the formation at most places where it is overlain by the bauxite-kaolin zone the Wills Point has a lower silica content and a correspondingly higher alumina content and ignition loss, and at many localities the clay has a chemical composition close to that of kaolin. This kaolinitic clay is part of a gradation that starts in the middle of the bauxite-kaolin zone in material lowest in silica and grades downward into

fresh clay of the Wills Point formation several feet below the top of the formation. Thus the upper contact of the formation can rarely be selected on the basis of chemical analyses but rather by physical appearance as described later. At most localities the clay is bleached or stained at the top of the formation by weathering.

A study of chemical analyses and core descriptions has shown that no direct relationship exists between the color of the weathered clay and its chemical composition. In two adjacent drill holes that cut the Detonti bauxite deposit in the SE¼SW¼ sec. 33, T. 3 S., R. 14 W., in Saline County, the fresh dark-gray clay is chiefly kaolinitic.

The weathering profile at the top of the formation.—Where the upper part of the Wills Point formation has not been deeply stripped by erosion subsequent to deposition its color has been changed. Along the flanks of the nepheline syenite hills, where the formation is overlain by kaolinitic clay of the Berger formation, the upper few inches to 20 feet of Wills Point clay is bleached white to light gray, or stained yellow, orange, khaki, olive green, red, purple, lavender, or a combination of these colors, either in solid intervals or horizontally banded with gray. The colors are particularly conspicuous along the lip of the formation where it thins and pinches out. These characteristic colors at the top of the formation were considered by Bramlette (1936, p. 6) to represent that part of the Wills Point affected by weathering after the withdrawal of the Midway sea and before the deposition of nearly all the sediments herein referred to the Berger formation. This was confirmed by the mass of evidence obtained from the cores of this interval taken during the present investigation.

The most common sequence of the colored clays where they are found together in the same drill hole is as follows: fresh blue-black clay at the bottom; khaki-colored clay immediately above; purple and red clay next above, locally interlaminated with gray clay in the upper part; and light-gray clay at the top. Where they are interlaminated the color layers usually are 2 to 3 millimeters thick but they reach a maximum of several centimeters. The boundaries between the colors generally are sharp and either parallel or at a slight angle to the bedding laminae. In places the banding was concentric around a central nucleus, or in anastomosing veinlets. At some localities the color sequence described above has been truncated by subsequent erosion. Fragments of both fresh and stained clay of the Wills Point formation were noted in a few drill holes in the basal kaolinitic clay of the Berger formation.

One of the most common and most widespread types of stained clay is khaki colored; also ocherous brown, yellowish brown, buff, or orange. This clay usually overlies the fresh clay of the Wills Point formation directly and in sharp contact with it. With the binocular microscope the coloring matter of the clay is seen to be a limonitic stain. The clay occurs either in layers of solid color or banded with olive green and locally with gray. It is found in a zone as much as 6 feet thick but generally less. In many drill holes, 6 inches to 1 foot of khaki-colored clay was found separating light-gray clay above from dark-bluish-gray clay below. In a few drill holes where the formation near its upslope lip is less than 20 feet thick, a thin zone of khaki-colored clay was also found below the dark-gray clay resting upon syenite debris of the Kincaid formation or upon syenite clay.

Purple, lavender, violet, or deep-red clay is generally found immediately above the khaki-colored clay. The thickness of the zone occupied by this clay is seldom greater than 3 feet. In some places it is interlayered with the khaki-colored clay, and in a few drill holes a thin layer was found below the khaki-colored clay. More commonly it is interlayered with gray clay. A lighter red clay is commonly found in bands associated with gray clay throughout much of the Midway surface. At many localities it is interlaminated with gray clay in the upper part and with khaki-colored clay in the lower part.

Bleached clay was found in many drill holes in the upper part of the formation. It is light gray to white, generally lightest in tone at the top and progressively darker downward, and grades into the dark bluish-gray to black clay below. In texture it cannot be distinguished from the dark clay. Commonly there are thin alternating pale and dark layers controlled by the bedding laminae that give it a faintly banded appearance. The thickness of this type of clay generally is greater than that of the stained clay and in some places reaches 20 feet.

It was noted during the drilling of ore bodies in the Woodyardville area in Pulaski County that the bleached clay is largely confined to crests of topographic rises on the buried Midway surface, and the ocher or khaki-stained clay occupied topographic depressions. The brighter colored clay is best formed at or near the base of buried slopes. Sections drawn by Jenke (written communication, 1945) through the East Bauxite and McNeil bauxite deposits in Saline County show that khaki-colored or buff clay is moderately thick in subsurface valleys and thins out on adjacent slopes; red-stained clay generally overlies the khaki clay near the base of the valley walls, is thickest on the slopes, and thins out below bleached clay toward the crests of the ridges.

This color distribution, shown in figure 6, is evidently

related to the position of the water table that existed after the withdrawal of the sea in Midway time. The bleached clay apparently was produced above the level of the water table. Carbonaceous matter was removed perhaps by bacteria or other organic agents or by aeration, and iron sulfide was dissolved and removed by descending ground water. Iron oxide was precipitated where the descending solutions met the gently fluctuating water table, particularly near the surface of the ground. Red stains probably resulted from intermittent aeration and the khaki color from little or no aeration under otherwise similar conditions. Pyrite probably is present in more than sufficient quantity to account for the iron oxide stains. It is relatively uncommon in the bleached or stained clay of the Wills Point.

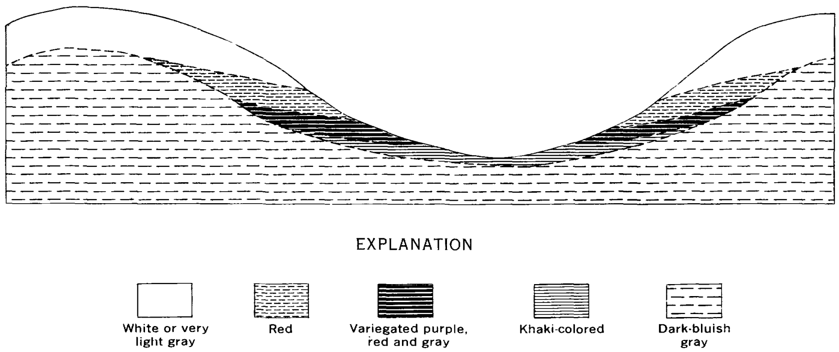

FIGURE 6.—Section across a buried valley on the post-Wills Point surface, showing the usual distribution of colored clay beds and their relation to paleotopography.

The distinctive weathering profile of the Wills Point surface has remained as a persistent and dependable marker of the erosion surface that separates the Wills Point and Berger formations, and is found at depths exceeding 1,100 feet, more than 800 feet below present sea level. It is lacking only in areas that formed major drainageways after Wills Point time, where green sand of the Berger or less commonly brown sand of the Saline directly overlies fresh dark-gray clay of the Wills Point. Except for these buried valleys, leaching and weathering proceeded faster than surface erosion of the relatively impermeable clay of the Wills Point.

Relation to underlying rocks.—The top bed of the Kincaid formation in much of the bauxite region is a sandy limestone or a calcareous sandstone. The basal bed of the Wills Point formation is clay. The contact is particularly sharp in the drilled areas along the nepheline syenite hills where the top of the Kincaid contains large quantities of igneous rock detritus. Aside from this sudden change in grain size, which is no greater than between adjacent beds in the Kincaid, there is little evidence to indicate a lack of conformity between the two formations. The basal foraminiferal clay beds of the Wills Point formation that crop out at Little Rock probably are also present in deeper buried parts of the region. These beds are somewhat calcareous and thus appear to be transitional between the highly calcareous sedimentary rocks of the Kincaid and the noncalcareous clay that constitute the bulk of the Wills Point. The seemingly limited distribution of the foraminiferal clay requires further study before conclusions can be drawn but probably is due to lateral changes of facies rather than a stratigraphic hiatus. It might also be due to the scarcity of good outcrops and the failure to recognize this zone in drill holes.

A quantity of clayey feldspathic and syenitic debris is present at some localities on the slopes of the nepheline syenite hills in the basal foot or two of the Wills Point, mixed with dark-gray clay. Chemical analyses of this interval indicate very little kaolinitic clay which would be expected had the nepheline syenite debris been exposed to much surface weathering before the deposition of the Wills Point formation.

Fossils and correlation.—The weathered yellowish-gray clay that lies above the sandy limestone of the Kincaid formation in the environs of Little Rock contains an abundant and remarkably well preserved microfauna. This includes many foraminifers, some ostracodes, and a few bryozoans, small mollusks, and fish remains. Microfossils can be collected at almost any horizon in this clay, but they are most abundant in the basal 1 to 2 feet.

Two collections were made in a gully at the southwest edge of the city.

Locality	
17282	About 1,000 feet south of Roosevelt Road viaduct and 200 feet south of Chicago, Rock Island, and Pacific Railroad tracks, in small gully heading east, upstream from small abandoned bridge, NE¼NW¼ sec. 16, T. 1 N., R. 12 W., Little Rock. Clay layer 1 foot above base of formation. Collected by R. A. M. Schmidt, J. A. Gardner, and M. W. Ellis, 1944. The underlying section of the Kincaid formation is described on p. 19.
17283	Same gully as locality 17282, 600 to 700 feet farther east and 20 to 30 feet stratigraphically higher, about 500 feet south of the NE. cor., NW¼ sec. 16, T. 1 N., R. 12 W., Little Rock. Collected by M. W. Ellis, 1944.

Foraminifers from these localities are listed on table 4, slightly modified by Cushman and Todd from earlier published identifications of the fauna of locality 17282 (Cushman and Todd, 1946; Cushman, 1947, 1948). Also listed are the ostracodes from locality 17282 identified by F. M. Swain. Present in the washed residue from this locality but not mentioned in the table are several bryozoans, the brachiopod *Argyrotheca* sp., prodissoconchs of *Ostrea pulaskensis* Harris, small echinoid spines and tiny shark teeth, some angular clear quartz grains, glauconite grains, and tiny phosphatic nodules.

The foraminifers and ostracodes from the Wills Point formation in Arkansas (table 4) are typical Midway species, many have been reported previously from equivalent strata in Texas and Alabama (Cushman and Todd, 1946) and in Clay County, Mississippi (Kline, 1943). Most of the foraminifers are typical upper Midway species occurring in the Wills Point of Texas and in equivalent formations in Alabama and Mississippi, but many occur also in the Kincaid formation and equivalent beds of lower Midway age. The distribution of the Arkansas species in formations of the Midway group in other states is shown in table 4.

TABLE 4.—*Foraminifera and Ostracoda of the Wills Point formation in the Arkansas bauxite region and their occurrence in formations of the Midway group at other published localities in the Gulf Coastal Plain*

	Arkansas bauxite region			East Texas [b]		Clay County, Miss.[c]		Alabama				
	USGS loc. 17282	USGS loc. 17283	Kincaid fm.[d]	Kincaid fm.	Wills Point fm.	Clayton fm.	Porters Cr. fm.	lower bed, Sucarnoochee clay [e]	upper bed, Sucarnoochee clay [e]	Type Naheola fm. [f]	Coal Bluff marl member, Naheola fm.[g]	Previous known range
Foraminifera (identified by J. A. Cushman and Ruth Todd): [a]												
Spiroplectammina cretosa Cushman.	×	---	×	---	---	×	×	---	×	×	---	Upper Cretaceous and Paleocene.
Textularia plummerae arkansasana Cushman.	×	---	×	---	---	---	---	---	---	---	---	
Clavulinoides midwayensis Cushman	×	---	---	×	×	×	×	---	×	---	---	Paleocene.
Robulus midwayensis (Plummer)	×	---	×	×	×	×	×	---	×	×	×	Paleocene and Eocene.
pseudomamilligerus (Plummer)	×	---	---	×	×	---	cf.	---	×	---	---	Paleocene.
alabamensis Cushman	×	---	---	---	---	---	---	---	---	---	×	Do.
turbinatus (Plummer)	×	---	---	---	×	×	×	---	×	---	---	Upper Cretaceous and Paleocene.
degolyeri (Plummer)	×	---	×	---	×	×	×	---	---	---	---	Paleocene and Eocene.
cf. *R. inornatus* (d'Orbigny)	×	---	---	---	---	---	---	---	---	---	---	Do.
**wilcoxensis* Cushman and Ponton, var. *dissentia* Cushman and Todd.	×	---	---	---	---	---	---	---	---	---	---	
**arkansasanus* Cushman and Todd	×	---	---	---	---	---	---	---	---	---	---	
sp	×	---	---	---	---	---	---	---	---	---	---	
Marginulina eximia Neugeboren	×	---	---			---	---	---	---	---	×	Do.
cf. *M. dubia* Neugeboren	×	---	---	---	---	---	---	---	---	---	---	
cf. *M. subrecta* Franke	×	---	---	---	---	---	---	---	---	---	---	Paleocene.
cf. *M. hamata* (Franke)	×	---	---	---	---	---	---	---	---	---	---	Do.
sp	×	---	---	---	---	---	---	---	---	---	---	
Dentalina gardnerae (Plummer)	×	---	×	×	---	×	---	---	×	×	---	Paleocene and Eocene.
colei Cushman and Dusenbury	×	---	×	---	×	×	×	---	---	---	×	Do.
plummerae Cushman	×	---	---	---	---	×	×	---	×	---	---	Paleocene.
eocenica Cushman	×	---	---	---	×	---	---	---	×	×	×	Do.
nasuta Cushman	×	---	---	---	---	---	---	---	---	---	---	Eocene.
naheolensis Cushman and Todd	×	---	×	---	---	---	---	---	---	×	×	Paleocene.
pseudo-obliquestriata (Plummer)	×	---	×	×	---	×	×	---	×	×	---	Do.
cf. *D. mucronata* Neugeboren	×	---	---	---	×	---	---	×	---	×	---	Paleocene to Recent.

See footnotes at end of table.

TABLE 4.—*Foraminifera and Ostracoda of the Wills Point formation in the Arkansas bauxite region and their occurrence in formations of the Midway group at other published localities in the Gulf Coastal Plain*—Continued

	Arkansas bauxite region			East Texas [b]		Clay County, Miss.[c]		Alabama				
	USGS loc. 17282	USGS loc. 17283	Kincaid fm.[d]	Kincaid fm.	Wills Point fm.	Clayton fm.	Porters Cr. fm.	lower bed, Sucarnoochee clay [e]	upper bed, Sucarnoochee clay [e]	Type Naheola fm. [f]	Coal Bluff marl member, Naheola fm.[g]	Previous known range
Foraminifera—Continued												
Dentalina—Continued												
**pseudonasuta* Cushman and Todd	×	---	---	---	---	---	---	---	---	---	---	
aculeata d'Orbigny	×	---	---	---	---	(?)	(?)	×	×	---	---	Cretaceous and Paleocene.
**inepta* Cushman	×	---	---	---	---	---	---	---	---	---	---	
**insulsa* Cushman	×	---	---	---	---	---	---	---	---	---	---	
sp	×	---	---	---	---	---	---	---	---	---	---	
Nodosaria affinis Reuss	×	---	×	×	×	---	---	×	×	×	×	Cretaceous to Eocene.
latejugata Gümbel	×	---	---	---	---	×	×	---	---	---	×	Paleocene and Eocene.
cf. *N. amphioxys* Reuss	×	×	---	---	×	---	×	×	---	---	---	Cretaceous and Paleocene.
? cf. *N. longiscata* d'Orbigny	×	---	---	---	×	×	---	×	---	×	---	Cretaceous to Pliocene(?).
**Chrysalogonium arkansasanum* Cushman and Todd.	×	---	---	---	---	---	---	---	×	---	---	Paleocene.
**eocenicum* Cushman and Todd	×	---	---	---	---	---	---	---	---	---	---	
Pseudoglandulina manifesta (Reuss)	×	---	---	---	×	×	×	---	×	×	---	Upper Cretaceous to Eocene.
pygmaea (Reuss)	×	---	---	×	---	×	×	×	×	---	---	Upper Cretaceous and Paleocene.
Lingulina cf. *L. wilcoxensis* Cushman and Ponton.	×	---	---	---	---	---	---	---	---	---	---	Eocene.
Vaginulina midwayana Fox and Ross	×	---	×	---	×	×	×	---	×	×	---	Paleocene.
longiforma (Plummer)	×	---	×	---	×	---	---	---	---	---	×	Do.
plumoides Plummer	×	---	---	×	×	---	×	×	---	---	---	Do.
sp	×	---	---	---	---	---	---	---	---	---	---	
Palmula budensis (Hantken)	×	---	---	---	×	×	×	---	×	×	---	Paleocene and Eocene.
Frondicularia naheolensis Cushman and Todd.	×	---	---	---	×	---	---	---	---	×	---	Paleocene.
sp	×	---	---	---	---	---	---	---	---	---	---	
Lagena cf. *L. apiculata* Reuss	×	---	---	---	×	---	---	---	---	---	---	Upper Cretaceous to Recent.
cf. *L. laevis* (Montagu)	×	---	---	---	---	×	×	---	---	×	---	Paleocene to Recent.
cf. *L. costata* (Williamson)	×	---	---	---	---	---	---	---	---	---	---	Do.
Guttulina problema d'Orbigny	×	---	×	---	---	×	×	---	---	cf.	×	Upper Cretaceous to Recent.
hantkeni Cushman and Ozawa	×	---	---	---	---	---	---	---	---	×	---	Upper Cretaceous to Eocene.
Globulina												
gibba d'Orbigny	×	---	×	×	×	×	×	×	---	×	×	Paleocene to Recent.
rotundata (Bornemann)	×	---	---	---	---	---	---	---	---	---	×	Do.
cf. *G. minuta* (Roemer)	×	---	---	---	---	---	---	---	---	---	---	Eocene to Recent.
Pyrulina cf. *P. cylindroides* (Roemer)	×	---	---	---	---	×	×	---	---	---	×	Cretaceous to Recent.
extensa (Cushman)	×	---	---	---	---	---	---	---	---	---	---	Oligocene to Recent.
Pseudopolymorphina sp	×	---	---	---	---	---	---	---	---	×	×	Paleocene to Recent.
Sigmomorphina terquemiana (Fornasini)	×	---	×	---	---	---	---	---	---	×	×	Paleocene and Eocene.
wilcoxensis Cushman and Ponton	×	---	---	---	---	---	---	---	---	---	---	Paleocene.
Polymorphina cushmani Plummer	×	---	×	×	×	×	---	---	---	---	---	Do.
sp	×	---	---	---	---	---	---	---	×	---	---	Do.
Ramulina cf. R. *aculeata* (d'Orbigny)	×	---	---	---	---	---	---	---	×	×	---	Cretaceous and Paleocene.
Bullopora chapmani (Plummer)	×	---	---	×	×	×	×	×	×	---	---	Paleocene.
Guembelina midwayensis Cushman	×	×	×	---	---	---	---	---	×	---	---	Do.
Eouvigerina excavata Cushman	×	×	×	---	---	×	×	---	×	×	×	Paleocene and Eocene.
Pseudouvigerina naheolensis Cushman and Todd.	×	---	×	---	---	×	---	---	---	×	---	Do.
Siphogenerinoides eleganta (Plummer)	×	---	×	×	×	×	×	×	---	---	×	Paleocene.
Bulimina midwayensis Cushman and Parker.	---	×	---	---	×	---	×	---	---	---	---	Do.
cacumenata Cushman and Parker	×	---	×	---	×	---	×	×	---	×	---	Do.
(*Desinobulimina*) *quadrata* Plummer	×	---	---	---	×	×	×	---	×	---	---	Cretaceous-Paleocene.
Virgulina wilcoxensis Cushman and Ponton	---	×	×	---	---	×	×	---	×	---	cf	Paleocene-Eocene.
Loxostomum applinae (Plummer)	×	×	---	---	×	×	×	---	×	---	---	Paleocene.
plummerae Cushman	×	×	---	---	---	---	---	---	---	---	---	Do.
**Nodosarella paleocenica* Cushman and Todd.	×	---	---	---	---	---	---	---	---	---	---	Do.

See footnotes at end of table.

TABLE 4.—*Foraminifera and Ostracoda of the Wills Point formation in the Arkansas bauxite region and their occurrence in formations of the Midway group at other published localities in the Gulf Coastal Plain*—Continued

	Arkansas bauxite region			East Texas [b]		Clay County, Miss. [c]		Alabama				
	USGS loc. 17282	USGS loc. 17283	Kincaid fm. [d]	Kincaid fm.	Wills Point fm.	Clayton fm.	Porters Cr. fm.	lower bed, Sucarnoochee clay [e]	upper bed, Sucarnoochee clay [e]	Type Naheola fm. [f]	Coal Bluff marl member, Naheola fm. [g]	Previous known range
Foraminifera—Continued												
Ellipsonodosaria plummerae Cushman	X	----	----	X	X	X	X	----	X	----	----	Paleocene.
**midwayensis* Cushman and Todd	X	----	----	----	----	----	----	----	----	----	----	Do.
**paleocenica* Cushman and Todd	X	----	----	----	----	----	----	----	X	----	----	Do.
Valvulineria allomorphinoides (Reuss)	X	----	----	----	X	X	X	----	X	----	----	Upper Cretaceous and Paleocene.
Gyroidina subangulata (Plummer)	X	X	X	----	X	X	X	----	X	X	----	Paleocene.
Eponides plummerae Cushman	X	X	----	----	X	X	X	----	X	----	----	Do.
Siphonina prima Plummer	X	X	X	X	X	X	X	----	X	X	----	Upper Cretaceous and Paleocene.
Alabamina wilcoxensis Toulmin	X	X	X	X	----	----	----	----	----	X	X	Paleocene and Eocene.
Parrella expansa Toulmin	X	----	----	----	X	X	X	----	X	----	----	Do.
Allomorphina paleocenica Cushman	X	----	----	----	X	----	X	----	----	----	----	Paleocene.
Pullenia angusta Cushman and Todd	X	X	----	----	X	X	X	X	X	X	----	Do.
Globigerina pseudobulloides Plummer	X	X	X	X	X	X	X	X	X	X	X	Paleocene and Eocene.
triloculinoides Plummer	X	X	X	X	X	X	X	----	X	X	X	Do.
Anomalina acuta Plummer	X	X	X	X	X	X	X	----	----	----	----	Do.
midwayensis (Plummer)	X	X	----	X	X	X	X	----	X	----	----	Paleocene.
cf. *A. clementiana* (d'Orbigny)	X	----	----	----	----	----	----	----	----	----	----	Cretaceous and Paleocene.
Cibicides howelli Toulmin	----	X	X	----	----	----	----	----	----	----	X	Paleocene and Eocene.
praecursorius (Schwager)	X	X	X	----	----	X	X	----	----	X	X	Do.
vulgaris (Plummer)	X	----	----	X	X	X	X	----	X	----	----	Paleocene.
Ostracoda (identified by F. M. Swain)												
Cytherella tumidosa Alexander	X	----	X	X	X							
symmetrica Alexander	X	----	----	----	X	X	X					
Cytherelloidea howei Swain	X	----	X									
Bairdia suborbiculata Alexander	X	----	X	----	X							
n. sp	X											
Brachycythere plena Alexander	X	----	X	X	X	X	X					
interrasilis Alexander	X	----	----	X	X	X	X					
Cythereis cancellosa Alexander	X	----	----	X	X							
midwayensis Alexander	X	----	X	X	X							
sculptilis Alexander	X	----	----	X	X							
spiniferrima Jones and Sherborn	X	----	X	X	X	X	X					
prestwichiana Jones and Sherborn	X	----	X	X	X	X	X					
Loxoconcha corrugata Alexander	X	----	----	----	X							
perdecora Alexander	X	----	cf.	X	X							
Cythereopteron aligerum Alexander	X	----	----	X								
Cytheromorpha scrobiculata Alexander	X	----	----	X	X	X	X					
Cytheridea fornicata Alexander	X	----	----	X								
n. sp. aff. *C. everetti* Berry	X	---	X									

[a] Slightly revised from Cushman, J. A., and Todd, Ruth, 1946, Contr. Cushman Lab. Foraminifera Research, v. 22, pt. 2, no. 277, p. 45–65, pls. 7–11.
[b] Foraminifera from Plummer, H. J., 1926, Univ. Tex. Bull., no. 2644; Ostracoda from Alexander, C. I., 1934, Jour. Paleontology, v. 8, p. 206–237, pls. 32–35, 1 fig.
[c] Foraminifera and Ostracoda from Kline, V. H., 1943, Mississippi Geol. Survey, Bull. 53.
[d] See table 2, this report.
[e] Cushman, J. A., 1940, Contr. Cushman Lab. Foraminifera Research, v. 16, pt. 3, no. 222, p. 51–73, pls. 9–12.
[f] Cushman, J. A., and Todd, Ruth, Contr. Cushman Lab. Foraminifera Research, v. 18, pt. 2, no. 237, p. 23–46, pls. 5–8, 1942.
[g] Cushman, J. A., 1944, Contr. Cushman Lab. Foraminifera Research, v. 20, pt. 2, no. 255, p. 29–50, pls. 5–8.

NOTE: Species in the above list with holotypes from loc. 17282, are marked with an asterisk (*).

Regarding the ostracodes listed in table 4, Swain (written communication, 1946) comments,

> The evidence seems to favor a Wills Point age for this collection, although *Cytheridea fornicata*, according to Alexander, is restricted to the Kincaid. Of interest is the occurrence of *Cytherelloidea howei* which has been described from the Eocene of Maryland.

Recognizable fossils are rare in the dark bluish-gray clay of the upper part of the Wills Point formation in the Arkansas bauxite region. Scarcity of fossils in this part of the section together with its characteristic lithology probably constitutes the strongest argument for its correlation with the Kerens member of the Wills Point formation in Texas. The macrofauna of this clay consists principally of dark phosphatic scales or fragments of bones and plates of fish, and pale pyritized molds and casts of molluskan shells, and echinoid tests. A small pelecypod from the blue clay was identified by J. A. Gardner as *Cucullaea macrodonta* Whitfield, a typical Midway species. It came from USBM drill

hole 20–048, 90 feet east-northeast of the southwest corner, SW¼NW¼ sec. 9, T. 1 S., R. 12 W., at a depth of 192 feet, 27 feet above the base and 39 feet below the top of the formation. Though the blue clay in this region has long been considered to be of Midway age because of its lithologic similarity to the clay of the Midway formation in other areas, this is the first direct paleontologic evidence to substantiate such a correlation.

A few fragmental and entire pyritized leaves have been found in the upper part of the formation. The best preserved specimens of these came from USBM drill hole 15–187, in the SW¼NE¼ sec. 21, T. 1 S., R. 12 W., in blue-black silty pyritiferous clay at a depth of 320.8 feet, 4.1 feet below the weathered surface of the Wills Point formation. It was identified by R. W. Brown as genus and sp. indet. cf. *Myrica wilcoxensis* Berry.

Conditions of deposition.—The Wills Point formation records a widespread change of conditions from those that accompanied the deposition of the highly calcareous Kincaid sediments and their coarse clastic fraction. The sediments are uniformly fine in the upper part of the Midway throughout the Gulf region and rarely exceed coarse silt particle or fine sand grain size. Even on the slopes of the nepheline syenite hills in the bauxite region the detritus is much finer grained and more completely kaolinized than that intercalated with the lip of the Kincaid formation. This indicates that chemical decay played a larger part than mechanical disintegration in weathering during Wills Point time. From this we infer that throughout the region the platform was relatively stable and the erosion cycle on shore had reached a stage of late maturity or early old age in which sluggish rivers deposited most of the coarse sediments on land and discharged only the fine material into the sea during Midway time. This hypothesis is supported in the bauxite region by the abundance of minutely crossbedded silt in the deep parts of the basin opposite the mouths of the major subsurface drainage valleys and the presence in nearshore areas of fine clays. The coarser sediments probably are deltaic deposits. The detrital silt-sized quartz probably was derived from the rocks of the Paleozoic upland north of the area covered by the sea.

The partly calcareous clay typical of the Mexia member at the base of the formation with their prolific foraminiferal fauna represents a transitional stage that is common to the Gulf region. Plummer (1926, p. 33) has suggested that, in east Texas at least, a relatively rapid deepening of the sea at the beginning of late Midway time brought the sea bottom to a greater depth than at any other time during the period of Midway deposition. Plummer based this statement largely on the fineness of the sediments and the abunddance of hyaline foraminifers, particularly of some globigerine species. In the Arkansas bauxite region, however, the deposition of fine sediments was probably brought about by factors other than deepening of the sea. One of these factors, the normal evolution of the erosion cycle on the land to the north to an advanced stage, has already been mentioned. A shift in prevailing winds and major currents along the Paleocene gulf shoreline might also have limited the area of deposition of the coarser clastics to a much narrower shoreward zone and the sediments deposited therein may have been removed subsequently by erosion. Another possibility would be a change in climate accompanied by an increase in vegetational cover, which would have had the effect of slowing the rate of erosion.

The foraminiferal fauna of the Wills Point formation contains most of the Kincaid species. It differs principally in the considerable influx of new species, all of which however are in the same families that were represented in the Kincaid. The Lagenidae is the most characteristic and common. The relative abundance of *Globigerina* in this fauna does not necessarily indicate deep-water deposition. *Globigerina* is a pelagic genus whose distribution is controlled by surface temperature, salinity, and currents, and occasionally is found in beach sand (Twenhofel, 1932, p. 165). Distribution of the benthonic fauna probably was governed largely by factors such as normal salinity, wave or current action sufficient to keep the water aerated, and physical and chemical properties of the sea water such as the availability of sufficient lime for shell material, and high pH and content of phosphorus. The foraminiferal families that are represented in the collections from the basal part of the Wills Point have a wide bathymetric range at the present time, when compared with the results of studies made by Norton (1930) mostly in the Caribbean region. They are partly lacking in the very shallow water of the sublittoral zone, but all are present in the neritic, bathyal, and abyssal zones. Norton states that the Lagenidae, Textulariidae, and Buliminidae are common in the neritic zone that ranges in depths from 5 to 60 fathoms. These families, and particularly the first, include many characteristic species of fauna from the base of the Wills Point formation. The pelagic Globigerinidae and Globorotaliidae are predominant in the two deeper zones in the Caribbean at the present time. In the basal Wills Point fauna, the Globigerinidae are common but not predominant and are represented by only two species; the Globorotaliidae are absent. This evidence indicates deposition in the neritic zone provided that the relationship

of these families to ecologic environment has not changed radically since the Paleocene epoch.

In the foregoing paragraphs the basal clay beds of the Wills Point and their microfauna have been discussed, but these constitute only a small part of the formation. Most of Wills Point deposition took place under conditions that were not favorable to animal life. The notable percentage of black carbonaceous matter and iron sulfide in the sediments indicates that they were deposited under stagnant conditions in sea water rich in hydrogen sulfide and low in oxygen. Black mud of this type is formed at present in bodies of water with weak tides, such as the Baltic sea, and in deep holes in neritic bottoms, according to Twenhofel (1939, p. 304). The dark sediments of the Wills Point formation and its lateral equivalents are unique in that they occupy the entire north edge of the ancient Gulf of Mexico and extend a considerable distance seaward. The waters of this area must have had very little circulation, as evidenced also by the absence of ripple marks and by the even lamination. The laminae may mark annual or seasonal deposition of the sediments, which indicates that the amount of turbulence in the sea water was negligible. The gradual retreat of the sea at the close of Midway time left these sediments exposed to the air in a wide malodorous mudflat.

EOCENE SERIES—WILCOX GROUP

GENERAL FEATURES

Overlying the marine sediments of the Midway group in central Arkansas is a thick series of nonmarine sediments including sand, silt, gravel, clay, and lignite. At the base of the series in the vicinity of nepheline syenite masses that protrude through the Midway sediments, and to a lesser extent interbedded with the lower part of this continental section, are the bauxite deposits of central Arkansas.

A. F. Crider (1906, p. 25–28) proposed the name Wilcox formation for 850 feet of similar continental strata that lie between the marine beds of the Midway group below and the Claiborne group above in Wilcox County, Ala. These strata had earlier been called the "Northern Lignitic group" or the "Lignitic stage." The last name was used for the lower Eocene continental beds of the Gulf Coastal Plain in Arkansas by Harris (1894, p. 55–86; 1896, p. 1–36). However this name was discarded because it is a descriptive term that was loosely applied to several different stratigraphic units. The name "Sabine formation," proposed by Veatch (1906) for equivalent beds in northern Louisiana, southern Arkansas, and eastern Texas, was dropped by the U. S. Geological Survey in 1910 as being synonymous with Crider's Wilcox formation of the area east of the Mississippi River.

In more recent years the Wilcox has been regarded as a stratigraphic group. It has been subdivided into several formations, both continental and marine, in other parts of the Gulf Coastal Plain but in Arkansas geologists who have mapped and studied it, such as Stephenson and Crider (1916, p. 54–63), Spooner (1935, p. 118–120), and Bramlette (1936, p. 7, pl. 9), have not attempted to divide it into smaller units. In central and northeastern Arkansas it has been confused with the overlying Claiborne group which also is composed of nonmarine beds. The true contact of the Wilcox and Claiborne has never been clearly identified at the surface and has been only approximated in mapping. Some geologists have included the Wilcox with the Claiborne beds as undifferentiated continental strata of Eocene age.

In the present work on the Arkansas bauxite region, a threefold division of the nonmarine sediments of the Wilcox group is recognized, in ascending order: Berger formation, Saline formation, and Detonti sand. The basal beds of the Wilcox group as thus defined rest unconformably upon marine sediments of the Midway group. The uppermost beds are overlain by variegated clay and sand and thin lignite beds similar to those assigned in other parts of Arkansas to the Claiborne group. Whether this represents the true contact of the Wilcox and Claiborne must be decided by later studies.

Geologic mapping in Alabama, Georgia, and Mississippi since 1942 by members of the U. S. Geological Survey has radically revised the stratigraphic position of the Wilcox and Claiborne contact, lowering it considerably in most places. F. Stearns MacNeil (1950, oral communication) believes it likely that the Wilcox in the Arkansas bauxite region, on a lithologic basis, probably should be restricted to the Berger formation. This problem, however, can be solved only by regional studies and in this report current usage for Arkansas is being followed.

The total thickness of the Wilcox group was drilled through in 18 of the deep holes to check the results of the geophysical surveys. In some of these holes a considerable part of the Wilcox was cored. The combined thickness of the three formations of the Wilcox group in these drill holes ranges from 741 to 1,025 feet.

BERGER FORMATION

Definition.—The Berger formation is proposed to include all the terrestrial rocks between the unconformity at the top of the marine sediments of the Midway group and the unconformity at the base of the Saline formation. It comprises a section of gray and greenish-gray silty clay and argillaceous sand and some interbedded lignite and sideritic layers, between the

dark-gray marine clay below and the chocolate-brown silty to sandy clay beds above. Where the formation abuts the nepheline syenite masses it includes many bauxite deposits of the Arkansas bauxite region and the associated kaolinitic fragmental underclay. Most of the bauxite deposits that were explored during this investigation were formed during Berger time.

The formation receives its name from the Berger siding on the Iron Mountain branch of the Chicago, Rock Island, and Pacific Railroad about 4 miles south of Little Rock in Pulaski County, along the west line of sec. 4, T. 1 S., R. 12 W. This siding serves the plants of the American Cyanamid and Chemical Corp. and is adjacent to many bauxite pits in which the bauxite, gray clay, sand, black carbonaceous clay, and lignite of the formation are exposed. Three-fourths of a mile west of Berger at the Brittain siding the formation is exposed in both the railroad and the highway cuts. This locality shows the best exposures of the formation except those in the bauxite pits. The locality is described as the type section because of its continued availability. The pits, when abandoned, will rapidly fill with water and their walls slump, thus obliterating the exposures.

Distribution and surface outcrop.—The formation is exposed in a narrow discontinuous band of outcrop as much as 1½ miles wide. The outcrop area extends northeastward from Hurricane Creek in Saline County to the northeast end of Fourche Mountain in Pulaski County. West of Hurricane Creek the formation wedges out beneath the Saline formation. In Pulaski County the Berger formation is absent between the Saline and Wills Point formations in Tertiary outliers north of the main Midway and Wilcox contact. At its east end the outcrop area of the Berger is truncated by Quaternary sediments of the Arkansas River flood plain. Most of the Berger outcrops are distributed along the south side of the broad low valley of Fourche Creek that flows in a general northeasterly direction. Several large drainage channels on the old post-Midway erosion surface intersect and trend southeastward at right angles to the valley of Fourche Creek. These channels are filled with the thicker parts of the Berger formation and have been exposed by recent erosion, so that they are the most extensive outcrops of the Berger formation. Most of the outcrops, however, are hidden by surface sand that has slumped down from the overlying Saline formation and the Berger formation is exposed only in a few roadcuts, or where bauxite deposits have been hard enough to resist erosion and stand out as topographic rises.

The soft clay and sand beds of the Berger do not make good outcrops and the normally hard lignite and lignitic clay beds when exposed to the air quickly slack. Therefore a topographic surface cut in the Berger formation is flat and poorly drained, much like a surface on the Wills Point formation. The Berger formation has been mapped largely by projecting the information obtained in drill holes near the contacts and correlating the known outcrops, the topography, the knowledge of the overlap by the Saline formation, and the inferred extent of erosion of the overlying formations to determine the approximate outlines of the outcrop areas. It is possible that some of the low flat areas mapped as Wills Point actually are Berger, also that a small part of the area mapped as Saline formation actually is the Berger formation covered by a thick deposit of sand and ironstone from overlying formations. However, the drill-hole data that were used during mapping ensure a reasonable accuracy of the location of the contacts.

Thickness.—In natural surface outcrops the Berger formation reaches a maximum thickness of 25 feet. In some localities the outcrops are covered by surface sand and not visible to the observer, but are as much as 90 feet thick. In the bauxite pit mines the formation ranges from 2 to as much as 90 feet. Its lower contact with the Wills Point formation is rarely exposed in the pits.

Drill-hole data along the flanks of the nepheline syenite masses indicate that the formation thins abruptly upslope and toward the heads of the valleys on the old Midway surface, pinching out entirely against the nepheline syenite and rocks of Paleozoic age. Downslope the formation thickens considerably and reaches a maximum thickness of more than 300 feet. Holes drilled along a narrow northeasterly strip about tangent to the downslope bases of the buried Pulaski, Ledbetter, Sardis, and Saline nepheline syenite highs in Pulaski and Saline Counties penetrated a thickness of the Berger formation that ranges from 142 to 208 feet and averages about 185 feet. The greatest thickness of the formation was found in the holes drilled in the southeastern part of the bauxite region to check the results of the geophysical surveys. As interpreted from geologists' logs a maximum thickness of 347 feet was drilled in two holes: USBM 6–002 in the NE¼NW¼ sec. 31, T. 2 S., R. 11 W., in Pulaski County, and USBM 6–018 in the NW¼NE¼ sec. 14, T. 3 S., R. 13 W., in Grant County.

Lithologic character.—The Berger formation contains sediments with considerable lateral variations, but the outstanding lithic features of the stratigraphic unit are the general gray to greenish-gray color of its sand and clay and the scarcity or local absence of coarse clastic material. The formation levels off the irregularities of the old Midway surface, combining material locally derived and deposited in small tributary valleys with material brought from more distant and

varied sources. The sediments largely of local origin include lignite and other carbonaceous material, kaolinitic clay, bauxitic clay, and bauxite. The sediments of more foreign origin consist principally of silt and sand ranging from coarse to very fine. They vary widely in mineralogic constituents but include an appreciable quantity of feldspathic detritus.

The comparatively fine grain size of the quartz and the large amount of admixed feldspathic material, a great deal of which has weathered and forms a clay binder, distinguish sands of the Berger formation from those of later Eocene formations in the region. Decomposed feldspar in these deposits has been noted in drill holes as far downslope as Sheridan in Grant County.

The formation in the bauxite region contains about equal amounts of sand, silt, and kaolinitic clay, including small amounts of other clay minerals, bauxite and bauxitic clay, lignite and lignitic clay, and sideritic siltstone in lenticular layers as much as 2 feet thick. Although some of the sand is coarse, and locally contains a basal clayball conglomerate bed as well as several intraformational conglomerate beds, most of the sand of the Berger formation is fine grained. Locally the formation also contains sideritic or limonitic concretions. Some of the limonitic concretions are flattened, are as much as a foot in length long, and are partly hollow inside. Most of the sideritic concretions are solid, granular, and reach a maximum of 3 feet in length. Some solid ferruginous concretionary lenses in the overburden of the bauxite pits preserve the bedding of the clay and silt contained in them and reach a length of 15 feet and a thickness of 18 inches.

A section of the Berger formation at its type locality at the Brittain siding exposure, three-fourths of a mile southwest of Berger, follows:

Section on the south side of the Chicago, Rock Island, and Pacific Railroad tracks on the east side of the viaduct and road crossing the tracks at the Brittain siding, Pulaski County, in the SE¼SW¼ sec. 5, T. 1 S., R. 12 W.

[The section extends from the bottom of the borrow pit north of the tracks and continues southward along the east side of the viaduct to the road level, then eastward to the top of the hill. Measured by M. W. Ellis]

	Thickness (feet)	*Approximate altitude top of bed (feet)*
Wilcox group:		
Saline formation:		
Covered interval, low flat slope littered with slabs of hard limonitic concretions and indurated sandstone	8.0	313.0
Covered interval, steep slope littered with slabs of hard limonitic concretions and indurated sandstone	6.0	305.0
Sand, red, yellow, and brown, medium- to coarse-grained, mostly well rounded clear quartz with a few beds containing white or pinkish clay balls and fragments from 1/64 to 3/8 inch in diameter. Beds range from 2 inches to 2 feet in thickness and are crossbedded; discontinuous layers of hard limonitic concretionary layers or indurated sandstone separate beds	19.3	299.0
Sand, white, medium- to fine-grained, mostly well rounded and sorted quartz, but containing abundant small weathered mica flakes, somewhat clayey	.7	279.7
Clay, chocolate-brown, silty to sandy, containing abundant mica, carbonaceous, thin-bedded, with sand and mica on bedding planes. Rests unconformably upon bed below	1.5	279.0
Berger formation:		
Clay, medium-to light-gray, dries white, massive, and has an irregular hackly fracture, contains abundant fine silt and scattered small brownish carbonaceous fragments. Sample 120	6.0	277.5
Clay, same as above and below except that it is darkened by more abundant carbonaceous matter. Sample 121	1.0	271.5
Clay, gray, with some yellow or orange staining and mottling by iron oxide. Contains abundant silt and some irregularly distributed fine-grained quartz sand as well as scattered brownish carbonaceous fragments. Siderite common in small disseminated pellets, most of which are partly altered to limonite. Large round brown limonite-stained siderite concretions, some reach a maximum of more than 1 foot in thickness. Bedding is apparent only in the lower few inches which are laminated and contain less silt. Sample 122	7.5	270.5
Lignite, brownish-gray to black. A dark-gray carbonaceous silty clay containing thin brownish-black stringy carbonaceous seams and a few thin (½–1 inch) layers of soft, spongy, sooty lignite. Most of the interval is poorly bedded as the carbonaceous seams are discontinuous, but in the upper part the bedding is more apparent and a 1-inch layer of medium-gray clay extends throughout the small exposure	1.8	263.0

Section on the south side of the Chicago, Rock Island, and Pacific Railroad tracks on the east side of the viaduct and road crossing the tracks at the Brittain siding, Pulaski County, in the SE¼SW¼ sec. 5, T. 1 S., R. 12 W.—Continued

	Thickness (feet)	*Approximate altitude top of bed (feet)*
Berger formation—Continued		
Clay, gray, darker at the top because of carbonaceous stain and a few rootlike carbonaceous fragments, some small spherical bodies filled with a yellowish granular clay occur sporadically. Sample 123	0. 7	261. 2
Clay, cream-gray, somewhat harder and tougher than the intervals above and below—gradational contacts. This clay is somewhat porous and contains spherical cavities about three-sixteenths inch in diameter as well as some clayey pisolitic structures. Samples 124 and 125	2. 5	260. 5
Clay, cream-gray to gray, somewhat porous at top but denser at depth, contains abundant disseminated limonite-stained pellets and aggregates of pellets which were probably siderite remnants. Limonitic films in irregular cracks in the clay. Sample 126	1. 5	258. 0
Covered interval ±100 feet wide occupied by railroad right-of-way	3. 0	256. 5
Clay, yellowish brown, limonitic, apparently a continuation of the interval across the tracks. The limonite is apparently replacing siderite pellets which occurred in abundance, particularly at the base of the interval. This part is very near the surface of the ground and is poorly exposed. (Sample 127. May be contaminated.)	3. 5	253. 5
Total thickness of the Berger formation	27. 5	--------
Midway group:		
Wills Point formation:		
Clay, white, stained with red and yellow iron oxide; some fine indistinct micaceous flakes and some traces of bedding are apparent. Breaks with a more nearly conchoidal fracture than any of the above clays and has a soapy appearance and touch. Sample 128	2. 0	250. 0
Clay, light- to dark-gray with red and yellow iron oxide stains; the upper part is mottled but the lower part is banded. Bedding is distinct but the clay breaks across the bedding with a conchoidal fracture and soapy appearance; fine micaceous flakes throughout. Samples 129 and 130	4. 0	[1] 248. 0
Clay, dark-gray, silty, micaceous, very plastic; breaks easily along micaceous bedding planes and conchoidally across bedding	3. 0	[1] 244. 0

[1] The lower 4 feet of this section is normally below the level of the water in the borrow pit at this point. A hand auger was used to determine the top of the fresh clay of the Midway.

Chemical analyses were made of some of the clay in the foregoing section. Analyses of the samples and altitude at which they were collected are as follows:

Analyses of clay samples from the Berger and Wills Point formations, Brittain siding exposure, Pulaski County, Ark.

[Samples 120–127 inclusive from the Berger formation; 128–130 from the Wills Point formation. Collector, M. W. Ellis. See section for more detailed localities of samples. Analyses by field laboratory of the U. S. Bureau of Mines, Little Rock, Ark.]

Sample	Altitude	Al_2O_3	SiO_2	Fe as Fe_2O_3	TiO_2	Ignition loss	Insoluble	FeO
120	274. 0	21. 5	66. 7	1. 0	1. 1	6. 7	3. 0	0. 3
121	271. 0	12. 2	78. 7	1. 2	1. 9	4. 0	2. 0	. 2
122	263. 4	29. 8	40. 3	14. 7	2. 0	11. 5	1. 7	. 2
123	261. 0	39. 2	41. 0	1. 1	2. 5	15. 0	1. 2	. 3
124	260. 0	40. 5	40. 8	1. 0	2. 3	14. 8	. 6	. 2
125	258. 5	39. 2	42. 5	1. 1	2. 8	13. 5	. 9	. 2
126	258. 5	38. 5	43. 7	1. 5	2. 0	13. 3	1. 0	. 2
127	252. 0	29. 0	46. 2	9. 8	2. 0	11. 5	1. 5	. 2
128	249. 0	26. 9	58. 8	4. 5	1. 1	8. 2	. 5	. 3
129	247. 0	26. 2	59. 3	4. 7	1. 1	8. 1	. 6	. 3
130	245. 0	25. 6	63. 8	1. 4	. 8	7. 6	. 8	. 2

Facies types.—Three distinct facies can be distinguished in the sediments referred to the Berger formation. These are deposits of bauxite, bauxitic clay, and kaolinitic clay that form a considerable part of what has been referred to by Bramlette (1936, p. 6) and other geologists as the "bauxite-kaolin zone;" deposits of lignite, lignitic clay, and gray silty clay that overlie the bauxite deposits in many open-pit mines; and deposits of gray "salt and pepper" or grayish-green sand that occupy channels in the lignitic beds in the overburden sections at several of the bauxite pits, that underlie lignite beds locally in several of the drilled areas, and that form a major part of the formation downslope from the bauxite area.

In the main subsurface drainage channels most of the Berger formation is composed of sand brought from the area of rocks of Paleozoic age to the northwest. Upslope, near the nepheline syenite hills, much of the sedimentary material in the formation is of local origin, and the sandy facies is absent at many localities. Where all three facies are present in the bauxite pit areas they usually occur in vertical section in the order listed above from base to top. The diagrammatic sketch, figure 7, shows the probable relationship between these three facies, particularly in the area along the west flank of the Pulaski nepheline syenite high and the east flank of the Saline dome.

The bauxite-kaolin facies is not a true stratigraphic zone, hence the term "bauxite-kaolin zone" is not employed in this discussion of the stratigraphy. It is a local lithic facies composed of weathered materials derived largely from the nepheline syenite and deposited at the lip of the formation along the nepheline syenite hills during the entire span of Berger time. The limited distribution of this facies as a fringe around the

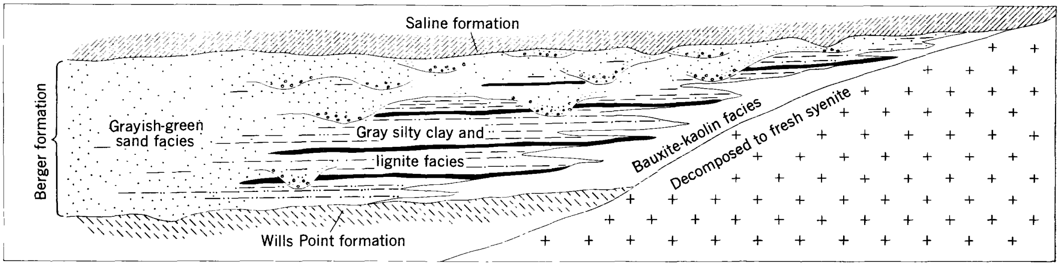

FIGURE 7.—Diagrammatic sketch showing the probable relationship of the three principal lithologic facies of the Berger formation at its upslope lip.

Pulaski nepheline syenite hill is shown on the subsurface map (pl. 2). The basal part of the bauxite-kaolin facies is a gray clay, normally fragmental and irregularly mottled by red iron oxide stain. It commonly contains a considerable amount of material derived from the immediately underlying rock as can be noted where the underlying rock is shale of Paleozoic age or clay of the Wills Point formation, weathered fragments of which can be easily recognized. Most of the material, however, is detritus derived from the weathered nepheline syenite higher up on the slopes and contains unaltered minerals of the parent rock, such as tiny ilmenite and, less commonly, magnetite grains. The fragmental clay also contains siderite in small flesh-colored pellets, generally about a millimeter in diameter but locally as much as 5 millimeters, or in larger aggregates or pockets of pellets. Upward toward the center of the bauxite-kaolin facies the clay is gradually less siliceous and in many places is gibbsitic and locally contains small fragments of bauxite. Irregular lenticular bodies of pisolitic bauxite occur in the middle of the bauxite-kaolin facies at closely spaced intervals laterally along the flanks of the nepheline syenite masses. The upper few feet of the interval is generally kaolinitic, gradually increasing in silica upward. At some localities the clay is fragmental. Above bauxite ore bodies the clay commonly is pisolitic and hard or tough, though composed largely of kaolin. The upper contact of the interval is normally an abrupt gradation upward to the overlying lignite and gray-clay facies. The total thickness of the bauxite-kaolin facies reaches 100 feet at several localities, notably in the SW¼NE¼ sec. 33 and the NW¼NW¼ sec. 36, both in T. 2 S., R. 14 W., but in most of the region it is less than 50 feet thick. The clay and bauxite deposits of this facies are described more fully in the economic section of this report, following page 169.

A lignitic bed directly overlies the bauxite-kaolin facies at many localities. This may be either a black carbonaceous kaolinitic clay or it may consist of as much as 6 feet of hard blocky woody lignite containing soft fissile layers of clayey partings. The bedding usually is well marked where the lignite is hard and fairly pure, but is not obvious where carbonaceous clay is present. Normally, light- to dark-gray or greenish-gray silty clay, 2 to 8 feet thick, overlies the lignitic bed. At some places this bed is kaolinitic and comparatively silt free; elsewhere it may consist of well-rounded pebbles and hard pisolites of bauxite that locally are sorted, stratified, or even crossbedded. The last occurs commonly where the underlying lignite bed rests directly upon pisolitic bauxite. The clay or bauxite bed above the lignite may be overlain by another bed of lignite or carbonaceous clay, kaolinitic clay or sandy to silty clay. This succession of beds or parts of it locally are repeated several times in ascending section and the succeeding clay beds often contain considerable silt and fine sand. As much as 60 feet of the lignitic interval is found overlying the bauxite-kaolin facies downslope from its outcrop. The top of the lignite and gray clay interval in some places is gradational upward into gray silty to sandy clay, and in other places is an irregular erosional contact caused by intraformational channeling. Later channels cut earlier ones across beds of the lignite. They reach 200 feet in width and are more than 20 feet in depth.

The beds of the third and uppermost lithologic facies in the bauxite pits of the Berger area are gray or greenish-gray silty to sandy clay and sand. Some parts are thin bedded, some massive; crossbedding is common (fig. 8) and thick irregular beds or large pockets of intraformational conglomerate are present locally. Clay "boulders" in these conglomerate beds in places are 3 to 5 feet in diameter but commonly are pebble size, ½ to 1 inch across. Most of the "boulders" and particularly the large ones are angular and are composed of gray to greenish-gray silty clay and sand derived from the Berger formation. Locally, near the base of the sandy interval, bauxite pebbles or lignite fragments and rarely fragments of the Wills Point formation or clay are derived from the kaolinization of nepheline syenite. The matrix of the conglomerate is a coarse greenish-

FIGURE 8.—Section of the Berger formation exposed in the east wall of the Winn mine near Berger, Pulaski County. It is about 65 feet from the ground surface to the top of the bauxite. Stripped waste (*a*). Grayish-green silty sand, gently cross-bedded (*b*). Lignite and cream to gray silty clay (*c*). Pisolitic bauxite bed, clayey at top (*d*).

gray sand. At some localities along the flanks of the nepheline syenite hills, lenses of white kaolinitic clay contain some sand or silt and more rarely small lenses of low-grade bauxite or bauxitic clay. These lenses are downslope from bauxite deposits of the bauxite-kaolin facies, and occupy channels that locally cut into the bauxite. The bauxite lenses are fragmental and some contain concentrations of dark heavy-mineral grains, particularly ilmenite, in small pockets and irregular layers. In drilled sections at several localities silty and kaolinitic clay beds, lignite, and bauxite beds have been found stratigraphically above sandy beds of the grayish-green sand facies. Surface exposures showing this relationship have not been observed. The sandy facies of the formation exposed in some of the bauxite pits near Berger reaches 60 feet in thickness, but drill-hole information indicates that it is considerably thicker basinward.

The three lithic facies described above grade into one another laterally and transgress the section at a low angle. The probable relations of the sediments are shown on the diagrammatic sketch, figure 7. Bauxite and kaolin are at the upslope edge of the formation on the surface of the weathered nepheline syenite. Lignite and carbonaceous clay are a short distance downslope on the same depositional surface of the Berger, and sand and silt are found farther out in the basin. The sand and silt encroach upslope on the lignite and clay, and the lignite and clay encroach upon and cover the kaolin and bauxite.

This relationship is also shown in the series of correlated columnar sections of drill holes along a northwestward-trending line in the Hurricane Creek drilling area in secs. 17 and 18, T. 2 S., R. 13 W., shown on plate 4. Location of the section is shown on plate 2. The line of sections extends from a subsurface drainage, sec. 18, T. 2 S., R. 13 W., Saline County, Ark., on the post-Midway surface upslope through the Hurricane Creek deposit. The stratigraphic features shown by these sections include the green sand as the dominant part of the Berger in the major subsurface drainage channels; the unconformity at the base of the Berger formation with the underlying Wills Point clay locally eroded so that the Berger formation rests on residual clay derived from the nepheline syenite; passage laterally and upslope of greenish-gray sand and bluish-gray "salt and pepper" clayey sand, through gray to white clayey sand, to dark-gray sandy clay, to lignite and carbonaceous clay; wedging out of this same lignite and carbonaceous clay between kaolinitic and bauxitic clay of the bauxite-kaolin facies; wider distribution of the sandy facies in the upper part of the Berger formation; the almost complete wedging out upslope of the Berger formation; and channeling of the top of the Berger formation by dark-brown carbonaceous sandy clay of the overlying Saline formation.

The lateral gradation of the lignitic and the bauxitic facies of the Berger formation also is indicated by sections observed in several of the bauxite pits and by a study of some of the closely drilled areas such as the ore bodies of the Woodyardville area in Pulaski County. Holes delimiting the Thomas-Williams bauxite deposit in secs. 35 and 36, T. 1 S., R. 14 W., in Saline County, cut as much as 10 feet of fragmental lignite and carbonaceous clay which had been deposited under the bauxite in the bottom of small enclosed basins on the weathered surface of the Midway. The carbonaceous clay is overlain by a thin fragmental underclay of the Thomas deposit. Along the north face of the Elrod bauxite pit in Saline County, beds of lignite and light-gray clayey sand are increasingly more kaolinitic and thinner upslope to the point where they merge inconspicuously into the kaolinitic clay in the upper part of the bauxite-kaolin facies.

In the vicinity of Woodyardville, holes drilled in beds of lignite and kaolinitic clay cut nearly horizontally through the bauxite of the Birnbach No. 1 deposit in the NW¼NW¼ sec. 11 and the Birnbach No. 3 deposit in the SW¼NW¼ sec. 11, T. 1 S., R. 12 W. These beds continue downslope into a typical lignitic facies. Lignite and carbonaceous clay beds between two bodies of bauxite have also been found at several other localities on the southeast flank of the Pulaski nepheline syenite hill, notably in the southern part of the Ratcliffe bauxite deposit in the E½SE¼ sec. 24, T. 1 N., R. 12 W.; also in the Glidewell deposit located in the SE¼NW¼ sec. 11, T. 1 S., R. 12 W. near the Birnbach

deposits mentioned above; and on the southwest side of the Brown bauxite deposit in the E½SE¼ sec. 15, T. 1 S., R. 12 W. A bed of lignite about 14 inches thick, which dips as much as 8° northwestward, divides the bauxite in the southern part of the Rummel deposit on the west side of the Pulaski nepheline syenite high, in the NE¼SE¼ sec. 21, T. 1 S., R. 12 W. In Saline County, where the Berger formation does not extend as high up on the nepheline syenite hills, lignite beds that cut bauxite deposits are less common. However, a wedge of lignite and clay is in the southern part of the thick bauxite deposit mined by the Reynolds Mining Corp. on the Fletcher 40, in the SE¼SW¼ sec. 11, T. 2 S., R. 14 W. In all the areas, the lignitic beds wedge into the bauxite deposits from the downslope side, and the bauxite above the lignite bed shows features of water deposition such as sorting, stratification, crossbedding, and small channels that locally contain pockets of loosely cemented hard pisolites and pebbles of bauxite. The Fletcher 40 deposit also shows channeling below the lignite and clay wedge, and several of the channels in the bauxite contain lignitic detritus.

The lateral gradation and the interfingering of the lignitic and the sandy facies of the Berger formation are indicated in the area drilled in secs. 29 and 32, T. 1 S., R. 13 W., where along the west flank of a major subsurface drainage system thick sections of gray silty clay and thin lignite beds were cut by the drill a short distance upslope from thick sections of greenish-gray clayey sand and interbedded gray silty clay.

In the major subsurface drainage systems and farther downslope in the basin, most of the section as shown by drill holes is silty and sandy, and lignite beds are scarce and thin where present. The following log of a drill hole in which the entire thickness of the Berger formation was cored will show the gradational and almost rhythmic succession of beds where the formation is thick.

Partial log of USBM drill hole 6–026

Location: SE¼SE¼NE¼ sec. 7, T. 2 S., R. 11 W., 2 miles northwest of Woodson, Pulaski County, Ark.
Elevation collar: 254.7 feet
Geologists: J. I. Tracey, Jr., and J. H. Morris

	Thickness (feet)	*Depth (feet)*
Berger formation:		
Silt, gray, laminated, micaceous; contact with overlying Saline formation very sharp; grades downward to interval below	8	570–578
Clay, dark-brown, waxy, carbonaceous, containing thin beds of lignite in middle of interval; grading in lower foot to interval below	7	578–585
Silt, clayey, to silty clay, green, grading downward through gray to greenish-brown, laminated, waxy	11	585–596

Partial log of USBM drill hole 6–026—Continued

	Thickness (feet)	*Depth (feet)*
Berger formation—Continued		
Clay, brown, carbonaceous containing some lignite	1	596–597
Clay, silty, light-brown, grading through green silt to interval below	2	597–599
Sand, light-green, fine-grained, chiefly quartz and feldspar, soft (indurated layer 606–607); increasingly silty in lower part of interval	14	599–613
Silt, clayey, medium-greenish-brown	1	613–614
Lignite and clayey lignite	4	614–618
Silt, brown, grading downward to green	2	618–620
Silt, and silty clay, green to greenish-brown, locally poorly laminated and interbedded with light-tannish-gray, fine-grained sand	24	620–644
Clayey silt, brown, grading to silty clay	10	644–654
Lignitic clay, dark-brown, with beds of lignite, 1 to 2 inches thick	9	654–663
Sandy clay, grayish-brown, grading through tan silty clay to carbonaceous clay and lignite	9	663–672
Silty clay, light-bluish-gray, plastic, grading downwards in about 4 feet to a brownish-gray, very fine grained, soft, feldspathic sand	23	672–695
Clayey silt, gray, grading to dark-gray, micaceous, carbonaceous with a few local fine laminae; several thin beds of greenish-gray and dark-gray, fine-grained sand are in the lower part of the interval and at 711 feet is an indurated sideritic siltstone 0.2 foot thick	48	695–743
Sand, light greenish-gray, fine-grained, soft, with silty laminae grading in 15 feet to dark-green, medium-grained, unsorted loose sand, composed of about 75 percent quartz and feldspar grains and 25 percent light- to dark-green decomposed grains. A 1.5-foot silt ball conglomerate bed marks the base of the interval	23	743–766
Conglomerate, soft bauxitic pisolites in a white sandy clay matrix; sand grains same type as in overlying interval	1½	766–767. 5
Total thickness of Berger formation cored	197+	

The basal part of the greenish-gray sand that occupies the lower part of the Berger formation in many of the major drainage areas contains bauxite fragments and reworked pisolites at many localities and lignite fragments at some. This indicates that the basal sand is younger than some of the bauxite deposits and lignite beds of the formation.

Relation to underlying rocks.—In most of the bauxite area the Berger formation rests upon the eroded and weathered surface of the Wills Point formation. Along the lower slopes of the nepheline syenite hills it generally

overlaps the Wills Point and rests on residual clay derived from weathering of the nepheline syenite or the rocks of Paleozoic age. In larger subsurface valleys, scour during or before the deposition of the Berger has removed the Wills Point formation, and the Berger rests upon calcareous beds of the Kincaid or upon the basement rocks.

Fossils and correlation.—Only a few plant remains have been found in the Berger formation. Most of them are fragmentary or unidentifiable leaves or stems, except for several small but moderately well preserved leaf imprints found in cores taken in exploratory drill holes. One of these from a sideritic siltstone layer immediately overlying the bauxite at a depth of 250.7 feet in USBM drill hole 6–143, in the SW¼SE¼ sec. 16, T. 1 S., R. 12 W., in Pulaski County, was identified by R. W. Brown as *Cercidiphyllum arcticum* (Heer) Brown (=*Cercis wilcoxiana* Berry), a typical Wilcox species.

A thin layer of brownish-gray carbonaceous silty clay in the upper part of the Berger formation, a few feet above the water level in the abandoned McGuire bauxite pit, has yielded a small but well-preserved flora. The fossil collection from locality 9063, made near the access road at the south side of the pit, was studied by R. W. Brown who reported that the following species indicate an Eocene age and the zone probably represents the early part of the Wilcox group.

Locality 9063. McGuire bauxite pit, south side. NE¼NE¼ sec. 8, T. 1 S., R. 12 W., five-eighths mile southwest of Berger, Pulaski County. In the Berger formation, 8 feet below the top.

[Collected by M. Gordon, Jr., M. W. Ellis, and J. I. Tracey, Jr. in 1945]

Anemia eocenica Berry
Unidentified monocotyledon
Ficus mississippiensis (Lesquereux) Berry
    myrtifolia Berry
Cercidiphyllum arcticum (Heer) Brown
Artocarpus pungens (Lesquereux) Berry
Menispermites wilcoxensis Berry
Fragments of other dicotyledons

In recent years in other parts of the Gulf Coastal Plain geologists have been placing the base of the Wilcox group at the base of the *Ostrea thirsae* bed or its supposed lateral equivalents where the marine facies is developed. This relegates to the Midway group in parts of that region some continental and deltaic beds overlying the black clay of the Midway, formerly considered to belong in the Wilcox group. In the Sabine uplift area in northwestern Louisiana deltaic beds deposited along a fluctuating seashore and aggregating more than 600 feet in thickness now are divided into three formations, the Naborton, Logansport, and Hall Summit formations, from oldest to youngest, all assigned to the Midway group (Murray and Thomas, 1945, p. 45–70). Some of these beds contain marine fossils believed to be of Midway age (Barry and Le Blanc, 1942; and Murray, 1941, p. 738–742), and others contain fossil leaves formerly thought to be typically of Wilcox age by Berry (1916, p. 56–57). As the succession of marine invertebrate faunas of the Gulf Coastal Plain is much better known than that of the terrestrial floras, the implication of these Louisiana fossils is that the flora of Midway age, if ever found in abundance, may contain many of the same species of plants as the flora of Wilcox age. Some of the abovementioned beds of the Sabine uplift are probably equivalent to the upper part of the Wills Point formation in other areas, but some are thought to be younger.

The stratigraphic succession in Louisiana suggests that in the Arkansas bauxite region continental sediments may have been deposited during the retreat of the sea in Midway time while marine sediments were being deposited farther downslope, and therefore that at least part of the Berger formation may be of Midway age. On the other hand, F. S. MacNeil (oral communication, 1950), who has mapped and studied the Coastal Plain sediments east of the Mississippi River and who has also seen the section in the Arkansas bauxite region, stated that the Berger formation is similar lithologically to the Wilcox of Alabama and Mississippi and is unlike any of the Midway sediments that he has examined. The writers, therefore, are following earlier workers in considering the lower continental sediments in the bauxite region to belong in the Wilcox group.

Conditions of deposition.—The sediments of the Berger formation are continental and combine material locally derived from the weathered nepheline syenite and the surface of the Midway group with material brought from a greater distance, some of it from outside the region. Much of this foreign material had its origin in the rocks of the upland that fringes the bauxite region along its north and northwest edges and the green color of many of the Berger sands in the major drainage area probably is in part due to chloritic detritus from these altered shale and sandstone beds of Paleozoic age.

The withdrawal of the sea during Midway time from the bauxite region resulted from a broad gentle uplift of the land mass at the north edge of the Paleocene shoreline. The sea gradually withdrew almost half the distance to the present Gulf Coast, and the sediments of the former sea bottom were exposed to weathering. The islands of nepheline syenite rock that had been eroded during Midway time now became low hills standing above the muddy flatlands. A drainage pattern was established on the Midway sediments, controlled in part by compaction over earlier drainage cut in the harder rocks. A period of weathering began

under a tropical or subtropical climate, as indicated by the bauxitization of part of the igneous rocks. Deposition began in the valleys and depressed areas, and weathering of the pre-Wilcox rocks was confined more and more to the elevated parts of the region.

Bauxite and kaolinitic clay formed as weathering products particularly of the nepheline syenitic rocks, almost concurrently with the withdrawal of the sea from the bauxite region. The period of bauxitization may have lasted throughout Berger time.

Probably the first sediments deposited at this time were the fragmental kaolinitic clay layers of the lower part of the bauxite-kaolin facies. These were laid down as a series of coalescing fans that formed a peripheral band around the lower slopes of the nepheline syenite hills. Into the upper clay layers were brought fragments of bauxite and bauxitic clay that were being formed farther upslope. Once the drainage system in the bauxite region had attained a state of equilibrium, a period of alluviation began with an accompanying rise in base level. The coarse sediments, mostly sands of Paleozoic age from the uplands to the north, were deposited in the major channels; finer sediments and carbonaceous material such as lignite, lignitic clay, and silty or nonsilty and kaolinitic clay were deposited along the margin of the major drainage channels and in lesser tributaries; and colluvial and alluvial aprons of bauxite and bauxitic and kaolinitic clay continued to be deposited at the base of the nepheline syenite slopes at the upslope edge of the formation.

The lignite resulted from the accumulation of vegetation, either where it grew in swampy areas of the flatland, or where it was washed into valley bottoms. The beds of lignitic and carbonaceous clay in the basal part of the fragmental kaolinitic underclay of the Thomas-Williams bauxite deposit in Saline County, occupy the bottom of small closed basins and indicate that vegetal matter probably accumulated before as well as during and after the deposition of the bauxite-kaolin facies. However, these materials were preserved only where conditions were peculiarly favorable for preservation, or conversely, where they were unfavorable to the abundant growth of micro-organisms that would destroy the carbonaceous residue of the macroflora almost as fast as it was formed.

As the base level of deposition rose the sedimentary material deposited by the main streams encroached upon the more locally derived sediments. The bauxite-kaolin facies was deposited higher and higher on the weathered nepheline syenite slopes, lignite and clay beds were deposited on parts of the bauxite-kaolin facies, and sandy strata on top of the lignite and clay beds. During late Berger time sand and silt from the major drainage channels were deposited throughout most of the area, and only at the upper end of small tributary valleys did the locally derived nonsilty clays continue to be deposited. At some localities erosion became more vigorous along the slopes of the nepheline syenite hills, and new channels were cut through the earlier deposited Berger sediments and were filled by green sand and silty clay brought in by the streams as well as by rubble from adjacent slopes. The final effect of Berger deposition was the leveling of the region by the widespread deposition of silt and fine sand carried by sluggish though seasonally active rivers.

SALINE FORMATION

Definition.—The name Saline formation is here proposed for the thick section of dark chocolate-brown laminated clay and silt and interbedded white, tan, orange, and red sand that lies above the top of the Berger formation and beneath the basal woody lignite bed of the Detonti sand. It is the most widely exposed of the Tertiary formations in Saline County. West of Hurricane Creek it rests directly upon the bauxite deposits in the bauxite pits where many good sections are temporarily exposed. The formation takes its name from the Saline River and the best exposures are on the east bluff near the Benton pumping station. The section in the large road cut immediately north of the pumping station, several hundred feet east of the northwest corner, SW¼SE¼ sec. 25, T. 2 S., R. 15 W., is considered to be the type locality of the formation.

Distribution and surface outcrop.—The formation crops out at the surface in an irregular band as much as 9 miles wide that extends in a northeasterly direction across the bauxite region and surrounds or covers a part of every nepheline syenite hill. The outcrop area has been mapped from the east bank of the Saline River in Saline County to the west bank of Fourche Bayou near Sweet Home in Pulaski County where the formation wedges out beneath a thick section of Quaternary alluvium of the Arkansas River flood plain. The outcrop area of the formation continues west of the Saline River but has not yet been traced.

Though composed largely of soft sediments, the formation is more resistant to weathering and erosion than the other older formations of Tertiary age in the area. This has given rise to a steeply rolling topography of rounded ridges and gullied hills separated by broad shallow valleys occupied by the major drainage streams. Most of the area underlain by the Saline formation is well drained except for a few swampy places.

Most of the good exposures of the beds are in road and railroad cuts, in the bauxite pits, and along the

banks of some streams. The thick clayey sand soil that usually is formed on the Saline formation is covered, except where the land has been cleared and cultivated, by a thick growth of oak and other hardwood trees and locally by some pine trees.

Thickness.—The Saline formation is about 350 feet thick at the type locality on the east bank of the Saline River. East of the river, between the type locality and Hurricane Creek, the thickness along the north edge of the outcrop of the Detonti sand has been determined from many exploratory drill holes. The thickness in holes drilled by the U. S. Bureau of Mines and by bauxite companies ranges from 287 to 370 feet. The formation thickens abruptly, though somewhat irregularly, basinward and reaches its maximum logged thickness of 495 feet in an Alcoa Mining Co. drill hole at the center of the east line of sec. 11, T. 3 S., R. 14 W.

On the west slope of the buried Ledbetter nepheline syenite high the difference between a surface elevation on the top indurated bed of the formation and the interpolated elevation of the top of the Berger formation between two company drill holes indicates that the Saline formation is about 190 feet thick in the NE¼SE¼ sec. 27, T. 1 S., R. 13 W. A similarly derived estimate at a locality about a mile downdip indicates that the thickness is 278 feet in the SE¼SE¼ sec. 34, T. 1 S., R. 13 W. In the northeast corner of Grant County USBM drill hole 6-003 in the NE¼NE¼NW¼ sec. 6, T. 3 S., R. 12 W. showed the thickness of the formation to be 375 feet.

The formation is thin over the buried Woodson nepheline syenite hill in the southeastern part of the bauxite region. In USBM drill hole 6-026 about 2 miles northwest of Woodson a thickness of only 165 feet was recorded. Thus the known thickness recorded in drill holes for complete sections of the formation ranges from 165 to 495 feet.

Lithologic character.—Although somewhat variable in composition, the Saline formation consists of several types of sediments, the general appearance and character of which are fairly uniform. An estimate of overall composition is three-fifths sand, one-third carbonaceous clay, silty clay, and silt, and the remainder composed in order of decreasing abundance, of gravel and rubble, gray argillaceous clay, siderite concretions and ferruginous layers, and lignite. Despite the predominance of sand, it is the chocolate-brown carbonaceous clay that gives the formation its distinctive character. This clay is common in the overburden of the bauxite pits as it is widespread in the lower part of the formation. In the Saline bauxite district the clay is interbedded and interlaminated chiefly with a nearly equal amount of fine- to medium-grained white micaceous sand. In Pulaski County the relative amount of sand and silt is much higher, and the carbonaceous clay is almost limited to the lower part of the formation. The upper part is composed mainly of fine- to coarse-grained gray, tan, and red sand containing some locally interbedded lenses of gray clay.

Normal facies:

Lithologic details at two localities for measured sections are given below.

Measurement of the first section near the Benton pumping station, starts 13 feet below road level and extends up the road cut on the east bank of the Saline River about 150-200 feet north east of the pumphouse. The road cut is on a small spur that has an apiary on the south slope. At the top of the road cut the section is several hundred feet to the southeast along the powerline road where a scraper cut exposed sand along the entire length of the roadside ditch. At the crown of the hill the section is exposed several hundred feet south and ends at the 445-foot summit about 1,000 feet southeast of the point where the section was begun.

Section at the type locality of the Saline formation near the Benton pumping station in the SW¼SE¼ sec. 25, T. 2 S., R. 15 W., Saline County, Ark.

[Measured by M. Gordon, Jr.]

	Feet
Sandstone, light-tan, weathering gray, medium-grained, containing some vertical hollow tubules as much as half an inch across representing leached rootlets This is the siliceous indurated layer that normally marks the top of the Saline formation. The bed is lenticular and the lower surface is uneven. It is essentially in place capping the hill though broken into blocks and partly slumped at the edges of the outcrop	0. 5-2. 5
Concealed, a sandy soil, slumped blocks of the bed above cover the area between the summit and the powerline road	40. 0±
Sand, light-gray to nearly white, locally stained red, orange, and purple, medium-grained, micaceous, exposed continuously along ditch of powerline road	75. 0±
Clay, grayish-brown, silty, carbonaceous, micaceous, interlaminated with light-gray, medium-grained sand. Top of main road cut at top of this unit	5. 0
Clay, chocolate-brown, silty, carbonaceous, micaceous, interlaminated with gray medium-grained sand	6. 0
Sand, gray to nearly white, massive, medium-grained, composed chiefly of quartz and some mica	6. 6
Clay, brown, carbonaceous, silty, laminated with light-gray sand that ranges from partings to layers an inch or more in thickness	6. 6
Sand, brownish-gray, clayey, laminated	1. 3
Clay, brown, carbonaceous, silty, thinly interlaminated with sand	. 5

Section at the type locality of the Saline formation near the Benton pumping station in the SW¼SE¼ sec. 25, T. 2 S., R. 15 W., Saline County, Ark.—Continued

	Feet
Sand, brownish-gray, clayey, laminated	1. 5
Clay, light-brown, carbonaceous, grading locally into almost black lignitic clay	. 3
Sand, tannish-gray, laminated at intervals with thin indurated ferruginous layers as much as half an inch thick; also a few brown clay layers	6. 1
Clay, light-chocolate brown, carbonaceous, silty, micaceous, thinly laminated with gray medium-grained quartz sand	. 5
Sand, brownish-gray, medium-grained quartz, micaceous, laminated with brown silty clay; fewer silty clay laminae at top	3. 0
Sand, light-gray mottled with orange, medium-grained quartz, micaceous, not laminated	1. 7
Sand, white or light-gray, micaceous, thinly laminated with grayish-brown silty clay	4. 8
Clay, very dark chocolate brown, carbonaceous, silty, interbedded with a little brownish-gray medium-grained quartz sand. An indurated ferruginous lenticular layer of dark reddish-brown medium-grained sand as much as 0.5 foot thick lies 0.5 foot above the base of the facies. The top 2 feet locally is partly weathered to grayish brown	5. 8
Sand, grayish-white to gray, locally stained orange, medium-grained quartz, micaceous, interbedded with some grayish-brown to light-brown carbonaceous micaceous silty clay	5. 5
Clay, grayish-brown weathering orange, carbonaceous, micaceous, and thinly interlaminated with light-gray medium-grained micaceous quartz sand	15. 0
Total measured thickness of Saline formation exposed	185+

Additional information concerning the lower part of the Saline formation which is not exposed at the type locality was obtained from a drill hole about 1,000 feet south-southwest of the pumping station and approximately along the strike of the formation from the summit capped by the top indurated sand bed. This drill hole was near the southwest corner of the SW¼SE¼ sec. 25, T. 2 S., R. 15 W. and its collar was at nearly the same level as the projected base of the measured section. The log of this drill hole shows the base of the formation at a depth of 163 feet and at an altitude of about 100 feet making the total thickness of the Saline formation at the type locality about 350 feet. The log indicates that the lower part of the formation concealed beneath the flood plain of the Saline River is composed largely of brown to very dark brown carbonaceous clay like that described in the lower part of the measured section above. The basal 23 feet of the formation is composed of gravel that overlies a 7-foot lignite bed of the Berger formation.

Measurement of the second section, in the Section 16 bauxite pit mine, starts at the top of the hill that has been cut to make the east wall of the mine from a point about 200 feet south and 200 feet west of the center of the south line of sec. 16, T. 2 S., R. 14 W., and descends the face to the top of the carbonaceous clay bed above the bauxite surface, thence a few hundred feet to the southwest along the southeast edge of the pit to a point near the center of the west line of the NE¼NW¼ sec. 21, T. 2 S., R. 14 W. Most of the carbonaceous clay beds are exposed at the center of the hill and lense laterally into sand at the edges of the hill.

Section along the southeast wall of the Section 16 bauxite pit mine, about 1 mile south-southeast of Bauxite, Saline County

[Measured by M. Gordon, Jr.]

	Feet
Pliocene(?) terrace gravel:	
Gravel, fine- to coarse-grained, mostly quartz, poorly sorted and crossbedded. A few slabs of sandstone from the top indurated sand bed of the Saline formation are scattered about the crown of the hill at the level of the base of the gravel facies. They probably are reworked	9. 0
Ferruginous layer, indurated, mostly limonite, making an uneven jutting bed at the base of the gravel. This bed between the gravel and the underlying sand and clay was cemented by secondary iron oxides after deposition of the terrace gravel	1. 0
Saline formation:	
Clay, dark-brown, very silty and micaceous to sandy, interbedded containing some gray sandy layers, gray sideritic and orange limonitic layers. The clay is massive but not compact and breaks with an uneven surface	13. 7
Sand, light-gray to white, stained tan and orange, medium- to fine-grained including a few clayey partings	12. 0
Clay, dark chocolate-brown, carbonaceous, silty, compact, laminated with very little light gray micaceous quartz sand in the lower two thirds; upper third sandy. The interval spalls off to form a smooth, slick, vertical outcrop, slightly rounded above	11. 5
Sand, light-gray to white, locally stained orange, medium-grained micaceous quartz interbedded with irregular thin lenticular layers of light-gray gummy clay	32. 0
Sand, light-gray to white, weathering to tan and orange, fine- to medium-grained, micaceous, quartzose, massive	16. 0
Clayey sand, gray, slightly indurated, grades laterally (northward) into dark-brown carbonaceous clay containing a few bauxite pebbles	1. 5
Sand, white, to light-gray, fine- to medium-grained, massive, but laminated and slightly clayey at the base	11. 5
Lignitic clay, black, slightly brittle	. 4

Section along the southeast wall of the Section 16 bauxite pit mine, about 1 mile south-southeast of Bauxite, Saline County—Con.

	Feet
Saline formation—Continued	
Clay, light-brown to gray, carbonaceous, silty, gummy	0.4
Sand, light-gray to white, fine- to medium-grained quartz, massive though locally laminated and somewhat crossbedded, particularly at the base which contains a few boulders of granitic bauxite partly imbedded in the underlying unit	7.7
Clay, dark-brown to black, carbonaceous, micaceous, silty to sandy containing fragments and lenticular layers of lignite, interbedded with some layers of light-gray, medium-grained micaceous quartz sand as much as 4 inches thick	12.5
Sand, brown, micaceous, laminated with layers of bauxite and gray kaolinitic clay as much as 0.8 foot thick, the top bed contains cobbles of granitic bauxite as much as 1 foot across	3.7
Clay, dark-brown, carbonaceous, and micaceous silty partings interbedded with brownish-gray layers of fragmental kaolinitic clay and bauxite as much as 0.5 foot thick and containing smooth elongate pebbles and cobbles of granitic bauxite as much as 4 inches long. This facies fingers laterally (westward) into a conglomerate bed of bauxite gravel containing fragments, pebbles, and grains of bauxitic and kaolinitic clay that is light creamy-gray and slightly indurated and rests unconformably upon the lignite and gray silty clay beds of the Berger(?) formation	3.1
Lignite, brown, brittle, somewhat clayey	.6
Sand, gray containing brown carbonaceous staining, medium-grained, micaceous, quartzose; bed wedges out to the west	2.5
Berger(?) formation:	
Clay, brown to brownish-gray, silty, carbonaceous	1.0
Lignite, dark-brown, brittle, containing some pyritized wood fragments	1.5
Clay, gray, silty, carbonaceous at top	1.0+
The base of the section is concealed by several feet of sand in the small stream that runs between the overburden and the stripped surface of the bauxite in the pit.	
Total thickness of Saline formation exposed	129+

The lower part of the section questionably referred to the Berger formation is believed to represent a local type of sedimentation in narrow, nearly closed valleys. In each of the few long narrow subsurface valleys that drain the nepheline syenite hill, a few lignite and gray clay beds of this lithologic facies were found locally in the valley bottoms at a much higher elevation than the nearest Berger strata known from drill holes.

Sections of the lower and more clayey part of the formation have been well exposed in the bauxite pit of the Midwest Mines Co. and the Cleveland and Ozark pit mines of the American Cyanamid and Chemical Corp. in sec. 24, T. 2 S., R. 14 W., in Saline County, and in the Burks-Nelson pit of the Pulaski Mining Co. in sec. 36, T. 1 N., R. 12 W., in Pulaski County. The carbonaceous clay is a rich chocolate-brown and turns nearly black on exposure to air. With continued weathering, it becomes gray and finally becomes nearly white. The chocolate-brown usually is not seen in exposures except deep road cuts, pit walls, or other excavations. Normally weathering produces vivid red and yellow shades in the higher surficial parts of the unit. The color distribution apparently is controlled by the porosity of the sediments and the relationship to the water table. Lamination of the clayey parts are often inconspicuous in the stained croppings. The clay is normally silty and contains micaceous flakes, particularly along the partings. In the lower part of the formation the clay usually contains very little interlaminated sand. Where the sand is predominant, however, the interbedded carbonaceous layers are often made up of large fragments of lignite and carbonaceous material and are weakly crossbedded, which gives them a ropy appearance in cross section. Thin lenticular layers of lignite are fairly common in the chocolate-brown carbonaceous clay. They are not restricted to any particular zone but locally are more abundant near the base. Iron sulfide in small quantities is widely disseminated through much of the chocolate-brown clay.

Several sand lenses, as much as 1 to 2 feet thick, are found in the Burks-Nelson open-pit mine. These are composed of gray medium-grained quartz sand with frosted grains that have an almost pearly luster when wet. In the same pit several beds of gravel, a few feet above the base of the formation, contain not only pebbles of bauxite and decomposed nepheline syenite, but also pebbles of quartzite, shale, novaculite and vein quartz of Paleozoic age. The irregular staining by iron oxide in the more pervious layers is vividly displayed in the east wall of this pit.

Ferruginous concretions are common in the carbonaceous clay beds, and some reach a length of 6 feet and a thickness of almost a foot. In the overburden of the Midwest Mines Co. pit concretions are composed principally of hard gray granular siderite covered with a thin surficial coating of orange limonite. Limonite layers, most of which are thin and platy, are abundant in the laminated clay beds of the formation. Some foliated limonitic concretions occur at several localities, particularly along the Berger and Saline contact.

Sand facies:

The massive sand beds that mark the upper part of the Saline formation in Pulaski County and in the eastern part of Saline County do not form prominent outcrops except where they are cemented by iron oxide to form a hard sandstone. The sand beds were found

in many drill holes around the southern periphery of the buried Pulaski nepheline syenite hill, and in all the deep holes drilled farther south in the basin. The sand is gray to tan, medium to coarse grained, massive and locally crossbedded, and contains some scattered large pebbles. Interbedded with the sand are lenses of gray plastic clay. In parts of Saline County the sand is ferruginous and red and locally indurated. At some localities the base of the sand immediately overlying the carbonaceous clay beds is green. Evidence from drill holes shows that the sand reaches a thickness of nearly 200 feet in Pulaski County and thins gradually westward. Along the top of Alexander Mountain which is capped by the sand, the thickness of this unit ranges from 40 to 60 feet. The sand is indurated with iron oxide and forms steep slopes and locally small bluffs near the top of the mountain. Here it contains many larger fragments and angular pebbles of quartz and a large quantity of plant detritus in the form of broken fragments on branches, wood, twigs, and leaves all of which have been replaced by limonite.

The sand facies extends as far west as the Saline nepheline syenite hill. It is exposed as a red coarse-grained sand overlying brown carbonaceous clay in a prominent triangular hill in the eastern part of the Section 15 mine. The base of the sand in this part of the mine is indurated with a ferruginous cement and forms a hard ledge a foot or more in thickness. This ledge can be seen in the photograph in figure 9. In several places on the surface of this indurated ledge, ripple marks and worm trails are preserved (fig. 10). In the western part of the same mine the interbedded white medium-grained sand and brown carbonaceous clay facies extend to the top of the formation which is

FIGURE 9. Section of the Saline formation in the Alexander Hill mine near Bauxite, Saline County. The hill is about 70 feet high. Sand facies ferruginous indurated bed at base (*a*). Chocolate-brown sandy clay, soft rubble bed at top (*b*). Residual bauxite deposit (*c*).

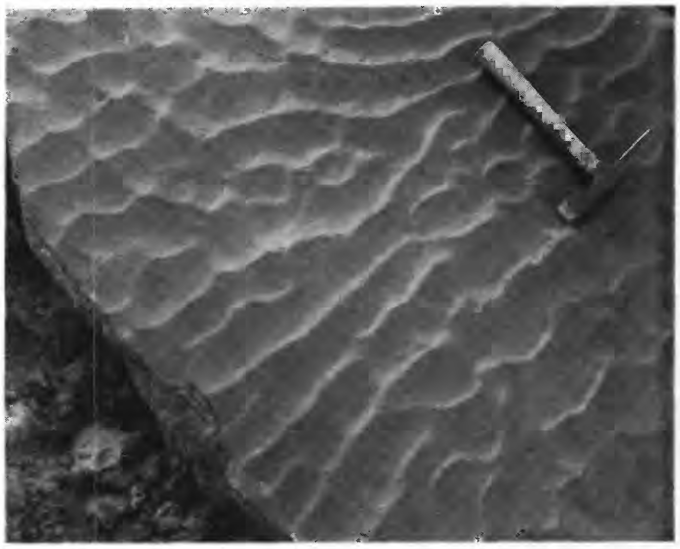

FIGURE 10. Current ripple marks and invertebrate tracks preserved in ferruginous sandstone from the base of the sand facies of the Saline formation. Shows a loose slab in the Alexander Hill mine.

exposed along the southwest edge of the pit. The sand overlaps the carbonaceous clay and rests directly upon the bauxite in the southwestern part of the Granite Branch mine and in the nearby Johnson and Ella mines. Locally the sand is separated from the uneven surface of the bauxite by an irregular layer of hard, light-gray clay.

The top bed of the Saline formation is a medium-grained quartz sand at many localities and locally the upper part of the sand bed is indurated. The degree of induration is greatest at the top and gradually decreases downward. The lower surface of the indurated part is more uneven than the top of the bed and has an almost botryoidal appearance (fig. 11). Immediately below,

FIGURE 11. Sandstone bed at the top of the Saline formation in the Julia mine near Bauxite, Saline County. Note the undulatory surface at the base of the indurated part of the bed. The hammer at lower left gives the scale.

the partly indurated sand is saccharoidal and friable and grades downward into a nonindurated sand in the space of several inches. The bed usually contains vertical, hollow or sand-filled impressions of roots as much as half an inch in diameter. Several miles northwest of Sardis this bed disappears and in its place laterally is the ferruginous sandstone of the sand facies.

Gravel and sand facies:

The gravel bed that marks the base of the formation in the previously mentioned company drill hole near the type locality extends northward and is exposed at the south edge of Benton. At this locality it has been quarried extensively in the Ball-Benton gravel pits together with a late Tertiary gravel that rests unconformably upon the Saline formation. A partial section of the lower part of the Saline strata follows:

Section on east-west bluff in the Ball-Benton gravel pits, about 700 feet south-southeast of the Chicago, Rock Island and Pacific Railroad depot in the southern part of Benton, Ark., SW¼NW¼ sec. 14, T. 2 S., R. 15 W.

[Measured by M. Gordon, Jr.]

	Feet
Pliocene(?) terrace gravel:	
Gravel and coarse sand, containing large smoothed but not spherical pebbles of quartz and rocks of Paleozoic age as much as 3 inches in diameter, poorly sorted, rests unconformably upon beds below	7. 0–9. 0
Saline formation:	
Clay, weathered to orange and gray with interlayered laminae of light-gray, medium-grained quartz sand	6. 0
Clay, light chocolate-brown containing a little more sand than the overlying interval	3. 0
Clay, dark chocolate-brown, carbonaceous, containing thin interlayered laminae of light-gray micaceous quartz sand	7. 0
Clay, orange and light-brownish-gray with a few a few laminae of medium- to coarse-grained orange sand	1. 5
Gravel and sand, orange, ferruginous, containing smoothed and frosted but not spherical peb-of quartz as much as 1½ inches in diameter; a thin light-tan layer at base of interval	. 7
Sand, coarse-grained, angular, somewhat coated with ferruginous stain	1. 3
Sand, medium-grained, grayish-white, stained with orange	. 6
Sand, medium- to coarse-grained, gray and locally in lower part with dark-red to brown ferruginous matter; a thin cream-colored clay layer at base of interval	1. 3
Gravel and sand, ferruginous, orange, with flattish pebbles of quartz up to an inch long	. 7
Sandstone, ferruginous indurated medium-grained quartz sand stained dark-brownish red, less indurated at base	. 3
Gravel and sand, with orange ferruginous stain like bed above	. 8

Section on east-west bluff in the Ball-Benton gravel pits, about 700 feet south-southeast of the Chicago, Rock Island and Pacific Railroad depot in the southern part of Benton, Ark., SW¼NW¼ sec. 14, T. 2 S., R. 15 W.—Continued

	Feet
Saline formation—Continued	
Sand, medium-grained, orange to tan, with abundant small quartz pebbles up to half an inch in diameter	1. 5
Concealed by slumping to floor of pit	6. 0±

The town of Benton is underlain throughout by the red sand and gravel facies of the Saline formation through which some of the streams have cut the underlying formations of the Midway group. Along the east edge of the town the gravel beds have been mined extensively in the pits known as the Haskell-Dickinson and the Kertin gravel pits. The following section describes the sand and gravel facies where it is mined:

Section in the east face of the northeasternmost pit of the Haskell-Dickinson gravel quarry, west of the road and east of the creek in the NE¼ SW¼ NE¼ sec. 11, T. 2 S., R. 15 W., about 1 mile east-northeast of the center of Benton, Ark.

[Measured by M. Gordon, Jr.]

	Feet
Pliocene(?) terrace gravel:	
Gravel, coarse-grained, smooth, angular, poorly sorted	4. 0
Saline formation (gravel facies):	
Sand, red, crossbedded, medium- to coarse-grained, mostly quartz, with scattered layers of slightly angular small pebbles and granule gravel	10 0±
Gravel and sand, made up of many smooth but not spherical pebbles of quartz and rocks of Paleozoic age as much as 1½ inches long, interbedded with a large quantity of coarse-grained red sand, partly crossbedded and sorted	5. 7–8 3
Gravel, similar to the one below but partly crossbedded and interlayered with coarse-grained red sand	3. 5–6 5
Bentonitic clay, light-creamy-gray, appearing sandy or silty in grain size but crumbling to fine powder when rubbed between the fingers and slacking rapidly in water. It contains a few poorly preserved fossil leaves, one of which was identified by R. W. Brown in September 1944 as *Dryophyllum tennesseense* Berry	0. 3–2. 3
Gravel and red sand, containing abundant smooth but not spherical pebbles of quartz and rocks of Paleozoic age, including novaculite and altered shale, as much as 4 inches long; an indurated ferruginous layer at the base, marking the unconformity with the underlying clay	10. 1
Wills Point formation:	
Clay, very dark gray, massive, hackly with a few yellowish-red soft ferruginous concretions. Exposed in the floor of pit	2. 0+

The sand and gravel unit of the lower part of the Saline formation thickens northward to almost 100 feet about 1½ miles north of the center of the town of Benton where it overlies unconformably the limestone and gray clay of the Kincaid formation. The gravel lentil forms an outcrop band that extends in a northeasterly direction along the upslope edge of the area of Saline formation outcrop. On its downslope side the gravel fingers into typical sand and carbonaceous clay beds of the Saline formation; the deposition of the two lithologic facies is synchronous. The gravel and sand were deposited as an alluvial apron or series of coalescing alluvial fans and extend a considerable distance downslope only where major drainage streams were continuously flowing at the time of deposition.

Beds of typical Saline lithology have been found at only a few localities within the gravel and sand outcrop area. Laminated brown carbonaceous clay was observed in a small spring in the floor of an abandoned clay pit near the center of the west line of the NW¼NE¼ sec. 11, T. 2 S., R. 15W. Brownish-gray weathered laminated clay crops out in a roadside ditch about three-fourths of a mile north of the Hicks clay pit near the center of the east line of the SW¼NE¼ sec. 12, T. 2 S., R. 15 W. Analyses of clay from this pit and from other pits in the vicinity of Benton have been given by Branner (1898, p. 62). Most of the clay associated with the gravel and sand lentil of the Saline formation is gray and occurs as lenses several hundred feet long and a few feet thick rarely reaching a thickness of 30 feet. Many of the clay lenses contain fossil leaves, particularly near the base where the clay layers have a brownish or a pinkish cast.

The sand and gravel deposits of the Benton area have been traced to the northeast in Saline County as far as the outlier at Collegeville in sec. 14, T. 1 S., R. 14 W. Sand and gravel are found in Pulaski County in small outliers in secs. 31 and 32, T. 1 N., R. 12 W., locally overlying a few feet of typical brown carbonaceous clay of the Saline formation, and in larger outliers capping the ridges in the city of Little Rock where the gravel unconformably overlies the lower part of the Wills Point formation. These gravel deposits of Pulaski County are like those of the Benton area in that they are locally bedded, though less so, and partly sorted; they contain large quantities of medium- to coarse-grained quartz sand and granule gravel, much of which is red, the larger pebbles reach 4 or 5 inches in diameter and are smoothed but only partly rounded; the deposits locally reach a thickness of almost 100 feet (near the south edge of Little Rock); they lie at or near the projected base of the Saline formation; and they progressively truncate the older formations of Tertiary age upslope. They differ from the gravel of the Benton area in the smaller amount of quartz and locally in the presence of chert pebbles containing fusulinids, brachiopods, bryozoa, and other fossils of Mississippian to Permian age. The significance of these fossiliferous pebbles is discussed on page 55. Despite these differences in contained material the gravel of both areas probably was deposited synchronously. Though the gravel beds in Pulaski County lack fossil evidence either to corroborate or to deny this assumption, they have been mapped as an extension of the gravel facies of the Saline formation.

Relation to underlying rocks.—The Saline formation rests with local unconformity upon the Berger, and in places unconformably on the Wills Point, and Kincaid formations and the nepheline syenite masses and their included small pendants of metamorphic rocks of Paleozoic age. In the vicinity of the Saline River and along the north edge of the Gulf Coastal Plain the gravel facies progressively overlaps the underlying section and rests in succession upon the Berger, Wills Point, and Kincaid formations. The gravel and clay outliers in secs. 31 and 32. T. 1 N., R. 12 W. rest directly upon bleached gray clay of the upper part of the Wills Point formation. South of these outliers along the main Midway and Wilcox contact the Saline formation rests upon the Berger formation and locally upon the Wills Point formation. The sand and gravel outliers of the Saline formation in Little Rock rest on yellow fossiliferous clay of the lower part of the Wills Point formation.

A sharp erosional contact is present between the Saline formation and the underlying Berger formation. This is caused by scour and does not imply a widespread hiatus in deposition. In the east wall of the southern part of the Quapaw bauxite pit (fig. 12), in

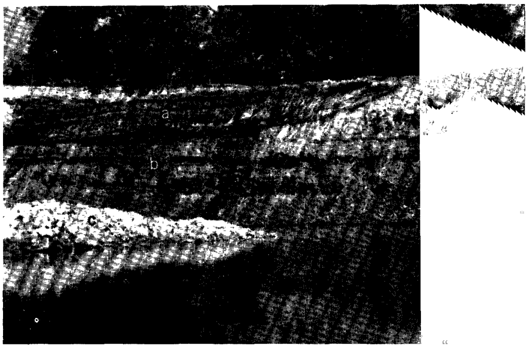

FIGURE 12.—Unconformable contact between the Saline formation (*c*) and the Berger formation (*b*) in the east wall of the Quapaw mine near Bryant, Saline County. A blasted but unmined remnant of the bauxite deposit (*c*) stands above the surface of the water at left. Photograph by A. L. Jenke.

the NE¼SE¼ sec. 3, T. 2 S., R. 14 W., the base of the Saline formation, which at this locality is composed of very dark brown clay containing carbonaceous fragments interbedded with nearly white medium-grained micaceous quartz sand, truncates the beds of the Berger formation northward. In the space of several hundred feet laterally, the base of the Saline formation cuts across several prominent beds of gray silty clay, fine-grained sand and dark-brown lignitic clay, reducing the thickness of the Berger formation by about 15 feet. In the Elrod bauxite pit about half a mile northeast of the Quapaw locality, the Saline formation lies disconformably upon the Berger formation. The top of the Berger formation contains many holes or depressions several inches deep that are filled with sand of the immediately overlying Saline formation. Cores of drill holes show a sharp break at the contact between the two formations. However, in some of the deep holes drilled in the southern part of the bauxite region, this break was marked by a change in color of the sediments.

Fossils and correlation. Forty-three species of fossil leaves and one brackish water clam have been identified from the Saline formation (table 5). Considering the large amount of carbonaceous material in the formation, including fragments and thin layers and beds of lignite, localities containing fossil leaves are comparatively scarce. The leaves, however, are well preserved at most localities.

In the Benton area, Saline County, leaves occur at or near the base of lenses of light-gray or buff to pinkish-brown plastic clay in the lower part of the prominent sand and gravel lentil that marks the base of the formation. A few feet of coarse sand and gravel generally lie between the leaf-bearing and the underlying clay beds of the Midway group. Berry (1916, p. 53, 54, 273–274) has listed the species collected at three localities in this area. These are included in table 5, which lists also species identified by R. W. Brown from six other localities. Descriptions of these localities, stratigraphic information, collectors, and dates of collection are also given.

With reference to the plants identified by him from the bauxite region, R. W. Brown (written communication, 1945) has made the following statement:

> All the plant species identified in these collections have been previously identified from deposits hitherto assigned to the Wilcox group. To date only a handful of extremely fragmentary plant impressions have been taken from the Midway formation, and consequently we have no standard Midway flora against which to compare the collections. * * * The flora of the Fort Union formation was presumably comparable, at least in part, to the Midway flora, but of this we cannot be certain inasmuch as considerable latitudinal and longitudinal distance separates the areas where these floras grew. On the basis of the plants, therefore, the evidence, such as it is, favors the allocation of the (Saline formation) to the Wilcox group as defined by E. W. Berry.

Although the fossil plants appear to indicate a Wilcox age, as based on the work done by Berry (1916, 1930) on the Wilcox floras of the southeastern United States, it is not yet definitely established that they are Wilcox. Recent field mapping and stratigraphic studies by the U. S. Geological Survey in Alabama and Mississippi (MacNeil, 1946, 1947) have shown that many of Berry's supposed Wilcox fossil-bearing localities are actually in beds now believed to be in the Claiborne group. The beds at Puryear, Tenn., from which Berry collected a large flora, are probably of Claiborne age. R. W. Brown (oral communication, 1948) has noted a strong similarity of several of the fossil plant collections from the Saline formation, including those from the Old Leach clay pit, the Burks-Nelson bauxite pit, and the farm near Landmark School localities, to the Puryear flora described by Berry. It is possible, therefore, that future regional mapping and stratigraphic studies will demonstrate that the Saline formation belongs in the Claiborne group, rather than in the Wilcox group. Until the problem is further studied by competent specialists in Coastal Plain stratigraphy, however, we are considering this formation to be a part of the Wilcox.

Conditions of deposition.—The sediments of the Saline formation are of continental origin throughout the bauxite region of central Arkansas. Most of these sediments were deposited by fluviatile action on a broad coastal flood plain though some probably were deposited under localized palustrine conditions. Local estuarine conditions moreover are indicated by the identification of a brackish water mollusk *Brachidontes* sp. in a fossil collection from one of the bauxite pits. Whereas the nature and distribution of the sediments of the Berger formation indicate that the source was from within or near the bauxite region, most of the sediments of the Saline formation appear to have been transported from outside the area. The large grain size of the transported material, the much larger amount of quartz in the sands, and the widespread accumulation of fine carbonaceous material indicate that the Saline formation was deposited during a period when rainfall was heavier than during Berger time.

The fossil plants from the different localities all indicate a strand, land-locked lagoon, and bayou habitat under subtropical conditions (Berry, 1916, p. 113–140; 1930, p. 29–40).

In the bauxite region where the upslope edge of the coastal plain meets the steeper slopes of the upland formed by rocks of Paleozoic age, large deposits of coarse-grained sand and gravel were deposited, probably as a series of coalescing alluvial fans on a low

TABLE 5.—*Distribution of fossils in the Saline formation*

	Localities								
	A	B	C	9046	9047	9048	9049	9264	9265
Plants:									
Lygodium trilobatum Berry						×			
Taxites sp						×			
?*Canna* sp							×		
Chamaedora danai (Lesquereux) Berry	×								
Sabalites grayanus Lesquereux	×		×						×
sp				×					
Myrica puryearensis Berry									×
Engelhardtia ettinghauseni Berry	×								
Dryophyllum moori (Lesquereux) Berry					×				
tennesseense Berry				×	×	×	×	×	(?)
Fagus asper (Berry) Brown						×			
Artocarpus pungens (Lesquereux) Berry			×						
Ficus puryearensis Berry					×				
Banksia tenuifolia Berry						×			
?*Proteoides wilcoxensis* Berry							×		
Magnolia leei Knowlton					×				
Anona ampla Berry					×				×
Nectandra lowi Berry									×
pseudocoriacea Berry	×								
wilcoxensis Berry					×	×			
Oreodaphne intermedia Berry					×				
mississippiensis Berry					×				
obtusifolia Berry									×
pseudoguianensis Berry									×
salinensis Berry	×		×						
Caesalpinites bentonensis Berry	×								
Cassia bentonensis Berry	×		×			×			
fayettensis Berry	×					×			
glenni Berry									×
lowi Berry				×					
wilcoxiana Berry						×			
Mimosites variabilis Berry					×				
Sophora wilcoxiana Berry					×				
Sapindus bentonensis Berry		×							
knowltoni Berry	×							(?)	
Ouratea eocenica Berry					×				
Terminalia lesleyana (Lesquereux) Berry								×	
Myrcia bentonensis Berry	×								
puryearensis Berry						×			×
Oreopanax oxfordensis Berry	×								
Osmanthus pedatus Berry									×
Apocynophyllum constrictum Berry	×								
sapindifolium Berry	×								
Pyritized wood				×					
Mollusks:									
Brachidontes sp				×					

A Henderson clay pit, on the southeastern slope of the valley of McNeil Creek, NW¼NE¼ sec. 2, T. 2 S., R. 15 W., about 1 mile northeast of the center of Benton, Saline County. Fossil leaves from massive bluish to brown plastic clay are exposed at bottom of pit. R. E. Call, 1891.

B East of Benton in sec. 28, T. 2 S., R. 14 W. Ark. Geol. Survey, 1891. (The middle part of the formation is exposed in this area.)

C Eagle Pottery Co. clay pit, south side of Highways 67 and 70, sec. 2, T. 2 S., R. 15 W., about one-half mile northeast of Benton. Plant fossils from brown sandy clay in same part of section as the leaf-bearing clay in the Henderson Pit. E. W. Berry, 1910.

9046 South end of the Stuckey bauxite pit in the NW¼NE¼ sec. 9, T. 2 S., R. 14 W., Bauxite, Saline County. Fossils from siderite layer in lignitic clay bed, immediately overlying the bauxite surface. R. W. Brown, 1944.

9047 Burks-Nelson bauxite pit, near top of north end, SE¼SW¼ sec. 36, T. 1 N., R. 12 W., about 1½ miles south-southwest of Sweet Home, Pulaski County. Plant fossils from buff-gray medium-grained sandstone containing shreds and fragments of dark-brown carbonaceous clay, 55 feet stratigraphically above top of uppermost lignite of Berger formation. R. W. Brown, M. Gordon Jr., J. I. Tracey, Jr., 1944.

9048 Hicks or Old Leach clay pit, south across Old Sheridan road (eastward extension of North Street) from Hicks or Old Leach Cemetery, E½NW¼NE¼ sec. 12, T. 2 S., R. 15 W., about 1½ miles east of the center of Benton, Saline County. Plant fossils from brownish-gray clay at bottom of pit, about 15 feet above base of Saline formation, which rests directly on Wills Point formation. R. W. Brown, 1944.

9049 Kenark bauxite pit on the Sweet Home cut off road opposite Fuller School, SW¼NE¼SE¼ sec. 25, T. 1 N., R. 12 W., Pulaski County. Plant fossils from brown carbonaceous clay at top and west end of pit, a few inches above base of Saline Formation. R. W. Brown, M. Gordon Jr., J. I. Tracey, Jr., 1944.

9264 Outcrop at west edge of Alexander Mountain near center of NW¼NW¼ sec. 36, T. 1 S., R. 13 W., Saline County. Plant fossils from an indurated limonitic ledge in coarse ferruginous sandstone that caps Alexander Mountain. Data from USBM drill holes 12-196 and 12-205, drilled within 150 feet of these localities show leaf-bearing horizon is 60 feet above base of sandstone and 253 feet above base of Saline formation. L. S. Gurney and R. A. Brown, 1944.

9265 Plant fossils from 20-foot dug well near farmhouse, a short distance west of Landmark School or Church, in SW¼ sec. 30 or NW¼ sec. 31, T. 1 S., R. 12 W., on Highway 167, Pulaski County. Fossiliferous layer is 14–15 feet below surface, in upper part of Saline formation. William Smith, geologist, U. S. Corps Engineers, 1948.

gradient starting at the beginning of the time of deposition of the formation. Locally, tree-fringed ponds were formed in which finer sediments were deposited and then covered again by coarser material. As the coastal plain gradually encroached on the upland, the locus of deposition of the coarse clastic sediments moved slowly upslope. The material in these deposits was derived from the rocks of Paleozoic age of the upland, and much of it came from the many quartz veins that cut these older rocks.

In Pulaski County the gravel contains many chert pebbles with molds of fusulinids and other fossils of late Paleozoic age. Some of these apparently have been derived from a formation of early Permian age, that does not crop out in Arkansas. L. W. Henbest (written communication, 1948) to whom some of the material was sent for study, has reported as follows:

> Eight collections comprising 78 cobblestones of flint, 2 to 8.5 cm. across, from gravel beds of supposed Wilcox, Eocene age south of Little Rock were submitted. These were of as well-rounded shape as the flint was capable of receiving. The largest cobblestone contains the peculiar columnal of *Platycrinus* that is especially characteristic of the lower Mississippian cherts of the central and northern Ozark region. The nearest exposures are about 100 miles north of Little Rock. I showed this specimen to Dr. Edwin Kirk who definitely confirmed my identification. The next largest is an 80 mm. segment of the cephalopod *Rayonnoceras* which is restricted to the Fayetteville shale, of upper Mississippian age. This identification was confirmed by Dr. A. K. Miller, University of Iowa, in a personal communication. The only silicified specimens of *Rayonnoceras* that I have found so far came from two localities respectively 100 and 150 miles west of north from Little Rock, though calcareous specimens are found in the Fayetteville shale toward the west of these localities in Arkansas and Oklahoma.
>
> Most of the other flint cobbles contain Fusulinidae that include *Schwagerina emaciata* (Beede), *Paraschwagerina* (or possibly *Pseudoschwagerina*) sp. and lower Permian forms of *Triticites*. As the Permian age of these fusulinids is definitely determinable, the source of the cobblestones poses a significant problem. The nearest existing exposures, and so far as known the nearest subsurface development, of beds that bear lower Permian Fusulinidae are 300 to 500 miles away to the northwest. If the gravel beds from which these Permian cobblestones were derived are, as they seem, of Eocene age, it is very strongly suggested that the marine Permian formerly extended over the Ozark region.

Similar deposits of coarse detritus, but composed largely of bauxite, kaolinitic clay, and decomposed syenite, were deposited at the base of the nepheline syenite hills that stood as monadnocks above the flat plain. These deposits extended in wide tongues, in some places as much as 2 miles over the lip of the Berger formation particularly near the main nepheline syenite mass in Saline County. They were covered by fine sediments of the Saline formation that continued to encroach upslope and cover the nepheline syenite, in many places stripped of its mantle of weathered detritus, and the remnants of the once extensive bauxite mantle. By the end of Saline deposition little of the Saline nepheline syenite hill remained exposed and probably not much of the Pulaski nepheline syenite hill. The Alexander Mountain hill had already been deeply buried.

Most of the fluviatile sediments came from the north and the northwest and this deposition probably continued to the end of Saline time, at least in the vicinity of the present Saline River. However, in Pulaski County deposition of coarse sediments began in the eastern and southeastern part of the area early in Saline time, and coming from the direction of the present Arkansas River, encroached steadily westward across the bauxite region. By the end of Saline time these sediments had reached far enough westward to extend across the already buried Alexander Mountain nepheline syenite hill and to lap against the east flank of the Saline nepheline syenite hill. Secondary ferruginous material has indurated the sands at many localities.

The Saline formation was laid down at a time of almost constant marsh, bayou, and river deposition. Fluviatile deposition of sand became more and more dominant until, with a marked change of conditions, a great swamp was formed at the beginning of Detonti time.

DETONTI SAND

Definition.—The Detonti sand is named for the little settlement of Detonti on the Missouri-Pacific Railroad in the SE¼SE¼ sec. 33, T. 2 S., R. 14 W., in the southern part of Saline County. This formation is a homogeneous sand unit several hundred feet thick, containing some interbedded gray-clay lenses and a prominent lignite bed at the base. It is best known from a few of the deeper drill holes in the southern and southeastern parts of the bauxite region. The type section, representing the basal part of the formation, is exposed on the east bank of the first prominent gully west of Detonti on the Detonti-Tull road near the center of the NW¼NW¼NW¼ sec. 4, T. 3 S., R. 14 W.

Distribution and surface outcrop.—The formation crops out in an irregular northeastward-trending belt up to 3 miles wide and is probably continuous across the bauxite region. Northeast of secs. 11 and 14, T. 2 S., R. 13 W., it could not be distinguished in surface outcrop from the Saline formation and it is shown on plate 1 as grading laterally into the upper part of that formation. Upslope from the main Saline and Detonti contact are many small outliers of Detonti sand wherever the top siliceous indurated bed of the Saline formation forms an irregular capping on scattered small hills. Some of these hills lie slightly more than 2 miles

away from the main contact. The outcrop area of the Detonti sand like that of the Saline formation extends southwestward across the Saline River but has not yet been traced. It is cut off at the northeast by overlap of the sediments higher in the section and by thick Quaternary alluvial sediments of the Arkansas River flood plain.

Good outcrops of the Detonti are few; the best outcrops are limited to the western part of the mapped area where a few fair exposures occur along the banks of larger streams and in road cuts. In this part the formation is exposed along ridges of moderate relief, but much of the area underlain by the Detonti sand has little relief though it is fairly well drained. The Detonti sand is covered at many localities by deposits of gravel of late Tertiary age. Where the gravel deposits are absent the sand is weathered to form a gray sandy soil that supports a good growth of timber. However, the forest cover is not thick and brushy as on land underlain by the Saline formation. The forests are open and have less undergrowth. Large pines and fine stands of hardwood are abundant.

Thickness.—The complete section of the Detonti sand was cut through in almost a third of the 60 holes drilled by the U. S. Bureau of Mines in the southeastern part of the bauxite region to check the results of the geophysical surveys. As interpreted from logs of these drill holes the thickness of the formation ranges from 207 to 412 feet and averages 320 feet.

Lithologic character.—The striking lithologic feature of the Detonti sand is its general uniformity and homogeneity. Most of the beds other than sand occur at or near the base and these are best known, at least at the surface. The average composition of the formation is estimated to be about four-fifths sand and one-fifth clay, with some lignite. The sand generally is light gray or more rarely brownish gray to tan and locally is orange stained. Usually it is loosely packed, well-sorted, and fine- to medium-grained containing moderately angular to subrounded quartz grains, locally slightly micaceous or with disseminated black mineral particles constituting as much as 3 percent of the mass. In several drill holes coarse-grained sand beds were found. Many fragments of lignite are scattered through the sand but few lenses of lignite are present.

The clay beds in the formation are relatively insignificant, at some localities occurring only as minor shaly partings, at others attaining a thickness of nearly 20 feet. The clay is chiefly light gray to gray, plastic or even sticky, and much of it is silty to sandy. Some of the clay is grayish brown and some is a tannish hue and nonplastic.

The lignite bed at the base of the formation is brown and woody and breaks into large pieces. Throughout most of the area the thickness ranges from 2 to 14 feet. This lignite bed is rarely seen at the surface, however, owing to its readiness on weathering to break down into a mushy loam and to be covered by the slumping of the overlying sand. The best exposures of the base of the section are between the settlements of Detonti and Shaw. The following measured sections give the details of the lithology at the only two exposures known where the lignite can be seen at the surface.

Section at the type locality of the Detonti sand in road cuts along the Detonti–Tull road near the center of the NW¼NW¼NW¼ sec. 4, T. 3 S., R. 14 W., on the east bank of the first large drainage channel west (about three-fourths of a mile) of Detonti, Saline County, Ark. Section starts near base of grade and continues eastward to where the road flattens out at the top of the grade

[Measured by M. Gordon, Jr.]

	Feet
Detonti sand:	
Sandy clay to clayey sand, gray, slightly micaceous, exposed in roadside ditches and cuts at each side of road intermittently to top of grade; lower part of this facies reached in USBM drill hole 21–071 drilled alongside the road a few feet below the top of the grade	27. 0±
Clay, sandy, medium-buff-gray, inconspicuously laminated, with bands and layers of limonitic staining and thin laminae of limonite, particularly in the lower part	5. 0
Lignite, brown, woody, soft, locally weathered and limonitic	2. 4
Saline formation:	
Sandy clay to clayey sand, gray to light-gray, fine- to medium-grained, slightly micaceous	14. 0+

The section above shows the similarity of the top of the Saline formation to the base of the Detonti sand that is typical of most of the area. Nearby drill holes show that the chocolate-brown carbonaceous clay is found almost immediately below the gray sandy clay to clayey sand that constitutes the lowest unit of the section. The Detonti sand in this section contains a little more clay in the lower part than is generally found.

Another section, about 1½ miles southwest of the first section, exposes the contact of the Detonti sand with the Saline formation. Lignite overlies the partly indurated sandstone at the top of the Saline formation below which dark-chocolate-brown sandy clay is present. Here, too, the Detonti sand contains more clay than is generally found in drill holes.

Section of the basal part of the Detonti sand, descending curve of county road near the southwest corner, NW¼NW¼SE¼ sec. 6, T. 3 S., R. 15 W. Saline County, Ark. Section starts on east side of road about 100 feet east of a tumbled-down barn; at second carbonaceous layer below, measurement shifts to west side of road cut

[Measured by M. Gordon, Jr.]

	Feet
Surface:	
Soil	1. 0
Detonti sand:	
Clay, sandy, red and gray mottled	5. 0
Clay, as above, but includes quartz and ferruginous sandstone pebbles, subrounded to subangular, as much as 2 inches in diameter	1. 0
Clay, sandy, gray, weathering red	. 6
Clay, slightly sandy, creamy-gray, containing shreds of carbonaceous material	. 5
Clay, brown, carbonaceous containing shreds of lignitic detritus	. 4
Sand, light-gray, locally weathering red, fine- to medium-grained	10. 3
Loam, rich brown, soft, carbonaceous to woody, a decomposed lignite	. 5
Saline formation:	
Sand, reddish-gray to tan, slightly indurated	1. 0
Sand, light-gray to gray, fine- to medium-grained, moderately clayey; as much as 2 feet at top fairly well indurated	5. 8
Carbonaceous clay, dark-chocolate-brown, laminated, sandy, micaceous	2. 0±

Gummy to brittle gray clay fragments, some nearly a foot long, are in a matrix of gray or red sand in the lower part of the formation, particularly where subsequent erosion has removed the lignite. This type of material has been found at widely scattered localities. In the north face of the west end of the Julia open-pit mine of the Alcoa Mining Co. the uppermost sand bed of the Saline formation is indurated at the top and may indicate the former presence of an overlying lignite bed. Instead of a lignite, however, the indurated sand is overlain by a conglomerate bed containing white-clay fragments and granitic bauxite pebbles and this in turn by a thick crossbedded gray sand with gray-clay layers. The section is as follows:

Section in the western part of the Julia open-pit mine of the Alcoa Mining Co.; the north wall of the pit north-northwest of a part of the pit utilized as the garbage dump for the town of Bauxite; on west line of sec. 22, T. 2 S., R. 14 W., about 1,750 feet south of northwest corner sec. 22, Saline County, Ark.

[Measured by M. Gordon, Jr.]

	Feet
Pliocene(?) terrace gravel:	
Coarse gravel and red sand	1. 0–3. 0
Detonti sand:	
Sand, gray, weathering red, medium-grained containing angular to subrounded quartz grains, crossbedded, interlayered with lenses, laminae, wisps and blebs of gray plastic clay, some of it brownish-gray; most of the bedding less than one-half inch thick and inclined at all angles; more clayey in the upper part	35. 0±
Detonti sand—Continued	
Clayball conglomerate, composed largely of white or light-gray tough, hard clay with an almost conchoidal fracture in smooth but not rounded, irregular masses or pebbles and smooth soft pebbles or cobbles of granitic-textured bauxite and syenite clay in a red clayey sand matrix	0. 5–1. 7
Saline formation:	
Sand, slightly clayey, light-gray to pure white locally stained orange in bands a few inches thick in the lower half to two-thirds of the interval, medium-grained, the top several inches to several feet indurated to a hard gray sandstone weathering tan and dug into an overhang in the southwestern part of the pit	15. 7
Sandy clay, gray, micaceous and slightly carbonaceous, or containing brown carbonaceous areas and a few clay pebbles. The top 1–6 inches of this bed is ferruginous indurated. The bed grades downward into the bed below	1. 0
Lignitic clay and lignite, black to brown, containing lenses of brownish-gray carbonaceous clay about 2–4 inches thick. One lens about 1.2 feet above the base contains gray bauxite pisolites and another layer 2.2 feet below the top contains pebblelike nodules of pyrite about 1 inch across; just above, the lignite contains hollow-centered tubules of pyrite about three-eighths inch in diameter; the lignitic clay contains some woody fragments. The bed overlies the rubbly top of the bauxite that was mined in the lower part of the pit	4. 5

Along the north wall of the pit east of this section the base of the Detonti sand cuts through the indurated layer and well into the uppermost sand beds of the Saline formation to within several feet stratigraphically of the lignitic clay bed. Locally the conglomerate bed is absent.

Relation to underlying rocks.—The Detonti sand overlies the Saline formation with apparent conformity except where local channels have been cut into the contact subsequent to the deposition of the lignite at the base of the formation, as cited above. Beneath the basal lignite bed of the Detonti sand the top of the Saline formation is bleached where it is a carbonaceous clay and indurated where it is a sand. Long lignitic roots and rootlets as much as half an inch thick extend downward from the lignite bed as much as 10 feet. Where the underlying sand is indurated and exposed at the surface the lignitic material usually is weathered and leached away, but the vertical hollow impressions of the roots and the quartzitic appearance of the sandstone, which is the only siliceous indurated bed in the entire

Tertiary section, makes this bed an easily identified marker.

The widespread swampy condition that prevailed at the time the basal lignite was deposited served only as a momentary halt in the progression of increasingly active fluviatile deposition that culminated in the deposition of the Detonti sand.

Paleontologic features.—No fossils have been identified from the Detonti sand. At several localities in the southeastern part of the area in the vicinity of Lorrance Creek petrified logs as much as 3 feet in diameter have been found. However, they occur where the surface of the formation is covered by terrace gravel of later age, and it is not yet known whether the petrified wood is related to the Detonti sand or to the gravel. Similar stumps and logs of silicified wood have been described by Call (1891, p. 102) from the clay of the Wilcox group in Green County, Ark.

CLAIBORNE AND JACKSON GROUPS

Overlying the Detonti sand and cropping out on many rolling hills in the southeastern part of the bauxite region is a section of variegated clay, sand, and lignite. These deposits and their contact with the Detonti sand and the Saline formation are in the southeast corner of the area as shown on plate 1. These beds were found in some of the deeper holes drilled by the U. S. Bureau of Mines and deserve a brief description.

The clay in this section includes light-gray, gray, bluish-gray and grayish-green and rarely cream colored and other plastic silty clay in beds ranging from thin layers to more than 30 feet in thickness. Some of the clay beds are interbedded with thin lignite, but most of the lignite is associated with beds of dark-chocolate-brown carbonaceous silty clay or clayey silt, and these carbonaceous beds are particularly characteristic of the lower part of the section. Most of the sand is composed of quartz but locally it contains a relatively high percentage of dark minerals. Much of it is fine to medium grained, and the grains are subangular to subrounded. Some of the sand is medium to coarse grained and the grains are partly to well rounded.

Locally in the lower part of the section is a lens, or perhaps several lenses, of bentonitic clay. In drill hole cuttings the clay is greenish brown, waxy, and breaks with an irregular hackly fracture. At the surface the clay is yellow and has a slightly greenish cast, is compact, brittle, and breaks with a conchoidal fracture, and becomes creamy white on drying. It has been mined as bentonite in Saline County for several short periods.

The sediments overlying the Detonti sand are thickest in the northeastern part of Grant County where deep drill holes of the U. S. Bureau of Mines cut 101 to 435 feet of beds above the sand. In the northwestern part of Jefferson County, according to records of the Arkansas Geological Survey, the Hensley No. 1 well of the Decem Oil Co. drilled in the SE¼SE¼ sec. 7, T. 3 S., R. 10 W., collar elevation 260 feet, cut a fine gray sand 310 feet thick at a depth of 350 feet. This locality is a short distance east of the southeastern part of the Bauxite region and is of particular interest because the classical Jackson section at Red Bluff, Arkansas River described by Call (1891, p. 10–13) lies about 1 mile to the west-northwest in the NE¼SE¼ sec. 12, T. 3 S., R. 11 W. The top of the section has an altitude of 276 feet. The literature on this section as well as that of the White Bluff section several miles down the Arkansas River from Red Bluff are listed in the selected bibliography of the groundwater report by Stephenson and Crider (1916, p. 79–84).

No proof of the presence of the Claiborne group in the southeastern part of the bauxite region exists though some earlier geologic maps have recorded its presence there. Some of the lower beds here arbitrarily assigned to the Claiborne and Jackson groups have been considered to represent part of the Wilcox group by some geologists. It is also possible that some of the beds below, that are now classified as Wilcox, will upon further study prove to be Claiborne in age.

UNDIFFERENTIATED TERTIARY AND QUATERNARY GRAVEL DEPOSITS

Small to large areas of the Arkansas bauxite region are covered by gravel that crops out on top of hills or on terraces. These deposits rest unconformably upon the slightly tilted rocks of early Tertiary age, including the bedded gravel of the Saline formation, and locally on rocks of Paleozoic age. As they are not important to the bauxite problem, most of these gravel deposits have not been mapped. However, many gravel pits have been indicated by symbol on the geologic map that accompanies this report. These will show the topographic levels at which the gravel deposits are found. At least three and probably more than four old erosion surfaces are delineated by the gravel deposits between an altitude of 300 and 520 feet. The slopes between the gravel terraces are locally covered by talus gravel derived more recently from the terrace deposits. The higher and presumably older of these deposits are probably of late Tertiary, possibly Pliocene, age and they have been questionably so indicated in lithologic sections given earlier in this report. Most of the deposits do not exceed 10 feet in thickness, are poorly sorted, loosely consolidated, and made up principally of pebbles and cobbles rather than of large quantities of coarse sand as are the gravel lenses of the Saline formation.

The lower and presumably younger gravel beds are more likely to be of Quaternary age as they occupy surfaces not far above the Quaternary terrace deposits. They are thicker and contain more sand than the higher deposits, hence are more difficult to distinguish from the gravel of the Saline formation. Along the east bank of the Saline River in the western outskirts of Benton, gravel deposits, possibly of Quaternary age, which rest upon rocks of Paleozoic age, have been included with the Saline formation gravel of the Eocene.

In Pulaski County, along the edges of the Fourche Bayou flood plain, two prominent thick gravel deposits of possible Quaternary age have been mapped separately. One is a crescent-shaped band about half a mile wide west of the Chicago, Rock Island, and Pacific Railroad tracks in the southeastern part of Little Rock, and the other extends from a point one-fourth mile northwest of Geyer Springs to a point a short distance across the Missouri Pacific Railroad tracks to the southeast. In both areas the deposits reach a maximum thickness of about 30 feet. The deposits consist of coarse-grained, reddish-brown sand and many irregularly bedded layers and lenses of gravel. The sand and the gravel are poorly sorted and most of the finer sand grains are subangular though most of the larger size grains are subrounded to rounded. The sand is predominantly quartz, and the gravel consists of about 40 percent white quartz or quartzite, 40 percent metamorphic rocks of Paleozoic age, such as altered shale, slate, schist, and dark-colored quartzite, while the remaining 20 percent is brown chert, ironstone, and some novaculite. The brown chert pebbles of this unit generally are unfossiliferous in contrast to the chert pebbles of the Saline formation gravel, and wherever fossils occur they usually indicate a rock source of early Paleozoic age.

Gravel from the two localities mentioned above have been used as road metal and for railroad ballast. A brown limonitic concretionary layer occurs at the base of the gravel in the Geyer Springs pit. The underside of this layer locally is covered with small nodules of manganese oxide, probably pyrolusite. Branching and stalactitic nodules of the same mineral occur also in the upper few inches of the underlying clay of Paleozoic age.

QUATERNARY TERRACE DEPOSITS

Outcrops of sand and red clay beds fringe the present flood plain of the Arkansas River and part of the flood plain of its tributary Fourche Bayou. These beds form a prominent terracelike topographic feature wherever they occur. They are best exposed in the low flat-topped ridges on the east side of the road just north of College Station. The ridges extend around the point of the syenite rocks to the east, and then southward along the west bank of Fourche Bayou for about half a mile south of Sweet Home. Here the ridges are cut by eastward drainage valleys into low steep hills. South of this point the outcrop band widens to the west forming a swampy, hummocky, pine-forested "flatwoods." Several good exposures are in the vicinity of Higgins. It is likely that the formation occurs also at several places above the level of the flood plain of Fourche Bayou between the city of Little Rock and Granite Mountain, but it can be identified only in the area west of the Arch Street Pike viaduct and southeast of the railroad junction, just outside of the south city limits of Little Rock.

The formation, as it should be considered, consists of a maximum of about 60 feet of dark brick- to salmon-red clay. The clay is very sticky and contains a variable amount of fine silt grading locally into sand. The sand is common towards the top of the unit and usually is well sized, subangular to subrounded, and consists predominantly of clear quartz though it contains many dull-white or cream-colored grains that appear to be decomposed feldspar. Bedding is not conspicuous in either the sand or the clay, but deep vertical joints are common. A whitish film accompanied by some induration along some of these joints indicates the deposition of lime carbonate. Irregularly shaped calcareous nodules are characteristic of weathered clay exposures. These nodules range from ¼ to 2 inches in diameter and generally are an earthy pinkish-gray on the outside. When broken they reveal many crescent-shaped cavities, dark gray to black, resembling flint. The large volumes of this clay that lie at shallow depths at many localities along its outcrop may eventually prove worthy of examination for ceramics industries.

QUATERNARY ALLUVIUM

Under this classification is included all the flood-plain deposits of the Arkansas and Saline Rivers, and part of Fourche Bayou as shown on the geologic map (pl. 1). In other drainage systems of the region where the underlying rocks crop out in stream beds or where the alluvial deposits are less than 12–15 feet thick and the underlying rocks are known from drill-hole data no alluvium was mapped even though it occurs in almost continuous patches and belts of gravel and debris.

In the major drainage areas the alluvium forms wide flood plains upon which most of the productive farmland of the area is located. Meager drill-hole data indicate that the alluvium in these flood plains reaches a maximum thickness of almost 120 feet and has cut out all the older formations and channeled down to basement rock for a considerable distance downstream from their normal contacts. The alluvium consists of gravel, sand,

silt, and clay and attempts to correlate individual beds have proved fruitless. In the smaller streams the alluvium consists largely of gravel or of gravelly clay and is derived from whatever formations occur toward the head of the valley occupied by each stream. Alluvial material is particularly abundant in the beds of streams that drain areas covered by older gravel.

INTRUSIVE IGNEOUS ROCKS

The Arkansas bauxite region has long been noted for the nepheline syenite deposits and related igneous rocks with which the bauxite is associated. The outcrops of these rocks in Pulaski and Saline Counties are the higher parts of cupolas or stocks, most of which, including still other cupolas, lie buried beneath the early Tertiary sediments of the Coastal Plain. The igneous rocks were intruded into older sediments, the youngest of which probably are Pennsylvanian.

The surface exposures of the Arkansas igneous rocks were the subject of an excellent detailed petrographic report by J. F. Williams (1891). As the preparation of the present report did not include a careful petrologic study of the igneous rocks, much of the descriptive material that follows is based upon the report of Williams. However, a brief study of thin sections from surface exposures and from cores taken from the bottom of some of the deeper drill holes has provided additional information as to the distribution of these rocks, particularly in the buried parts of the complex. Also, new chemical and spectrographic analyses of several varieties of nepheline syenite were made by the Geological Survey for inclusion in this report. The most distinctive igneous rocks have been differentiated in the geologic map (pl. 1).

Two coarsely granular varieties of nepheline syenite are the principal source rocks of the bauxite. They are distinguished in surface exposures by color, texture, and resistance to weathering. These rocks are: nepheline syenite, or the so-called gray granite of the quarrymen; and pulaskite, or so-called blue granite. Associated with them and particularly with the pulaskite are fine-grained tinguaitic border rocks, as well as many granular dike rocks. Some of the rocks are felsic, including porphyritic and pegmatitic nepheline syenite, quartz syenite, and miarolitic nepheline syenite dikes. Some are mafic, including fourchite and several varieties of monchiquite. These rocks are described briefly on the following pages.

NEPHELINE SYENITE

Under the name eleolite syenite (eleolite being in part an old name for nepheline) Williams (1891) included the coarse-grained intrusive rocks known locally as "gray granite." Some geologists prefer to use the name "foyaite" for this Arkansas rock which is similar to the original type from Foya, Portugal. Considerable confusion would be averted by using this term to distinguish the rock from pulaskite, which also is a nepheline syenite. However, in this report which is concerned primarily with bauxite, the original terminology of Williams has been followed.

The nepheline syenite is readily distinguished in the field by its light-gray color and its tendency to crop out in large flat masses. This apparently is caused in part by the structure of the rock which in some places is distinctly sheeted, and in part by its comparatively rapid rate of weathering. The characteristic outcrops are flat surfaces and broad low knolls. Some are set in picturesque cedar glades, others are bare of vegetation. The surface of many of the exposures is lacking in scattered loose blocks because the rock on weathering crumbles evenly. Weathering has progressed to a depth of several inches on quarry faces, road cuts, and rock slabs that were blasted 15 to 20 years ago.

In Pulaski County the outcrops of gray nepheline syenite are confined to the lower slopes of Granite Mountain in two separate areas that are irregularly elongate southwest. One of these is along the west base of the mountain and in scattered patches in the relatively flat area east of Little Fourche Bayou, mostly in secs. 22 and 28, T. 1 N., R. 12 W. The other is at the east side of Echo Valley, in the SW¼ sec. 26 and adjacent corners of secs. 27 and 34. Chemical analyses of samples from both exposures are given below in table 6. In Saline County nearly all of the exposed igneous rock is "gray granite." The outcrops are shown on the geologic map (pl. 1). Chemical analyses of Saline County nepheline syenite is also given below in table 6.

Spectrographic determinations of the minor elements in three of the samples chemically analyzed are given in table 7.

The light-gray rock has a pinkish to buff cast where nepheline is common and may have a bluish cast where the feldspars are particularly fresh. Slight weathering whitens the feldspar crystals. The rock is granular and commonly is coarse grained. Fine- to medium-grained as well as coarse-grained pegmatitic varieties (fig. 13*A*) occur locally, but most of these varieties are in ellipsoidal or veinlike segregation bodies in the rock. In some exposures the feldspar laths exhibit a marked parallelism and the rock has a trachitoid structure (fig. 13*C*, *D*). Outcrops in which this structure is conspicuous were noted by F. A. Hildebrand in patches along the west margin of the nepheline syenite exposure in the SE¼ sec. 21 and NW¼NW¼ sec. 27, T. 2 S., R. 14 W., and also in the NE¼ sec. 34 and W½NW¼ sec. 35.

TABLE 6.—*Chemical analyses of Arkansas nepheline syenite*

[Nos. 1, 3, and 5 are recent analyses by the U. S. Geological Survey. C. M. Warshaw, analyst. Figures marked with an asterisk (*) were determined with a flame photometer by W. W. Brannock. Nos. 2, 4, 6, and 7 are analyses of the Ark. Geol. Survey from Williams (1891, p. 39, 70, 81, 88, 135, and 139)]

	Pulaski County				Saline County		
	1	2	3	4	5	6	7
Al_2O_3	17.94	18.85	18.60	20.76	21.11	18.67	20.85
SiO_2	59.91	59.70	59.56	60.03	56.51	59.62	58.74
Fe_2O_3	1.88	4.85	1.54	4.01	1.80	5.07	4.15
FeO	1.54		1.84	0.75	1.20		
MgO	.80	.68	.95	.80	.48	.84	.22
CaO	1.26	1.34	2.05	2.62	.91	1.80	.36
Na_2O	*6.90	6.29	*6.56	5.96	*9.13	6.95	9.72
K_2O	*6.41	5.97	*6.18	5.48	*6.34	5.65	4.23
TiO_2	1.13		.91		.50		
ZrO_2	.07		.06		.04		
P_2O_5	.16		.28	.07	.06		
SO_3	.07		.11		.15		
Cl	.03		.10		.39		
MnO	.20		.17	Tr.	.24		
BaO			*.18				
SrO			*.05				
H_2O-	.04		.07	.06	.09		
H_2O+	1.77	1.88	.88	.53	1.50	.80	1.82
Total	100.11	99.56	100.09	101.07	100.45	99.40	100.09
$(O-Cl_2)$	.01		.02		.09		
	100.10		100.07		100.36		

1. Nepheline syenite ("gray granite"). Quarry on Arch Street Pike, at the northwest edge of Granite Mountain, in the SW¼SW¼ sec. 22, T. 1 N., R. 12 W., Pulaski County; collected by H. B. Foxhall.
2. Nepheline syenite ("gray granite"). East side of Fourche Cove (Echo Valley) in the SW¼SW¼ sec. 26, T. 1 N., R. 12 W., Pulaski County. Analyst, W. A. Noyes.
3. Pulaskite ("blue granite"). Minnesota Mining and Milling Co. quarry at College Station, Pulaski County, collected by H. B. Foxhall.
4. Pulaskite ("blue granite"), light-colored variety. Granite Mountain, SW¼ sec. 13, T. 1 N., R. 12 W., Pulaski County. Analysts, R. N. Brackett and J. P. Smith.
5. Nepheline syenite ("gray granite"). Small outcrop beside underpass on the Bryant-Benton road, 0.6 mile east of Bauxite Station, NW¼SW¼SW¼ sec. 10, T. 2 S., R. 14 W., Saline County, collected by H. B. Foxhall.
6. Orthoclase nepheline syenite ("gray granite"). Saline County. Exact locality not specified by Williams. Analyst, W. A. Noyes.
7. Plagioclase nepheline syenite ("gray granite"). Exact locality not specified, but probably from the SE¼ sec. 14, T. 2 S., R. 14 W., Saline County (Williams, 1891, p. 129, 139). Analyst, W. A. Noyes.

TABLE 7.—*Spectrographic determination of minor elements in Arkansas nepheline syenite samples*

Element	1	3	5
Ti	>1	0.9	0.2
Zr	.07	.05	.03
Mn	.1	.09	.1
V	.006	.005	.003
Ga	.002	.002	.002
Y	.02	.009	.01
La	.03	.02	.04
Nb	.02	.01	.009
Ba	.009	.2	.003
Sr	.02	.04	.02
Cu			.0005
Sc	.0005	.0005	
Cr		.0002	
Pb	.002		
Mo	.001	.0007	
Be	.0002	.0001	.0002

Looked for but not found: Co, Ni, Zn, Cd, As, Sb, Bi, In, Tl, Sn, Ag, B. [Analyst, K. J. Murata. Numbers of specimens given above are the same as those in table 6 of chemical analyses. Refer to that table for locality descriptions]

Specific gravity of a Granite Mountain specimen was determined by Williams (1891, p. 74, 132) to be 2.557 and of a specimen from Saline County to be 2.603.

Tabular feldspar crystals, which make up more than half the rock, (pl. 10*A*) range from 10 to 25 millimeters in length, and a few reach 35 millimeters. They are opaque, dull white or faintly bluish, yellowish, or flesh colored, and are distinctly white where the surface has been exposed to the air and partly weathered to kaolinite. In thin section the crystals are moderately translucent to nearly opaque. They show distinct cleavage cracks as light lines, parallel to the base and tabular edge (pl. 11*A*). Most of the crystals are twinned according to the Carlsbad law and between crossed nicols also appear to be intergrown in slender wedges with polysynthetically twinned feldspar, forming a microperthitic structure. Williams (1891, p. 76, 132) identified the feldspar in the nepheline syenite from Granite Mountain, Pulaski County, as microcline-microperthite, and that of the common Saline County rock as microperthitic orthoclase.

Nepheline occurs in greasy-appearing yellowish, brown, or flesh-colored grains as much as 10 millimeters between the feldspar and other crystals. The nepheline grains are broad wedges or polyhedrons, the edges of which were controlled by the crystal faces of the bounding minerals. Nepheline (including analcime, in places an alteration product of nepheline) makes up 25 percent of the rock, but more commonly averages 10–15 percent. Under the microscope nepheline is transparent, colorless, and generally in triangular or polygonal sections, and has a slightly lower birefringence than that of the feldspar.

The principal ferromagnesian minerals are biotite, pyroxene, and soda amphibole. The last of these, however, has not been noted in Pulaski County specimens. Biotite is common in dark-brown to black six-sided crystals as much as 25 millimeters in diameter, but in many outcrops the crystals are less than 3 millimeters across. The pyroxene minerals are diopside and aegirine, which are generally less abundant than biotite, but locally make up as much as 10 percent of the rock. Diopside occurs in small greenish-black euhedral to subhedral crystals, generally with aegirine along the borders.

The main accessory mineral is sphene in yellowish resinous euhedral crystals as much as 2 millimeters in diameter. Apatite is also common in transparent long, narrow crystals with pyramidal terminations. Magnetite occurs in elongate subhedral crystals, and ilmenite locally in euhedral crystals. Natrolite, in well-formed crystals as much as 2 centimeters long, has been found in cavities in the Granite Mountain rock. Small grains of pyrite and purple fluorite are rare.

Analcime, which replaces nepheline in the rock and parts of feldspar crystals, is clear and colorless to slightly yellow. In thin section it appears colorless, and shows a poor cleavage in three directions at right angles (pl. 11*A*). Between crossed nicols it shows a very weak birefringence and in places is polysyn-

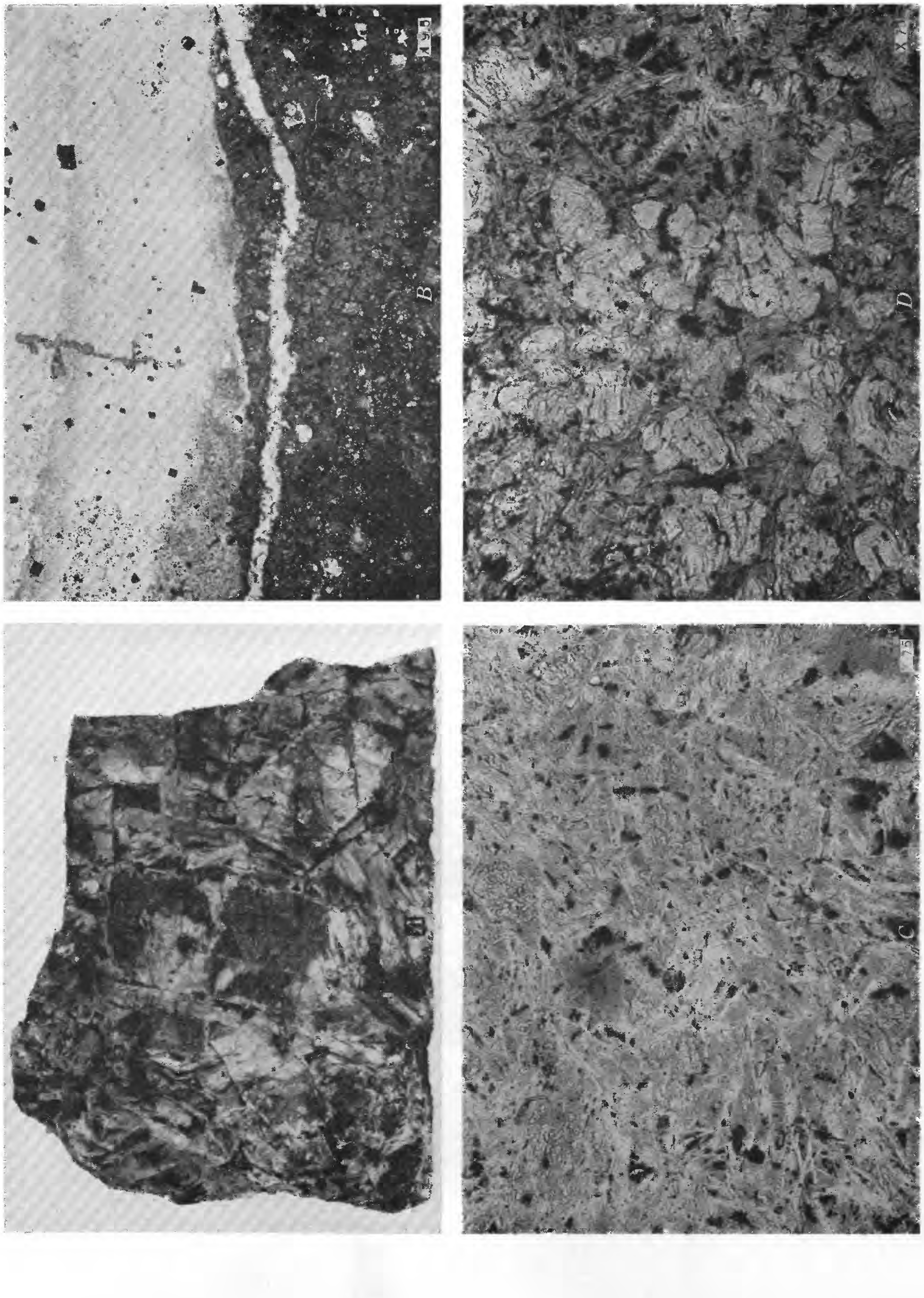

FIGURE 13.

thetically twinned. Some areas contain tiny scattered needles of aegirine. Sodalite is found in some of the Saline County specimens in small clear grains wedged between the feldspar crystals. Other secondary minerals, such as kaolinite, calcite, and gibbsite are found as decomposition products of this rock.

Williams (1891, p. 136–140) has also described a relatively rare variety of gray nepheline syenite from Saline County that contains a considerable amount of plagioclase. An analysis of this rock, taken from his report (p. 139), is given in table 6, column 7. It is higher in sodium than any of the other nepheline syenite samples and is similar to the analysis of another Saline County sample from the SW¼ sec. 10, T. 2 S., R. 14 W. The analysis of this sample in the laboratory of the U. S. Geological Survey, Washington, D. C., appears in table 6, column 5. Thin sections of this rock (pl. 11*C*), however, fail to show any single plagioclase crystals. The high sodium content is associated with the high proportion of feldspathoidal minerals and analcime in the rock.

PORPHYRITIC ALKALIC SYENITE (INCLUDING PULASKITE)

Under this heading are included the porphyritic syenite rocks commonly known in the region as "blue granite." In Pulaski County those containing nepheline as an essential mineral were given the name pulaskite by Williams (1891, p. 56). In the few small scattered exposures in Saline County, the rock is not known to contain nepheline, and it was described by Williams (1891, p. 140–143) as porphyritic syenite. The so-called blue granite is distinguished in the field from the gray nepheline syenite by the light-to-dark-bluish-gray color, the porphyritic texture, and its tendency in outcrop to form moderately steep slopes that are thickly covered with weathered talus blocks.

Pulaskite was defined by Williams (1891, p. 69) as a nepheline-bearing syenite with a trachytic or porphyritic(?) structure in which soda-amphibole usually predominates among the mafic silicates; soda-pyroxene and biotite are present in small quantities. This rock makes up the greater part of Granite Mountain, particularly the ridges and higher slopes (pl. 1).

In Saline County the similar-looking bluish-gray porphyritic syenite crops out in patches in the NW¼ sec. 23, T. 2 S., R. 14 W. The rock is resistant to weathering and erosion and forms small hills covered with subangular talus blocks. The highest of the little hills is 1,200 feet east and 1,600 feet south of the northwest corner of sec. 23. Other small patches of bluish-gray porphyritic rock form elevated knolls in the SW¼SW¼ sec. 26, the NE¼NE¼ sec. 34, and the NW¼ sec. 35, in the same township. These have not been differentiated on the geologic map.

The texture of these rocks ranges from coarse to porphyritic granitoid. A core specimen is shown in plate 9*B*. Some of the large feldspar crystals have a subparallel arrangement that gives the rock a rough trachitoid texture (the "trachytic structure" of Williams). The bluish-gray pulaskite is harder, more resistant to wear and weathering, and slightly denser than the gray nepheline syenite. The average specific gravity of the Granite Mountain rock was determined by Williams (1891, p. 50) to be 2.656. The chemical composition of pulaskite is similar to the gray nepheline syenite. Analyses of two specimens from the eastern part of Granite Mountain are given in table 6, columns 3 and 4. Spectrographic analyses of the minor elements of one of these samples is given in table 7.

Orthoclase is the most abundant mineral in pulaskite. It occurs in two distinct generations—early large crystals about 10 to 30 millimeters long, and later small ones that reach a maximum of 3 millimeters. The crystals are gray to bluish gray, semitranslucent. Some of the large ones are euhedral, but the edges of others are interrupted by smaller ones. The large crystals scattered through aggregates of the small grains give

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EXPLANATION FOR FIGURE 13

Igneous and metamorphic rocks. *A*, Gray nepheline syenite, pegmatitic facies from a segregation; feldspar crystals as much as 40 millimeters long. Hand specimen (AB–201–4) from same locality as rocks shown on plate 10*A*. Natural size. *B*, Photomicrograph of a light-gray devitrified feldspathic glass containing scattered pyrite cubes in contact with a dark-brown dike rock in which pyroxene and olivine phenocrysts have been altered to chlorite and clay minerals (p. 69). Veinlets of carbonate minerals cut both rocks. Thin section (AB–6019A–2) from bottom of USBM drill hole 6019A, depth 1409 feet, NE¼SW¼ sec. 11, T. 3 S., R. 13 W., Grant County. One millimeter indicated by scale. × 9.5. *C*, Photomicrograph of weathered trachyte partly altered to montmorillonite and kaolinite. Trachytic texture is well preserved. White laths are mostly feldspar; darker areas between are montmorillonite apparently replacing glassy matrix; light areas of high relief scattered through rock are masses of fine-grained kaolinite replacing feldspar; darkest parts are biotite flakes and opaque minerals. Thin section from core specimen (AB–12042–3) from USBM drill hole 12–042, depth 335 feet, Stover property, SE¼SW¼ sec. 25, T. 1 S., R. 14 W., Saline County. × 75. *D*, Photomicrograph of large kaolinite crystals in the same rock. Unusually large wormlike crystals of kaolinite have nearly obliterated the trachytic texture. Part of the same thin section (AB–12042–1) shown in *C*. The core specimen came from 9 feet below top of residual rock which lay beneath a few feet of sediments of the Midway group. × 75.

the rock a porphyritic appearance. Under the microscope the crystals are translucent, and show cleavage commonly formed in two directions. They contain minute inclusions of mafic silicate, apatite, magnetite, and locally nepheline, as well as tiny needlelike cavities that are alined parallel or at right angles to the cleavage planes. In some crystals an indication of zoning is heightened where the central part of the crystal has been altered to kaolinite and the rims are unaltered (pl. 9*C*). Many of these feldspar crystals have ragged edges, even where fresh, and the composition of the interior appears to be slightly different than that of the rims. Williams (1891, p. 59) observed an indistinct microperthitic structure in many of the crystals and from the general crystallographic form and microscopic structure, as well as from a chemical analysis of the feldspar concluded that it should be classed as cryptoperthite, although the soda content is low.

The dark mafic silicate occurs in euhedral to anhedral grains in small nests or groups scattered through the feldspar. Biotite, apparently the earliest to crystallize, occurs rarely in pseudohexagonal crystals, more commonly in plates with irregular edges. In thin section it is reddish brown to dark brown, and has characteristically strong absorption. Locally the biotite contains inclusions of irregular grains of magnetite, feldspar, and apatite. The pyroxenes are diopside in small stubby greenish-black crystals, containing an aegirine-like mineral along the edges as in the nepheline syenite. Under the microscope the crystals are light green or nearly colorless, some are darker green near the edges. In sections parallel to the vertical axis the interior parts have extinction angles (*Zc*) from 40° to 50° and the aegirine borders from 8° to 10°.

Nepheline is a characteristic mineral of the pulaskite, in some places making up as much as 10 percent of the rock, but generally less. It is in small colorless to yellowish-colored grains rarely reaching a millimeter in diameter, in shapes similar to those in the gray nepheline syenite. It likewise is commonly replaced by analcime. Rare inclusions of acicular apatite and secondary aegirine crystals are present locally. Sodalite in crystals about 0.5 millimeter in diameter was identified by Williams (1891, p. 67) in some of his slides.

The accessory minerals, in the order of their relative abundance, are as follows: yellowish resinous euhedral crystals of sphene, as much as 1.5 millimeters long; slender transparent euhedral prisms of apatite, as much as 2 millimeters long and generally terminated at both ends by pyramidal facies; tiny scattered black opaque euhedral crystals of magnetite, generally less than 0.1 millimeter in diameter; and minute purple crystals of fluorite. Small second-generation aegirine crystals in slender prisms, similar to those in the gray nepheline syenite, are scattered through the rock, locally in radial groups.

Analcime is the most common secondary mineral in the unweathered rock. It generally replaces nepheline and less commonly, parts of adjacent feldspar crystals. It has about the same properties as those in the gray nepheline syenite. Where the rock is partly decomposed, kaolinite is the most common secondary mineral, replacing the cores of feldspar crystals (pl. 9*C*) and extending inward from the outside.

The porphyritic syenite in Saline County differs from the pulaskite described above, chiefly in the absence of nepheline. The scarcity of pyroxene as compared to hornblende also is marked. Orthoclase crystals are large and tabular and are scattered through a relatively fine grained feldspathic matrix, giving the rock a marked porphyritic texture. Sphene is a common accessory mineral, apatite is rare, and magnetite occurs associated with ilmenite and its alteration products.

MINOR INTRUSIVE ROCKS

NEPHELINE SYENITE AND QUARTZ SYENITE DIKE ROCKS

The coarse-grained plutonic rocks of the nepheline syenite stocks are cut by many dike rocks of similar composition. The oldest are pegmatitic, porphyritic, and granitic-textured nepheline syenite dikes. Younger types, particularly in Pulaski County, include miarolitic nepheline syenite and quartz syenite dikes.

Pegmatitic dikes.—Nepheline syenite pegmatite dikes, from several inches to several feet wide, are common in Saline County, particularly in sec. 16, T. 2 S., R. 14 W. They consist chiefly of large microperthitic orthoclase crystals and grains of nepheline, a small amount of mafic silicate of which aegerine is the most common, and in some places contain metallic sulfide. Seven of these dikes were described by Williams (1891, p. 143–146) and appear in a tabulation by Kemp and Williams (1891, p. 424, 425). In Pulaski County similar rocks occur in small ellipsoidal and veinlike segregations, in gray nepheline syenite and in pulaskite. Some of these contain a few percent of fluorite.

Porphyritic dike rocks.—Porphyritic dike rocks are not common. One of these, in the SE¼SE¼ sec. 16, T. 2 S., R. 14 W., was described by Williams (1891, p. 146) as "aegirite tinguaite." Another, at the old Letts mine in the N½NE¼ sec. 21, in the same township, contains, according to Williams (1891, p. 147–149, more than 50 percent nepheline associated with orthoclase, plagioclase, aegirine, apatite, magnetite, and secondary cancrinite. Tinguaite dikes near Bryant containing unusual orbicular structures have been described by Hildebrand (1949). These are distinguished by Hildebrand from the tinguaitic border rocks discussed on page 66.

The pegmatitic and porphyritic dikes are small and hence are not shown on the geologic map (pl. 1). They are of little importance to the bauxite problem except that they were minor source rocks of the bauxite.

Nepheline syenite dikes.—Two nepheline syenite dikes with a granitic texture ("brown granite") cut the pendant rocks of Paleozoic age and the porphyritic border rocks along the south edge of Granite Mountain in sec. 35, T. 1 N., R. 12 W. and are shown on the geologic map (pl. 1). The rock is grayish- to pinkish-brown has a medium- to coarse-grained texture, and often has scattered large tabular feldspar crystals that give it a porphyritic appearance. This rock is described in detail by Williams (1891, p. 83–90) and a chemical analysis shows the rock to be similar to both pulaskite and gray nepheline syenite. The principal constituent is pinkish to brownish orthoclase in tabular subhedral to euhedral crystals with bluish transparent centers. It occurs with biotite, diopside with brown aegirine borders, nepheline in anhedral grains, and euhedral crystals of apatite, sphene, and magnetite. Secondary minerals include analcime, calcite, and cancrinite. Some of the mafic silicate has been serpentinized.

Miarolitic nepheline syenite dikes.—The miarolitic dike rocks represent a late stage as some dikes cut pulaskite and others cut fourchite bodies. They are limited to the Granite Mountain area where they occur in weathered boulders on the surface, or in narrow veinlike masses cutting the older rocks.

A large miarolitic nepheline syenite dike trends northeastward across the NE¼ sec. 35, T. 1 N., R. 12 W., and probably is continuous with a larger mass of similar trend in sec. 25, T. 1 N., R. 12 W. Exposures of the larger mass are poor except for a small area in the creek bed northwest of the Fuller School. The amount of miarolitic material thrown out during the construction of the Big Inch Pipeline, however, indicates that the outcrop of this rock near the center of sec. 25 is much larger than that shown on earlier maps.

Small nepheline syenite dikes of this type in the fourchite and in rock outcrops of Paleozoic age at the southwest end of Echo Valley are not shown on the geologic map. The rock in these dikes is light tan to tannish gray and has a very porous miarolitic texture. The dikes appear zoned parallel to their strike, and each zone is characterized by a high degree of uniformity in the size of miarolitic cavities and by the tabular euhedral to subhedral feldspar crystals that bound them or protrude into them. The cavities and the feldspar crystals are about the same length in any one band, and most commonly are 8 to 10 millimeters long but range in length in different bands from 2 to 30 millimeters. The feldspar is a microperthitic intergrowth of orthoclase and albite and is associated with biotite, soda amphibole, sphene, apatite, and nepheline; most of this last mineral has been altered to analcime.

Quartz syenite dikes.—Syenite dikes that contain crystals and grains of quartz occur in several places in the northern and northeastern parts of Granite Mountain. A northeastward-trending dike along the top of the ridge in sec. 13, T. 1 N., R. 12 W., is similar in color and texture to the "brown granite" of sec. 35, T. 1 N., R. 12 W., which was described by Williams (1891, p. 20) as a "miarolitic nepheline syenite dike." However, careful examination of most of the large rounded boulders of which the exposures are composed will disclose a few cavities or small vugs that contain one or more subhedral quartz crystals. These crystals are generally 3–5 millimeters in diameter, or slightly smaller than the subhedral feldspar crystals with which they are associated. Rare anhedral quartz grains occur sporadically in the compact granitoid rock.

Along the same trend, another dike was mapped by Williams as a coarse-grained quartz syenite, in a tributary valley at the northeast end of Echo Valley, in the SW¼NW¼ sec. 24 and the E½ sec. 23, T. 1 N., R. 12 W. According to Williams (1891, p. 93–97) its recognizable minerals are quartz in anhedral grains, orthoclase, and plagioclase; the ferromagnesian silicate minerals, among which aegirine can be recognized, have nearly all been altered to a reddish-brown ferruginous substance.

Another light-brownish-gray dike, described by Williams as a fine-grained quartz syenite, is exposed in the SE¼SE¼ sec. 13, T. 1 N., R. 12 W. The rock cuts pulaskite and dips a little less than 40° N. in the quarry of the Minnesota Mining and Milling Co.

Megascopically the rock is much like the miarolitic nepheline syenite from the center of sec. 25, except that drusy groups of quartz crystals, each less than 2 millimeters in diameter, in some places coat the faces of euhedral feldspar crystals. Amber crystalline siderite in a similar relation to feldspar was noted where the dike was cut by the pipeline. The two minerals are secondary but not necessarily contemporaneous in origin.

Chemical analyses of the coarse- and fine-grained varieties of quartz syenite, published by Williams (1891, p. 99), show that the silica content is 4 to 5 percent higher than in the nepheline syenite of Pulaski County.

Two outcrop areas of a rock containing much quartz have been mapped as quartz syenite. The smaller exposure is in the flat bottom of Fourche Bayou in the SE¼SW¼ sec. 21, T. 1 N., R. 12 W. The deeply weathered rock at this locality consists of nearly equal amounts of anhedral quartz and feldspar and a lesser quantity of soft reddish-brown ferruginous matter. The larger and more southerly exposure lies at the northeast corner of a triangular terrace remnant in the NW¼

sec. 28, T. 1 N., R. 12 W. Much of the rock is similar to that in the small exposure to the north, but quartz is less abundant in the southern and southwestern parts, where the rock is coarse grained and contains vugs in which there are euhedral to subhedral feldspar and quartz crystals as much as 30 millimeters in diameter.

Feldspathic veinlets containing quartz and amphibole, locally miarolitic, were noted in a specimen collected by E. F. Burchard from an outcrop near Bauxite, Saline County (pl. 9A). The veinlets, as much as 1 centimeter wide, are nearly parallel and have been intruded into a rock that probably was once a shale or sandy shale but now is made up almost entirely of small feldspar grains among which biotite flakes are scattered, some of which show alinement.

MAFIC DIKE ROCKS

Many dikelike bodies of augite-bearing rocks cut the coarse nepheline syenite and pendant rocks of Paleozoic age and are themselves cut by miarolitic nepheline syenite dikes. On the geologic map (pl. 1) these lamprophyre dike rocks have been included under Williams' name fourchite in the Granite (Fourche) Mountain area. They are exposed along the slopes of the mountain at the southwest end of Echo Valley, as far as the summit of the ridge in the E½ sec. 33 and adjacent parts of the NW¼ sec. 34 and the SW¼SW¼ sec, 27, T. 1 N., R. 12 W. The small exposures in Saline County are not shown on the geologic map.

The typical fourchite is a bluish- to brownish-black rock in which stubby phenocrysts of titanaugite, as much as 5 millimeters across, are scattered through a fine-grained matrix that contains considerable hydrous iron oxide. In thin section some of the monoclinic pyroxene shows an hourglass and zonal structure between crossed nicols. Leucoxene is scattered through the rock in tiny transparent yellow globules. In one thin section examined by R. L. Smith, a tiny veinlet in the matrix is filled with analcime.

In Saline County 14 lamprophyre dikes, most of which are in secs. 14, 16, 21, 22, and 26, T. 2 S., R. 14 W., have been described in a tabulation by Kemp and Williams (1891, p. 424–427, maps 3 and 3A). A nearly circular monchiquite body, about 50 feet across that cuts the nepheline syenite 900 feet south and 1,000 feet west of the center of sec. 26 was found by F. A. Hildebrand during the present field mapping. Along the southeast edge of this mass small angular gray fragments of the syenitic wall rock, as much as 2 inches in diameter, are scattered through the dark rock. Some of the dikes are now covered by overburden stripped from the bauxite mines, but several large ones are still accessible.

Most of the Saline County lamprophyres contain, in the order of their abundance: phenocrysts of titanaugite in thick, light-brown, prismatic crystals that reach a millimeter in length, basaltic hornblende in reddish-brown prismatic crystals that reach 2 millimeters in length; tiny pseudomorphs of serpentine minerals after olivine; and small flakes of biotite. The groundmass is partly glassy and contains small needles of apatite, pyrite cubes, and feldspathic material probably including orthoclase and plagioclase. Williams (1891, p. 150–157) called this type of rock an amphibole monchiquite. A similar rock in which the amphibole is entirely lacking and the light-colored silicate and light glassy base are absent, or nearly so, was classified by Williams as monchiquite.

PORPHYRITIC BORDER ROCKS

In the southeastern part of Granite Mountain some bodies of syenitic rock consist essentially of small feldspar phenocrysts in a dense greenish-gray to black or purplish matrix, in places associated with tiny pyroxene or biotite crystals. This rock borders some of the pendant rocks of Paleozoic age that are surrounded by pulaskite, particularly where the pendants are cut by large nepheline syenite dikes. It constitutes a border phase between the crystalline rocks and the metamorphosed sedimentary rocks.

Williams (1891, p. 99–106) has identified this rock as tinguaite, a rock found first in the Serra de Tinguá, State of Rio de Janeiro, Brazil. Tabular orthoclase crystals are associated with nepheline, sodalite, aegerine locally intergrown with amphibole, and biotite, sphene, fluorite, and apatite.

The largest tinguaite outcrop is in a small hill on the Dixon property in the SE¼NW¼ sec. 35, T. 1 N., R 12 W., Pulaski County. The rock is dense, hard, and jointed, and weathers deeply into scattered loose blocks. Some specimens contain masses of tiny feldspar laths and tabular crystals. In some places the alinement of laths indicates flowage around the tabular crystals. Similar trachytic rocks have also been found within the pendants.

Distribution of these rocks in Pulaski County is shown on the geologic map (pl. 1).

PENDANT AND CONTACT ROCKS

The shale and sandstone beds of Paleozoic age that were engulfed by the nepheline syenite intrusive rocks were locally metamorphosed. On the geologic map (pl. 1), within the exposed Pulaski nepheline syenite mass, areas in which the pendant rocks are dominantly quartzite have been shown separately from those in which altered to relatively fresh shale predominates. Nearly all the pendant rocks have a northeasterly alinement. Some of these rocks, particularly the shale beds, have been altered to a finely crystalline rock composed largely of feldspar. The feldspathic rock is found near

the edge of the pendants or where the pendants are cut by nepheline syenite dikes. Some of the small bodies and inclusions of sedimentary origin in the nepheline syenite are composed almost entirely of this type of rock. In Pulaski County some feldspathic rocks appear to grade into the porphyritic border rocks, but because of poor exposures and abundant soil the details of the transition have not been observed.

These contact rocks appear thinly laminated and stratified and resemble indurated shale or shaly sandstone on casual inspection. Examination under the microscope reveals that they are composed largely of anhedral feldspar grains that in some cases reach 2 millimeters in diameter but generally are much smaller. Tiny biotite flakes are scattered among the feldspar grains and in places they are alined in parallel planes. In some of these contact rocks black oxides, presumably magnetite, are disseminated.

In the contact rocks from Saline County Williams (1891, p. 157–161) identified several other minerals: aegirine, astrophyllite, pyrite, and possibly leucoxene.

ROCKS OF THE MORE DEEPLY BURIED PARTS OF THE LITTLE ROCK IGNEOUS COMPLEX

During the Federal drilling program 60 holes were drilled to check the results of the magnetic and gravimetric geophysical survey conducted by the U. S. Bureau of Mines. The location of these drill holes is shown in plates 5 and 6. The maximum depth of 1,500 feet was reached in 8 drill holes without striking the basement rock; of these, 7 stopped drilling in sediments of the Midway group and 1 in sand of the Wilcox group. Nine other holes were bottomed in the Midway at depths less than 1,500 feet and 2 bottomed in the Wilcox at relatively shallow depths. The remaining 41 drill holes reached the basement rock. The location and altitude of the collar of each of the 41, its total depth, and the depth, altitude, and description of the basement rock, are given in table 8.

An asterisk (*) before the rock name in the final column indicates that it was examined in thin section. Those unmarked were identified from core specimens, except for four identified from cuttings only, and two in which no cuttings were recovered as noted in the table.

The thin sections of these rocks were examined by R. L. Smith who assisted the writers with the mineral identifications that form the basis for brief descriptions on the following pages.

One result of the deep drilling has been the confirmation of what was suspected since the geophysical work of Stearn (1930), namely that the two principal areas of nepheline syenite exposures in Pulaski and Saline Counties are continuous and are the elevated parts of a large igneous body or complex that lies mainly south and east of the surface exposures. This igneous body is referred to in this report as the Little Rock igneous complex. The area now proved to be underlain by the nepheline syenite rocks is estimated to be about 300 square miles. An outline of the area is shown in the sketch map (pl. 5). These limits have been interpreted by the writers from drill-hole data from the magnetic intensity map by Stearn (1930), and from the magnetic and gravimetric maps by Malamphy and Vallely (1944) and Malamphy and others (1948, v. 1).

All the deeply buried parts of the Little Rock batholithic complex, are overlain directly by marine sediments of the Midway group. No Cretaceous sedimentary rocks have been recognized in the drill holes. It is possible, however, that the buried edge of the Cretaceous sediments reaches the igneous complex and that several of the drill holes that terminated in sedimentary beds at 1,500 feet, had they been drilled farther, might have cut into Cretaceous sedimentary rocks as well as igneous rocks beneath. The pyroxenite (Moody, 1949, p. 1415) recorded in Youngblood No. 1 well of the Shafer Oil and Refining Co. near Sheridan, in Grant County, is overlain by 193 feet of Cretaceous sedimentary rocks. This well is only 7 miles southwest by south of the nearest of the 60 drill holes under discussion.

The deep drilling also has shown that the main magnetic anomalies represent bosses or stocks that protrude above the average surface of the complex. The rocks that form the buried hills called highs in this report are almost identical with those that form surface exposures of nepheline syenite. Another notable feature is the similarity of the rocks of the large buried nepheline syenite hills northwest and west of Woodson, in southernmost Pulaski County, and also in the vicinity of Ico, in northern Grant County, with those of the Pulaski nepheline syenite hill near Little Rock. The rocks of the Woodson and Ico highs include pulaskite; altered trachytic dike or border rocks, some of which originally had a glassy base; and altered lamprophyric dike rocks of the fourchite-monchiquite group.

Nepheline syenite.—Most of the deep drill holes, particularly those in the western and central parts of the igneous complex, bottomed in gray nepheline syenite. Three of the cores were examined in this section and are described below.

USBM drill hole 6–004, about 3 miles west by south of Woodson, bottomed at 1,283 feet below ground level in a coarse-grained gray nepheline syenite containing abundant orthoclase and considerable nepheline, and sodalite, sphene, biotite, and a soda amphibole related

TABLE 8.—*Depth, altitude, and lithologic character of the basement rocks in deep drill holes in Pulaski, Saline, and Grant Counties*

[Asterisk (*) indicates that the rock was examined in thin section]

USBM drill hole	Approximate location	Altitude at collar (feet)	Total depth (feet)	Basement rock		
				Depth (feet)	Altitude (feet)	Description
6-001	SW¼NW¼ sec. 24, T. 2 S., R. 12 W	293.8	1,295.3	1,295	−1,001	*Altered fine-grained syenite porphyry.
6-002	NE¼NW¼ sec. 31, T. 2 S., R. 11 W	279.8	1,452.5	1,451	−1,170	*Green altered lamprophyric dike rock.
6-004	SW¼NW¼ sec. 25, T. 2 S., R. 12 W	255.7	1,283.3	1,283	−1,027	*Dark-gray coarse nepheline syenite.
6-005	NE¼NE¼ sec. 34, T. 1 S., R. 12 W	272.6	855.2	853.5	−580	*Gray nepheline syenite.
6-012A	NW¼NW¼ sec. 18, T. 3 S., R. 12 W	341.3	1,253.5	1,250	−909	*Bluish-gray pulaskite.
6-014	NW¼NW¼ sec. 18, T. 3 S., R. 12 W	314.6	1,446.4	1,446	−1,131	*Do.
6-015	SW¼SW¼ sec. 7, T. 3 S., R. 12 W	331.8	1,199.0	1,198	−866	*Tan trachitoid syenite dike rock.
6-017	SW¼SE¼ sec. 11, T. 3 S., R. 13 W	281.5	1,426.5	1,420	−1,138	*Altered green lamprophyric dike rock.
6-019	NE¼SW¼ sec. 11, T. 3 S., R. 13 W	285.2	1,409.8	1,407	−1,122	*Altered green lamprophyric dike rock over gray spherulitic altered glass (fig. 13*B*).
6-021	NW¼NW¼ sec. 17, T. 2 S., R. 11 W	257.0	976.5	974	−717	Gray nepheline syenite boulders and nepheline syenite.
6-022	NE¼NW¼ sec. 17, T. 2 S., R. 11 W	230.1	1,012.0	1,010	−780	Gray nepheline syenite pebbles.
6-023	SW¼SW¼ sec. 17, T. 2 S., R. 11 W	252.5	1,251.5	1,250	−977	*Bluish-gray nepheline syenite.
6-024	NW¼NW¼ sec. 17, T. 2 S., R. 11 W	249.0	806.0	806	−557	Very hard rock (no cuttings). Nepheline syenite(?).
6-025	NW¼NE¼ sec. 18, T. 2 S., R. 11 W	258.2	1,192.2	1,192	−934	Do.
6-026	NW¼SW¼ sec. 8, T. 2 S., R. 11 W	254.7	1,082.2	1,080	−825	*Pulaskite.
6-027	SW¼SE¼ sec. 8, T. 2 S., R. 11 W	228.9	879.5	878	−649	Hard rock (no cuttings). Nepheline syenite(?).
6-028	NW¼SE¼ sec. 7, T. 2 S., R. 11 W	255.6	1,118.2	1,116	−860	*Tan, altered fine-grained nepheline syenite porphyry.
6-030	NW¼SE¼ sec. 23, T. 2 S., R. 12 W	292.2	1,312.6	1,311	−1,019	Nepheline syenite.
6-031	SE¼NE¼ sec. 36, T. 1 S., R. 13 W	341.7	662.6	660	−319	Light-gray nepheline syenite (cuttings)
6-032	NE¼NE¼ sec. 36, T. 1 S., R. 13 W	333.0	518.1	518	−185	Hard black fine-grained igneous rock (cuttings).
6-033	SW¼SW¼ sec. 29, T. 1 S., R. 12 W	310.6	426.9	426	−115	Light-bluish-gray coarse nepheline syenite.
6-034	NE¼NW¼ sec. 36, T. 1 S., R. 13 W	386.2	436.2	436	−50	Bluish-gray nepheline syenite.
6-035C	SE¼NW¼ sec. 8, T. 3 S., R. 13 W	345.2	1,177.7	1,177	−832	Very hard rock (cuttings). Paleozoic(?)
6-036	SE¼SW¼ sec. 5, T. 3 S., R. 13 W	326.2	1,101.5	1,099	−773	Gray quartzite. Paleozoic.
6-037	SW¼SW¼ sec. 6, T. 3 S., R. 13 W	354.0	1,044.0	1,043	−690	Dark-gray novaculite. Paleozoic.
6-038	SE¼NW¼ sec. 17, T. 3 S., R. 13 W	347.1	1,425.0	1,401	−1,054	Gray micaceous shale. Paleozoic.
6-039	NW¼NE¼ sec. 5, T. 3 S., R. 13 W	313.6	714.0	713	−400	Gray nepheline syenite.
6-040	NE¼NE¼ sec. 5, T. 3 S., R. 13 W	343.4	602.7	602	−259	Gray altered nepheline syenite.
6-042	NW¼NW¼ sec. 35, T. 2 S., R. 13 W	303.1	1,164.9	1,162	−859	Nepheline syenite.
6-043	SE¼SW¼ sec. 23, T. 2 S., R. 13 W	342.3	975.5	976	−634	Do.
6-044	NW¼SE¼ sec. 14, T. 2 S., R. 13 W	367.3	858.0	858	−491	Gray coarse nepheline syenite.
6-045	NE¼SE¼ sec. 14, T. 2 S., R. 13 W	338.3	1,053.0	1,048	−710	Pink coarse nepheline syenite.
6-046	NW¼NW¼ sec. 12, T. 2 S., R. 13 W	383.0	1,042.0	1,036	−653	Light-gray conglomerate. Paleozoic.
6-047	SW¼SW¼ sec. 5, T. 2 S., R. 12 W	328.2	1,042.0	1,038	−710	Novaculite. Paleozoic.
6-049	SW¼NW¼ sec. 4, T. 2 S., R. 12 W	305.3	1,002.0	1,000	−695	Nepheline syenite.
6-050	SE¼NW¼ sec. 3, T. 2 S., R. 12 W	273.8	1,048.0	1,047	−773	Do.
6-051	SE¼SW¼ sec. 28, T. 1 S., R. 12 W	348.1	921.4	920	−572	Do.
6-053	SE¼NW¼ sec. 10, T. 2 S., R. 13 W	399.9	707.0	704	−304	Do.
6-056	SE¼NE¼ sec. 16, T. 2 S., R. 12 W	278.1	1,162.0	1,160	−882	Do.
6-057	NW¼SW¼ sec. 34, T. 1 S., R. 12 W	242.4	927.0	925	−683	Do.
6-059	SW¼NW¼ sec. 1, T. 2 S., R. 12 W	261.9	1,121.5	1,120	−858	Do.

to arfvedsonite. Some secondary carbonate and a sericitic mineral are present.

In USBM drill hole 6-005, about 3½ miles south by west of Wrightsville, the basement rock, reached at a depth of 853 feet, was a gray coarse-grained nepheline syenite that is almost pegmatitic in texture. It is composed predominantly of feldspar, with interstitial analcime, sphene, biotite, aegirine, considerable apatite, and scattered ilmenite or magnetite blebs. The analcime has two forms that apparently merge, one with a strain pattern or zoning and an apparent slight birefringence, and the other isotropic, but clouded with scattered tiny inclusions.

The easternmost nepheline syenite in place was reached in USBM drill hole 6-023, about a mile and a half northwest by west of Woodson, at a depth of

1,250 feet. This rock in which feldspar is predominant is coarse grained and is associated with analcime, nepheline, aegirine, a little biotite, and magnetite or ilmenite. Other records of nepheline syenite in the deep drill-hole cores are given in table 8.

Porphyritic alkalic syenite (pulaskite).—Coarse-grained porphyritic varieties of nepheline syenite were noted in three thin sections of cores of basement rocks from drill holes on the Woodson and Ico magnetic anomalies in southern Pulaski County and northern Grant County. On the south slope of the Ico high, in USBM drill hole 6–012, at a depth of 1,250 feet, the coarse-grained basement rock has the peculiar porphyritic texture of pulaskite in which clusters of large feldspar crystals are scattered through a mass of small ones. Analcime is abundant, cutting through the feldspar. Biotite, orthopyroxene, clinopyroxene, apatite, and possibly nepheline are also present.

A similar rock, differing mainly in that the pyroxenes are somewhat larger than in the first, was found at a depth of 1,446 feet in USBM drill hole 6–014, about a quarter of a mile south of drill hole 6–012.

About 2⅓ miles north-northwest of Woodson, in USBM drill hole 6–026, at a depth of 1,082 feet, another coarse-grained syenitic rock was cored which showed a texture similar to those described above. Both orthoclase and plagioclase can be recognized although they have been altered in part to carbonate. Some apatite, biotite, and chlorite are present.

Trachytic dike or border rocks.—Fine-grained syenitic rocks with a porphyritic or trachytic texture were cored in several of the deep drill holes. They resemble particularly those associated in surface exposures with tinguaite and other border rocks around and within pendant rocks of Paleozoic age. In USBM drill hole 6–001, about 2½ miles west of Woodson, the basement rock at a depth of 1,295 feet below ground level is an altered fine-grained syenitic rock, composed principally of feldspar, and secondary carbonate and a sericitic mineral.

A similar rock was cored in USBM drill hole 6–028, about 2¼ miles northwest of Woodson, at a depth of 1,116 feet. It is composed of feldspar phenocrysts in a fine feldspathic groundmass through which is disseminated considerable iron oxide, carbonate, and a fine-grained micaceous material, probably a hydromica.

A trachitoid syenite dike rock occurred in USBM drill hole 6–015, at a depth of 1,199 feet, at the most elevated part of the basement rock reached in drilling the Ico magnetic anomaly near the village of Ico. This rock is composed essentially of large feldspar phenocrysts in a groundmass of small feldspar laths, exhibiting flow structure. Hydromica is sprinkled through the groundmass.

Near the west end of the Ico magnetic anomaly in USBM drill hole 6–019 at a depth of 1,409.5 feet, the rock in contact with an altered mafic rock of the fourchite-monchiquite group (fig. 13*B*) is a light-gray, fine-grained, flow-banded, altered feldspathic rock. Apparently it was once a spherulitic glass that has been devitrified. Scattered trichites are discernible. The spherulites in places are well formed, concentrated in little blebs, pods, or veinlets. Small pyrite cubes are scattered sporadically through the rock.

Mafic dike rocks.—Extensively altered lamprophyric rocks that probably belong in the fourchite-monchiquite group were found in holes drilled to explore the small Hensley magnetic anomaly near the south edge of Pulaski County and the western part of the Ico magnetic anomaly in northern Grant County.

USBM drill hole 6–002, about 1½ miles west of Hensley, reached an altered lamprophyric rock at 1,450 feet containing relict crystals of olivine and monoclinic pyroxene. These minerals which were altered largely to chlorite are scattered through a groundmass of chlorite, muscovite, secondary carbonate minerals, some feldspar, secondary amphibole (actinolite?), and tiny black specks of opaque iron oxide minerals. The relict olivine phenocrysts indicate that the rock may originally have been a monchiquite.

USBM drill hole 6–017, about 1¼ mile west of Ico, reached a similar highly altered dike rock at a depth of 1,426 feet. Relict phenocrysts of pyroxene are contained in a groundmass composed chiefly of feldspar, and considerable chlorite, epidote or zoisite(?), and carbonates and oxides. About a third of a mile away, in USBM drill hole 6–019 at a depth of 1,409 feet, an almost identical rock was found in contact with a light-gray, fine-grained rock of the trachyte group, described above, that probably is a devitrified glass (fig. 13*B*). The dark rock is composed chiefly of decomposition products of a highly ferrogmagnesian rock. Outlines of relict crystals now altered to chlorite and a greenish clay mineral, probably nontronite, indicate olivine and monoclinic pyroxene. There is also some secondary calcite or other carbonate and secondary oxides. In one of two thin sections of this rock only relict pyroxene was noted. The original rock probably was fourchite or monchiquite.

Moody (1949, p. 1410–1428) reviewed the exposures of the igneous rocks of Mesozoic age of the northern Gulf Coastal Plain and discussed the subsurface distribution of similar rocks found in deep wells. Alkalic rocks related to the nepheline syenite of the Arkansas bauxite region have been found as far southeast of Little Rock as Jackson, Miss. Moody (1949, p. 1416), regards the trachyte porphyry, tinguaite, nephelinite, and monchiquite rocks present in some of the deep holes as

"essentially complementary dike types produced by late differentiation of a parent peralkaline magma." Most of the buried igneous bodies probably occur in the form of highly differentiated stocks.

STRUCTURAL RELATIONSHIP

Evidence indicates that the bodies of alkalic igneous rock were intruded along a fault or shear zone of northeasterly trend and that movement along this fault zone may have continued intermittently until as late as early Tertiary time. This is indicated in part by the strong difference in strike of the rocks of Paleozoic age north and northwest of the igneous complex from those in pendants within the complex, and by the straight trend of the northwest edge of the igneous mass. Several northeasterly elongate depressions in the buried Paleocene surface, centering in sec. 35, T. 1 S., R. 14 W., were found during the drilling of the Thomas-Williams deposit. These coincide closely in position and trend with the northwest edge of the Little Rock igneous complex and may indicate that some movement along a probable fault took place in this area as late as Paleocene time. These depressions, buried beneath the Eocene Wilcox sediments, are discussed more fully in the description of this area on page 216.

AGE AND GENETIC RELATIONSHIP OF IGNEOUS AND SEDIMENTARY ROCKS

Whatever information has been added to the knowledge of the igneous rocks of the central Arkansas province by this study does not invalidate the ideas and conclusions of Williams (1891, p. 119–125; 161–162) as to their age and mode of origin. Despite the lack of decisive evidence for accurately dating the igneous rocks in Pulaski and Saline Counties, Williams (p. 3) believed that they, like the diamond-bearing peridotites in Pike County, Ark., were formed toward the close of the Cretaceous period. The peridotite rocks were intruded into the Trinity formation of Early Cretaceous age and are overlain unconformably by the Tokio formation of Early Cretaceous age (Miser, and Purdue, 1929, p. 99–117). Water-deposited basic igneous material in the lower part of the Tokio indicates that at least part of the eruption was concurrent with the deposition of these beds. Whether the peridotite was formed at the same time as the nepheline syenite rocks is a matter of conjecture, but the peridotite is similar to some of the monchiquite dike rock of the bauxite region.

The pyroxenite reported from a drill hole near Sheridan, Grant County (Moody, 1949, p. 1415), is directly overlain by the Nacatoch sand of Late Cretaceous age. It probably is closely related to the fourchite of the bauxite region. Altered dike rocks of the fourchite-monchiquite group were found in drill holes on the Ico high, about 10 miles north of the pyroxenite locality. Geophysical data (Stearn, 1930; Malamphy and Vallely, 1944) indicate, however, that the buried igneous body near Sheridan is not actually a part of the Little Rock igneous complex.

Evidence is well established for a long period of widespread volcanism in the West Gulf Coastal Plain during early and middle Late Cretaceous time. The Woodbine formation, lowest of the Upper Cretaceous units, contains in southwestern Arkansas, southeastern Oklahoma, and northeastern Texas a considerable amount of volcanic debris, concentrated in places in tuff and tuffaceous sandstone beds (Ross, Miser, and Stephenson, 1929). Similar material has been found in the overlying Eagle Ford clay and in the Tokio formation. The Tokio contains water-deposited igneous materials near Murfreesboro, Pike County. These materials include in the lower part thin beds of probable peridotitic tuff and also beds of kaolin probably derived from the alteration of volcanic dust (Ross, Miser, and Stephenson, 1929). The same formation in southern Howard County, contains concentrations of ilmenite in red sands associated with tuffaceous sandstone in its upper part (Holbrook, 1948). Volcanic lapilli are found occasionally in sandy parts of the Brownstown marl and the Ozan formation in Arkansas (Moody, 1949, p. 1414).

The pyroclastic material in the Woodbine and Tokio formations is largely of the phonolite type, but it also includes minor amounts of orthoclase and rock fragments of the trachyte type, particularly near Nashville, Ark. Ross, Miser, and Stephenson (1929, p. 189) concluded that much of this igneous material in Arkansas came from ancient volcanoes probably located in Howard, Pike, and Sevier Counties. They pointed out the similarity in composition between a phonolite boulder from Howard County, and the nepheline syenite (foyaite) of Pulaski County. Ross (1938) identified volcanic rocks at Magnet Cove, Hot Spring County, and added the nearly circular pluglike igneous body at that locality to the growing list of volcanoes that were active in Late Cretaceous time.

The nepheline syenite rocks of Pulaski and Saline Counties probably were intruded at about the same time that the volcanic materials of similar composition in southwestern Arkansas were erupted. Thus the evidence favors an early Late Cretaceous age for the intrusive rocks of central Arkansas. The formation of these rocks, as pointed out by Williams (1891, p. 3), doubtless continued for a considerable time.

Evidence that the Little Rock complex was intruded in places beneath a comparatively thin sedimentary cover is indicated by the fine matrix of trachytic and lamprophyric dike rocks, found in exposures and in

deep drill holes. Originally the matrix of many of these rocks probably was a glass. These and other porphyritic rocks are found on several of the more elevated parts of the mass—on the bosslike hills or cupolas that originally protruded upward into the overlying sedimentary rocks of Paleozoic age. These rocks occur locally on small hills on the slopes of large ones composed mainly of pulaskite. Williams (1891, p. 121) believed that the pulaskite formed above the coarse-grained nepheline syenite where the alkalic magma cooled more rapidly and therefore assumed a semiporphyritic texture. In places the partly solidified pulaskite cracked and was injected by additional magma from the less congealed mass below to form the granular nepheline syenite dike rocks.

Three steps were suggested by Williams for the sequence of formation of the igneous rocks in the Pulaski County exposures. First, the introduction of the main mass of the magma resulted in the crystallization of the nepheline syenite, the pulaskite, and their associated dike rocks, as described above. Second, the fourchite and related rocks were intruded. Third, the pegmatitic and miarolitic dikes of syenitic rock were intruded before the earlier rocks had entirely cooled. A similar sequence of events probably took place to form the rocks of the now deeply buried, though originally elevated parts of the batholith near Woodson and Ico.

In the central and western parts of the complex, including the Saline, Sardis, and Bryant buried hills the principal rock is coarse-grained nepheline syenite, which indicates cooling under a cover thicker than in the elevated areas in the eastern part of the complex. The sequence of events in the western part is more simple. On the domelike Saline hill, alkalic syenite porphyry, similar in appearance to pulaskite, formed in a few places where the magma was quickly cooled, possibly where it entered cracks and recesses in the overlying country rock. Tinguaitic border rocks formed locally around small pendants and inclusions of country rock, most of which were completely altered to feldspar. Pegmatitic dikes and later porphyritic syenitic dikes were formed in cracks and fissures in the coarse-grained nepheline syenite while the mass was still cooling. The monchiquite dikes were probably the last to form in that part of the region.

COMPOSITION, CLASSIFICATION, AND ORIGIN OF BAUXITE DEPOSITS

HISTORY AND DEFINITION OF TERMS

USAGE OF THE TERMS "BAUXITE" AND "LATERITE"

Bauxite was discovered by P. Berthier (1821, p. 531), a French chemist, while investigating specimens believed to be iron ore found on the hill of Les Beaux near Arles, in Provence, southern France. Chemical analysis showed that the red claylike rock was virtually free of silica, either as free quartz or combined in a silicate, and that it contained 52 percent alumina (Al_2O_3), 27.6 percent ferric oxide (Fe_2O_3), 20.4 percent combined water (H_2O), and a trace of chromic oxide (Cr_2O_3). Berthier believed that the rock was a mixture of red iron oxide with a mineral in which aluminum oxide is present in the dihydrate form ($Al_2O_3.2H_2O$).

The name "beauxite" for this substance was first used in a report by A. Dufrenoy (1847, v. 3, p. 799), although presumably it was used informally even earlier. Deville (1861, p. 309) later adopted the name "bauxite" in place of the older spelling, to conform with the modern version of the name of the town and hill at the type locality, Les Baux.

The concept of bauxite as a mineral of definite composition ($Al_2O_3{\cdot}2H_2O$) was generally accepted among geologists, particularly in America. However, it is doubtful that Dufrenoy believed bauxite to be a mineral species.

Deville (1861, p. 309–342) considered the bauxite of southern France to be aluminous ores, although he included under this name some rocks that contained as much as 60 percent ferric oxide (Fe_2O_3). Lacroix (1901, v. 3, p. 342) concluded that the term referred to a mixture of minerals including several colloidal hydroxides of aluminum, mixed with similar hydroxides of iron and other impurities, and that bauxite is in reality a true rock. Fermor (1911, p. 559–561) also concluded that "the name bauxite was not given to a definite mineral, but to an impure aluminium-ore of very variable composition, and that consequently its application has, really, always been to a rock and not to a mineral."

Bauxite is the term generally accepted for aluminum ores. These ores are largely mixtures, in different proportions, of boehmite or diaspore, the monohydrates of alumina ($Al_2O_3{\cdot}H_2O$), and gibbsite, the trihydrate of alumina ($Al_2O_3{\cdot}3H_2O$), generally containing some impurities. The most common impurities include kaolinite or similar clay minerals and the oxides and hydroxides of iron and titanium. Harder (1930, p. 64) has defined bauxite as "an aluminum ore, more or less impure, in which aluminum is largely present as hydrated oxides." This is the generally accepted use of the term in many countries, particularly by economic geologists in the Americas.

Some geologists, especially in Europe, have put other limits on the use of the name than those generally accepted in the United States. Early European geologists applied the name broadly to include rocks having a high content of iron oxide. This continued until Max Bauer (1898, p. 192) suggested that bauxite and laterite were one and the same kind of rock. This idea

was quickly accepted by geologists who came to use "laterite" as the more general term and "bauxite" for the highly aluminous variety.

The residual weathered rocks were divided into two groups by Harrassowitz (1927). For the rocks composed essentially of hydrated aluminum oxides he proposed the name "allite," and for those composed largely of hydrated aluminum silicates, he proposed the name "siallite." He restricted the term "bauxite" to the variety of allite that occurs in the European terra rossa type of deposit associated with limestone, from the leaching and weathering of which the bauxite is supposedly derived. Because this bauxite usually is composed largely of the monohydrate of alumina, he also called it "monohydrallite." He applied the term "laterite" to the tropical type of allite that is formed by the weathering of crystalline rocks and is usually composed largely of the trihydrate of alumina, and he further designated it "trihydrallite." Harrassowitz's terminology has not been widely accepted, but the restriction of the name bauxite to the material in deposits of the European terra rossa type has been followed by some geologists.

Fox (1932) in the preface to the second edition of "Bauxite and aluminous laterite" states that there are two substances with different modes of origin, the the first the terra rossa or French type, and the second lateritic or Indian type, and he notes that the Arkansas deposits belong to the second type. In the text, however, he uses the name bauxite loosely in the commercial sense. De Weiss (1948, p. 94) has used these two distinctions as a means of classification and divides the rocks of alteration rich in hydrates of alumina into two principal groups: terra rossa bauxite and lateritic bauxite.

The name laterite was introduced by Francis Buchanan (1807, v. 2, p. 440–441) for a ferruginous residual rock he saw in many places in the Malabar and Kanara territories of southern India. This rock which hardens quickly on exposure was widely used in blocks for building in this region. Buchanan gave no chemical analysis of the rock. The name was used by geologists and engineers in tropical regions for many ferruginous weathering products, most notably the red earthy rocks that cap tablelands and plateaus in peninsular India. The high alumina content of some of the "laterites" in central India was pointed out by F. R. Mallet (1883, p. 103).

Through the work of Max Bauer (1898, p. 163–219; 1907, p. 33–90), on "laterites" from the Seychelles Islands and also from Madagascar, "laterite" and bauxite were shown to be varieties of the same type of rock, both being formed by a process of rock weathering that leaves a residue rich in the sesquioxides. The material from the Seychelles Islands included the weathering products of two igneous rocks, "granite laterite" and "diorite laterite." According to Clarke's Data of Geochemistry Bauer's laterite is deduced to be a mixture of free silica (more than 50 percent quartz in the "granite laterite"), the trihydrate and monohydrate of alumina, together with hydrated ferric oxide. Studies by Warth and Warth (1903, p. 154) on the chemical composition of Indian "laterites" showed that there is a gradation from "laterite" to bauxite.

The work of Bauer and the Warths won acceptance by geologists the world over and the term "laterite" was adopted for the hydroxide decomposition products of a variety of rocks, formed by "lateritic weathering" in many lands with warm humid climates. "Laterization," the process by which "laterite" is formed, was shown to be limited to tropical regions. Laterite according to the Bauer-Warth conception has been defined by Clarke (1924, p. 497) in the Data of Geochemistry as "essentially a mixture of ferric hydroxide, aluminum hydroxide, and free silica in varying proportions." Fermor (1911, p. 460) did not believe free silica was necessarily typical of laterite and defined the rock as "a hydrated mixture of oxides of aluminum, iron, and titanium, of extremely variable composition, and showing every gradation from ferruginous laterite almost free from alumina to aluminous laterite almost free from iron." He added, "When pure enough to be used as aluminium-ore the laterite is usually known as *bauxite*."

Fermor suggested the use of qualifying adjectives for siliceous impurities such as "quartzose laterite" where more than 50 percent free silica in the form of quartz is present, or "lithomargic laterite" where similar amounts of combined silica in the form of clay minerals related to kaolinite are present. He also proposed the use of the term "lateritite" for detrital laterite; as well as "lateritoid" for a cavernous mixture of iron oxides that resembles laterite but actually is a metasomatic replacement deposit in certain metamorphic rocks and retains structures of the original rock (Fermor, 1909, p. 381).

It was not until more than 125 years after Buchanan's introduction of the term "laterite" that an effort was made to determine the true nature of this material as first described. In 1933, at Fermor's request, C. S. Fox (1936, p. 389–422) revisited Buchanan's original Malabar and Kanara localities, collected a number of samples, and had chemical analyses made. To his surprise he found (p. 401) that "Buchanan's rock is really a

vermicular lithomarge with a considerable amount of ferric hydrate present in the upper part." The chemical analyses showed that the silica ranges from 17.1 to 32.8 percent, the alumina from 16.6 to 25.3 percent, and the ferric iron from 4.9 to 39.1 percent. Fermor, in an introductory statement to Fox's paper, said that the rock was what he would term a "lithomargic laterite." Both men urged retention of the name "laterite" in the Bauer-Warth sense.

Those who have proposed that the name laterite be restricted to the original Buchanan rock include Pendleton (1936), Pendleton and Sharasuvana (1942; 1946), and Vadasz (1946). According to Pendleton and Sharasuvana (1946, p. 433) laterite is a soil term. It is

> an illuvial horizon, largely of iron oxides, with a slaglike cellular or pisolitic structure, and of such a degree of hardness that it may be quarried out and used in building construction.

They continue,

> With only occasional exceptions the laterite horizon develops within the soil in the zone in which the upper surface of the water table fluctuates. Where laterite is exposed at the soil surface (some authors call this an "ironstone pavement") it is, with few exceptions, the result of the soil profile's having been truncated, that is, erosion has carried away the overlying soil—the eluvial horizon.

In summarizing the foregoing discussion, it appears that there are two different materials commonly called "laterite."

Buchanan's laterite—an indurated slaglike, locally pisolitic rock composed of hydrous aluminum silicates (clay minerals related to kaolinite) and hydrous iron oxides, that hardens noticeably on exposure to the air. This has been called by some authors "low level laterite" and "ground water laterite." It is probably formed in an illuvial layer in the soil profile in equatorial regions in the zone of fluctuating water table on peneplains where ground-water conditions are relatively stable.

Bauer-Warth laterite—a mixture of hydrous oxides, principally of iron and aluminum, also of titanium and manganese, indurated and pisolitic in some places. This has been called by some writers "high level laterite." It probably forms in an eluvial soil zone in tropical areas of good drainage where the water table is moderately deep.

There is at present a general inclination among geologists and soil scientists toward a broader interpretation of the term. Both types of laterite, it may be argued, are products of the process of lateritization and differ only in degree. A laterite, therefore, may be said to be a rock rich in the oxides of iron or alumina, or both, that has been formed as a product of tropical weathering. In this report the word laterite, where used, has this broad interpretation.

BAUXITE AS DEFINED IN THE PRESENT REPORT

Bramlette (1936, p. 11) defined Arkansas bauxite as "rock high in aluminum hydroxide." He added that its physical characteristics generally are sufficient for its recognition but for positive identification a chemical analysis is necessary. He recognized complete gradations from bauxite to kaolin on the one hand and bauxite to iron oxide on the other and suggested that rock with characteristics of bauxite but high in clay be called "bauxitic clay" and rock high in iron oxide or hydroxide be called "laterite."

Harder (1930, p. 64) defined bauxite as "an aluminum ore, more or less impure, in which the aluminum is largely present as hydrated oxides." Because of the changeable nature of economic factors a slight modification of Harder's definition was adopted for this investigation by J. H. Thoenen and R. P. Bryson (written communication, 1944). Bauxite, according to their accepted definition is "an aggregate of aluminous minerals, more or less impure, in which aluminum is present largely as hydrated oxides."

In Arkansas bauxite the principal ore mineral is the trihydrate of alumina, gibbsite. Whatever monohydrate of alumina may be present occurs in such small quantities that it has no commercial significance. The main impurities are the hydrous aluminum silicate, kaolinite; ferrous carbonate, siderite; and other iron and titanium oxides. As chemical analyses were available for nearly all the bauxite samples collected during the field program, it was convenient to assign chemical and mineralogic limits to the varieties of aluminous rocks that were in the drill cores. The specific limits adopted for the Arkansas bauxite region are discussed below.

Bauxite.—A mixture of gibbsite with kaolinite, siderite, and other impurities in which gibbsite makes up more than 50 percent of the rock is regarded as bauxite in this report. For convenience in designating chemically analyzed samples of aluminous rocks a lower limit of 24 percent of available alumina was placed on rock called "bauxite." (Available alumina as used in this report, is the percentage of alumina in the rock, less 1.1 times the percentage of silica.) This lower limit of 24 percent includes nearly all the aluminous rocks in the region that would be called bauxite in the field on the basis of physical appearance. Notable exceptions are rocks that contain secondary kaolinite or siderite in excess but still retain essentially the general aspect of the earlier unaltered gibbsitic rock.

The limits for bauxite do not correspond closely with those used for ore in this report. Ore is regarded as that part of the bauxite that contains 32 percent or more of available alumina, and the ore bodies are delimited on that basis. The low-grade rock containing between 24 and 32 percent available alumina is referred to as "high-silica bauxite" provided the iron content is low. Bauxite containing more than 10 percent iron oxides is called "high-iron bauxite" in this report. The chemical limits for bauxite, bauxitic clay, and kaolinitic clay are shown graphically in figure 30.

Bauxitic clay.—This is a mixture essentially of kaolinite possibly associated with related clay minerals, and gibbsite, with siderite and other impurities, in which the gibbsite content is less than 50 and greater than 15 percent. Rock so defined is commonly light grayish tan or cream colored, with a clayey to mealy texture, moderately plastic to nonplastic, and commonly containing sparsely scattered oolites and small pisolites or fragments of bauxite and kaolinitic clay. At the field laboratory any rock of this type containing between a fraction of a percent and 24 percent available alumina was called "bauxitic clay."

Kaolinitic clay.—The composition of this clay is essentially kaolinite possibly associated with related clay minerals, with siderite and other impurities; gibbsite, if present, does not exceed 15 percent. Where pure this clay can be called kaolin, but this designation has been avoided in most of this report and where used, it is without ceramic implications ("bauxite-kaolin zone"). Kaolinitic clay occurs in the general vicinity of the bauxite deposits in sedimentary beds commonly with a fragmental texture; in residual deposits commonly preserving in their lower part the texture of the underlying nepheline syenite; in the weathered part of the Wills Point formation; and in small veins and scattered bodies and masses in bauxite.

PHYSICAL PROPERTIES

Because bauxite is a rock containing a mixture of minerals in different proportions, its physical properties are diverse. The Arkansas ore ranges in consistency from a tough, well-consolidated material that is difficult to break with a hammer, to a soft earthy substance that can be crumbled to a powder between the fingers.

Color.—The color of the Arkansas ore ranges from light buff to dark brown but is most commonly light tan. In some places pink to red predominates; in other deposits orange or yellow are common, particularly in flesh tones. Even greenish or bluish tones are found rarely in high-silica bauxite or bauxitic clay. Where pyrite and related iron sulfides are present, the ore may be black. Lighter shades of tan or gray are generally associated with lower grades of bauxite or bauxitic clay, but pure white specimens have been found that are composed of nearly pure gibbsite. Red or orange staining generally indicates iron impurities, but some tannish-gray varieties are filled with siderite and contain considerably more iron than many of the red specimens, and some granitic-textured specimens high in alumina are orange. Color is therefore no index of the quality of the ore, nor does it indicate the amount of iron present except in a general way.

Hardness.—Wysor (1916, p. 46) measured the hardness of many samples of Arkansas bauxite, noting especially the relative hardness of different types of pisolites and matrix (table below). He found that the matrix ranges in hardness from 2 to 4, and the pisolites range from 2 to 7. Vitreous well-formed pisolites with conchoidal fracture are the hardest.

Physical properties of selected samples of Arkansas bauxite. After Wysor

[Samples with same exponent (a, b, c, d, e) came from same specimen of ore. The word "pisolite" is used to replace Wysor's term "oolite"]

Sample	Form	Color	Luster	Structure	Fracture	Streak	Hardness	Specific gravity
1 ^{a}	Pisolite	Red	Dull	Massive	Smooth	Chestnut brown	4	2.43
2 ^{a}	Matrix	Gray	do	do	do	Wood brown	4	2.35
3 ^{b}	Pisolite	Red	do	Massive and porous	Hackly	Honey yellow	2–4	2.42
4 ^{b}	Matrix	do	do	Massive and oolitic	do	do	2–4	2.36
5 ^{c}	Pisolite	do	do	Massive	Smooth	Brownish red	4	2.41
6 ^{c}	Matrix	Buff	do	do	Hackly	Yellowish brown	4	2.38
7 ^{c}	Pisolite	Black	Vitreous	do	Conchoidal	Brownish black	6–7	3.01
8 ^{d}	do	Buff	Dull	Porous	Hackly	Ocher yellow	2–3	2.41
9 ^{d}	Matrix	Gray	do	do	do	Greenish yellow	2–3	2.38
10	Pisolite	Brown	Vitreous	Massive	Conchoidal	Reddish brown	5–6	2.77
11	do	Black	do	do	do	Grayish black	5–7	2.93
12	do	Red	Subvitreous	do	Hackly	Wood brown	1–5	2.48
13 ^{e}	do	Brown	do	do	Smooth	Grayish brown	4–5	2.53
14 ^{e}	do	Red	Dull	do	Hackly	Red	4	2.43
15 ^{c}	do	do	do	do	do	Hair brown	4	2.40
16 ^{c}	do	Brown	Vitreous	do	Conchoidal	Chocolate	5–7	2.78
17	do	do	do	do	do	do	4–6	2.69
18	do	Red	Subvitreous	do	Smooth	Red	4–5	2.55

Physical properties and chemical analyses of selected samples of Arkansas bauxite. After Wysor

[Sample numbers are the same as in the preceding table]

Sample	Hardness	Specific gravity	H_2O	SiO_2	TiO_2	Fe_2O_3	Al_2O_3
Pisolites							
7	6–7	3.01	14.58	2.20	1.70	9.00	72.52
11	5–7	2.93	17.66	1.54	2.00	10.70	68.10
10	5–6	2.77	19.62	2.52	2.20	11.50	64.16
17	4–6	2.69	20.42	3.32	2.00	9.80	64.44
18	4–5	2.55	26.02	3.48	2.40	7.40	60.70
13	4–5	2.53	27.54	3.76	2.70	5.70	59.30
1	4	2.43	29.82	2.16	2.20	6.50	59.32
3	2–4	2.42	31.96	2.08	3.40	2.70	59.86
Matrices							
6	4	2.38	32.14	2.64	3.70	2.00	59.52
9	2–3	2.38	31.90	1.56	4.20	5.30	57.14
4	2–4	2.36	32.00	1.64	3.60	2.00	60.76
2	4	2.35	32.50	.68	4.00	5.50	56.72

Specific gravity.—Dana lists the specific gravity of massive gibbsite as 2.3 to 2.4, so presumably if Arkansas bauxite had few or no impurities it would fall within this range. According to Wysor (1916, p. 46) the specific gravity of samples of Arkansas bauxite ranged from 2.35 to 2.38 for specimens of matrix bauxite, and from 2.42 to 3.01 for selected pisolites. Hardness, luster, and specific gravity are related to the mineralogical character of the bauxite, particularly to the amount of the monohydrate present. Chemical analyses of the bauxite specimens studied by Wysor, however, show that iron content in part results in the higher specific gravity of several of his samples.

Porosity.—Most of the bauxite is very porous, and generally between 30 and 40 percent of the volume is taken up by pore space. Specimens of granitic-textured bauxite, called "sponge ore" by the miners, have a porosity as high as 60 percent. Mead (1915, p. 39) reported that the average of a number of tests showed that the bauxite has 38.5 percent pore space. Much lower grade less porous ore, however, is being used now than was mined in Mead's time. Most high-silica and high-iron bauxite probably averages about 30 percent pore space.

The adsorptive properties of bauxite are very great and lead to highly specialized uses of the material for refining and catalysis. Special grades, when calcined at 700°F, have an effective surface area of 273 square meters per gram, according to a study by King, Laughlin, and Gwyn (1944, p. 239).

The porosity of the material in place has a pronounced effect on the retention of moisture during a dry season and on the runoff of surface water during a wet season. The porosity therefore influences the physiographic character and the distribution of the bauxite deposits.

Plasticity.—Bauxite is generally hard and brittle and has no plasticity. Where soft it is typically non-plastic—of a mealy consistency, particularly noticeable if a small fragment is ground between the teeth. Lower grades of soft bauxite and bauxitic clay that contain a large quantity of kaolinite may be somewhat plastic, and at least one example has been noted of high-grade soft gibbsitic rock that is extremely plastic. Chemical analysis of a sample of this white clayey material collected by Alcoa engineers from a mine near Bauxite showed the composition to be almost entirely gibbsite; yet it had about the consistency of very soft putty.

The friable and nonplastic nature of most bauxite makes its recovery in a drill core difficult. In earlier drill holes of the Federal drilling program, cores were taken with a 2-inch double-tube barrel, using oil as a drilling fluid. Later it was found that the required 80 percent recovery of core could be secured by using a 3-inch double-tube barrel with water as a drilling medium.

LITHIC FEATURES OF BAUXITE

Bauxite in Arkansas occurs in many forms, among which the three most distinctive are: granitic-textured bauxite that bears the relict texture and structure of the nepheline syenite from which it was formed, pisolitic bauxite that contains or is largely formed of concretionary structures; and textureless or claylike bauxite. The pisolitic variety is by far the most common. Any of these three forms may be modified by subsequent addition or replacement of gibbsite, kaolinite, or of iron minerals to form other, more specialized types, or may be eroded and redeposited in beds that exhibit a variety of textures and structures characteristic of sedimentary deposits.

GRANITIC-TEXTURED BAUXITE

The bauxite that preserves the original texture of the nepheline syenite varies greatly in appearance. This rock is found in deposits in place on the higher slopes of buried nepheline syenite hills where it generally overlies kaolinized nepheline syenite and underlies pisolitic bauxite. It also is found as small boulders and pebbles in detrital deposits. Generally the granitic texture can be discerned only faintly in the hand specimen, but a pit face of this rock viewed from some distance bears a striking resemblance to a stained and weathered surface of nepheline syenite (fig. 18). Where the texture of the original rock is well preserved, as in the typical "sponge ore" of the miners' terminology, pseudomorphs of microgranular gibbsite after feldspar are abundant. The rock is extremely porous and large individual relict feldspar crystals commonly are marked by groups of

parallel linear cavities, as shown in the photographs of hand specimens in plate 10*B*. In less porous specimens the tabular pseudomorphs after feldspar stand out in low relief on the weathered surface. Polished sections of some of these specimens are mottled light tan and reddish brown, in the manner indicated in the photograph on figure 14. The lighter areas generally include the central parts of pseudomorphs after feldspar and the darker areas are the iron-stained interspaces.

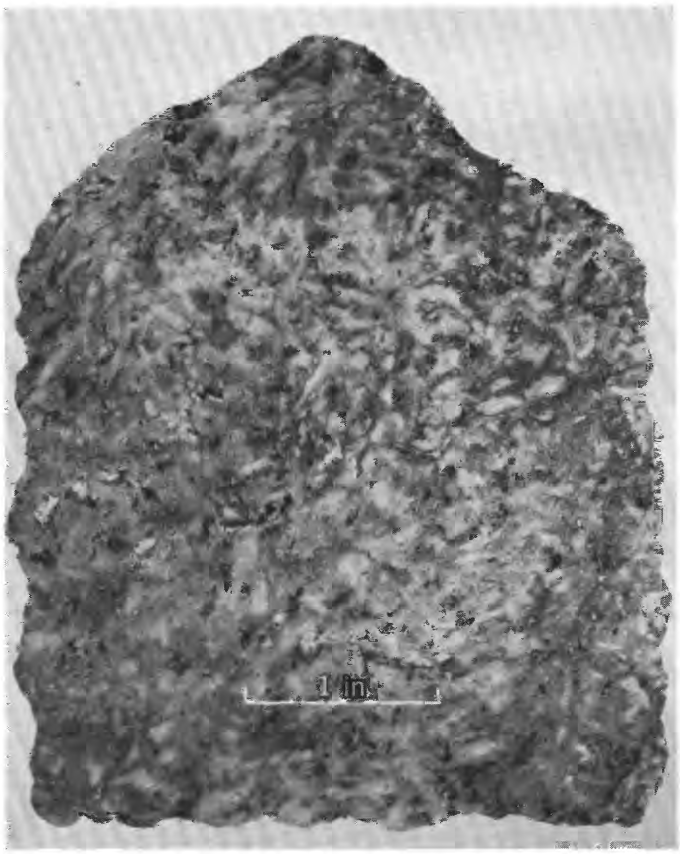

FIGURE 14.—Granitic-textured bauxite from Saline County (natural size). Tan and gray mottled bauxite derived from nepheline syenite. Light areas are mostly within original feldspar laths that have been replaced by gibbsite. Sawed face of specimen (AB-80-3) from the top of the bauxite bed in the northeast part of the Section 16 mine. Photomicrograph shown in plate 11*D*. For X-ray analysis see page 111.

Under the microscope the masses of microcrystalline gibbsite in patches, many of which have the outlines of the original feldspar crystals, are the most striking features of this type of bauxite. The gibbsite forms an open lattice in part of the rock, and in some places can be seen to have formed extensively along original feldspar cleavage planes (pl. 11*D*). Clear microcrystalline gibbsite patches also lie outside the crystal boundaries, but in most places the groundmass in the interspaces has a ferruginous stain and appears finely granular (pl. 11*B*). Much of this groundmass also appears to be made up of an isotropic material which probably is a cryptocrystalline variety of gibbsite. Several thin sections of granitic-textured bauxite also show skeletal pseudomorphs after sphene of a yellowish-brown to dark-brown opaque mineral that resembles leucoxene under the microscope. This is probably the same material that was identified by X-ray analysis in several specimens of this rock as anatase and is discussed later.

PISOLITIC BAUXITE

Much of the bauxite in all the deposits is in the form of concretionary structures known as oolites or pisolites which differ only in size. Those less than 2 millimeters in diameter are called oolites; those greater than 2 millimeters are called pisolites. The nearly spherical bodies that have or appear to have a concentric concretionary structure range from tiny pellets about 0.1 millimeter in diameter to pebblelike forms as much as 5 centimeters across. The oolites are generally less than 1.0 millimeter in diameter; the pisolites are most commonly 3–20 millimeters. Although there are intermediate sizes between the oolites and the pisolites, they are not common, and in most of the specimens examined the two are distinct, though apparently they both form in the same manner. Compound pisolites—larger pisolites enclosing smaller ones or oolites—are not uncommon, and one of these is illustrated in the photomicrograph on plate 14*B*. Fragmental or incomplete pisolites are found in some places, together with whole ones.

Pisolites have thin but well-developed rinds, generally tan to gray, that are lighter in color than the centers. Some are concentrically banded in different colors within the rinds but others are apparently homogeneous. The interiors of many are hard and cherty-looking, have a porcellaneous to vitreous luster, and break with a conchoidal fracture. These hard pisolites are red, tan, brown, gray, and black, and the densest generally are the darkest. Centers of other pisolites are soft, earthy, semiliquid, or even hollow. Many of the soft pisolites are tan or cream colored, having about the same color and texture as the surrounding matrix. In the lower part of some deposits, pisolites commonly are light to dark gray or tan, and generally have a slight bluish cast. The interiors of some are black, but are semiliquid, though apparently of about the same chemical composition as the bauxite rinds. Similar gray to dark-gray or grayish-tan pisolites in the upper part of many deposits also have soft centers but are composed largely of kaolinite; some are hollow.

Under the microscope the pisolites and oolites are translucent and cloudy to opaque. They consist largely of a fine brown isotropic material that is probably a cryptocrystalline variety of gibbsite. In some pisolites, particularly in pisolitic bauxite associated with the granitic type in Saline County deposits, patches of

microcrystalline gibbsite are found within the cryptocrystalline, or so-called amorphous material. They are generally fragmentary, but some are recognizable pseudomorphs after feldspar. A few pisolites are found with whitish spots at or near the center, but normally there is no definite evidence of pisolites having formed around a tiny central nucleus.

A network of nearly radial cracks or veinlets cuts many of harder pisolites. The veinlets are usually filled with microcrystalline gibbsite which also lines tiny cavities. Siderite and associated iron oxides are found in small irregular patches within some pisolites. Kaolinite fills veinlets in others, and several have been observed where the interiors are completely filled with light-gray kaolinite, probably of secondary origin. In a few places pyrite or marcasite fills the central core of pisolites, and small veinlets of this mineral radiate outward from the center.

The material forming the matrix between the pisolites may be dense and hard, firm and mealy, or soft and clayey. In some places it is almost textureless, but in others it is finely oolitic, usually composed largely of oolites and small grains that are less than 0.5 millimeter in diameter. The distribution of pisolites in the matrix ranges widely; they may be sparsely scattered or closely packed. The extremes are also fairly common; that is, matrix material in which there are no pisolites, and groups of loose pisolites in which there is no matrix. Generally, even where they are abundant, the pisolites are spaced in the matrix without touching one another. This evidence indicates that they formed in place. Under the microscope the matrix of most of the pisolitic bauxite is seen to be composed of cloudy "amorphous" gibbsite that appears isotropic between crossed nicols. Brownish-yellow to dark-brown earthy patches of leuxocene also are present. The matrix commonly is cut by small veinlets and contains cavities. These are lined or filled in places by many secondary minerals. In the general order of their abundance these are granular siderite; reddish-brown to black iron oxides; kaolinite in masses, flakes, and wormlike or accordionlike crystals; microcrystalline gibbsite; and pyrite in tiny cubes and other forms. Barite, chlorite, and chamosite crystals have also been found although they are rare.

A general correlation is recognized between the varieties of pisolitic bauxite and their position within a deposit, or the position of the deposit in relation to the underlying rocks. In any single deposit, however, the types tend to merge.

A variety of pisolitic bauxite, called "birdseye ore" by the miners, is characteristic of the residual deposits on the higher slopes of the Saline igneous mass and is not found elsewhere. It occurs in the upper part of the bauxite section, overlying the "granitic" type and contains pisolites, many of which are large, subspherical to ellipsoidal, red to black, dense, having subvitreous to vitreous luster, and a conchoidal fracture. Tiny broken fragments of this bauxite are slightly magnetic. Rinds, 1–2 millimeters thick, envelop pisolites or groups of pisolites giving an appearance of accretionary layers. The matrix is brick red to gray, and is commonly differentiated into small lobes of several color tones. It is hard and brittle and where the rock is broken the pisolites also are broken across. A polished specimen of this type of ore is shown in figure 15*A*. The matrix of some of the bauxite associated with this type, particularly on the lower slopes is soft and tan; in some places the pisolites weather from it easily.

Pisolites in the gently sloping deposits near the bases of the buried nepheline syenite hills are usually less than a centimeter in diameter, averaging between 5 and 8 millimeters, rather uniform in size, and closely packed (figs. 16 and 17). Though all variations are present from those with hard centers to those with viscous interiors, most of them are softer and less highly colored than the ones in the bauxite on the higher slopes. The matrix likewise is soft and generally tan to brown, and more drab in appearance than that of bauxite higher on the slopes. The hardest pisolites usually occur in the upper middle part of a deposit; and lower in the section they are fewer, smaller, and softer. Pisolitic bauxite commonly grades downward to oolitic, fragmental, or massive varieties in these deposits.

MASSIVE OR CLAYLIKE BAUXITE

Bauxite possessing no distinctive texture, the so-called amorphous bauxite of some writers, is found in all deposits, but is not as common as the other two types just described. It is white to tan, in places resembling kaolinitic clay, and occurs in small irregular bodies or "horses" in the residual high-level deposits, where it grades into both the pisolitic and the granitic-textured type of ore. According to Bramlette (1936, p. 12), horselike masses of fine-grained, massive bauxite of good quality were present in the lower part of the ore deposit in Alcoa Mine 14. Chemical analyses were necessary to distinguish this material from similar clay horses and the underlying clay.

This type of bauxite also is commonly found in lenticular bodies in the lower part of the bauxite in deposits that fringe the nepheline syenite hills, where it commonly grades into oolitic, pisolitic, and fragmental varieties.

VERMICULAR STRUCTURE

A variety of bauxite having a crude vermicular appearance is associated with the birdseye ore in the upper part of the bauxite in Saline County residual

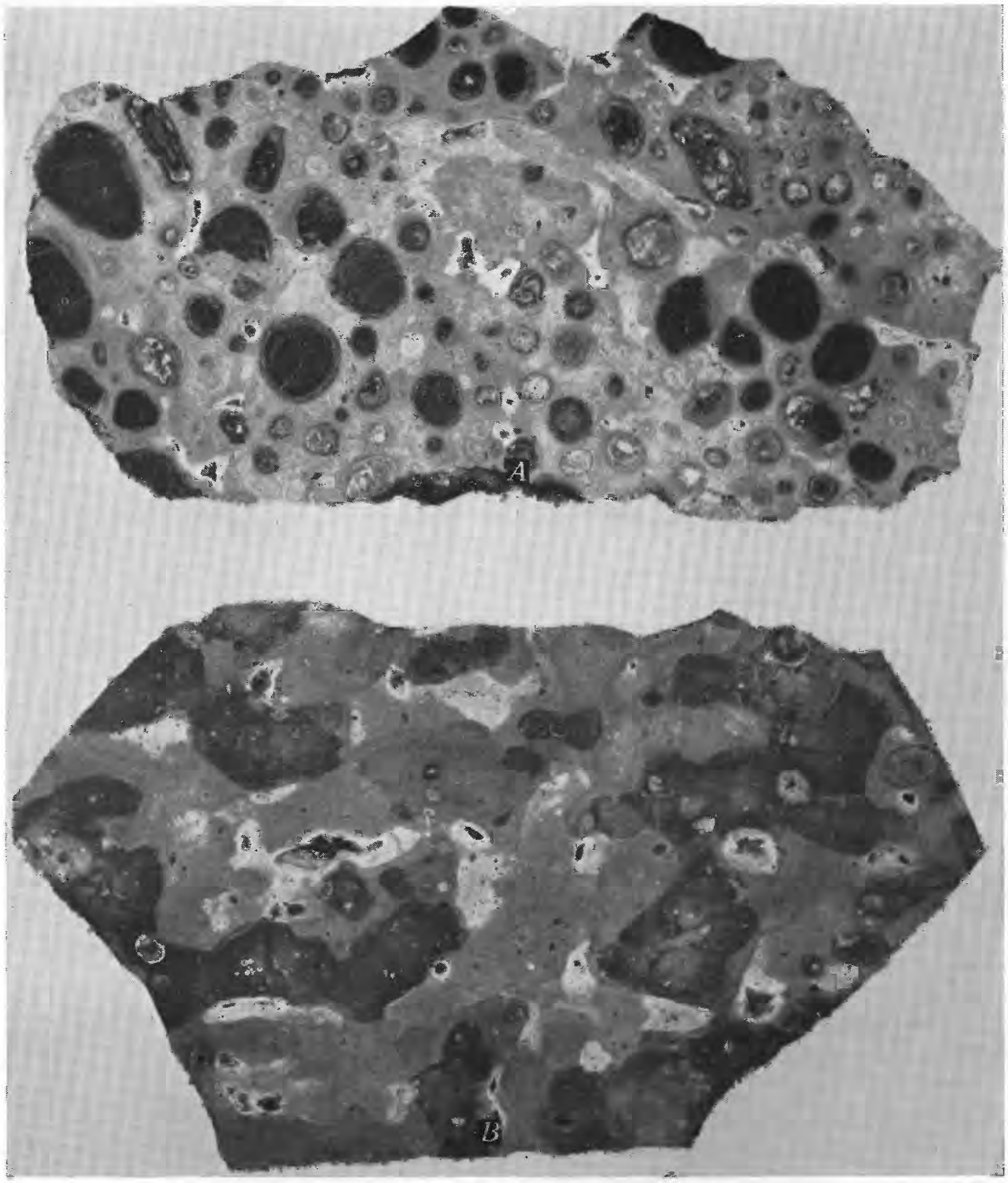

FIGURE 15.—Concretionary structures in bauxite from the Section 16 mine (natural size). *A*, Pisolitic bauxite ("birdseye ore") of soft light-tan and pink pisolites and hard dark-brown to black pisolites in a brownish-red hard matrix. Sawed face of specimen (AB-80-1). Note vermicular structures in matrix and fragmentary black pisolites, also note included block of more finely pisolitic bauxite. Chemical analysis given on page 109, spectrographic analysis given on page 108, X-ray determinations on page 110. *B*, Red vermicular bauxite showing distribution of areas of different degrees of iron staining. Lightest areas surround tubelike bodies, some of which are filled with siderite. Sawed face of hand specimen (AB-80-2).

deposits. It closely resembles the matrix of birdseye ore and apparently represents parts of the rock in which pisolites have not formed. A polished face of a hand specimen is shown in the photograph on figure 15*B*. The vermicular appearance is due largely to the distribution of the iron-stained parts in irregular tubes and fingerlike bodies. Some of these are small and resemble worm borings; others are larger and irregular, reaching 3 centimeters across. The limits of some are vague; others are well defined.

Under the microscope the groundmass is seen to be composed of scattered aggregates and grains of microcrystalline gibbsite in a fine matrix that appears isotropic between crossed nicols. Parts are heavily stained with iron oxides. Lighter colored gray to tan areas commonly surround elongate cavities that usually are filled with very irregular siderite grains and aggregates surrounded by brown to black iron oxides.

A similar example of this kind of bauxite, from India, has been illustrated by Fox (1932, p. 38, photograph 3),

who considered it to be a typical form of aluminous laterite. The Indian specimen contains many small irregular cavities, fissures, and tortuous tubes. These are fewer in the Arkansas specimens, and all appear to have been filled with aluminous matrix material, and lastly by siderite and iron oxides. Another example, from French Guinea, has been illustrated by Lacroix (1913, p. 277, pl. 12, fig. 3).

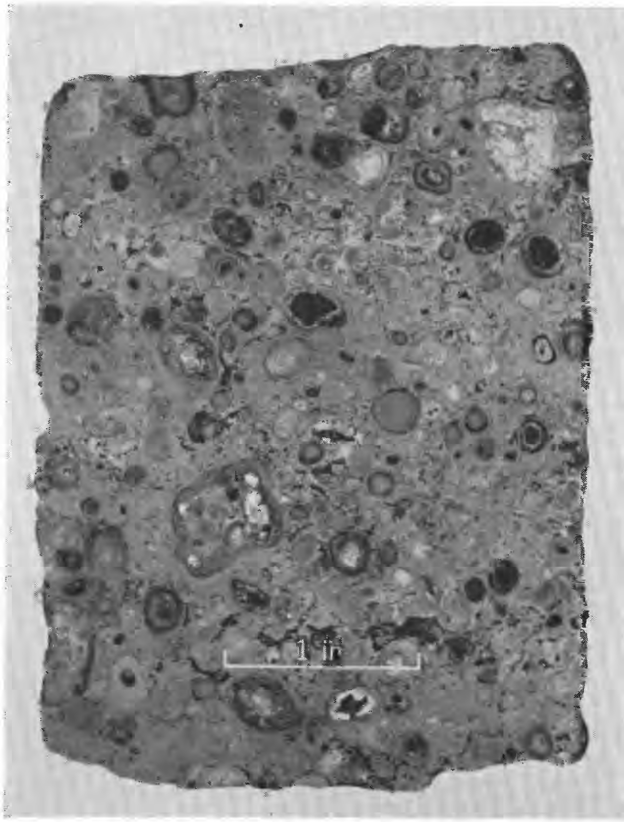

FIGURE 16.—Tan pisolitic bauxite. Typical specimen containing several small bauxite pebbles. Sawed face of core specimen (AB-16047-1) from East Bauxite deposit, USBM drill hole 16-047, depth 432 feet, SE¼NW¼ sec. 31, T. 2 S., R. 13 W., Saline County. Natural size.

OTHER STRUCTURES FORMED BY CONCRETIONARY PROCESSES

A variety of forms that closely resemble breccia or conglomerate have been produced by alteration of bauxite in place. These are common in the middle and upper parts of residual deposits near Bauxite. The resulting forms range from pebblelike concretionary structures within granitic-textured bauxite (figs. 19–21) to boulderlike blocks of pisolitic and granitic bauxite in a pisolitic matrix (fig. 22). Massive granitic-textured bauxite is cut into blocks and fragments by anastomosing veins and masses of pisolitic or claylike bauxite. The blocks are angular and mosaiclike to well rounded and scattered. Locally the boundaries between concretionary bauxite and the relict granitic blocks are poorly defined, but more commonly they are emphasized either by kaolinization or by the growth of thick gibbsitic crusts.

Remnant rounded blocks of birdseye pisolitic bauxite and of vermicular rock are also found in a matrix of pisolitic bauxite that has apparently formed by concretionary processes. Locally blocks of pisolitic or granitic-textured bauxite occur in a matrix of kaolinitic or bauxitic clay retaining remnant pisolitic structures. This rock has the appearance of a rubble but was formed in place by weathering. It commonly grades downslope without any perceptible break into a true

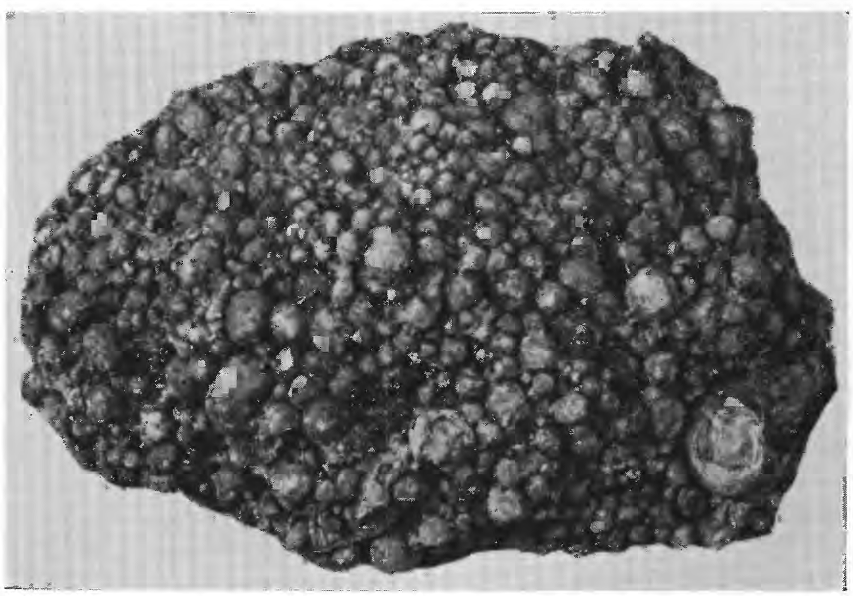

FIGURE 17.—Aggregate of tan pisolites loosely cemented by siderite crystals. Hand specimen (AB-24-1) from Weiss mine near Woodyardville, Pulaski County. Natural size.

FIGURE 18.—Section of granitic-textured bauxite of the zone of leaching, near outcrop of deposit in the Pruden mine. Note sheeting, probably a relict structure from the original nepheline syenite. The height of the bauxite face is about 15 feet.

FIGURE 19.—Section in the north wall of Alexander Hill mine showing small pebblelike concretionary structures that have formed in granitic-textured bauxite. Light-colored rock at lower right is kaolinitic underclay.

rubble—actually broken up by transporting agencies and recemented—that fingers into the Wilcox as described in the following section. So imperceptible is the change from concretionary to transported rubble that only those rocks can be differentiated that are extreme examples of the two modes of origin.

CELLULAR AND SCORIALIKE FORMS

Some of the bauxite associated principally with the deposits near Bauxite has a cellular appearance in outcrop. The surface is riddled with small round cavities resembling the vesicles in some extrusive igneous rocks. When this rock is broken, however, the interior is seen to contain vague outlines of relict feldspar crystals or poorly formed pisolites.

Another form of bauxite in the same outcrops resembles a scoriaceous lava. When broken, this material

FIGURE 20.—Face in the Section 15 mine 100 yards north of portal of the Davis underground mine showing concretionary bauxite rubble formed within granitic-textured bauxite. A concretionary area in lower center, indicated by hammer.

FIGURE 21.—Close-up view of the concretionary area shown in figure 20. Kaolinization of part of the bauxite matrix has emphasized the rubbly appearance of the rock.

FIGURE 22.—Rubbly surface of bauxite in the downslope part of a residual deposit. Boulderlike blocks of pisolitic and granitic-textured bauxite in a matrix of pisolitic bauxite exposed at the top of bauxite bed near the southwest end of the Section 16 mine.

also exhibits a granitic or pisolitic texture, or may be almost structureless. Similar scoriaceous forms of bauxite have been described in other parts of the world, for example in the India and New Guinea deposits. Both cellular and scoriaceous forms are confined to bauxite in outcrop, and are relatively rare in Arkansas deposits, where the proportion of outcrop to mined faces and cored sections is very low compared with the apparent dominance, judging from published reports, of this material in deposits elsewhere that have been examined largely in outcrop.

SEDIMENTARY STRUCTURES

In many of the Arkansas deposits there is abundant evidence of the erosion, transportation, and redeposition of bauxitic material either by mass wasting or by running water resulting in several distinct types of bauxite that exhibit structures characteristic of sediments. Although a good proportion of the Arkansas ore could be classed as sedimentary deposits, the amount that preserves diagnostic structures is comparatively small.

Commonest of the sedimentary types is the rubbly bauxite in boulder beds, consisting of blocks or boulders of pisolitic and granitic-textured ore in a matrix of bauxite, clay, or rarely sand. A bed of this sort is shown in figure 23. Where not too contaminated by matrix derived from clastic and carbonaceous Wilcox sediments, this bauxite has been mined. In the Saline County deposits good ore of this type consists of fair to well-rounded masses broken up by slumping and landsliding of the deposit, in a matrix of fine material and has no visible stratification or other evidence of deposition by water. It is restricted to the upper part of the bauxite in the downslope parts of the large high-level deposits near Bauxite, or is interbedded with the Wilcox that fringes these areas. This rubbly transported ore is similar in appearance to concretionary bauxite that occurs in the middle, and locally the upper part of the bauxite in the same high-level deposits, but has a totally different origin, as described earlier.

Another type is the well-bedded or stratified bauxite (figs. 24–27) that is exposed in several mines in Pulaski County and that also has been found in some of the drilled deposits in that district. It occurs in the upper part of bauxite deposits fringing the nepheline syenite masses and usually is found in channels that tongue into the Berger formation downslope. Photographs of stratified bauxite in the Ratcliffe and England pit mines are shown in figure 24*A*, *B*, and in the Rummel shaft mine on figure 27. In the Ratcliffe deposit, which contains some of the best exposures of this rock, the stratification is pronounced. Beds as much as 4 inches thick of well-sorted pisolites and hard bauxite pebbles

FIGURE 23.—Bauxite rubble bed within the Saline formation in the southwestern part of the Section 16 mine, in sec. 21, T. 2 S., R. 14 W., Saline County. Dark-brown carbonaceous sandy clay, indurated, limonitic (*a*). Rubble of bauxite and bauxitic clay (*b*). Carbonaceous clay and lignite (*c*); upper layers penetrate rubble above as at hammer. Dark-gray silty carbonaceous clay (*d*).

are interstratified with layers of granules and grains of the same material (fig. 26). Parts of the stratified deposit contain a cement of microcrystalline gibbsite in which are scattered tiny grains and oolites of dark cryptocrystalline gibbsite (fig. 25*D*, *B*), and locally the pisolites are coated with tiny gibbsite crystals (fig. 24*D*). In other parts of the deposit granular siderite is the cementing agent and the upper layers of the deposit are highly ferruginous. Scattered masses of light to dark cherty-looking kaolin fill cavities and veinlets in the upper part of this deposit (fig. 25 *A*, *B*, *C*). Some of the bauxite in these deposits has a well-defined crossbedding, as was observed in the England, Reichardt, and Rummel mines, all in Pulaski County. A sample of pisolitic gravel from a crossbedded layer in the Reichardt mine is shown in figure 24*C*.

Near the base of the bauxite in some deposits are small lenses and channels filled with bauxitic detritus from sand and granule to moderately coarse gravel. They range in thickness from a few inches to a few feet. Concentrations of heavy minerals are common at the base of the lenses, and fragments of lignite are found in the more gravelly parts. Rarely, a thin lignite or carbonaceous layer is at the base of the lens

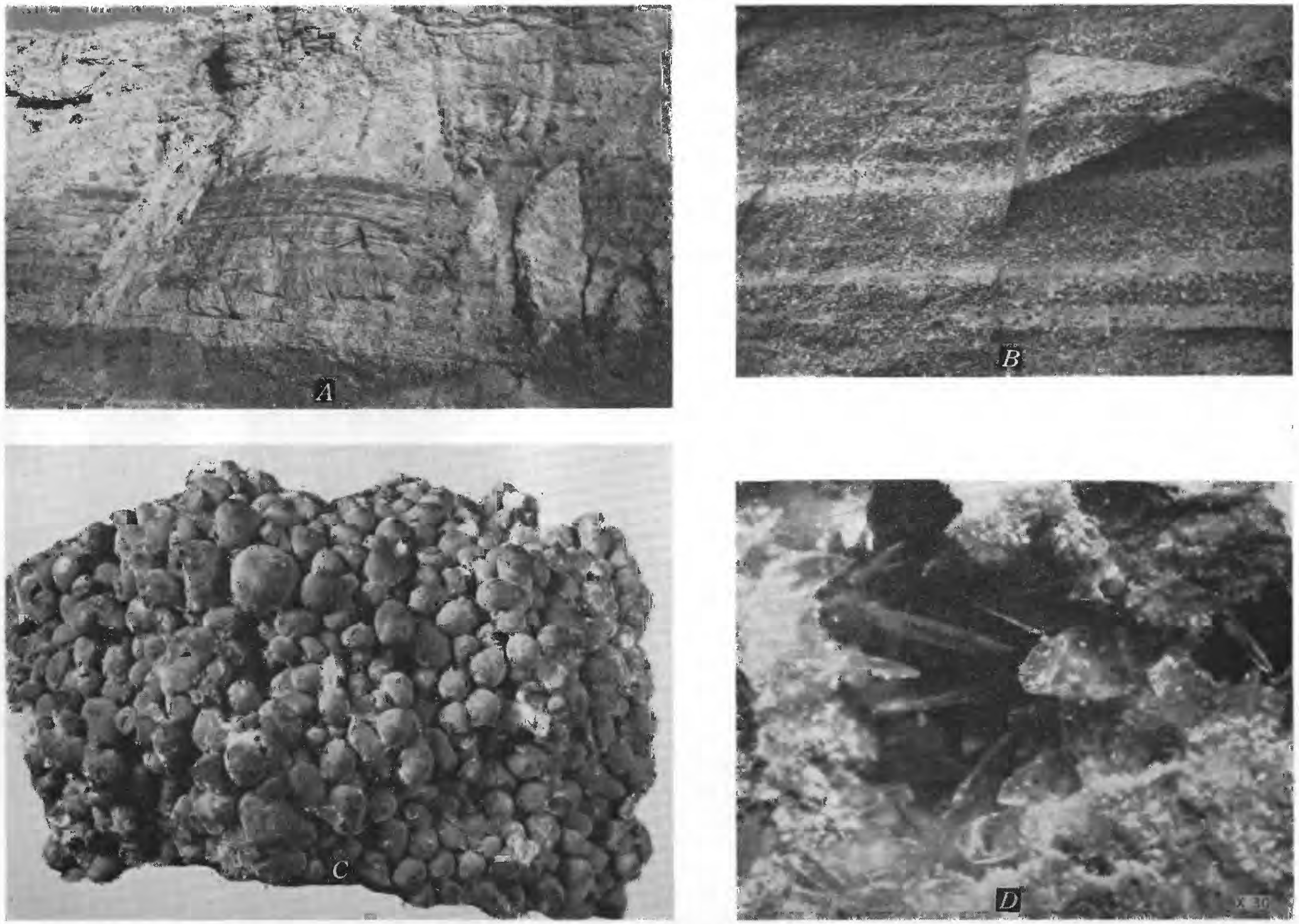

FIGURE 24.—Stratified bauxite exposures in Pulaski County mines. *A*, 12-foot face of bauxite of fluviatile deposition in the southern part of the Ratcliffe mine. Note prominent stratification in the lower half of bed. *B*, Prominent horizontal banding in hard pisolitic bauxite in the England mine. Bands are due to sorting of hard brown pisolites and pebbles and smaller tan to gray pebbles. About 2 feet of vertical section is shown. Photograph by S. S. Goldich, 1943. *C*, Cemented cherty pisolites and small pebbles. Hand specimen (AB-28-2) from a lens of crossbedded bauxite in the Reichardt underground mine. Spectrographic analysis given on page 132. *D*, Photomicrograph of white, pointed tabular gibbsite crystals protruding into a cavity in stratified bauxite from an encrusting crystalline gibbsite mass coating the pisolites. Specimen (AB-11-1) from the east face of the Harley mine. × 30.

(fig. 52). These lenses have been observed in a few of the Saline County deposits, such as those in the Fletcher 40 and Midwest pit mines and the Childress shaft mine. They probably are common in other similar deposits in that district but, as they would be difficult to recognize in drill cores and are well preserved only in freshly cut pit and mine faces, they are easily overlooked.

Still another type of bauxite of detrital origin is referred to as "fragmental bauxite" (pl. 14*C*). It occurs beneath pisolitic bauxite, in the lower part of the bauxite profile and in the downslope ends of gently dipping bodies that fringe the buried nepheline syenite hills where they are lapped by the tapering edge of the Midway. It is associated with and grades into oolitic and massive varieties, and overlies and grades into bauxitic clay with about the same fragmental texture. The matrix is mealy to clayey, tan or grayish tan; scattered through it are varicolored angular bauxite fragments, some are bright orange, and locally a few are grayish kaolinitic clay fragments.

MINERALOGIC CHARACTER OF BAUXITE

The mineralogy of bauxite is now fairly well known, but many details require additional studies. The finely divided minerals in intimate mixtures in the bauxite rocks are not easily identified and require specialized methods of study. It is hoped that eventually an exhaustive mineralogic study will be made of the bauxite cores collected in the Arkansas field.

For the purpose of this report, optical studies of thin sections and polished sections and X-ray examination of prepared samples of typical bauxitic rocks have been made. These form the basis for the descriptions in the following paragraphs.

ALUMINUM MINERALS

GIBBSITE

This mineral, aluminum hydroxide, $Al(OH)_3$, also written as the trihydrate of alumina, $Al_2O_3 \cdot H_2O$, is the principal aluminum ore mineral of Arkansas bauxite. It is present in two forms: the one crystalline or microcrystalline; the other cryptocrystalline—so finely crystalline that it appears isotropic under the microscope and for many years was thought to be an amorphous mineral.

The crystalline form occurs in microcrystalline aggregates or in minute crystals that generally line cavities. Under the microscope the crystals are seen to be colorless to pale brown, have a moderate relief, and between crossed nicols show a moderate birefringence and inclined extinction. The crystalline form is particularly characteristic of granitic-textured bauxite, and in this material many of the microcrystalline aggregates are pseudomorphous after feldspar (pl. 11*D*). It also is found in tiny veinlets cutting the "amorphous" form in pisolitic bauxite and as a cementing material surrounding hard cherty pisolites in some sedimentary bauxite. There are, therefore, at least two generations of crystalline gibbsite. Crystals visible to the naked eye are rare. Tabular white gibbsite crystals, some as large as a millimeter across, were found in a veinlet in hard pisolitic bauxite at a depth of 434 feet in Alcoa drill hole *X*–258, in the NE¼SE¼ sec. 36, T. 2 S., R. 14 W., Saline County. Similar masses of small crystals, some in clustered groups, were found lining cavities between cherty-looking pisolites and pebbles in stratified bauxite in the Harley pit mine, Pulaski County, and are shown in the photograph on figure 24*D*, and the photomicrograph on figure 25*D*.

The cryptocrystalline or so-called amorphous form of gibbsite is much more common than the crystalline variety. It forms most of the matrix and all the pisolites and rind structures of the bauxite, except where there are fragments or veinlets of the crystalline variety. In many places the two forms are intimately mixed. Under the microscope the cryptocrystalline form is moderately translucent to opaque, in places stained light yellow or red to dark-reddish brown; the relief is moderate. Between crossed nicols it appears isotropic, or is cloudy. This substance has been called cliachite by some authors (Rogers and Kerr, 1942, p. 204) in the belief that it is a truly amorphous mineral in a colloidal state. Thermal and chemical analyses and X-ray studies indicate, however, that it possesses the chemical composition and crystal lattice of gibbsite. According to G. T. Faust (oral communication, 1949) differential thermal analyses of "amorphous" bauxite in United States deposits all show an endothermic peak at the temperature at which the trihydrate of alumina normally gives up its combined water of crystallization. Thousands of chemical analyses of the Arkansas ore, made at the field laboratory of the U. S. Bureau of Mines from the samples collected by the joint drilling program, indicate these samples, almost without exception, contain alumina and water in the same proportion as the trihydrate. X-ray examination by J. M. Axelrod of several samples of Arkansas bauxite yielded diffraction patterns, some of which had clearly defined gibbsite lines, others had diffuse ones.

An intimate relationship exists between the gibbsite and the finely disseminated iron oxides. Staining by iron oxide gives the bauxite its usual tan color and in part causes the opacity of many of the pisolites.

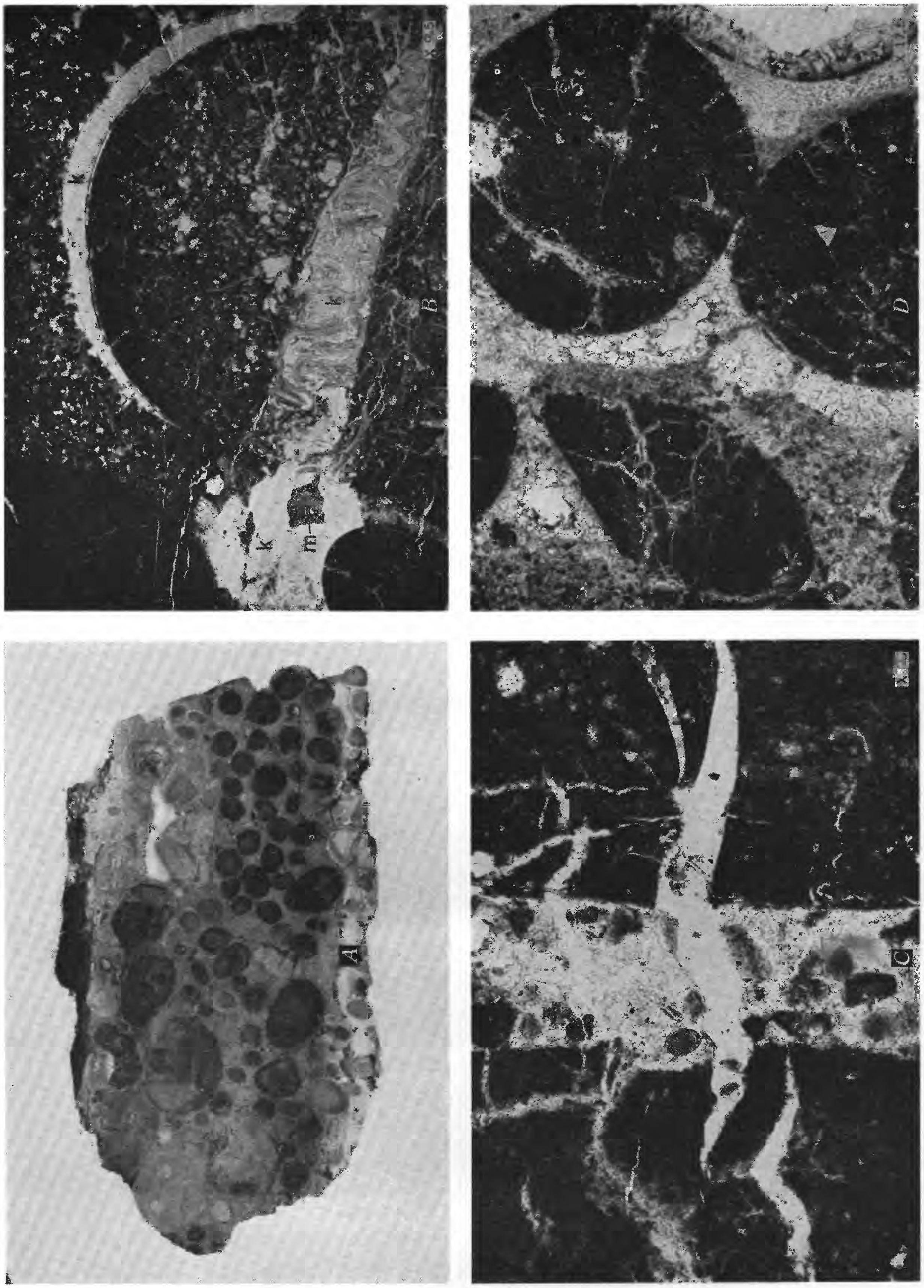

FIGURE 25.

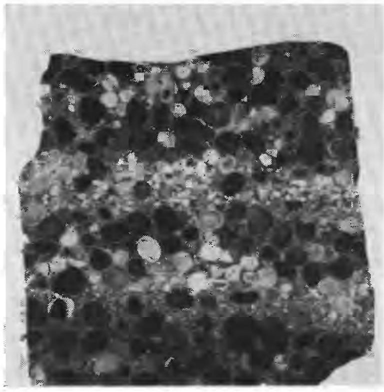

FIGURE 26.—Well-sorted stratified bauxite. Sawed face of core specimen (AB-7009-1) from upper bauxite bed in the Birnbach No. 1 ore body, USBM drill hole 7-009, depth 252.5 feet, SW¼SE¼ sec. 2, T. 1 S., R. 12 W. Natural size.

BOEHMITE

The presence in hard cherty-looking pisolites in Arkansas bauxite of a hydrated aluminum oxide containing less combined water than gibbsite was first noted by Wysor (1916). He pointed out that the water content in some of this material is as low as 14.58 percent and the alumina content as high as 72.52 percent and that the deviation from the normal ratio of 34.6 percent of combined water to 65.4 percent of alumina as in gibbsite is about proportional to the hardness and specific gravity of the pisolites. He attributed this to the presence of diaspore ($HAlO_2$ or $Al_2O_3{\cdot}H_2O$) and the dihydrate "bauxite" which at that time was still considered to be a distinct mineral.

Another monohydrate of alumina was discovered in 1925 by Boehm and named boehmite in 1926 by J. de Lapparent. It is the principal aluminum mineral in most of the European deposits. The high alumina content of some pisolites in the Arkansas deposits is due to boehmite. Its presence in Arkansas bauxite at two localities was noted by Allen (1946): "associated with Paleocene gibbsite in black pisolites in the Townsend 40 property, about 2 miles east of Bauxite; and near Berger, Pulaski County." The mineral also has

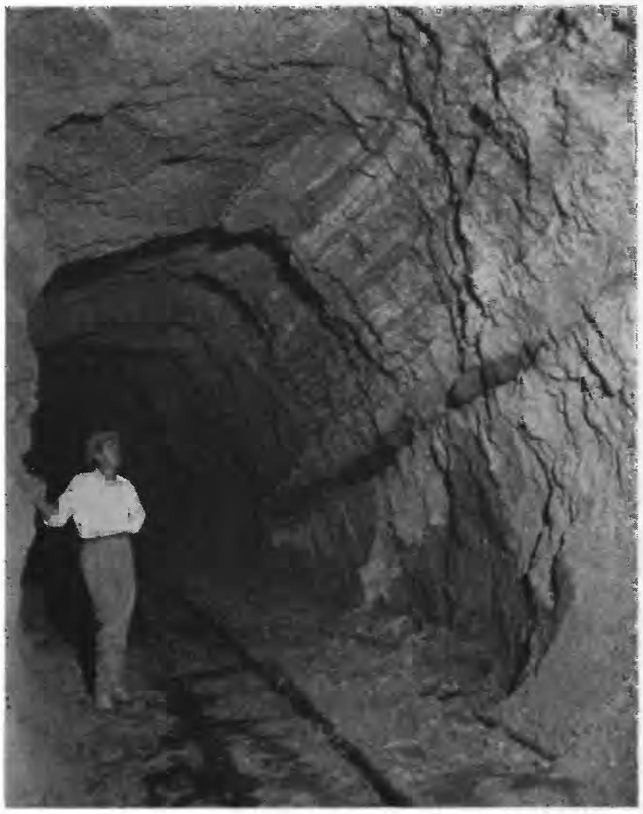

FIGURE 27—Stratified bauxite resting on unstratified bauxite in the Rummel mine, Pulaski County. Prominent dark siderite bed in wall opposite man marks base of the stratified rock. Bauxite below is massive and pisolitic.

been identified in specimens from the following localities in Saline County by means of X-ray examination by J. M. Axelrod: in red bauxite containing black pisolites ("birdseye ore") from the Section 16 mine near Bauxite, a trace only; in black cherty-appearing bauxite pebbles filling channels within the lower bauxite bed in the Fletcher mine; and in Alcoa drill hole C-603, depth 406-410 feet, Hudspeth-Fletcher property, in the NW¼SE¼ sec. 36, T. 2 S., R. 14 W., Saline County.

The material from the Alcoa drill hole C-603 first aroused interest because small flakes chipped from the hard dark pisolites were attracted by an alnico magnet. The pisolites, on analysis, showed a high alumina con-

EXPLANATION FOR FIGURE 25

Stratified bauxite specimens from Pulaski County. *A*, Bauxite cut by hard whitish kaolin veins. Bulk of rock consists of light and dark pisolites and pebbles in a brownish-gray gibbsitic matrix. Sawed face of hand specimen (AB-12-1) from upper part of bauxite bed in the Dixie Lease mine in the Ratcliffe deposit. *B*, Photomicrograph showing relations of kaolin and bauxite. Thin section (AB-12-1) is taken from specimen shown in *A*, cut from basal part just right of center. Most of one semiopaque pisolite and part of two dark opaque ones are shown, together with matrix of tiny opaque grains in microcrystalline gibbsite. Kaolinite (*k*) is seen cutting pisolite, inserted between pisolite and matrix, and surrounding torn fragment of matrix (*m*). X 9.5. *C*, Photomicrograph showing minute relations of kaolin and bauxite. View at higher magnification of part of thin section shown in lower left hand corner of *B*. Kaolinite (lighter color and low relief) cuts two dark pisolites and light grayish gibbsitic matrix. X 9.5. *D*, Dense opaque gibbsitic pisolites in a matrix of microcrystalline gibbsite and tiny dark gibbsitic fragments. Large gibbsite crystals protrude into two small cavities. Thin section (AB-11-1) from same specimen in figure 24*D*. Spectrographic analysis given on p. 132. X 17.5.

tent and a low ignition loss, as shown in the table below. The magnetic pisolites in sample 1 in the table below were brown to black with a vitreous luster, and the hardness ranged from 5 to 6 on the Mohs scale. Sample 2 consisted chiefly of the matrix, together with fragments of the softer light-colored pisolites. No magnetic material was present in sample 2.

Chemical analyses of magnetic pisolite samples and their matrix from Alcoa drill hole C–603, Saline County

[Analyses by U. S. Bureau of Mines field laboratory, Little Rock, Ark.]

	1 Pisolites	2 Matrix
Al_2O_3	71. 0	52. 9
SiO_2	4. 0	8. 3
Fe as Fe_2O_3	6. 0	2. 0
TiO_2	1. 2	2. 0
Ignition loss	16. 6	29. 1
Insoluble	1. 2	. 7
FeO	1. 4	. 2

1. Brown to black pisolites only, selected and cleaned.
2. Matrix material crushed, sieved, and separated in bromoform to eliminate heavy pisolites; analysis from +20 mesh–40 mesh, bromoform floats only.

Examination under the petrographic microscope has not revealed any recognizable crystalline boehmite in additional specimens from the localities at which it has been reported, so presumably, like much of the gibbsite, the mineral is in very finely divided form and further obscured by iron-staining.

KAOLINITE AND HALLOYSITE

The hydrous aluminum silicate ($Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$) kaolinite is one of the main impurities in Arkansas bauxite. It occurs abundantly in residual and sedimentary deposits associated with the bauxite with which the kaolin intergrades, so that there are all degrees of mixture from fairly pure gibbsite rock to almost pure kaolin. Kaolinite, where present, occurs in white to gray masses of fine micaceous crystals in veins and veinlets cutting the bauxite, and as cavity fillings.

In thin section the mineral is transparent to translucent, appears finely granular, and has a low relief. Between crossed nicols it displays a weak birefringence. Much of it is in structureless masses or in plates and flakes without distinct outlines. Some is very finely divided and appears isotropic. It also forms vermicular crystals or long accordionlike books, which in thin sections of bauxite have been observed to range in width from 0.005 to 0.7 millimeter. They frequently are contorted to fit the space they occupy and have a characteristic wavy extinction. The optical properties, chemical composition, and X-ray pattern of some vermicular crystals, taken from kaolin seams cutting bauxite in the Old Globe mine near Bauxite, have been given in a fundamental paper on the kaolin minerals by Ross and Kerr (1930, p. 162–164, 166, 173, pl. 42A), to which the reader is referred. At this locality the crystals are associated with a beidellitelike clay, of a dark color and a high birefringence, which completely disperses in water, whereas the kaolin does not.

Kaolinite is absent or rare in much of the granitic-textured bauxite, but in some specimens it fills spaces between microcrystalline gibbsite pseudomorphs after feldspar and also occurs in veinlets and cavities in the rock. In pisolitic bauxite, kaolinite usually fills veinlets and cavities in the matrix; less commonly it occurs in tiny veinlets that cut pisolites, or it fills their interiors.

The upper part of many bauxite deposits has a hard siliceous cap and in a few alluvial deposits spaces between the pisolites and pebbles near the top of the bauxite are filled with a light to dark-gray or brown cherty-looking substance that fractures conchoidally, which some geologists have called "halloysite." Under the microscope, however, this substance appears to be kaolinite, commonly in long contorted wormlike crystals. Some of it is shown in the photograph of a hand specimen from the stratified bauxite bed in the Dixie Lease mine, Pulaski County (fig. 25*B*). In this specimen the clay mineral fills cavities and surrounds and cuts pisolites and their gibbsitic matrix, as shown in the photomicrographs in figure 25*B*, *C*. An X-ray examination of a small fragment of this material by J. M. Axelrod confirmed its identity as kaolinite.

Halloysite has been identified by F. A. Hildebrand, by means of the electron microscope, in several samples of clay and bauxite collected by him from outcrops (fig. 28*A*–*D*). He reported that some of the clay beds

EXPLANATION OF FIGURE 28

Electron micrographs of Saline County bauxite and clay specimens. *A*, Kaolinite in kaolinized nepheline syenite from beneath 3 feet of sand and clay of Wilcox age in a small creek (since covered by waste pile) at the southwest end of Echo Lake, SW¼SE¼ sec. 35, T. 1 S., R. 14 W. Other specimens from the same outcrop show halloysite in small amounts. *B*, Halloysite in kaolinized nepheline syenite from the crest of the east wall of the Old Globe mine, west center of sec. 26, T. 2 S., R. 14 W. A few small hexagonal plates of kaolinite can also be seen. The kaolinized surface lay beneath several feet of ferruginous sand of Wilcox (Detonti?) age that had been stripped off during mining. *C*, Halloysite and kaolinite from the outer shell of a kaolinized spheroidal "boulder" in the east wall of the Elrod open-pit mine, NW¼NW¼ sec. 2, T. 2 S., R. 14 W. The weathered "boulder" was about 3 feet in diameter. *D*, Halloysite in granitic-textured bauxite from a 4-inch block or "cobble" of granitic-textured bauxite collected near the north end of a large outcrop of pisolitic bauxite near Echo Lake, east section line, NE¼ sec. 2, T. 2 S., R. 14 W. Photomicrographs by F. A. Hildebrand.

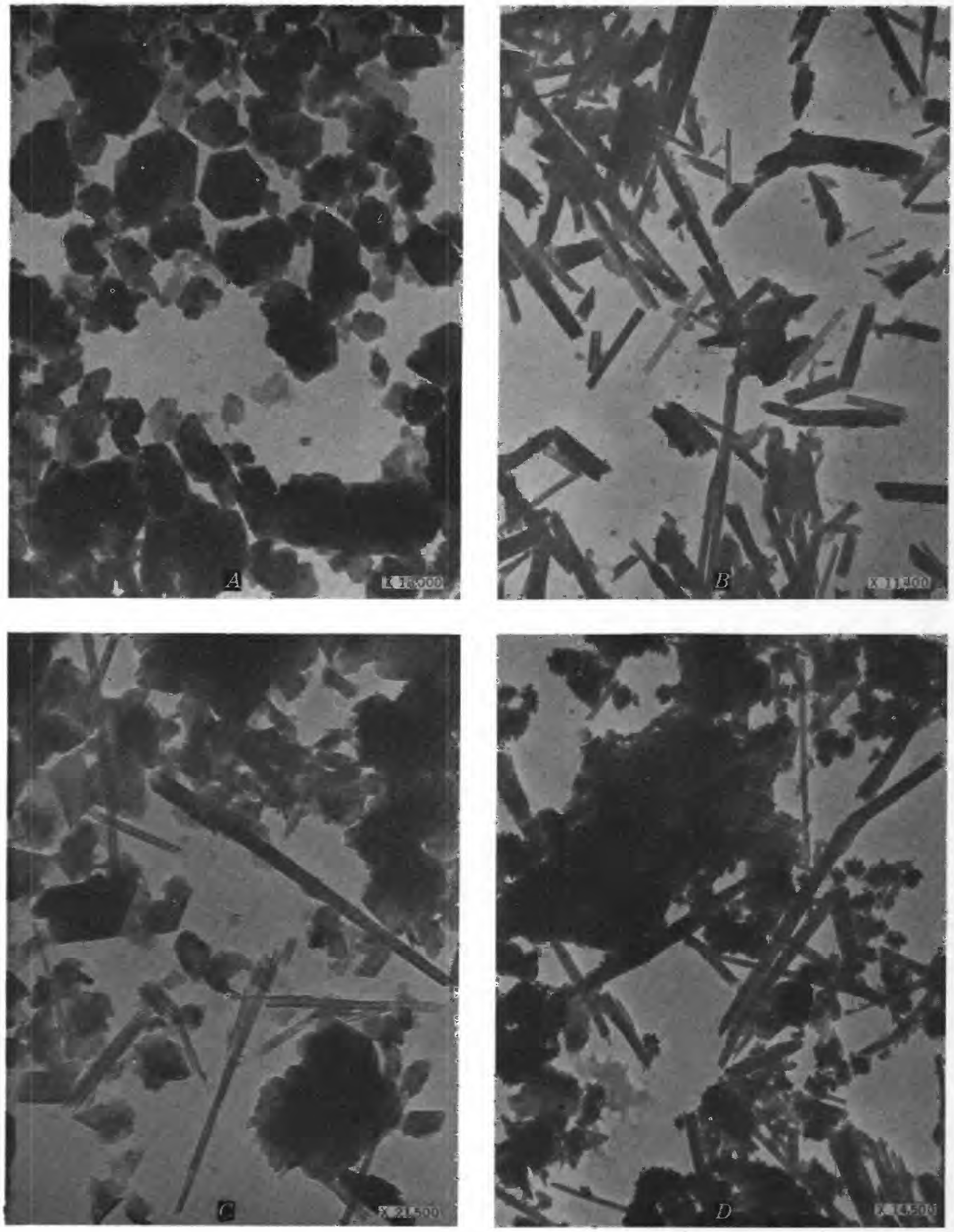

FIGURE 28.

contain as much as 50 percent of this mineral. This is the first positive identification of halloysite in the bauxitic rocks of the region.

IRON MINERALS

SIDERITE

The principal iron impurity in the bauxite is siderite, ferrous carbonate ($FeCO_3$), which is widely distributed in the bauxite. Three principal modes of occurrence of this mineral have been observed: in grains, crystals, and crusts lining and filling cavities; in masses replacing part of the bauxite; and in small spherulitic pellets or aggregates scattered through the bauxitic and kaolinitic clay associated with the bauxite deposits.

The granular form is reddish brown to amber, but locally has a purplish irridescence, particularly where it forms botryoidal crusts as much as 3 millimeters thick. Incrustations and stalactitic aggregates were found in large cavities, during the mining of the pisolitic ore in the Stuckey mine at Bauxite. Scattered crystals are found in cavities. These crystals are usually distorted rhombohedrons with curved faces but more rarely are scalenohedrons terminating in pinacoid faces that look like broken dog teeth. Most abundant of all are the grains and granular aggregates that in places fill every available vug and cavity in the bauxite and locally cement pisolites. Under the microscope the mineral appears principally in grayish clusters of anhedral to subhedral grains. In a thin section of stratified bauxite it is the principal cementing material between pisolites. The aggregates and grains are surrounded by irregular areas of brown to black iron oxides that appear flat and opaque in contrast to the siderite. The index of refraction of granular material from an incrustation was determined by C. S. Ross to be $\omega=$ about 1.85.

The granular siderite is irregularly distributed through the bauxite. Although not characteristic of any particular zone, it generally is more common in the middle and lower parts of the bauxite section and is rare in the siliceous hardcap. It is found, however, in all lithologic types of ore and also is associated with lignite bodies and layers in the bauxite, occurring between the carbonaceous material and the bauxite. In the Rummel mine in Pulaski County a lenticular siderite bed occurs in the bauxite that apparently is the lateral extension upslope of a lignite bed.

At some localities siderite has invaded and replaced the original bauxite, as indicated by relict concretionary structures of the bauxite preserved in siderite. Examples of this replacement were found in drill cores from the East Bauxite deposit in sec. 36, T. 2 S., R. 14 W. and in the South Harris deposit in sec. 36, T. 1 S., R. 14 W.

Small pellets of siderite are abundant in the fragmental kaolinitic clay underlying bauxite deposits and in residual clay derived from the weathering of nepheline syenite and of sedimentary deposits of the Wills Point formation. They are not common in bauxitic clay associated with the deposits and are rare in the bauxite. The pellets are white, pink, or tan, becoming red to brownish red on continuous exposure to the air, and are scattered or aggregated in layers or patches in the clay. They are spheroidal or nearly so, and range in size from less than 1 to 4 millimeters in diameter, but generally average between 1 and 2 millimeters. Under a hand lens, the interiors appear structureless, but most pellets are radiating or concentric. According to C. S. Ross (written communication, 1942) the index of refraction for the siderite concretions is omega$=$1.845, which corresponds to about 88–90 percent $FeCO_3$. In thin section the pellets appear to be irregularly concentric near the outer edge, but within are spherulitic and show a well-defined polarization cross between crossed nicols. Some contain radially arranged grains, each with separate extinction.

HEMATITE

A relatively minor constituent of Arkansas bauxite, hematite (Fe_2O_3) constitutes a significant part of the heavy magnetic fraction in 3 of the 10 bauxite specimens submitted to J. M. Axelrod for mineral determination by X-ray analysis. A trace of this mineral was noted in a fourth sample. The specimens containing hematite were from Saline County deposits residual on weathered nepheline syenite. They included the granitic-textured and pisolitic varieties of bauxite, and generally were distinctly red, but one specimen was a black cherty-looking bauxite gravel from a Saline County channel-fill deposit. Hematite was also detected by X-ray examination in red high-iron pisolitic bauxite in deposits overlying the Wills Point formation in Saline County. In this rock the hematite generally is associated with goethite and magnetite.

Optical and X-ray data show that hematite is intimately associated with gibbsite on some of the larger crystals of which it forms a coating. Pink to red tones in bauxite are generally the result of staining by hematite.

Another form of iron oxide was found in two of the same specimens that contained hematite. This was identified by comparison with data in the American Society for Testing Materials card file as δ–Fe_2O_3, a substance hitherto unknown in nature. It apparently occurs as a black opaque mineral in the magnetic fraction heavier than methylene iodide. Samples containing this unknown mineral have been retained by the Geological Survey for further study.

GOETHITE

In nearly all Arkansas bauxite is a disseminated yellowish-brown earthy material that has been identified as limonite. It is a common oxidation product of siderite in the bauxite and surrounds partly altered siderite grains in many thin sections. It also occurs on bauxite in pit faces as a black thin encrustation, which has a yellowish-brown streak. X-ray examination at the laboratories of the Geological Survey has shown that this material is composed of the mineral goethite ($Fe_2O_3 \cdot H_2O$ or $FeO(OH)$).

This finely disseminated hydrous iron oxide probably causes the tan color of much of the bauxite. In high-iron bauxite deposits it has been found in association with hematite, but more commonly where one is present the other is absent, or at least occurs in small quantity.

Limonite is now used only as a rock term for certain of the hydrated iron oxides. X-ray studies have shown that the only two hydrated iron oxide minerals are goethite and lepidocrocite. Both are monohydrates but differ in crystal structure. Limonite is goethite that contains a small quantity of water by absorption. Lepidocrocite has not been found in bauxite (De Weisse, 1948, p. 145).

MAGNETITE (AND MAGHEMITE?)

Magnetite is absent in most Arkansas bauxite deposits. Forms of ferruginous pisolitic bauxite, however, particularly those of a distinctly red type, are slightly to moderately magnetic. Cores of this material can be rolled along a flat surface such as a table top by means of their attraction to an alnico magnet. Investigation has shown that the pisolites contain most of the magnetic material. The association of boehmite with magnetic pisolites has been mentioned on page 85. Studies by Charles Milton and his associates of the Geological Survey have established magnetite ($FeFe_2O_4$) as the principal magnetic mineral, but have not yet excluded maghemite (γ–Fe_2O_3) as a possible source of part of the magnetism.

Red pisolitic bauxite containing slightly magnetic pisolites (specimen AB–80–1; fig. 15*A*), from the Section 16 mine, was examined in thin and polished section. A magnetic substance, a black opaque mineral with the optical properties of magnetite, was scattered through the pisolites in small irregular grains. X-ray examination by J. M. Axelrod of several of these grains, removed from the polished section, indicated that the material is magnetite in association with hematite and a little gibbsite.

Chemical tests for ferrous and ferric oxide were made on red high-iron bauxite obtained in a drill hole on the Federal housing project at Pine Haven, Saline County. The results of the analyses are given in the table below.

Chemical determination of ferrous and ferric oxide content, in percent, of the magnetic iron mineral in red ferruginous pisolitic bauxite samples from Pine Haven, Saline County

[Analyst, M. L. Lindberg; samples prepared by Charles Milton and J. M. Axelrod]

	Samples		
	1	2	3
FeO	8. 26	9. 08	7. 99
Fe_2O_3	50. 34	64. 31	61. 58

1. Black to brown heavy opaque magnetic residue obtained by crushing red ferruginous bauxite (specimen AB–901–1) and hand picking with the aid of a strong magnet.
2. Part of same material after boiling in nitric acid to remove any siderite present.
3. Same as sample 2 but rubbed between glazed paper to remove any soft material on the surface of particles and grains.

Samples 2 and 3 indicate that nearly a third of the material is magnetite, which probably is intergrown with hematite containing small amounts of impurities.

Secondary origin of magnetite in the bauxite is indicated by its concentration locally in red ferruginous bauxite, and its occurrence principally in small lobate branching masses in pisolites and in disseminated particles in pisolites and matrix.

PYRITE

The iron sulfide mineral in the bauxite has been identified by optical and X-ray examination to be pyrite (FeS_2). In the upper or middle parts of bauxite deposits pyrite occurs as a replacement of siderite. In a specimen of pisolitic bauxite from the East Bauxite deposit the pyrite occupies the large central part of pisolites and is scattered in small irregular grains and blebs through the bauxite matrix. A polished specimen of this rock was examined by Charles Milton who reported that no marcasite is present.

Pyrite occurs in the hardcap and kaolinitic overclay above pisolitic bauxite, and in some places as small cubic crystals. It is abundant in the carbonaceous beds overlying bauxite deposits where it generally is associated with siderite.

TITANIUM MINERALS

ILMENITE

A minor accessory mineral in the nepheline syenite rocks, ilmenite ($FeTiO_3$) is a characteristic residual mineral in all types of bauxite deposits, where it normally alters to anatase. Ilmenite also occurs in the fragmental kaolinitic clay that consitutes a large part of the bauxite-kaolin facies of the Berger formation. It is scattered evenly throughout the clay, a little more profusely in the lower part; in places it is concentrated

in streaks and small channels and it is locally abundant at the base of channels filled with bauxite gravel or kaolinitic clay debris, at the top of the bauxite-kaolin facies. This mineral occurs as dark-gray to black metallic subhedral to euhedral grains, or in the form of skeleton crystals. Ilmenite was also identified by X-ray analysis in several bauxite and clay specimens.

SPHENE

One of the minor accessory minerals in the nepheline syenite, sphene ($CaTiSiO_5$) is rare or absent in the bauxite and kaolin deposits, except as relict crystals that have been altered to anatase. The alteration may be so complete that none of the original mineral remains, but the characteristic crystal form of pseudomorphs indicates its former presence. Of 10 bauxite samples submitted for X-ray analysis, sphene was detected in only one, and the pattern was inconclusive. Sphene has been reported in thin sections from a single drill core from Saline County by Frederickson (1948, p. 374).

ANATASE

An earthy dark-yellowish- to reddish-brown mineral has replaced sphene in many parts of the bauxite. The granitic-textured bauxite contains abundant relict skeletal sphene crystals with characteristic wedge-shaped cross sections that are replaced by anatase (pl. 10*C*). Cavities in these relict crystals contain gibbsite. The same brownish titanium mineral coats grains and crystals of ilmenite in the bauxite, or occurs in scattered masses and specks. It is whitish in reflected light, and exhibits other optical properties characteristic of leucoxene. In all samples of Arkansas bauxite examined by X-ray methods J. M. Axelrod identified this titanium mineral as anatase, one of the polymorphs of TiO_2. It is the most common titanium mineral in all the bauxite samples examined.

Anatase is widespread likewise in kaolinitic rocks. Two minerals that appeared to be titaniferous alteration products were found in a gray fragmental clay overlying the Wills Point formation in USBM drill hole 6–139 (depth, 349 feet), beneath the Bates deposit, Pulaski County. Samples were submitted to J. M. Axelrod for X-ray analysis and to J. J. Glass for petrographic examination. The first was a yellowish-brown earthy mineral with a high index of refraction and birefringence, in the shape of relict sphene crystals and fragments of crystals. X-ray examination showed this mineral to be anatase. The second was a very dark gray, fine grained, soft, homogeneous substance, opaque under the microscope, in the form of skeletal crystals as much as 5 millimeters across. X-ray examination disclosed both anatase and ilmenite. The color of the anatase apparently depends on the mineral after which it is pseudomorphous; yellowish brown after sphene and dark gray after ilmenite.

Bramlette (1936, p. 17) prepared a concentrate of the yellowish-brown mineral of very high refractive index that replaces sphene, and had a chemical analysis made which is reproduced in the following table:

Analysis of titanium mineral in bauxite

[Analyst, Charles Milton]

	Percent
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

At least part of the Al_2O_3 and Fe_2O_3 is attributed to the impurities in the concentrated sample, as these consisted of gibbsite and ilmenite, but Bramlette also suggested that part of these sesquioxides and the P_2O_5 are due to solid solution in the hydrous titanium oxide. He identified the titanium mineral as xanthitane.

According to Frondel *in* Palache, Berman, and Frondel (1944, p. 587) xanthitane, xanthotitane, and hydrotitanite are identical with anatase, as determined by X-ray powder study. Leucoxene is now regarded as a general term for the dull, fine-grained, gray or yellowish-brown alteration products of titanium minerals. Leucoxene consists, in most examples of rutile, and less commonly of anatase or sphene (Frondel *in* Palache, Berman, and Frondel, 1944, p. 560).

Frederickson,[2] by means of X-ray analysis, identified a yellow earthy-appearing alteration product of ilmenite in bauxite from a drill core from Saline County as brookite.

RUTILE

This form of TiO_2 is a scarce accessory mineral in bauxite. Rutile was identified by means of X-ray analysis in 3 of 10 bauxite specimens submitted to J. M. Axelrod for heavy-mineral determinations by this method. It generally is associated with ilmenite, anatase, and zircon. These three specimens and those in which it was earlier identified in the heavy-mineral studies of Bramlette, according to his unpublished notes, are all from the upper parts of the pisolitic bauxite, including hardcap, in low-level deposits associated with the Berger formation. Mineralogic study of much more material will be needed to determine whether rutile actually is limited to these deposits. Bramlette (1936, p. 16) suggested that inasmuch as

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[2] Frederickson, A. F., 1948, The mineralogy of a drill core of Arkansas bauxite: Unpublished Doctor of Science thesis, Massachusetts Inst. Technology, p. 374.

rutile is one of the common accessory minerals in the adjacent Wilcox sedimentary rocks, it may have entered the bauxite by reworking of the upper pisolitic bauxite with the overlying Eocene sedimentary deposits. If rutile is characteristic of the entire Wilcox formation, it might be expected locally in the upper parts of any of the deposits, and in the lower parts of others.

MINOR ACCESSORY MINERALS

CHLORITE

A chloritic mineral in hexagonal platy crystals is found in parts of the district. Chlorite is a common accessory mineral in the East Bauxite deposit where it is associated with siderite in the middle and lower parts of the low-silica pisolitic bauxite. The mineral was identified from USBM drill holes 16–048 (depth, 455.2 feet), USBM 16–050 (depth, 449 feet), and USBM 16–052 (depth, 473 feet). X-ray analysis by J. M. Axelrod identified the mineral in these samples as very close to, or identical with chlorite. The mineral also was recognized by X-ray analysis in a block of granitic-textured bauxite ("sponge ore") from the Middle Maud mine near Bauxite. Lack of sufficient comparative data on minerals of the chlorite group precluded a more positive identification by X-ray methods.

Material from USBM drill hole 16–052 was selected, cleaned, and examined under the petrographic microscope by Charles Milton and also by J. J. Glass. The pale green minute hexagonal plates were found to be optically negative, $2V=0°$. It has a low birefringence; β and γ near 1.660. The optical properties thus agree with those of chlorite.

CHAMOSITE

This chlorite mineral, a hydrous iron magnesium aluminum silicate, $15(Fe,Mg)O{\cdot}5Al_2O_3{\cdot}11SiO_2{\cdot}16H_2O$, was identified from its optical characteristics by Charles O. Milton and from an X-ray analysis by J. M. Axelrod. It was found in a core from an Alcoa drill hole (C–614) at a depth of 472 feet in the NE¼SE¼ sec. 36, T. 2 S., R. 14 W., Saline County. The core sample came from the basal foot of the Hawkins bauxite deposit, 9 feet below the bottom of the minable ore, and probably 10–15 feet above the top of the Wills Point formation. The enclosing rock is a reddish-brown highly ferruginous fragmental pisolitic bauxite. The matrix is hard and contains dark-brown limonite nodules, bluish-green veinlets of siderite and scattered brown siderite fragments. The chamosite is in clusters of minute green acicular crystals lining small cavities. Concerning these crystals Milton reported as follows (written communication, 1944):

> The identification was based on the optical characters, a bit hazy on account of the extremely small size of the crystals, and on a good X-ray pattern; both of which agree well with those of another chamosite I identified for Dr. Ross two years ago, a bauxite from Mississippi (D–1476). Gibbsite and siderite accompany the chamosite in both occurrences; in your bauxite the siderite forms large colorless crystals, with excellent cleavage; the gibbsite occurs in glistening druses and coatings on the pisolites. Also present are pyrite, and magnetite (or maghemite?)—this being a constituent of the black pisolites. Lastly, filling cavities, is a white snow-like mass, composed of microscopic plates of kaolinite.

ZIRCON

This mineral, ($ZrSiO_4$), was cited by Mead (1915, p. 44) as a characteristic heavy accessory mineral in Arkansas bauxite, "occurring in a variety of crystal forms and varying in color from white to dark brown through shades of yellow." Zircon has been identified optically by M. L. Lindberg and through X-ray analysis by J. M. Axelrod in 8 of 10 bauxite and bauxitic clay specimens. These analyses indicate that the mineral is present in the upper concretionary part of the residual deposits near Bauxite, both in blocks of granitic-textured "sponge ore" and in the surrounding pisolitic rock; in pisolitic bauxite in colluvial deposits near the buried edge of the Midway sediments; and in hard kaolinitic matrix rock associated with bauxite pebble layers of Berger age.

The presence of zircon in the bauxite is puzzling, because it has never has been identified in the underlying nepheline syenite. According to Frederickson[3] who studied exhaustively a single drill core from the Northern mine in Saline County, zircon crystals are found only within pisolites. The crystals are well formed in red unleached pisolites containing gibbsitized feldspar remnants, and have corroded, irregular outlines in pisolites that have been leached by later solutions. Bramlette (1936, p. 16) attributed the presence of zircon in the pisolitic upper part of the bauxite and its absence in the granitic-textured lower part of residual deposits to a certain amount of reworking or mixing of the upper pisolitic bauxite with the overlying Eocene deposits in which zircon is a common accessory mineral.

Where present in the ore, zircon generally represents less than 4 percent of the minerals denser than methylene iodide. Unpublished notes of Bramlette, however, indicate that in a bauxite outcrop along the Wills Point and Berger contact in the NW¼SW¼ sec. 12, T. 1 S., R. 13 W., zircon constitutes about 18 percent of the heavy accessory minerals. The writers believe the low-grade bauxite in that area has been derived from the Tertiary formations.

BARITE

A rare secondary mineral in the bauxite, barite ($BaSO_4$) was noted first by Mead (1915, p. 44) in the

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[3] Frederickson, A. F., op. cit., p. 376.

Arkansas deposits. Abundant well-formed crystals, as much as 2.5 centimeters in length, were found in vugs and cavities in pisolitic bauxite mined in 1944 in the Stuckey mine at Bauxite. Many of the cavities in the ore were lined with beautiful variegated botryoidal crusts of siderite to which the platy bundles of barite crystals were attached.

OTHER MINERALS

Fluorite and the rare feldspar celsian were both reported by Mead (1915, p. 44) among the accessory minerals in Arkansas bauxite. They have not been found in the present study. Tourmaline, kyanite, and garnet were mentioned by Bramlette (1936, p. 16) as characteristic of the Wilcox and as being reworked locally into the upper pisolitic part of the bauxite. Unpublished field notes of Bramlette show that tourmaline and kyanite, as well as zircon, rutile, and magnetite were present in bauxite collected from the outcrop in the NW¼SW¼ sec. 12, T. 1 S., R. 13 W., Pulaski County.

REMARKS ON PARAGENESIS

As bauxite is an alteration product derived from the weathering of other rocks, and as the minerals are not completely known owing to their finely divided state, only limited conclusions regarding paragenesis of the minerals in bauxite can be drawn at the present time.

Gibbsite, in the microcrystalline or finely crystalline state, appears to be the earliest primary mineral in residual Arkansas bauxite. Most of it was derived from the alteration of feldspar in nepheline syenite, the outlines and details such as cleavage are preserved in some places to a remarkable degree in the microcrystalline gibbsite aggregates. Most of the nepheline and analcime in the nepheline syenite apparently were leached out, though no doubt they were a source of gibbsite. Primary iron oxides, probably goethite or hematite, or both, were derived largely from the alteration of ferromagnesian silicate minerals and of magnetite. Anatase, derived principally from the alteration of sphene and partly of ilmenite, was formed contemporaneously with gibbsite and the primary iron oxides in granitic-textured bauxite. Whether kaolinite and other clay minerals were present in primary bauxite is not known, but if so, they probably are in a very finely divided state and cannot be distinguished satisfactorily from finely divided gibbsite or from kaolinite that was introduced much later.

In the formation of pisolitic bauxite from the granitic-textured variety the crystalline form of gibbsite was changed to the cryptocrystalline form. A late stage in the formation of pisolites resulted in the loss of part of the water of crystallization of the gibbsite and the formation in places of boehmite. The local association with the boehmite of a magnetic iron mineral (magnetite, and possibly maghemite) indicates a secondary origin for the iron mineral. Presumably magnetite could have formed from the primary iron oxides in the bauxite reacting to the same changes in physical chemical conditions that produced the boehmite. The magnetic iron mineral is present only in pisolites and therefore is not likely to be residual from the nepheline syenite.

Residual accessory minerals in bauxite derived from the nepheline syenite include ilmenite, sphene, fluorite, and celsian; the last three are rare. Heavy accessory minerals in parts of some bauxite deposits, believed to indicate mixture with or derivation from other Tertiary deposits are zircon, rutile, magnetite, tourmaline, kyanite, and garnet.

As zircon has not yet been found in Arkansas nepheline syenite or in granitic-textured bauxite in the lower part of residual deposits, its presence in the bauxite as a residual accessory mineral appears doubtful.

Late secondary minerals formed in small cavities, cracks, and fissures in the bauxite include finely crystalline gibbsite, chamosite, chlorite, kaolinite, siderite, pyrite, and barite. Secondary gibbsite nearly always is older than kaolinite, but in two thin sections was seen along tiny veinlets and lining cavities in secondary kaolinite. Chamosite, in the single core specimen in which it was found, occurs in tiny radiating needle-like crystals in cavities lined with thin crystalline druses of gibbsite; in several cavities powdery flakes of secondary kaolinite cover the chamosite clusters. Chlorite crystals occur in clusters scattered through the matrix of pisolitic bauxite and lining cavities in which brown siderite crystals formed later. Kaolinite and siderite were formed contemporaneously, but siderite in most places fills the central parts of cavities. Pyrite most commonly replaces siderite in cavities, along veinlets, and rarely within pisolites. In some cavities tiny cubes of pyrite are attached to siderite crystals. In specimens from the Stuckey mine barite crystals are attached to botryoidal crusts of siderite; pyrite is associated with siderite crusts and stalactitic structures in other specimens. Alteration of siderite and pyrite to limonite (goethite) is seen in many bauxite exposures and appears to be largely related to weathering much later than that in Eocene time.

Limonitic and other encrustations are forming on bauxite faces in pit mines at the present time. The mine waters that circulate through the bauxite have a high content of CO_2 and sulfuric acid, derived from pyritiferous lignite beds and chocolate-brown silty clay in the overburden. These waters deposit yellowish-brown limonitic crusts in standing pools and on the faces of pit mines. Crusts as much as one-eighth inch

thick have been noted on surfaces that have been exposed for less than a month. A whitish efflorescent mineral, possibly melanterite, is formed on some pit faces. It has a bitter astringent taste and is soluble in water.

CHEMICAL FEATURES

COMPOSITION OF MINERAL CONSTITUENTS

The characteristic mineral constituents of the bauxite, including some that are present in very small amounts, are listed in the table below together with their chemical composition and the calculated theoretical percentage of their principal oxides. The chemical constituents of bauxite are discussed in following paragraphs.

Minerals found in Arkansas bauxite, their chemical composition, and theoretical percentage of principal oxides

Mineral	Chemical composition	Oxides							
		H_2O	CO_2	Al_2O_3	SiO_2	Fe_2O_3	FeO	TiO_2	ZrO_2
Gibbsite	$Al_2O_3·3H_2O$	34.6		65.4					
Boehmite	$Al_2O_3·H_2O$	15.0		85.0					
Kaolinite	$Al_2O_3·2Si_2O·2H_2O$	14.0		39.5	46.5				
Siderite	$FeCO_3$		37.9				62.1		
Hematite	Fe_2O_3					100.0			
Goethite	$Fe_2O_3·H_2O$	10.1				89.9			
Ilmenite	$FeTiO_3$						43.6	56.4	
Anatase	TiO_2							100.0	
Rutile	TiO_2							100.0	
Zircon	$ZrSiO_4$				32.8				67.2

SILICA

Nearly all the silica in Arkansas bauxite is combined with alumina and water in kaolinite. The other silicate minerals such as zircon, chamosite, and celsian that have been identified in Arkansas bauxite are rare and occur only locally.

Silica does not occur in the free state in residual bauxite deposits. Mechanically admixed quartz sand and silt are found in some conglomeratic bauxite deposits, but normally the kaolin and the bauxite are quartz-free. As the bauxite grades into kaolin, the silica content may range from a fraction of 1 percent to more than 40 percent, depending upon the amounts of other impurities present.

ALUMINA AND "AVAILABLE ALUMINA"

Alumina in the bauxite occurs in the hydrated form (as gibbsite and rarely as boehmite) and also combined with silica (in kaolinite). Rarely does the alumina content approach within 1 percent of the 65.4 percent present in pure gibbsite and only locally does it exceed that figure where the monohydrate of alumina is present. As the content of kaolinite in the bauxite increases the alumina content decreases to a minimum of 39.5 percent provided no other impurities are present.

In the Bayer process for the extraction of alumina from bauxite the rock is crushed and heated in a solution of sodium hydroxide (caustic soda). The alumina in gibbsite dissolves readily in this solution but a certain proportion of the alumina in kaolinite cannot be freed. Empirical data from alumina plants indicate that for every pound of silica in the bauxite, 1.1 to 2 pounds of alumina are lost (Edwards and Mason, 1930, p. 127). This alumina therefore is not available for extraction. The remainder which goes into solution and can be recovered is known as the "available alumina." As the amounts that can be extracted vary in different plants, the value of the constant applied to determine available alumina varies from one company to another. During World War II the Federal agencies concerned with the problems of bauxite production used the factor of 1.1 times the silica content of a sample subtracted from the alumina content to determine available alumina. This value for available alumina has been used in this report. As available alumina is based upon actual milling experience it is a useful measure for grading bauxite, exclusive of iron content. For the purposes of the present study 32 percent available alumina was taken as the lower limit of metal ore in the Arkansas bauxite region.

IRON OXIDES

Ferrous iron occurs in Arkansas bauxite largely in siderite, the common secondary iron carbonate. This oxide occurs also in ilmenite, magnetite, and chamosite; the last two minerals are rare constituents of the bauxite. Ferric iron occurs in goethite, the principal mineral constituent in limonite, and in hematite, magnetite, and chlorite.

In all analyses of the drilling program in Arkansas, the total iron content is recorded as Fe_2O_3. The ferrous ion as FeO has been recorded in a column to the right of those listing the other chemical constituents. Thus the FeO content appears twice in each analysis record, as part of the ferric oxide content and also as ferrous oxide. The chemical analyses recorded in this report, therefore, constitute 100 percent if the FeO column is excluded.

Malamphy and others (1948, v. 1, p. 55) averaged a great many bauxite analyses to determine the normal content of hydrated iron oxides and iron carbonate. The samples analyzed were mostly cored specimens from low-lying bauxite bodies under considerable cover of overburden, described as type 2 deposits later in this report. Comparison of ferrous and ferric iron content in these samples indicated a fairly constant ratio of about 80 percent siderite to 20 percent limonite, if it were assumed that the iron was present almost exclusively as these two substances. In samples containing more than 15 percent total Fe expressed as Fe_2O_3 there usually is a higher proportion of ferric iron, or relatively more limonite than in the 80 to 20 ratio given above.

TITANIA

In Arkansas bauxite titania occurs commonly as anatase, less commonly as ilmenite, and rarely as rutile.

In granitic-textured bauxite a small amount may be present as sphene, but this mineral most commonly is completely altered to anatase in bauxite and in kaolin. An average TiO_2 content of 2.8 percent in bauxite was determined from a large number of analyses (Thoenen, Malamphy, and Dale, 1945, p. 11). Most of the samples studied were from low-level type 2 deposits. TiO_2 content as high as 8 percent was recorded locally in some of these deposits.

No high-level residual bauxite (type 1) deposits were delimited by the drilling program, but from examination of analyses in company files it appears that they have a lower average TiO_2 content than the type 2 deposits. An average TiO_2 content of 1.8 percent was calculated for 41 analyses of fairly high grade bauxite selected as examples and cited later in this report in the section describing the type 1 deposits.

In some of the bauxite gravel (type 3) deposits a local mechanical concentration of the heavy titanium-bearing minerals has occurred. One of the mine operators, P. H. Dulin (oral communication, 1944), reported several analyses of samples collected in the Reichardt shaft mine in Pulaski County in which TiO_2 content was as high as 19 percent. A sample from a bauxite gravel lens in the Stuckey pit in Saline County was reported to analyze 13 percent TiO_2.

INSOLUBLE MATTER

In the triacid method of chemical analysis a small residue is left which does not go into solution in the triacid digestion and which is not volatilized when ignited with hydrofluoric acid. The insoluble material represents minor impurities in the original sample. Analysis showed that it consists principally of aluminum silicates, with perhaps some iron and titanium minerals (Malamphy and others, 1948, v. 1, p. 52). Averages of many analyses indicated that 1.3 percent of the bauxite analyzed consists of acid-insoluble material (Thoenen, Malamphy, and Dale, 1945, p. 10).

COMBINED WATER AND CARBON DIOXIDE

During ignition at high temperature (Malamphy and others, 1948, v. 1, p. 51) several of the constituents of the bauxite are volatilized. These include the combined water of crystallization of hydrated alumina and iron oxides, and the carbon dioxide in any carbonate and carbonaceous matter present. A small and negligible amount of water is also present as adsorbed water in several minerals, such as goethite and anatase.

The loss of weight of the bauxite sample as the result of ignition is reported as the "loss on ignition." Despite the fact that it includes several constituents in varying amounts, determination of the loss on ignition, coupled with a lithologic examination of the bauxite sample, will permit a reasonably close estimate of its grade. If partial analyses of the rock are available the amount of alumina present can be calculated fairly closely.

For practical purposes the combined water in Arkansas bauxite can be attributed to three principal minerals: gibbsite ($Al_2O_3{\cdot}3H_2O$), kaolinite ($Al_2O_3{\cdot}2SiO_2{\cdot}2H_2O$), and goethite ($Fe_2O_3{\cdot}H_2O$). Similarly, carbon dioxide is attributed to siderite ($FeCO_3$). Calcium carbonate and carbonaceous matter, which also contain CO_2, are present only in very small quantities or are concentrated locally.

Thoenen, Malamphy, and Dale (1945, p. 5) found, on averaging many bauxite analyses mostly from low-level (type 2) bauxite deposits, that in bauxite containing less than 15 percent total Fe expressed as Fe_2O_3, the iron oxide content multiplied by 0.38 is about equivalent to the amount of loss on ignition of the iron minerals. This product represents the part of the ignition loss that can be attributed to the CO_2 content of siderite and the combined and adsorbed water in limonite (goethite), with a ratio of 4 parts siderite to 1 part limonite. This proportion of volatile material to ferric oxide content appears to be reasonably constant and can be applied to all low-iron bauxite in the region that is beneath the level of the present water table. In high-iron bauxite and in bauxite from above the water table in which there has been oxidation of the siderite, the proportion of limonite is higher and the percentage of volatile materials in the minerals accordingly lower.

The remainder of the ignition loss, once the part attributable to the iron minerals has been subtracted, represents the combined water present both in kaolinite and in gibbsite. If the silica content of the sample has been determined and it is assumed that all the silica present is in the form of kaolinite, the part of the ignition loss that can be assigned to combined water in kaolinite is equal to the silica content multiplied by 0.30. Each percent of water in kaolinite is combined theoretically with 3.32 percent of silica and 2.82 percent of alumina.

The rest of the ignition loss represents the combined water in gibbsite. Water in this mineral is combined with alumina in a ratio of 1:1.89.

Approximate calculations of alumina content and of the principal minerals in low-iron bauxite can be made in this manner if only silica, ferric oxide, and loss on ignition of the sample are known. The alumina content can be determined approximately by subtracting from 100 the sum of the percentages of the three known constituents plus a uniform allowance of 4.0 percent for titania and insoluble constituents. Any significant amount of the monohydrate of alumina in the sample will be evident by a low-silica content and ignition loss and therefore by a disproportionately large alumina content obtained by difference.

GRAPHIC REPRESENTATION OF BAUXITE COMPOSITION

The composition of samples from Arkansas deposits can be shown graphically by plotting alumina against silica on rectangular coordinates. The resulting graph is shown in figure 29 and, except for modification of the "impurities" designation at the point of origin, is the same as that prepared by J. R. Thoenen and R. P. Bryson (written communication, 1943) on the results of a study of the commercial grades of bauxite. This report, advocating a classification of bauxite based on the content of "available alumina" was not published, but a later one, on the application of the ternary diagram to Arkansas bauxite, by Thoenen, Malamphy, and Dale (1945) has been published.

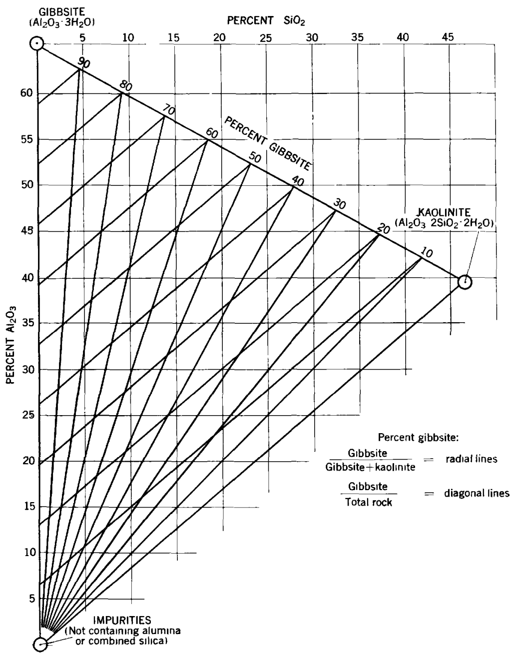


FIGURE 29.—Relationship between mineral and chemical composition of Arkansas bauxite.

In the graph, pure gibbsite and pure kaolinite appear as points, plotted on the rectangular coordinates according to their content of alumina and silica. Mixtures of the two substances are shown along on the line that connects these points. The percent of gibbsite is indicated by numerals along this line.

The point of origin represents the impurities that do not contain aluminum and combined silica. Where the triacid method of analysis has been used, quartz or other forms of free silica, if present, would appear as part of the insoluble residue and would thus be considered among the impurities, rather than as part of the combined silica. The point of origin has been connected by heavy lines to the gibbsite and kaolinite points on the graph, completing a triangle.

Radial lines connect the point of origin with the gibbsite-kaolinite line and divide the triangle into sections that represent the ratios of gibbsite to gibbsite plus kaolinite. Lines parallel to the one connecting the point of origin with the point of 100 percent kaolinite divide the triangle into sections that represent the ratio of gibbsite to total rock. The diagram may thus be used to determine these ratios in analyzed samples for which the amounts of alumina and combined silica are known. A point on the rectangular coordinates representing these two values will fall within the triangle except in rare cases where the monohydrate of alumina is present in excess. The percent of gibbsite as compared either to gibbsite plus kaolinite or to total rock may then be determined by referring to the radial or parallel lines cited above.

A modification of this diagram in which the triangle is divided by parallel diagonal lines that represent the percentage of loss on ignition due to kaolinite and gibbsite was used in the field laboratory to check the accuracy of analyses made by the triacid method (Thoenen, Malamphy, and Dale, 1945, p. 2–6, fig. 1; Malamphy and others, 1948, v. 1, p. 54–56, fig. 29).

"Available alumina" (alumina content less 1.1 times silica content) also can be plotted graphically in this manner. In figure 30 both gibbsite-kaolinite ratio and available alumina values are shown along the line that connects the points of pure gibbsite and pure kaolinite.

Diagonal lines representing 48, 40, 32, and 24 percent available alumina have been drawn in this diagram. These values constitute convenient limits for an informal classification of metallurgical ore for field use. Bauxite containing more than 32 percent available alumina was considered to be ore. Twenty-four percent available alumina was taken as a convenient boundary between bauxite and bauxitic clay. In rock containing few or moderate impurities this value coincides approximately with a 50–50 ratio of gibbsite to kaolinite, represented in the diagram by a radiating line from the point of origin to the middle of the upper edge of the triangle. The line of "zero available alumina," above which available alumina has a plus value, was taken as the boundary between bauxitic and kaolinitic clay. This corresponds to a ratio of about 15.5 percent gibbsite to 84.5 percent kaolinite. The three rock types are represented by different patterns in the figure. A zone of overlap between the patterns indicates that the boundaries are approximate and somewhat flexible. A boundary between low- and high-

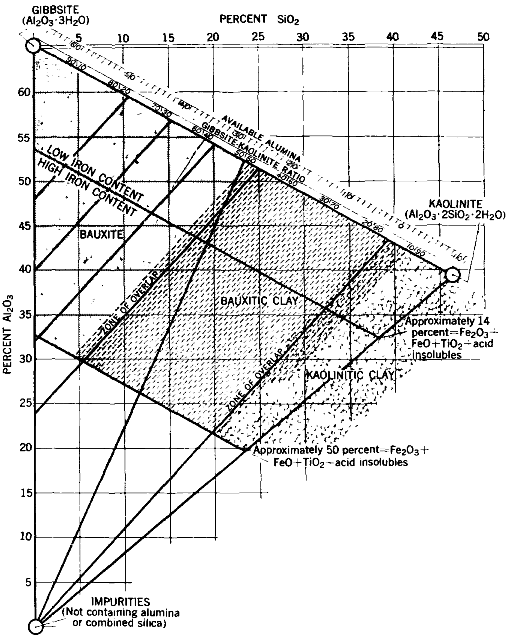


FIGURE 30.—Chemical-mineralogical classification of bauxite and high-alumina clay in Arkansas.

iron rock has been drawn to coincide approximately with 17.4 percent impurities as these normally would average about 10 percent total Fe represented as Fe_2O_3, 2.8 percent TiO_2, 1.3 percent acid insolubles and 3.3 percent ignition loss attributable to the iron minerals in the ratio of 4 to 1 siderite to limonite. Any increase in impurities more than this figure would be most likely in iron content. Where the impurities constitute more than 50 percent other names would be given to the rock.

MINOR ELEMENTS IN BAUXITE

Fourteen samples of bauxite and bauxitic clay were selected from the four types of deposits into which the bauxite is subdivided in this report. Determinations of the minor elements in these samples by spectrographic methods were made by K. J. Murata of the Geological Survey. The averages of the analyses compared with those from three samples of nepheline syenite are shown in table 9. Averages are given for all 14 samples of bauxitic rock and for those from each type of deposit.

Altogether 21 minor elements were noted in the bauxitic rocks, 18 of which are also in the parent igneous rock. Boron apparently is limited to deposits within the Berger formation (types 2 and 3). Source of the boron, which commonly is found in sea water, may have been connate water in the marine sediments of the Midway group. Cobalt and nickel were found only in alluvial (type 3) deposits. Not listed in the table but present either in the nepheline syenite or the bauxite, or both, are aluminum, ferric and ferrous iron, carbon, oxygen, sulfur, and chlorine.

TABLE 9.—*Averages of spectrographic determination of minor elements in nepheline syenite and bauxite and bauxitic clay samples from Arkansas*

[Analyst, K. J. Murata. Figures in table indicate percent by weight]

Element	1	2	3	4	5	6
	Nepheline syenite (3 samples)	Bauxite, all types (14 samples)	Bauxite deposits			
			Type 1 (3 samples)	Type 2 (7 samples)	Type 3 (3 samples)	Type 4 (1 sample)
Ti	[1] 0.51	1.06	0.73	1.1	1.0	1.8
Zr	.050	.13	.12	.12	.13	.2
Mn	.097	.12	.083	.17	.040	.05
Ca	[1] 1.01	.12	.033	.11	.20	.2
Nb	.013	.050	.050	.050	.040	.08
Mg	[1] .38	.037	.0053	.050	.037	.09
Sr	.027	.019	.0035	.010	.053	.03
Ba	.071	.017	.0013	.0030	.060	.04
Y	.013	.015	.0057	.020	.012	.02
Cr	.0001	.011	.0043	.0089	.018	.02
La	.030	.010	.012	.0096	.0067	.02
V	.0047	.0092	.0060	.0077	.016	.01
Ga	.0020	.0086	.0063	.0060	.0093	.008
B	----------	.0031	----------	.0029	.0070	.002
Mo	.00057	.0018	.0010	.0016	.0030	.002
Cu	.00017	.0014	.0013	.0019	.00067	.001
Sc	.00033	.00069	.00053	.00074	.00077	.0006
Pb	.00067	.00067	.00033	.00067	.00090	.001
Ni	----------	.00064	----------	----------	.0030	----------
Be	.00017	.00022	----------	.000057	.00090	----------
Co	----------	.00014	----------	----------	.00067	----------

[1] Calculated from chemical analyses.

Looked for but not found:
In nepheline syenites. As, Sb, Bi, In, Tl, Sn, Ag, Zn, Cd.
In bauxites and bauxitic clays. As, Sb, Bi, In, Tl, Sn, Ag, Ge, Ta, P.

Phosphorus, shown by chemical analysis to average 0.17 percent P_2O_5 in the nepheline syenite samples, was not detected spectrographically in the bauxitic rocks. Small amounts are probably present in the bauxite but cannot be detected spectrographically as the limit of sensitivity for this element is about 0.5 percent P_2O_5. Only one chemical analysis is available to show the amount of phosphorus pentoxide in a weathered rock in this region. The sample is a kaolinitic clay immediately overlying a bauxite deposit. The clay probably was derived largely from the resilication of bauxite. It contains 0.08 percent P_2O_5. The complete analysis of this rock (specimen AB–10148–1) is given on page 129.

The relative concentration of the 18 elements in table 9 common to the nepheline syenite and bauxitic rocks is shown in figure 31 for all bauxitic samples and for each type of deposit. The relative concentration for each element is expressed as a ratio to 1, obtained by dividing its content in the bauxitic sample by its content in the nepheline syenite. The elements are arranged in this table according to the values of these quotients, in descending order. Those with values

	Elements	RATIOS OF CONCENTRATION				
		In bauxite, all types	In bauxite deposits			
			Type 1	Type 2	Type 3	Type 4
		B/A	C/A	D/A	E/A	F/A
> Al	Cr	100	40	90	180	200
	Cu	8	8	11	4	6
	Ga	4.3	3.2	3.0	4.7	4
	Nb	3.8	3.8	3.8	3.1	6
			$\boxed{3.0}$			
	Mo	3.2	1.8	2.8	5.3	4
	$\boxed{\text{Al}}$	$\boxed{2.7}$		$\boxed{2.4}$	$\boxed{3.0?}$	
Concentrated < Al	Zr	2.6	2.4	2.4	2.6	4
	Ti	2.1	1.4	2.1	2.0	3
						$\boxed{2.9}$
	Sc	2.1	1.6	2.2	2.3	2
	V	2.0	1.3	1.6	3.4	4
	Be	1.3	—	.3	5.3	—
	Mn	1.2	.9	1.8	.4	.5
	Y	1.2	.4	1.5	.9	1.5
	Pb	1.0	.5	1.0	1.3	1.5
Depleted	Sr	.7	.1	.4	2.0	1.0
	La	.3	.4	.3	.2	.7
	Ba	.2	.02	.04	.8	.6
	Ca	.1	.03	.1	.2	.2
	Mg	.1	.01	.1	.1	.2

FIGURE 31.—Relative concentration or depletion of minor elements in bauxite and bauxitic clay as compared to nepheline syenite.

greater than 1 have been concentrated relative to the total volume of rock by the weathering processes; those with values less than 1 have been depleted. Similar average values for aluminum, computed from chemical analyses of the specimens where available, are shown on the table to indicate those elements in greater or less concentration relative to aluminum.

A statement regarding the concentration of minor elements in bauxite appeared in a report by Goldschmidt (1937, p. 667) and is as follows:

> Besides beryllium and gallium which follow aluminum, the elements titanium, zirconium, tin, and quinquevalent niobium are found to be concentrated in bauxite, together with aluminum hydroxide, and the factor of concentration is about the same as that of alumina, being as a rule about 4-5-fold as compared with their mother rock. (I [Goldschmidt] may mention that the alkali aluminate solutions of the Baeyer process for making alumina are a potential source for very large quantities of gallium.) In some cases vanadium also is somewhat concentrated in the bauxites. The tervalent elements with somewhat lower ionic potential, such as the lanthanides, yttrium, and even scandium, are as a rule not concentrated in typical bauxites, because their lower ionic potential permits their removal in aqueous solution.

Goldschmidt was referring to European bauxite deposits, judging from his remark about the fourfold to fivefold concentration of alumina, which would be possible only in bauxite containing alumina largely in the monohydrate form. Nevertheless, the present

study of Arkansas bauxite in which alumina is concentrated 2½ to 3 times provides an excellent verification of the statement quoted above.

The field of elements can be divided into three principal groups, based on the relationship between their ionic radii and their valences or ionic charges. This relationship is commonly expressed as ionic potential, a value which is the quotient of the valence divided by the ionic radius. Although ionic potential has no physical or chemical entity in nature, as a concept it is useful in explaining certain chemical reactions that are otherwise puzzling.

Many of the elements are plotted in the graph (fig. 32) to show the relation of their ionic radius to ionic charge. This value is modified from a similar one by Goldschmidt (1937, fig. 2), the elements are replotted according to the values for ionic radii given in the seventh edition of Dana's System of Mineralogy (Palache, Berman, and Frondel, 1944, p. 4, 5).

Diagonal lines radiating from the point of origin are lines of constant value for ionic potential, *Z/r*. The first of the solid diagonal lines represents an ionic potential of 3. Elements of low-ionic potential are left of this line; many form basic oxides. These elements remain in true ionic solution in the process of weathering and transportation, thus they are carried off and depleted. Substances between the two solid diagonal lines, representing ionic potentials of 3 and 12, are amphoteric elements. They are precipitated by hydrolysis, their ions being associated with hydroxyl radicals from aqueous solutions (Goldschmidt, 1937, p. 665). A broken diagonal line has been drawn in the figure to indicate an ionic potential of 9.5 because this value probably represents more closely the upper limit of the elements concentrated in bauxite. The elements with higher ionic potential form complex anions containing oxygen and are usually soluble and remain in true ionic solution.

Agreement is not complete, however, between the theoretical behavior of the elements as based on their ionic potential and their concentration as actually determined. A comparison of the graph (fig. 32) with figure 31 shows that the discrepancies concern principally beryllium, copper, and chromium.

Beryllium, which theoretically should be concentrated in bauxite as is aluminum, actually has an erratic dis-

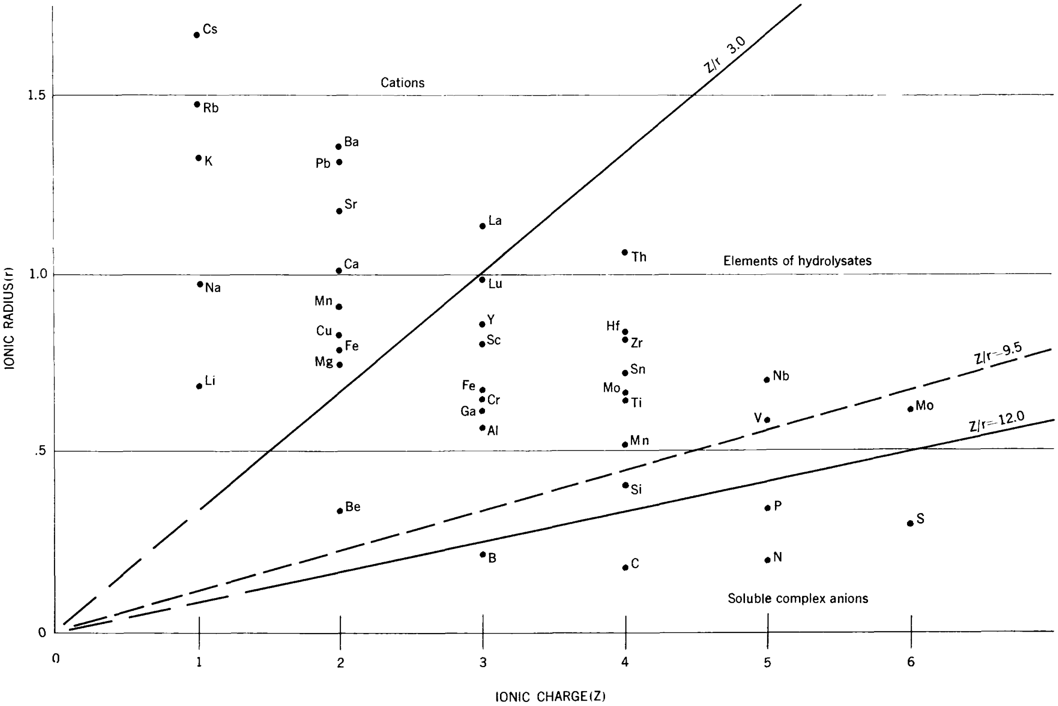


FIGURE 32. —Grouping of certain elements according to their ionic radii and charges.

tribution in the Arkansas rocks. It was detected in only four specimens—two of kaolinitic to bauxitic "hardcap" and two of bauxite gravel deposits. Its average concentration of 1.3 times in the 14 bauxitic specimens is due mostly to an unusually high content recorded in one sample of bauxite gravel. Beryllium is absent or less concentrated in most of the bauxite than in the nepheline syenite. Ionic potential, therefore, does not explain the behavior of this element. Nor could a satisfactory explanation be found for the high concentration of chromium recorded in the bauxitic samples. The spectrograph is sensitive to a lower limit of about 0.0001 percent for chromium and for beryllium. It is possible, however, that the nepheline syenite samples were not typical for the region in chromium content.

Copper is present in the nepheline syenite samples in very small amounts and theoretically should have been depleted during weathering. It actually is 4 to 11 times more concentrated in the bauxitic rocks.

Spectrographic determinations were made of two samples each of siderite and pyrite separated from bauxite specimens, to determine if copper, chromium, nickel, and cobalt were introduced with ferrous iron and sulfide ions. The results of this study are shown in the table below. Among the elements sought, however, only copper was present in sufficient quantity to be positively identified spectrographically and in one of the pyrite samples. It is not known what caused the unusually high concentration of molybdenum in the pyrite sample, or the amount of vanadium associated with one of the siderite samples, the content of which is greater than in bauxite from the same hand specimen (see table below).

Goldschmidt called attention to the recovery of large quantities of gallium from the alkali aluminate solutions of the Bayer process. In 1949 the Aluminum Corp. of America announced the perfection of a process to recover gallium from bauxite as a byproduct in the manufacture of alumina.

One of the most interesting results of the present spectrographic study is the discovery of a significant concentration of niobium in the bauxite. Rankama (1947) pointed out that the concentration of this element is greater in nepheline syenite deposits than in other igneous rocks and also that in hydrolysates the highest niobium content is found in bauxite and laterite deposits. In Arkansas bauxite, derived from nepheline syenite, the average niobium content is 0.05 percent and probably is in combination with several titanium- and zirconium-bearing minerals that are found in the heavy-mineral fraction of the bauxite, such as anatase, ilmenite, rutile, and zircon (Rankama, 1947, p. 13). It is conceivable that a process might eventually be devised for the extraction of niobium as a byproduct of the manufacture of alumina from bauxite.

Spectrographic determination of minor elements in samples of pyrite and siderite from bauxite deposits

[Analyst, K. J. Murata. Values shown in the table are in fractions of a percent]

Element	*1* *Pyrite*	*2* *Pyrite*	*3* *Siderite*	*4* *Siderite*
Cu	0.0002	------	------	------
Mo	.04	------	------	------
V	------	------	0.01	------

Looked for but not found: Ag, As, Sb, Sn, Bi, Pb, Tl, Ge, In, W, Zn, Cd, Co, Ni, Cr.

1. Pyrite from a cavity in bauxite (specimen AB-105-1), from crosscut 5 in the Neilson underground mine of Alcoa Mining Co., SW¼NW¼ sec. 26, T. 2 S., R. 14 W., Saline County. Collector, J. I. Tracey, Jr.
2. Pyrite mostly from within pisolites in low-grade bauxite (specimen AB 14026A-1) from USBM drill hole 14-026A, depth 330.1 to 330.5 feet, East Bauxite deposit, SE¼SE¼ sec. 25, T. 2 S., R. 14 W., Saline County.
3. Siderite in rough rhombic crystals lining a fissure in tan pisolitic bauxite (specimen AB-16048-1), from USBM drill hole 16-048, depth 455.2 feet, East Bauxite deposit, International Paper Co. property, SE¼NW¼ sec. 31, T. 2 S., R. 13 W., Saline County.
4. Botryoidal crust of siderite lining cavity in pisolitic bauxite (specimen AF-53-1), from the stockpile of the Stuckey mine, NW¼SE¼ sec. 9, T. 2 S., R. 14 W., Saline County. Collector, M. I. Goldman.

DISTRIBUTION OF BAUXITE DEPOSITS

Bauxite in Arkansas occurs in irregular discontinuous blanketlike deposits scattered over the uneven weathered surface of nepheline syenite hills and on the surrounding gently sloping weathered surface of the Wills Point formation. The general distribution of the outcrops and buried deposits is shown in the subsurface map (pl. 2) and also in the isometric sketches of the Pulaski and Saline mining districts (pls. 7 and 8).

The bauxite bodies range in dimensions and in tonnage, from small lenses, covering a fraction of an acre and containing only a few tons, to large lenticular blanket deposits, several hundred acres in area and containing several million tons. The thickness of the bauxite ranges from a fraction of an inch to 60 feet. In most of the large deposits the thickness reaches a maximum of 35 feet and averages about 14 feet. Some nearly flat-lying deposits on the Wills Point formation locally attain 20 feet in thickness and average about 10 feet.

The distribution, size, and quality of the deposits are determined chiefly by three geologic controls: the nature of the source rocks; the local and regional physiography of the post-Midway erosion surface; and erosion and deposition during Wilcox time. The effect of these factors on the bauxite is discussed below.

FACTORS CONTROLLING THE OCCURRENCE OF BAUXITE

SOURCE ROCKS

Alkalic igneous rocks.—Nepheline syenite or "gray granite" is the principal source rock of the bauxite deposits because of its high alumina content, its susceptibility to deep weathering that permits free percolation and thorough leaching by ground waters, and its

topographic relief in hills that stood high enough above the flatter surface of the Wills Point to ensure free ground-water movement.

Much less bauxite is associated with the pulaskite, or "blue granite" of Pulaski County, which contains less nepheline and more closely interlocked feldspar, and which weathers more slowly than the nepheline syenite. These rocks are the principal source of the bauxite deposits but other rocks have contributed minor amounts of bauxite.

The igneous dike rocks, having been subjected to the same weathering processes as the more widespread types of igneous rock, no doubt were the source of some of the bauxite. For example the large size of relict feldspar crystals in some specimens of granitic-textured bauxite indicates a derivation from pegmatitic varieties of the nepheline syenite. Two specimens of this type are shown in plate 10*B*. Bauxite with a texture resembling that of fine-grained trachyte also has been recognized in thin section.

Paleozoic rocks.—A few deposits, particularly in Pulaski County, overlie in part roof pendants or large inclusions of rock of Paleozoic age in the nepheline syenite. They are underlain in places by brittle variegated clay that grades downward into black or green shale of probable Paleozoic age, or into fine-grained igneous border rock adjacent to such shale. Bauxite overlying the roof pendants probably was derived mostly from coarse-grained igneous rock farther upslope rather than from the metamorphic rocks. Some fragments of shaly rock, however, have been altered to gibbsite. Pebbles of laminated structure altered to gibbsite were found at the west end of the Section 15 mine in Saline County, in the north face, about 600 feet northeast of a small pendant of metamorphic rock described as the "Cedar Park Paleozoic mass" by Williams (1891, p. 127, map 3). They occur in a conglomerate of well-rounded bauxite pebbles in a red to gray gritty clay matrix. Some of the pebbles have well-developed shaly laminations and are fissile. A gibbsite pebble was analyzed at the field laboratory of the U. S. Bureau of Mines at Little Rock; the results are given in the table below. The gibbsite content is slightly more than 90 percent.

Analysis of gibbsite pebble by U. S. Bureau of Mines, Little Rock, Ark.

	Percent
Al_2O_3	61. 8
SiO_2	. 8
Fe as Fe_2O_3	1. 8
TiO_2	1. 5
Ignition loss	33. 4
Insoluble	. 7
FeO	. 4

The shale in many of the pendants is highly altered and much of it has been replaced by tiny feldspar grains along the laminae, discussed in the section of this report dealing with the igneous rocks (see page 67). High-grade bauxite that preserves shaly structures probably was derived from these altered feldspathic parts of the pendant rocks of Paleozoic age. Bauxite may also have formed on the uplands of Paleozoic age northwest of the bauxite region, but if so erosion has since removed all traces of it.

Wills Point formation.—The gummy black silty clay that forms most of the Wills Point formation was not a favorable source rock for bauxite. Commercial deposits of bauxite are concentrated around nepheline syenite hills and are not widely scattered over the Wills Point surface. In Pulaski County they do not extend more than three-eighths of a mile out on the Wills Point surface and in Saline County not more than 1 mile. The bauxite is underlain by kaolinitic clay at least parts of which contain minerals derived from the nepheline syenite. The clay of the Wills Point formation is relatively impermeable and generally is found on gentle slopes. Such conditions would hardly favor the free downward movement of ground water, generally believed necessary to form significant amounts of bauxite from the clay.

Weathered zones, 10–20 feet thick, are common in the upper part of the clay that was exposed in the interval between Wills Point and Berger deposition. At the top of this weathered zone where part of the silica has been removed, chemical analyses approximate that of kaolin. A gradational increase in silica, occurs downward until the normal high-silica content is reached in the unweathered black clay, as discussed in the stratigraphic section of the report, page 31.

Near Mabelvale, small bauxite bodies, exposed or buried near the Midway and Wilcox contact, lie isolated from any source of nepheline syenite detritus. These deposits are generally high in silica; only one contains a significant amount of commercial-grade ore. Many drill holes were sunk by the Federal drilling program downslope from the Midway and Wilcox contact in the Mabelvale area. Cores were taken in several holes through bauxite into fresh blue-black clay of the Wills Point formation. The cores all showed a gradation from pisolitic bauxite through bauxitic clay to kaolinitic clay. The kaolinitic clay merges imperceptibly with material recognizable as weathered clay of the Wills Point formation in place, and grades downward within several feet to fresh black silty clay. No unconformity could be recognized, and it was concluded that the bauxite weathered directly from the Wills Point formation.

Unpublished field notes of Bramlette indicate that one of these deposits, in the NW¼SW¼ sec. 12, T. 1 S., R. 13 W., Pulaski County, contains the following heavy accessory minerals in order of decreasing abundance: zircon, tourmaline, rutile, magnetite, kyanite, and anatase. This assemblage indicates derivation of the bauxite at this locality from the Tertiary deposits rather than from the alkalic syenite rocks.

The Mabelvale bauxite possibly was derived from the weathering of detritus transported from the uplands of Paleozoic age, but the lack of a fragmental texture in any of the bauxite or underclay opposes such an origin. Neither does it appear likely that debris from any of the known nepheline syenite hills could have reached this area. Most of the bauxite bodies are located on topographically elevated parts of the post-Midway surface.

SUBSURFACE TOPOGRAPHY

The bauxite deposits shown on the subsurface map of the bauxite region (pl. 2) are grouped on and around three major nepheline syenite masses called "highs", or domes. These are eroded stocks or bosses on the Little Rock igneous complex that protrude above the surface of the deposits of the Midway group and are mostly covered by deposits of the Wilcox group. The easternmost eminence is the large bifurcate nepheline syenite mass called the Pulaski high that crops out as Granite Mountain in Pulaski County. About 10 miles to the southwest is the buried Bryant high that crops out in several places on the slopes of Alexander Mountain, Saline County. About 2 miles farther southwest is the large Saline dome with which the majority of the commercial deposits are associated.

In between the Pulaski and Saline masses are the small Ledbetter and Sardis highs. The latter is a northeast extension of the Saline dome. These do not crop out on the present surface but are buried beneath the Wilcox. They are almost barren of bauxite except for one or two minor accumulations on the Sardis high, which have no commercial importance. Other elevated parts of the buried Little Rock batholith, farther to the southeast and described briefly under igneous rocks, do not protrude above the Midway surface and hence would not have been available to the post-Midway weathering processes that formed bauxite.

The drainage pattern that was cut on the nepheline syenite slopes during Kincaid and Wills Point time extended onto the Midway surface after the sea withdrew and aided in localizing the bauxite deposits. Bauxite formed along ridges and slopes in the minor valleys and locally in the bottoms of minor drainage channels. Bauxite and other material was stripped from the major drainage areas. The relation of the bauxite deposits to subsurface topography is shown in the subsurface map (pl. 2) and also in the isometric diagrams of the two producing districts (pls. 7 and 8).

Major subsurface drainageways lie between the five nepheline syenite hills and cut deeply into the Midway sediments. Bauxite was not formed in these drainage areas where erosion of the Tertiary sediments and earlier rocks was taking place.

EROSION AND REDEPOSITION

Bauxite and clay were removed from the place at which they were formed and were carried basinward. The means of transportation probably ranged from landsliding and soil creep to erosion and redeposition by stream action. The detritus that moved downhill under different forms of mass wasting, such as soil creep, landsliding, and mudflow, was deposited in a fringe of coalescing fans and colluvium along the bases of hills, or where the grade decreased sufficiently to impede or stop further movement of the material downslope. This fringe is referred to frequently in this report as "the colluvial apron." Many residual bauxite deposits were formed in this apron and these have about the same relationship to subsurface topographic features that have been noted in the deposits on weathered nepheline syenite upslope.

Most of the bauxite that was eroded from the nepheline syenite hills was dissipated and lost. Locally, however, bauxite gravel was deposited in channels along the margins of the nepheline syenite hills. The hard bauxite pebbles making up the gravel probably are not far from their source, perhaps from a few tens of feet to about half a mile. The bauxite gravel deposits apparently are associated exclusively with the Berger sediments into which they tongue.

Bauxite boulder deposits are associated with the basal part of the Saline formation and mark a period of intensified erosion that ushered in early Saline time.

TYPES OF BAUXITE DEPOSITS

The bauxite in Arkansas formed almost entirely from the nepheline syenite rocks in place or from detritus derived from these rocks. As discussed in the foregoing sections the deposits have a definite relation to the topography of the post-Midway erosion surface, and to the Wilcox sediments that cover this surface. Field studies of the bauxite bodies in Pulaski and Saline Counties indicate that they can be classified in four

types listed below, or a combination of two or more of them.

Type 1. Residual deposits on nepheline syenite.
2. Deposits in the bauxite-kaolin facies of the Berger formation.
3. Bedded deposits in the Berger formation.
4. Conglomeratic deposits at or near the base of the Saline formation.

The first two types are almost equally important economically; the residual deposits, however, are limited to the Saline nepheline syenite dome. The last two types have provided ore in many mines but are much less important economically than the first two. A diagrammatic sketch showing the general field relations of all four types appears in figure 33. Each type has its own peculiar lithologic characteristics.

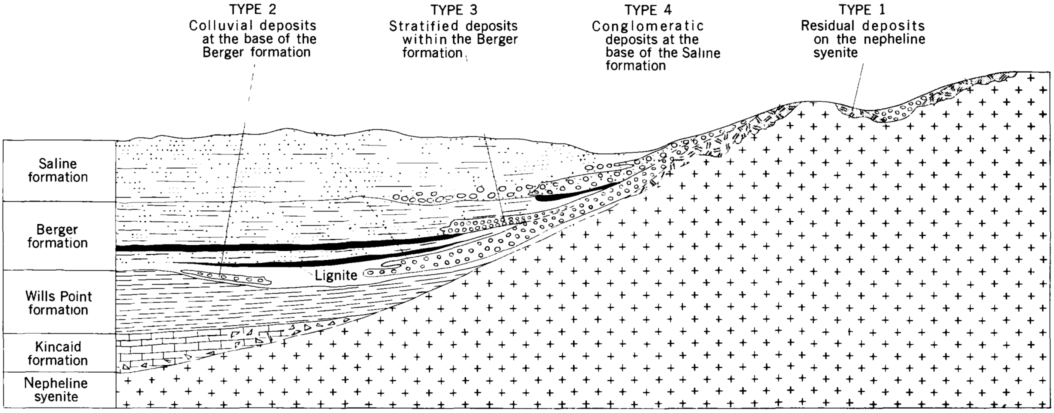


FIGURE 33.—Diagrammatic section of the principal types of deposits in the Arkansas bauxite region.

TYPE 1. RESIDUAL DEPOSITS ON NEPHELINE SYENITE

DISTRIBUTION

Residual deposits of commercial size are restricted to the higher nepheline syenite slopes of the Saline dome. They occur in secs. 9 to 11, 13 to 16, and 21 to 28, inclusive, T. 2 S., R. 14 W., and in sec. 18, T. 2 S., R. 13 W. Small remnants of this type have also been found in two places on the Bryant high and in four places on the Pulaski high. Those in Saline County lie upslope from the edge of the Berger formation except in several places where they extend downhill a short distance beneath it. They are limited upslope by their outcrops, truncated by relatively recent erosion.

UNDERLYING ROCKS

Between the fresh nepheline syenite and the overlying bauxite deposits is a layer of white to greenish-gray kaolinitic clay. The lower part of the clay preserves the texture of the nepheline syenite but the upper part, adjacent to the bauxite is textureless, massive, or fragmental. This interval is described in more detail below.

RANGE IN ALTITUDE

In Saline County the residual deposits are found at an altitude ranging from about 100 feet in the Bailey ore body, to 520 feet near the Neilson mine (pl. 2). This difference of altitude of about 420 feet is along a line that coincides with the regional strike of the Tertiary sediments. No special significance is attached to this fact, but it stresses the difference from type 2 deposits, the altitude of which is partly controlled by the regional dip of the sediments.

In Pulaski County several small remnants of type 1 deposits occur from about the 100-foot contour in the Rummel mine, to below the 350-foot contour in an outcrop near the northwest corner of sec. 36, T. 1 N., R. 12 W.

SHAPE AND RELATION TO THE POST-MIDWAY EROSION SURFACE

Residual deposits blanket the flanks of the large valleys cut in the nepheline syenite. Their thickest and highest grade parts are associated with ridge spurs that jut into these valleys. Generally the bauxite is thick on the steep flanks of the spurs and thin to absent on the crests. In many places, however, thick, gently sloping bauxite overlies low saddles and broad knolls; and, more rarely, the thickest bauxite is at the crest of steep slopes. Downslope the total thickness of the bauxite varies greatly but minable ore is generally thinner. The grade of the bauxite drops notably in the tributary drainage between the spurs. The bottoms of the major drainage channels are filled with a thick accumulation of bauxite material, normally low

in grade but containing scattered bodies of high-grade bauxite. The distribution of the ore along valley flanks is well shown in the subsurface map (pl. 2), and in the perspective diagram (pl. 8).

As the type 1 deposits have formed largely in place from the weathering of the nepheline syenite, the upper surface of the bauxite has almost the original configuration of the nepheline syenite before it was weathered. This is particularly true of the surfaces on the upslope parts of the residual deposits. In these areas the top of the bauxite coincides, generally, with the post-Midway erosion surface. Downslope toward the centers of valleys, there has been modification of the original surface by mass wasting, including soil creep, landslide, and possibly mudflow; and to a minor degree by erosion and redeposition. In some places the irregular surface of undisturbed residual rock lies in the middle or just below the bauxite section, or within the kaolinitic clay beneath.

The stripped surface of a type 1 deposit reveals, with the exceptions and modifications noted above, the original topographic configuration of the nepheline syenite. This surface has been well exposed in many mines of the Alcoa Mining Co. near Bauxite, in the African Camp, Bertha, Bertha Extension, Maud, Pruden, Section 14, Section 15, Section 16, and Section 26 mines. Broad, gently rounded slopes with well-defined valleys and minor tributaries are the rule. Slopes in excess of 20°, however, are present in the uphill parts of the deposit in the Maud mines. Locally they exceed 40° in the Section 26 mines, where the bauxite dips so steeply beneath the overburden that underground mining by inclined shaft was necessary. A section drawn through six drill holes at the south end of the Section 26 mine, just north of the boundary with the Old Globe mine is shown in natural scale (fig. 34). The average slope of the bauxite surface from crest to toe, a horizontal distance of 200 feet, is 30°; the maximum slope, between drill holes T–954 and R–204, is 42°. Stripped bauxite surfaces are shown in photographs in figure 35 *A*, *B*. On the subsurface map (pl. 2) contours on the post-Midway erosion surface have been drawn on top of the upslope parts of type 1 deposits.

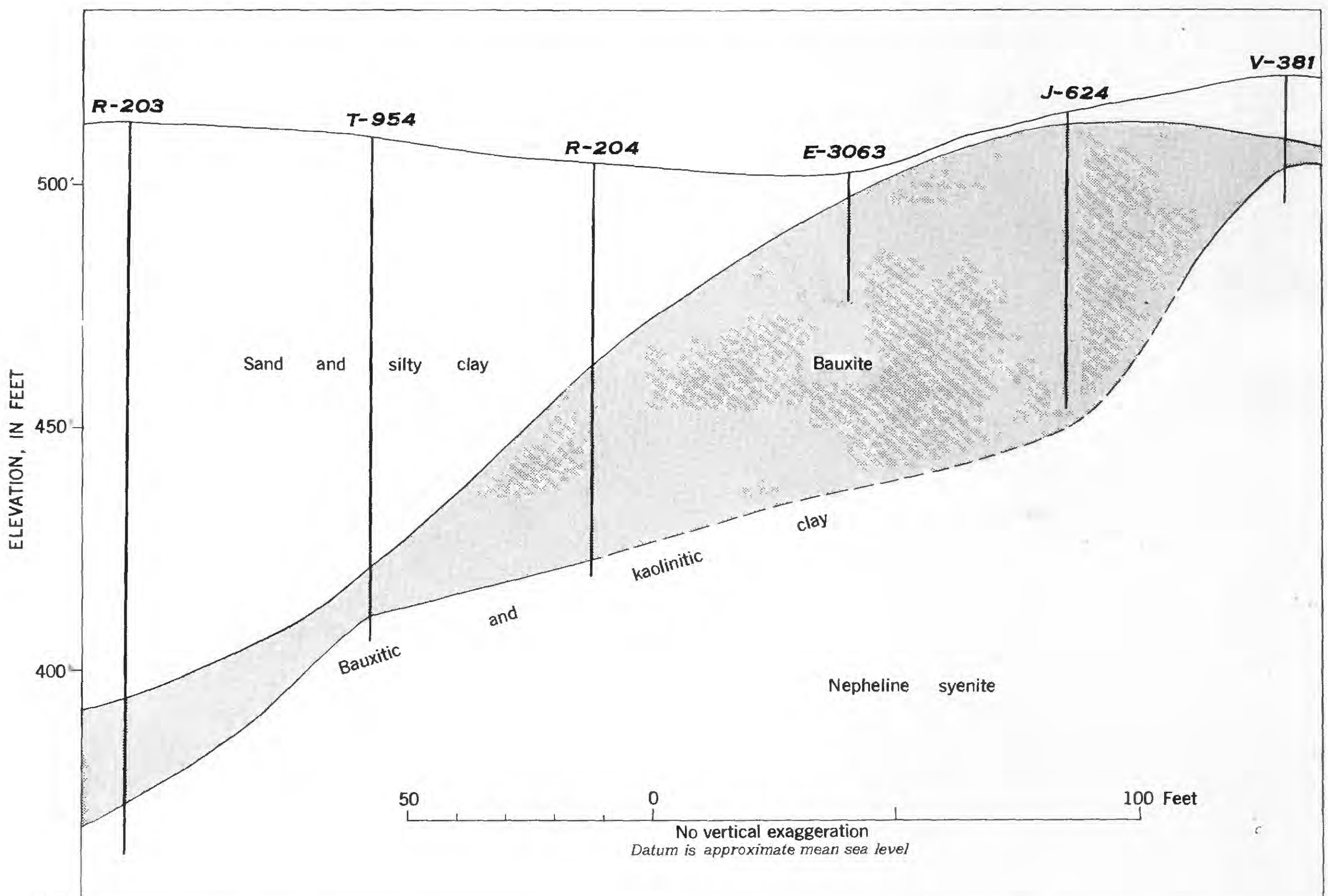


FIGURE 34.—Cross section showing the steep slope of the bauxite su·face in a part of the Section 26 mine.

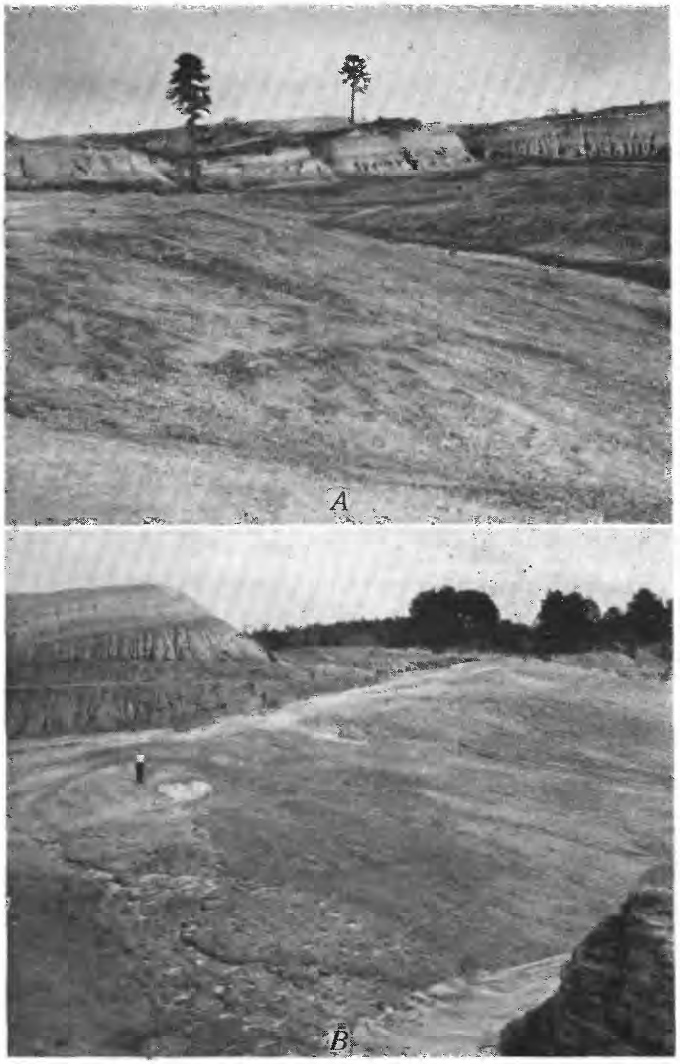


FIGURE 35.—Stripped bauxite surfaces of type 1 deposits in Saline County mines. *A*, Ancient valley in the bauxite surface. View looking toward the southeast corner of the African Camp mine. *B*, Mass of kaolinized nepheline syenite (light area next to the man) reaches the upper surface of the bauxite. Looking eastward across the eastern part of the Section 16 mine.

THICKNESS

Bauxite varies in thickness, because of the irregular lower surface of the residual type of deposit. Mead (1915, p. 37) has estimated an average thickness of 11.5 feet of merchantable ore. Present standards, based on utilizing ore of considerably lower grade than was mined in Mead's time, would raise this figure to about 14 feet, but not much more because the grade of the bauxite decreases abruptly at the top and bottom of the deposit. Hayes (1901, p. 450) records the prevailing thickness of the bauxite at 10 to 15 feet, with a maximum of 30 feet or more in sec. 16. The greatest known thickness of a type 1 deposit was exposed in 1927 at the boundary between the Old Globe mine and the adjacent Alcoa property. A photograph of this 60-foot face of bauxite was published in a report by Cash and Von Bernewitz (1929, fig. 113). The cross section shown in figure 34 was drawn parallel to and near the boundary mentioned above, using Alcoa Mining Co. drilling data. Drill hole J–624 contained 58 feet of ore that averaged more than 50 percent of available alumina, and did not reach the base of the ore. It is noteworthy that this, the thickest known section of bauxite, lies at the crest of the steepest known bauxite slope. This indicates that the usual thinness of the bauxite over ridge crests is caused by erosion after its formation.

CROSS SECTION OF THE DEPOSITS

For greater facility in describing the type 1 deposits (fig. 36), two terms are proposed by Lacroix (1913, p. 272) in discussing similar residual deposits that overlie nepheline syenite in the Los Islands in French Guinea. Lacroix divided the bauxite into two nearly horizontal zones, a lower zone of leaching *(zone de départ)* and an upper zone of concretion *(zone de concrétion)*. The lower zone is characterized by the persistence of the structure of the original nepheline syenite, from which constituents such as alkalies, lime, magnesia, and silica have been leached. The upper zone is characterized by the disappearance of the original texture and rearrangement of the remaining hydrated oxide minerals into concretionary structures, accompanied by an increase in iron content. A comparison of the textures of the nepheline syenite and the granitic bauxite, and the development of concretionary structure is shown in the sequence of plates 9 to 14.

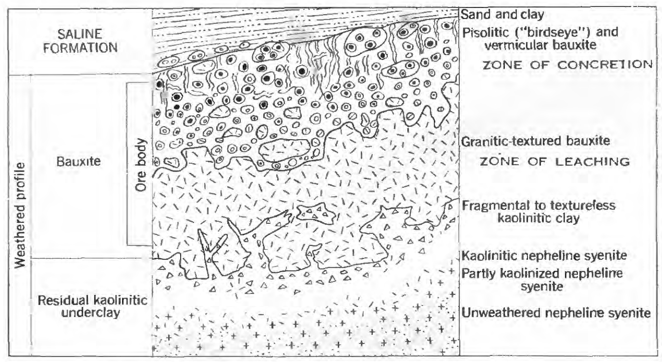


FIGURE 36.—Diagrammatic section of a type 1 deposit.

In Arkansas, granitic-textured bauxite, in an irregular layer at the base of the deposits, may be referred to the zone of leaching; the overlying pisolitic bauxite ("birdseye ore") and rock with vermicular structures belong in the zone of concretion. High iron is not necessarily associated with the zone of concretion, as much of the iron is secondary to the bauxite. The Arkansas deposits differ from those of the Los Islands in having a

thick kaolinitic interval, here called the "residual kaolinitic underclay," between the bauxite and the unweathered nepheline syenite. In the Los Islands deposits the kaolinitic interval separating fresh nepheline syenite from bauxite is generally not more than 1 millimeter thick.

Among the type 1 deposits studied in some detail, the one exposed in the Pruden mine in the SE¼NW¼ sec. 16, T. 2 S., R. 14 W., probably has received the most attention. Some of the relations between the bauxite and kaolin in this mine have been pointed out by Goldman and Tracey (1946). The map and sections of the typical residual deposit exposed in part of this mine are shown in figures 37 and 38. The map and sections were prepared from a topographic and geologic field map of the area, surveyed in December 1944, before much of the ore had been removed. The map has been altered slightly to eliminate mine cuts and piles of overburden.

Many lithologic specimens from this mine have been studied petrographically. Chemical analyses of 16 specimens are given in table 10, arranged in the order that they occur stratigraphically, from the top downward, and also according to lithologic type. The location at which they were collected are indicated in figure 37, and the specimens are further discussed in the descriptions that follow.

The minor elements in three hand specimens from Saline County mines have been determined by spectrographic methods and are listed in table 11. The significance of these minor elements has been discussed earlier in the section on chemical constituents of Arkansas bauxite.

RESIDUAL KAOLINITIC UNDERCLAY

The clay beneath type 1 deposits is kaolinitic and grades downward through partly kaolinized nepheline syenite to unaltered rock. The thickness of this kaolinitic zone between the base of the bauxite and the top of the unaltered igneous rock ranges from 15 to 60 feet and averages about 30 feet. Adjacent to the unaltered igneous rock is a gradational partly decomposed layer, 3 to 10 feet thick, in which the granitic texture is well preserved and which disintegrates readily into sand

TABLE 10.—*Chemical analyses of bauxite and kaolin specimens from the Pruden mine, Saline County, Ark.*

[Analyses by U. S. Bureau of Mines field laboratory, Little Rock, Ark.]

	1	2	3	4	5	6	7a	7b	8
Zone of concretion									
Al_2O_3	45.6	61.2	56.7	61.2	60.7	60.9	59.4	61.7	57.6
SiO_2	24.8	3.7	6.9	1.8	3.0	6.9	3.8	1.1	5.8
Fe as Fe_2O_3	1.8	1.4	2.1	1.9	1.5	1.2	3.4	1.6	3.6
TiO_2	6.0	1.2	4.4	2.3	2.4	1.2	1.5	2.6	2.0
Ignition loss	21.2	32.2	29.1	32.4	32.2	29.6	31.2	32.6	30.4
Insoluble	.6	.3	.8	.4	.2	.2	.7	.4	.6
FeO	.2	.2	.2	.2	1.4	.2	.2	.2	.2
Zone of leaching									
	9	10	11	12	13a	13b	14	[1] 15	[1] 16
Al_2O_3	59.7	62.0	52.6	49.4	50.3	40.4	40.7	39.6	37.2
SiO_2	5.4	4.6	22.2	25.1	19.5	39.0	38.7	44.0	42.9
Fe as Fe_2O_3	1.1	.9	.8	1.1	3.0	2.5	2.4	1.1	.8
TiO_2	3.7	.4	.8	1.4	2.6	1.9	2.5	.6	1.9
Ignition loss	29.7	31.6	23.2	22.7	24.2	15.9	15.4	14.4	13.5
Insoluble	.4	.5	.4	.3	.4	.3	.3	.3	3.7
FeO	.2	.2	.2	.2	.3	.5	.3	.2	.2

[1] Underclay.

1. Gray partly kaolinized pisolites and rinds (specimen AB-74-7) from near the upper surface of the bauxite.
2. Red centers of pisolites (specimen AB-74-8) associated with sample 1.
3. Small block of bauxite with red pisolites enclosed in a drab matrix (specimen AB-74-16), from the top of the deposit.
4. Pisolitic bauxite block in red pisolitic bauxite ("birdseye ore") from the top of the deposit (specimen AB-74-3a).
5. Brown and white dense vesicular-appearing bauxite (specimen AB-74-13), from the top of the deposit.
6. White and pink scoriaceous bauxite (specimen AB-74-6) from the upper 5 feet of the deposit.

7a. Orange-red bauxite interpenetrating drab vesicular matrix in a vermicular structure, from the upper part of the bauxite; orange material only (specimen AB-74-15a).

7b. Drab matrix from the same specimen (specimen AB-74-15b).

8. Hard tan ocherous, very porous granitic-textured bauxite ("sponge ore") from a block (specimen AB-74-14) at the surface of the deposit.
9. Greenish-gray to pale-tan crumbly granular (granitic-textured) bauxite (specimen AB-74-11) from between two kaolinized nepheline syenite cores.
10. Tan granular (granitic-textured) bauxite in place (specimen AB-74-5), about 30 inches above sample 11.
11. Grayish-tan soft granitic-textured bauxitic clay (specimen AB-74-4) in the lower part of the deposit.
12. Porous pale-gray clay (specimen AB-74-12) in cut near the north edge of the deposit.

13a. White granitic-textured bauxitic clay (specimen AB-74-1b) in contact with 13b.

13b. Gray fragmental-appearing kaolinitic clay (specimen AB-74-1a) in an irregular body cutting granitic-textured and granular bauxite.

14. Gray fragmental-appearing clay (specimen AB-74-2) from near 13a.
15. White granitic-textured kaolinitic clay (specimen AB-74-9) adjacent to a hard nepheline syenite core.
16. Light-bluish-gray kaolinized nepheline syenite (specimen AB-74-10) adjacent to a core of fresher rock.

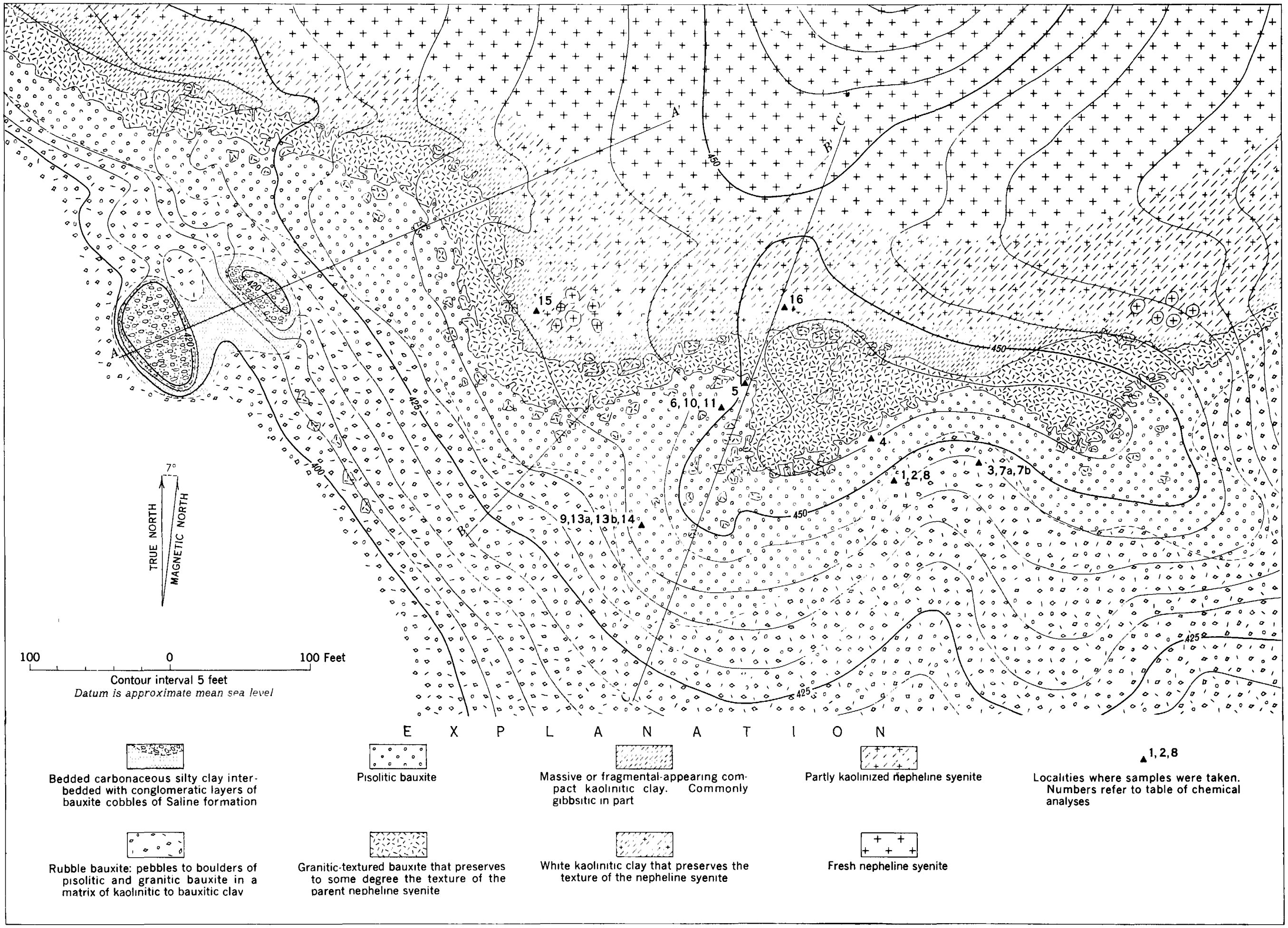


FIGURE 37.—Geologic map of a part of the Pruden mine. Geology and topography by J. I. Tracey Jr., and A. L. Jenke, December 1944.

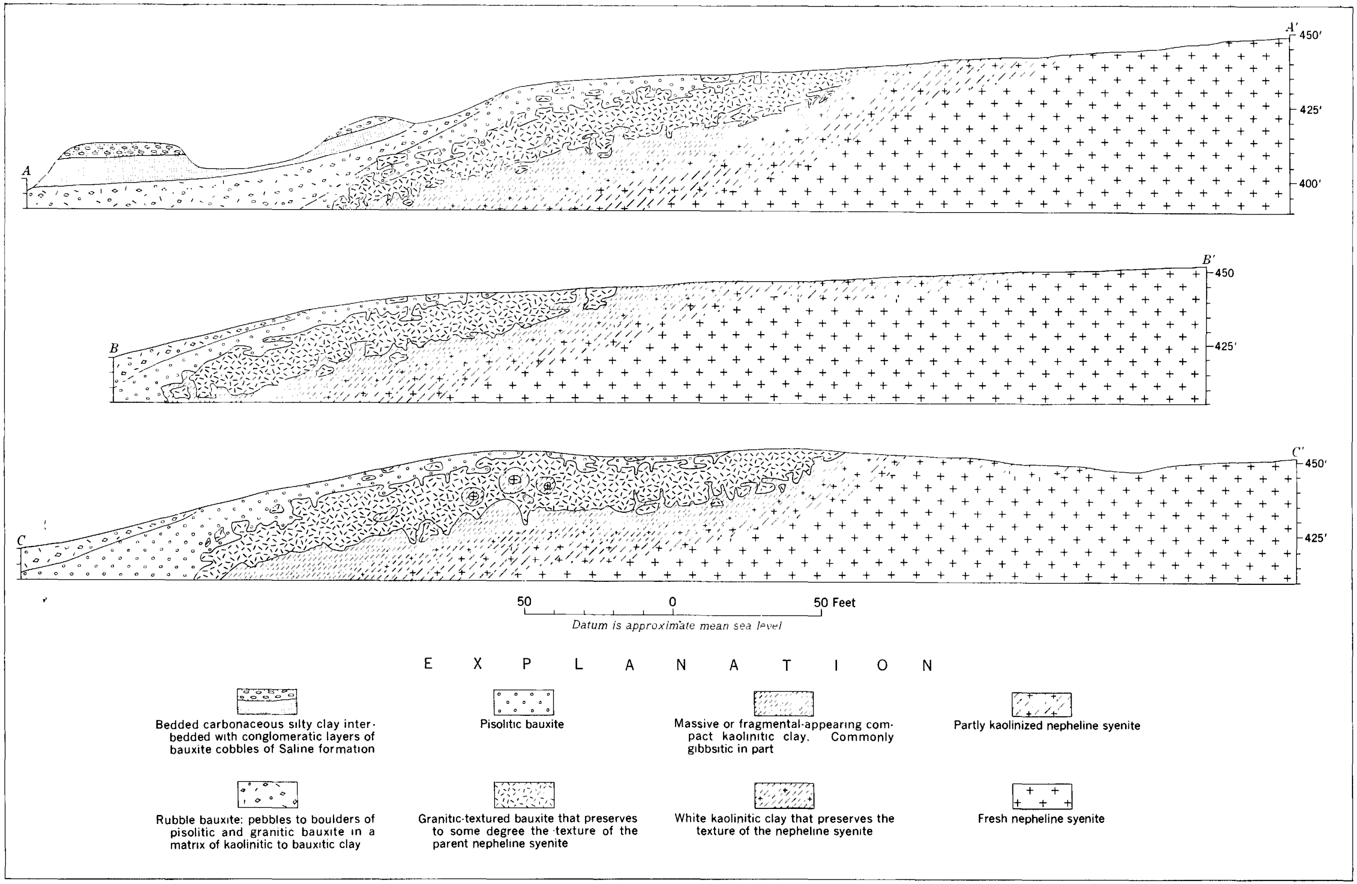


FIGURE 38.—Sections of a part of the Pruden mine.

TABLE 11.—*Spectrographic determination percentages of minor elements in bauxite from type 1 deposits in Saline County*

[Analyst, K. J. Murata]

Element	1	2	3
	Granitic-textured bauxite	Pisolitic bauxite	Granitic-textured bauxite
Ti	0. 5	0. 9	0. 8
Zr	. 08	. 1	. 2
Mn	. 06	. 1	. 09
Nb	. 04	. 05	. 06
Ca	. 03	. 04	. 03
La	. 008	. 008	. 02
Ga	. 005	. 008	. 006
Mg	. 004	. 01	. 002
V	. 004	. 009	. 005
Y	. 004	. 007	. 006
Cr	. 002	. 007	. 004
Sr	. 002	. 0004	. 008
Ba	. 0009	. 001	. 002
Cu	. 001	. 002	. 001
Pb	--------	--------	. 001
Mo	--------	. 003	--------
Sc	. 0004	. 0005	. 0007

Looked for but not found: Be, B, Sn, Ag, Bi, Sb, As, Tl, Ge, In, Co, Ni, Ta.

1. Oxidized ferruginous granitic-textured bauxite (specimen AB-74-17; from a weathered outcrop just above the nepheline syenite outcrop in the Pruden mine, Alcoa Mining Co., NE¼SW¼ sec. 16, T. 2 S., R. 14 W.
2. Red "birdseye" bauxite with black pisolites (specimen AB-80-1; fig. 15.4) from a mine face in the west part of the Section 16 mine, Alcoa Mining Co., SE¼SW¼ sec. 22, T. 2 S., R. 14 W.
3. Tan granitic-textured bauxite (specimen AB-111-2; a loose "sponge ore" block rom the north face of the Middle Maud mine, Alcoa Mining Co., in the SW¼SE¼ sec. 22, T. 2 S., R. 14 W.

on further weathering. Overlying this layer, the igneous texture is not so well preserved in the freshly exposed soft clay, but the outlines of relict feldspar crystals become more apparent when it has been exposed to the air for several days. Scattered within the clay are decomposition boulders of fresh to partly decomposed nepheline syenite that represent parts of the igneous rock that have resisted weathering. These boulders grade abruptly into the surrounding clay. Chemical analyses of the kaolinized rock surrounding two such boulderlike cores in the underclay of the Pruden mine are given in table 10, samples 15 and 16. Both samples have a composition similar to that of kaolin, but in sample 16, 3.7 percent of insoluble residue indicates that the feldspathic minerals have not completely altered to kaolinite.

Writers who previously have described the kaolinitic underclay, such as Hayes (1901, p. 447–448), Mead (1915), and Bramlette (1936, p. 11), have stated that it grades upward into the granitic-textured bauxite. This relationship was not found by Goldman and Tracey (1946, p. 571) who said:

> We have nowhere seen bauxitized nepheline syenite grading into kaolinized nepheline syenite. The sequence from kaolinized nepheline syenite with more or less open texture to bauxitized nepheline syenite is marked, wherever we have seen it, by an intermediate zone of compact kaolinitic clay, massive or with a pseudo-fragmental structure, but lacking an open granitic texture.

The experience of the writers confirms these observations. The presence in all observed sections of massive, structureless, or fragmental-appearing kaolinitic clay between bauxite preserving the texture of nepheline syenite and kaolin crudely preserving the texture of nepheline syenite indicates that the bauxite was not derived from the kaolin. The secondary relationship of kaolin to bauxite, where the two are in contact, is discussed in some of the sections that follow.

LITHOLOGIC CHARACTER OF THE BAUXITE

As shown in the cross sections in figure 38 and also in the diagrammatic section in figure 36, the kaolinitic clay is overlain by bauxite that preserves in varying degree the original texture and structure of the nepheline syenite. This "granitic" bauxite of the zone of leaching forms an extensive layer with irregular boundaries above and below. A large part of this rock is a soft crumbly greenish-gray to pale-tan, granular bauxite. Most of it does not preserve the igneous texture as well as typical "sponge ore," but a face of this rock has the same massive jointed character and general textural appearance as a face of weathered nepheline syenite.

In thin section the granular bauxite is seen to be composed chiefly of microcrystalline gibbsite aggregates pseudomorphous after feldspar. The interspaces are porous and contain cryptocrystalline or microcrystalline gibbsite and some ferruginous staining matter and locally dark-brown opaque areas of leucoxene (anatase), some of which is pseudomorphous after sphene. In parts of the bauxite, pore spaces and veinlets are filled with granular siderite or kaolinite masses and crystals.

Analyses of two typical specimens of granular bauxite are given in table 10, samples 9 and 10, which contain 53.6 and 56.9 percent of available alumina. Another specimen, sample 11 in the same table, which was collected 30 inches below sample 10, has an available alumina content of 28.2 percent; the analysis indicates that the rock may contain as much as 48 percent of kaolinite.

The specimen of granitic-textured ore yielded the following chemical analysis by the triacid method.

Chemical analysis of red granitic-textured bauxite from the Pruden mine outcrop

[Analyst, M. L. Lindberg, U. S. Geological Survey. Specimen AB-74-17]

	Percent
Al_2O_3	57. 36
Fe_2O_3	8. 04
TiO_2	. 54
Ignition loss	31. 87
Insoluble	. 65
Total	98. 46

In thin section a network of thin sheets of microcrystalline gibbsite within large gibbsite pseudomorphs after feldspar is coated and stained with hematite. These two minerals, together with ilmenite and anatase, were identified in the same specimen by X-ray analysis by J. M. Axelrod from heavy-mineral separations prepared by M. L. Lindberg. The titania content is low in the specimen, similar to that in much of the nepheline syenite. Anatase apparently has formed by alteration of sphene and perhaps in part from ilmenite. Hematite apparently accounts for all the ferric iron, but at least part of it may have been derived from the oxidation at the surface of the ferrous iron in siderite.

The irregular lower contact of the granitic-textured zone of leaching consists of roots and scattered blocks of the bauxite, surrounded by massive or fragmental-appearing kaolinitic clay, some of which permeates pore spaces of the bauxite. A photograph of a part of the old Tank mine at Bauxite (Mead, 1915, pl. 3) shows the peculiarly uneven surface of a type 1 deposit after the ore had been removed by the selective methods of mining then used.

The upper contact of the zone of leaching with the overlying zone of concretion is likewise exceedingly irregular. Locally, however, it is sharp and regular, as in the main incline of the Section 26 mine where the contact was exposed along the walls from the entrance to the base of a 20° slope—a distance of 300 feet. The bauxite had a granitic texture for 6 to 8 feet above the floor; the upper walls and roof were cut in pisolitic or rubbly-appearing concretionary bauxite. Most commonly, the contact is gradational, with every transitional stage present from the granitic-textured to the pisolitic rock. In places crude pisolites have formed in pockets deep within granitic-textured rock. These pisolites normally consist of microcrystalline gibbsite aggregates in the form of broken relict feldspar fragments, surrounded by a thin cushion of semi-opaque, partly iron stained cryptocrystalline gibbsite, enclosed in a narrow rind of the same material. These concretionary bodies, although well rounded, are more lumpy than spherical. Where the granitic-textured ore has broken evenly into finely divided material, the rind structures are more symmetrical. A photomicrograph shown by Mead (1915, pl. 5) illustrates the tendency of the aluminous and ferruginous rind structures to seal off the nearly spherical bodies of finely divided fragmental bauxite.

Upward in the deposit the matrix and pisolites are harder and denser. They grade near the top into "birdseye ore," an advanced form of pisolitic bauxite described on page 77 and illustrated in figure 15*A*. A chemical analysis of "birdseye ore" is given in the table below. Analysis of similar rock, samples 3 and 4 from the Pruden mine, are given in table 10.

Chemical analysis of a specimen of pisolitic bauxite ("birdseye ore") from the Section 16 mine

[Analyst, W. W. Brannock. Specimen AB-80-1]

	Percent
Al_2O_3	54. 02
Fe_2O_3	11. 65
TiO_2	2. 16
Na_2O	. 08
K_2O	. 06
Ignition loss	29. 31
Insoluble	2. 39
Total	99. 67

In these specimens the pisolites range from spherical to ellipsoidal, and are from 5 to 30 millimeters in long dimension. The centers are red, brown, or black, porcellaneous to subvitreous, and range in hardness from 4 to 7½ on the Mohs scale. Some are formed around fragments of light-gray or orange bauxite in the shape of broken relict feldspar laths. The layered rinds are mostly tan or reddish to black, most of them are lighter than the centers, others contain darker layers. Many "pisolites" are indistinct and appear to be bodies of matrix sealed off by rind structures.

In the thin section of the specimen of which the chemical analysis is given in the table above, the pisolites are seen to be composed mostly of cryptocrystalline gibbsite that appears isotropic between crossed nicols. Large parts of the centers consist of masses of microcrystalline gibbsite, which is also scattered through the matrix. Both pisolites and matrix are stained brick red. Small blebs of brown and black opaque minerals occur within the pisolites and in the matrix. The pisolites and matrix are cut by a ramifying network of tiny veinlets. Several large veinlets in the matrix are filled with kaolinite, partly obscured in thin section by iron staining. Tiny cavities and veinlets are lined with gibbsite crystals, and in places these cut the kaolinite masses. Latest and most common of the cavity-filling minerals is siderite in interlocking subhedral grains, both in the cavities and

also in tiny veinlets, several of which are lined with gibbsite.

Bromoform and methylene iodide separations of the same specimen (AB–80–1) were examined with the petrographic microscope by M. L. Lindberg, and through X-ray analysis by J. M. Axelrod. From the fractions denser than bromoform the following minerals were recorded: Gibbsite, a trace of boehmite, siderite, hematite, anatase, zircon, and unidentified brown and black opaque minerals.

Vermicular forms of bauxite are closely associated with the pisolitic variety (fig. 15*B*). These closely resemble the matrix of the birdseye ore and grade into it. The rock is evenly fine grained and consists of tones of brick-red to orange bauxite interpenetrated with drab-grayish bauxite. The drab material usually is along irregular tubelike bodies that resemble worm borings. They are commonly filled with siderite grains and iron oxides. Passages of this sort in bauxite have been discussed by Campbell (1917, p. 172), who considered that important secondary changes occur along them during the formation of the concretionary structures. Analysis 7*a* shown in table 10 is the orange-colored part of a specimen of vermicular bauxite; the sample has an available alumina content of 55.2 percent. The drab-grayish part of the same rock, 7*b* shown in the same table, contains more gibbsite and has an available alumina content of 60.2 percent. The drab-gray material in some bauxite specimens, however, is composed chiefly of kaolinite.

Another characteristic lithologic type in the upper part of the bauxite is a dense and cherty-looking rock riddled with small cavities that give it a vesicular aspect. A few relict feldspar crystals and indistinct round structures can be distinguished but no well-developed pisolites occur. A chemical analysis of such a rock is given in table 10, sample 5, containing 57.4 percent of available alumina. Closely associated white and pink bauxite that appears "scoriaceous," sample 6 in the same table, has an available alumina content of 53.3 percent.

Granitic-textured bauxite also is found in the zone of concretion, where some of the best examples of sponge ore occur. This rock is limited, however, to scattered blocks, most of which are surrounded by thick gibbsitic crusts. These blocks represent the parts of the original granitic-textured mass that have survived the alteration of the surrounding rock to concretionary structures. They generally decrease in abundance upward from the zone of leaching. A striking example of such a boulderlike block from the West Maud mine was photographed at the offices of the Alcoa Mining Co. at Bauxite (fig. 39). The block, about 15 by 12 by 8 inches, has a light-brown to dark reddish-brown dense, hard bauxite shell, 1 to 3 inches thick, enclosing a core of tan, very porous, granitic-textured bauxite that is loose within the shell. The crust has an inner lining of granitic-textured rock, as much as 5 millimeters thick, which grades into the dense bauxite. The crust of these "boulders" generally contains a little more silica than the interior. Chemical analyses of several boulderlike blocks and their rinds, including the one described above, are given below. Another, sample 8 from the Pruden mine, appears in table 10.

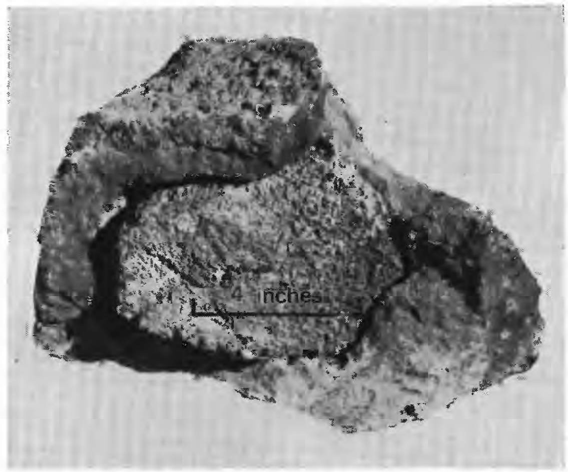


FIGURE 39.—Concretionary bauxite boulder from the West Maud mine. The concretion contains a soft porous core of granitic-textured bauxite ("sponge ore"), surrounded by a thick dense bauxite rind. Scale is indicated by a line 10 centimeters long. Chemical analyses below.

Chemical analyses of granitic-textured bauxite ("sponge ore") from the zone of concretion of type 1 deposits in Saline County mines

[Sample 1: Analyst, M. L. Lindberg. Less than 0.10 percent each of K_2O and Na_2O also are present, as determined by flame photometer by W. W. Brannock. Samples 2a to 4b, inclusive: Analysis, U. S. Bureau of Mines field laboratory at Little Rock]

	1	2a	2b	3a	3b	4a	4b
Al_2O_3	60.46	56.5	62.6	61.7	59.0	61.9	62.0
SiO_2	4.39	1.5	.6	.5	1.3	1.4	1.7
Fe as Fe_2O_3	2.50	7.0	2.1	3.3	4.7	1.3	1.6
TiO_2	.54	2.2	1.0	1.3	1.4	1.5	.9
Ignition loss	31.56	32.3	33.2	32.9	33.5	33.3	33.4
Insoluble	.28	.5	.5	.3	.1	.6	.4
FeO	--------	4.5	.8	.6	2.4	.2	.2

1. Light tan, porous, fairly coarse, granitic-textured bauxite surrounded by a thin crust of pisolitic bauxite (specimen AB–111–2; loose block from north face of Middle Maud mine, SW¼SE¼ sec. 22, T. 2 S., R. 14 W.

2a. Coarse granitic-texture bauxite from Section 15 mine (specimen AB–72–1; pl. 10*B*), north face at west end of pit, near the south end of the NE¼SE¼ sec. 16, T. 2 S., R. 14 W.

2b. Same as 2a; analysis of the fraction lighter than bromoform.

3a. Tan to ocher, soft, finely granitic textured bauxite from large boulder near center of Cleveland mine, NW¼SW¼ sec. 24, T. 2 S., R. 14 W.

3b. Same as 3a, but from ½ to 1-inch dense bauxite crust surrounds boulder.

4a. Porous granitic-textured bauxite from loose core inside Alcoa boulder specimen (fig. 39), from West Maud mine, NE¼NW¼ sec. 27, T. 2 S., R. 14 W.

4b. Same as 4a, but from compact light-brown to dark-reddish-brown crust, 1 to 3 inches thick, which surrounds loose core of sponge ore.

Two blocks of this sponge ore have been studied by means of optical examination of heavy-mineral separations and by X-ray analysis. The constituent minerals determined by these methods appear in the tabulation below.

Minerals identified by X-ray analysis in granitic-textured bauxite ("sponge ore") blocks from Saline County mines

Analyst, J. M. Axelrod. Heavy-mineral separations by M. L. Lindberg]

Minerals	1a	1b	1c	2
	Light	Heavy	Heavy	Heavy
Gibbsite	×	×	×	×
Kaolinite	×	------	------	------
Chlorite	×	×	------	------
Hematite	×	×	------	------
Goethite	------	------	------	×
Unknown mineral ($SiFe_2O_3$)	------	×	×	------
Sphene	------	------	(?)	------
Ilmenite	------	×	×	×
Anatase	------	×	×	×
Zircon	------	×	×	×
Unidentified opaque minerals	------	×	×	------

1a. Granitic-textured bauxite block from the Middle Maud mine (specimen AB-111-2); same as sample 1 in the table above. Slime and bromoform floats only.
1b. Same specimen, but methylene iodide sinks only.
1c. Pisolitic bauxite crust from same block. Methylene iodide sinks only.
2. Granitic-textured bauxite block (specimen AB-80-3; fig. 14) from the eastern part of the Section 16 mine, SW¼SE¼ sec. 16, T. 2 S., R. 14 W., from surface shown in figure 35*B*. Methylene iodide sinks only.

In the map and cross sections (figs. 37 and 38) the zone of concretion has been divided into two parts: a lower subzone in which the pisolitic structure is dominant, and an upper one in which the appearance of the structure is that of rubble. Much of the rubbly appearance apparently has been caused by the breaking apart and recementing of blocks of pisolitic bauxite, together with vermicular and vesicular forms and granitic-textured remnants. This alteration probably was accomplished with comparatively little downhill movement, at least in the part of the deposit shown in the plate. Farther downslope, however, much of this bauxite merges laterally with truly conglomeratic bauxite that fingers into the lower part of the Saline formation. A photograph of the rubbly surface in the upper part of a type 1 deposit is shown in figure 22.

In residual deposits the thickness of the zone of leaching relative to the zone of concretion is determined chiefly by the steepness of the slopes. Granitic-textured bauxite is dominant on steep slopes, whereas in more flat-lying parts of the deposits pisolitic and rubbly concretionary ore is the thicker.

HARDCAP

The uppermost 1 to 2 feet of bauxite is in many places much harder or tougher than that below. It is generally left as a roof in underground mining operations, and is called "hardcap" by the miners. The top of the bauxite commonly is higher in silica than the parts below. Reports indicate that it has been necessary in many strip mines to remove 1½ to 2 feet of high-silica bauxite from above the ore before mining.

Kaolinization of the upper part of the pisolitic bauxite is shown by chemical analyses of samples 1 and 2 from the Pruden mine (table 10). The gray pisolites and rinds that constitute sample 1 contain 18.3 percent of available alumina and indicate about 53 percent of kaolinite if all of the silica in the analysis is attributed to this mineral. The red interiors of some of these pisolites, represented by sample 2, contain 57.1 percent of available alumina indicating about 8 percent of kaolinite.

The upper part of the bauxite likewise is usually more indurated than the lower part. Induration and high silica do not in all places coincide, however, and miners have reported that in some localities as much as 4 feet of very hard bauxite at the top of the section is of better grade than any below it.

Especially in valley bottoms or at the bases of slopes, the deposits are overlain by a conglomeratic bauxite bed with a matrix of kaolinitic or carbonaceous clay. Although this bed forms a covering locally high in silica, it is of different origin than the siliceous hardcap formed in place by chemical alteration, and is discussed under type 4 deposits.

KAOLIN VEINS IN THE BAUXITE

Kaolin veins extend upward into the bauxite from the irregular lower contact with the kaolinitic underclay. They occupy joint planes, fissures, and fractures in the granitic-textured bauxite, and are characteristic of the mines at higher elevations in the Saline nepheline syenite hill, but are revealed only in places where cuts have been made in the ore. An excellent example of this type of veining was exposed in the central part of the Alexander Hill mine in 1948. The veins are on the south face of a pit from which several carloads of clay were removed for experimental purposes and above which a 15-foot blanket of ore had been mined. The face shown (fig. 40*A*) is predominantly tan granitic-textured bauxite which appears to have formed from nepheline syenite in place. It is cut by anastomosing white kaolin veins, some of which are 8 inches wide. The arrangement of the veins indicates an original joint pattern of the nepheline syenite. The kaolin appears massive, structureless, or locally fragmental, and nowhere does it have a granitic texture.

Westward and downslope along the south face of the pit, as well as downward in the section, the kaolin veins are wider and the remnants of granitic-textured bauxite are small, irregular, and scattered (fig. 40*B*). Blocks of grayish-brown, granitic-textured bauxite are surrounded by large masses of kaolinitic clay with a fragmental-appearing texture, alined along veinlike cracks. The boundaries of the bauxite blocks are almost parallel to the veining which indicates that the veins commonly formed along joints. The clay appears to have formed at the expense of the bauxite. The

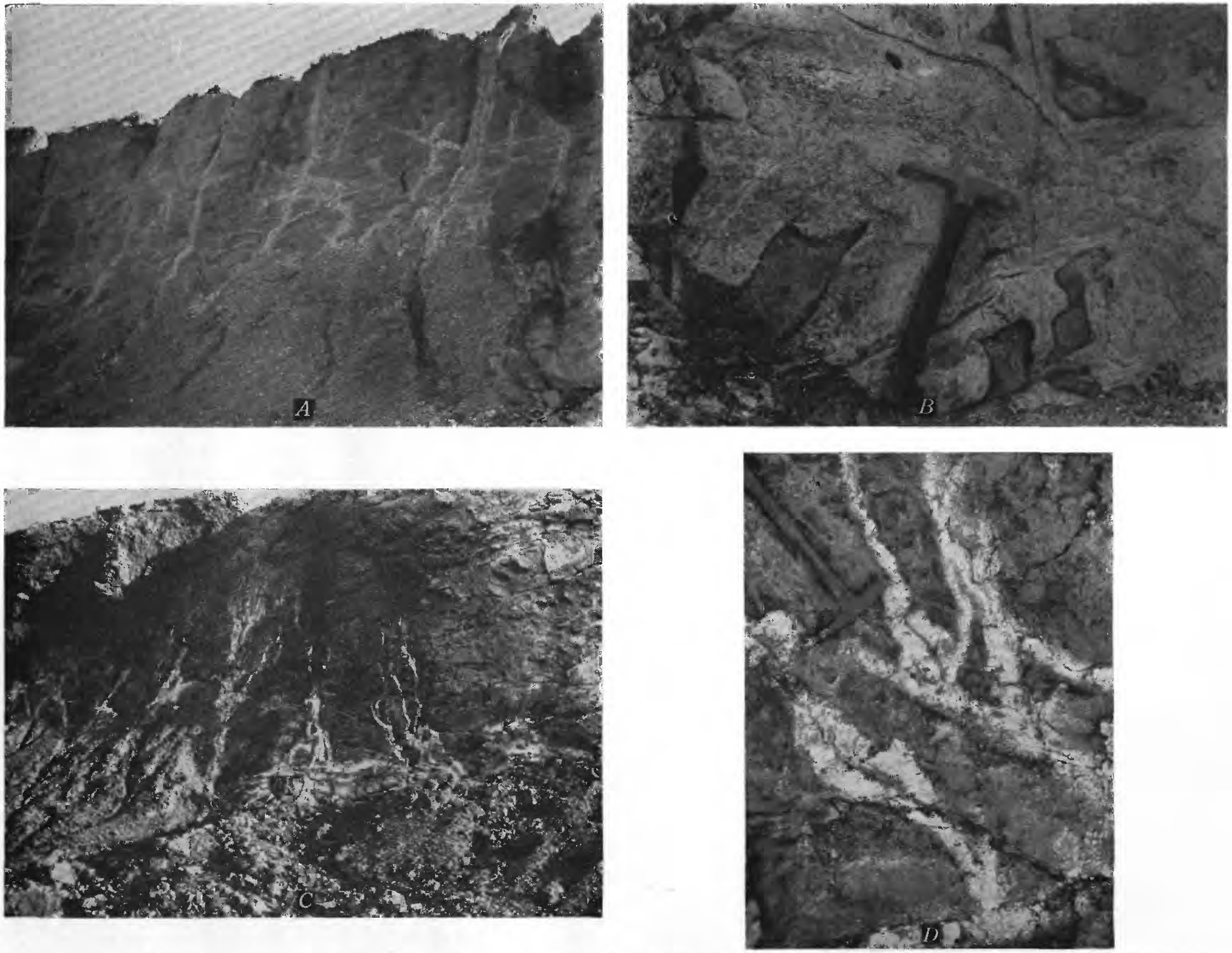


FIGURE 40.—Secondary kaolin bodies in type 1 deposits. *A*, Kaolin veins cutting granitic-textured bauxite. South face of clay pit in the Alexander Hill mine showing white kaolin veins in the darker bauxite. The veins apparently were formed along relict joint structures in the bauxite originally present in the parent nepheline syenite and preserved during weathering. *B*, Advanced stage of kaolinization along veins in bauxite. Photograph taken at same pitface as *A*, but to right of that photograph and lower in section. Formation of kaolin at the expense of bauxite has reached a point where only small dark remnants of granitic-textured bauxite remain. Kaolinization has spread outward from centers of veins marked by dark cracks. *C*, Braided kaolin veins cutting bauxite. Veins cut through from beneath but do not reach surface of bauxite. Taken near middle of south wall of the Norton mine. Collecting bag gives scale. Photograph by S. S. Goldich. *D*, Braided kaolin veins cutting bauxite. Closeup of part of the central group of veins shown in *C*.

bauxite blocks are probably the small remnants of a once continuous mass of granitic-textured bauxite. At the west end of the clay pit and still lower in the section, much of the kaolinitic clay preserves the texture of the nepheline syenite, but it is separated from the granitic-textured bauxite by at least 3 feet and in most places by more than 10 feet of the massive or fragmental-appearing clay.

Veining has also been observed at the east edge of the Elrod mine, where remnants of a type 1 deposit truncated by erosion are preserved.

Veins along nearly straight fractures are exposed in the African Camp mine. Ferruginous kaolinitic clay veins, as much as 10 inches wide, form a network cutting granitic-textured bauxite, and appear to have formed along relict joints in the bauxite inherited from joints in the parent nepheline syenite (fig. 42). A sketch of an 8-inch vein showing well-defined zones of kaolinitic clay fragments and small ferruginous nodules is shown in figure 41. As the bauxite preserves

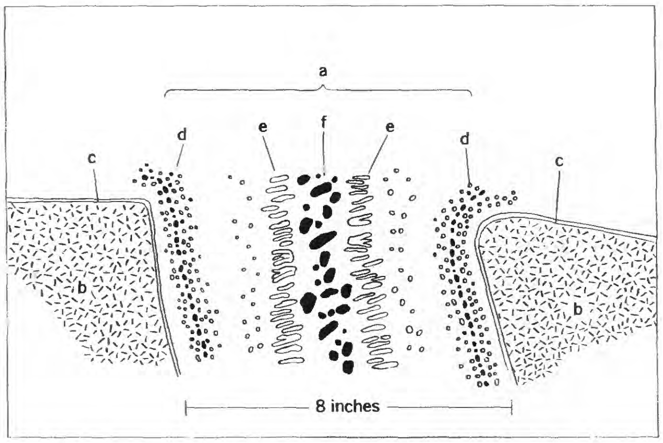


FIGURE 41.—Symmetrical zoning of a kaolinitic clay vein in granitic-textured bauxite. Ferruginous kaolinitic clay vein (*a*), 8 inches wide, with a massive grayish-brown matrix, cutting granitic-textured bauxite (*b*) into blocks that are rimmed by mottled red and white kaolinitic clay (*c*). Vein (*a*) contains small angular bodies of white clay concentrated at (*d*); larger ones at (*e*) are elongate and feather into the matrix at right angles to the trend of the vein. Ferruginous nodules are heavily concentrated at the center of the vein (*f*), and to a lesser extent in the middle of zone (*d*).

the original texture of the nepheline syenite and the clay veins do not, the formation of the clay veins must have occurred later than the bauxite. Moreover, the zonation of the veins and the structure of the small kaolin bodies indicate a formation primarily by replacement or alteration rather than a filling of open fissures by clay carried in suspension by downward percolating waters.

Where the joint structures of the original nepheline syenite did not exert a pronounced control, particularly in the concretionary zone where pisolites have formed, the kaolin veins are distributed irregularly through the bauxite (fig. 43). Irregular braided veins of kaolin, as much as 5 inches wide, cut the bauxite in the Norton mine (fig. 40*C*, *D*). They apparently cut the bauxite from beneath, and die out upwards before reaching the surface of the deposit.

In addition to the veins that can be seen readily, numerous tiny veinlets cut the bauxite, and aggregates of kaolinite fill minute cavities. Kaolinization also permeates extensive bauxite masses without obvious channels or veins (fig. 44). These features are abundant near the base of the deposits, or in bauxite surrounding boulderlike cores of kaolinized nepheline syenite. They resulted in the high silica content of the bauxitic rock that borders large kaolin bodies, as shown in chemical analyses of samples 11 and 13a in table 10.

IRREGULAR CLAY BODIES

Clay bodies more irregular in shape than the kaolin veins are common throughout the bauxite section. The miners refer to them as "clay horses" (Branner, 1932, fig. 27). Mead (1915, p. 37) called attention to the relative abundance of these clay bodies in the early mines as follows:

> In places the underlying clay extends through the bauxite to the surface, and throughout the bauxite beds horses and stringers of clay are so abundant that in the average case 40 percent of the material handled in mining must be discarded as waste. This figure is greatly exceeded in some places. The clay horses are everywhere abundant—they occur in every variety of shape and size, and add greatly to the cost of mining.

An example of such a clay body, from the Pruden mine, is shown in figure 45, taken from Goldman and Tracey (1946, fig. 4). The clay has invaded the bauxite irregularly. Lateral branches and tongues extend outward almost horizontally from the center of the mass and are overlain and underlain by undisturbed residual bauxite with a well-defined granitic texture. The clay is at the top of the bauxite and also downward as far as the mine cut permitted observation—nearly to the base of the bauxite. Goldman and Tracey (1946, p. 572) stated that apparently the direction of kaolinization was downward but the writers believe that it is not clear from which direction the kaolinization originated.

The clay appears fragmental; the matrix is light to neutral gray or reddish, and contains scattered light- and dark-gray fragments. Fragments of kaolin that appear to be clastic actually have formed in place by the resilication of bauxite along fissures and joints. The rock, thus, has a pseudofragmental texture as pointed out by Goldman and Tracey (1946) and is not formed of kaolin and bauxitic clay fragments that have been transported and redeposited. A hand specimen is shown in figure 46 in which the clay is in contact with

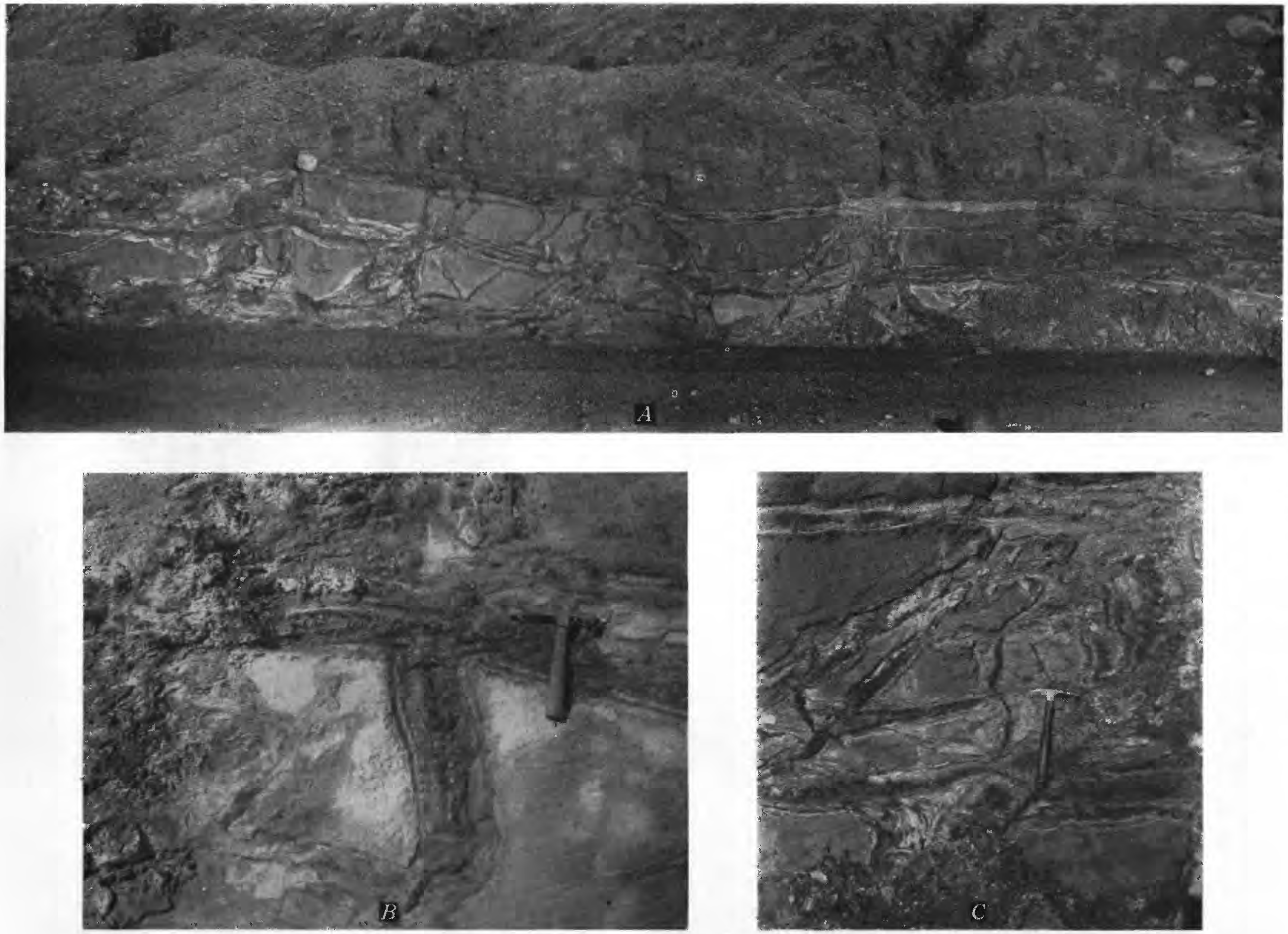


FIGURE 42.—Zoned kaolin veins along relict joint structures in bauxite in type 1 deposit.

A, Panorama of the bauxite face exposed in a drainage ditch in the northwest part of the African Camp mine. Granitic-textured bauxite has been cut and divided into blocks by kaolin veins that follow relict joint structures of the original nepheline syenite that have been preserved in the bauxite. *B*, Closeup of the area in left center of the panorama, showing the zoned appearance of kaolin veins and marked angularity of "granitic" bauxite blocks. Sketch of this vein is shown in figure 41. *C*, Closeup of the area of complex veining in right center of the panorama, showing details of zonation of the veins.

FIGURE 43.—Kaolin veining in a rubbly bauxite surface. Kaolinitic patches are small irregular light-gray bodies in the darker bauxite. Photograph taken in the Section 16 mine a few feet downslope from figure 22.

FIGURE 44.—Mass kaolinization of granitic-textured bauxite in a type 1 deposit. Face in the Section 15 mine, 150 feet north of the portal of the Davis underground mines showing a rounded kaolinitic mass that has formed at the expense of the bauxite.

granitic-texture bauxite. Megascopically the contact appears to be sharp, with few irregularities. Bauxitic fragmentlike bodies in the clay have remnants of a granitic texture. Chemical analyses of such clay show that it approaches kaolin in composition but is slightly gibbsitic; typical examples are samples 13b and 14 in table 10, collected 65–70 feet away from the face shown in figure 45 on the opposite side of the mine cut.

Adjacent to the clay, the bauxite is high in silica and usually falls within the chemical limits of a bauxitic clay. A chemical analysis of a white granitic-textured rock adjacent to the gray fragmental-appearing kaolinitic clay of sample 13b, table 10, is given in 13a in the same table. Samples 1 and 12 are similar bauxitic clay. Sample 1 is from the upper part of the zone of leaching; it has a concretionary structure of gray pisolites in a

FIGURE 45.—Irregular kaolin body in bauxite. Photograph of face near north edge of the Pruden mine, in which kaolinitic parts (*k*) are distributed irregularly through granitic-textured bauxite (*bx*). Scale is indicated by hammer near center of photograph. Note point marked *X* from which specimen illustrated in figure 46 was collected.

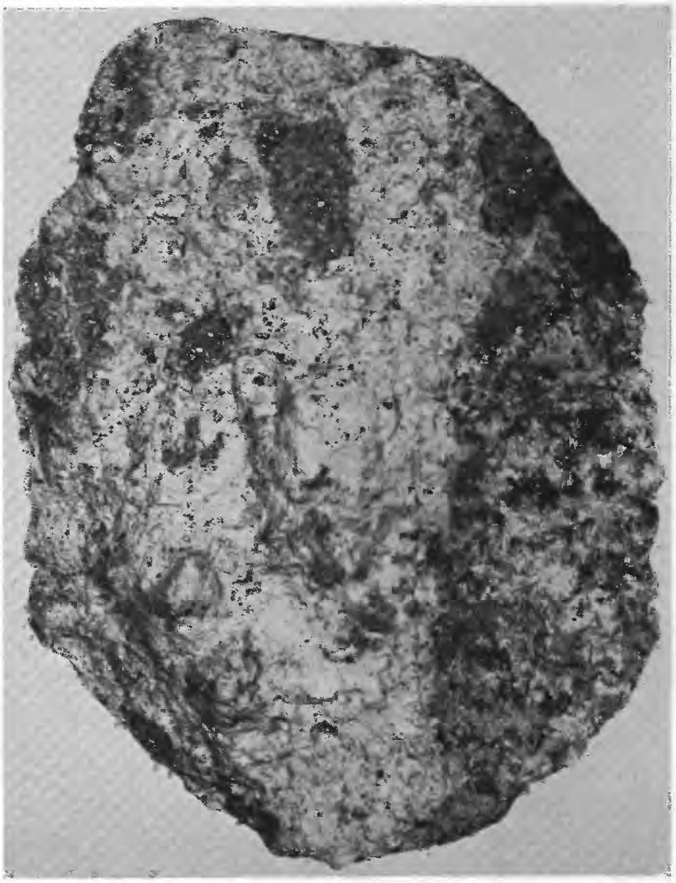


FIGURE 46.—Kaolinitic vein in bauxite. Light-gray kaolinitic clay in contact with mottled brown and green granitic-textured bauxite. Dark remnants of granitic-textured bauxite resembling fragments can be seen in the clay. Specimen from point marked *X* in figure 45.

red matrix. Sample 12 is a pale-gray porous clay from the lower part of the bauxite section.

DECOMPOSITION BOULDERS OF KAOLINIZED NEPHELINE SYENITE

Writers have mentioned the boulderlike bodies of kaolinized nepheline syenite, from about 1 to 20 feet in diameter, that are scattered through the bauxite in some places. Photographs of them have appeared in reports by Mead (1915, p. 45, fig. 5, pl. 6) and by G. C. Branner (1932, pl. 9, fig. A). They are generally cited as proof that the bauxite was formed as the end product in the weathering cycle from nepheline syenite to kaolin to bauxite. The present report agrees with Goldman and Tracey (1946) in questioning this interpretation that kaolin is necessarily an intermediate stage in the formation of bauxite; the question is discussed later in the section on origin.

The boulderlike bodies are confined to type 1 deposits. As pointed out by Mead (1915, p. 46) they are decomposition boulders formed in place by the weathering of the nepheline syenite, and are hard cores that remained unweathered. Many can be found in the Maud, Pruden, Section 26, and Julia mines. A large one in the Section 26 mine is shown in plate 10*D*. The largest and most abundant occur where slopes are steep and residual ore is thick, and apparently are more concentrated along the axes of spurs of nepheline syenite. This distribution is illustrated in the map of a part of the Pruden mine (fig. 37). Residual nepheline syenite boulders are common along the axis of the body (fig. 38, *C–C'*), but have not been found on the flanks on either side, although the deposit has been reexamined since being mined.

A study in considerable detail was made by Goldman (1949, p. 1890; 1955, p. 586–609) of a suite of seven thin sections from specimens collected from a large kaolinitic boulderlike core in the Section 26 mine near the one shown in plate 10*D*. A diagrammatic section of such a decomposition boulder is shown in figure 47, drawn to indicate schematically the observed relationship with the surrounding rock. The specimens were collected from the center outward through a surrounding rim of kaolinized granitic-textured bauxite and pisolitic bauxite. Locations are shown by numbers on figure 47, and photomicrographs of the sections appear in plates 12 and 13.

The first thin section, from the central part (pl. 12*A*), shows partial kaolinization of the rock core. Feldspar and possibly feldspathoid minerals have been partly replaced by kaolinite and by siderite. Some of the feldspar grains appear to be completely kaolinized; others are largely unaltered. Kaolinite of two generations is identifiable; one earlier than the siderite, the other later. The earlier kaolinite is in groups of dirty-looking flakes, of very weak birefringence, that contain a dust of tiny grains, of high birefringence. These grains are too small for positive identification but appear to be siderite. The later kaolinite is in clear-looking veinlets cutting along cleavage planes in the feldspar, and irregularly through and around siderite and earlier kaolinite. Much of it is in well-formed long, sinuous, wormlike crystals. Some of these crystals follow earlier siderite veinlets.

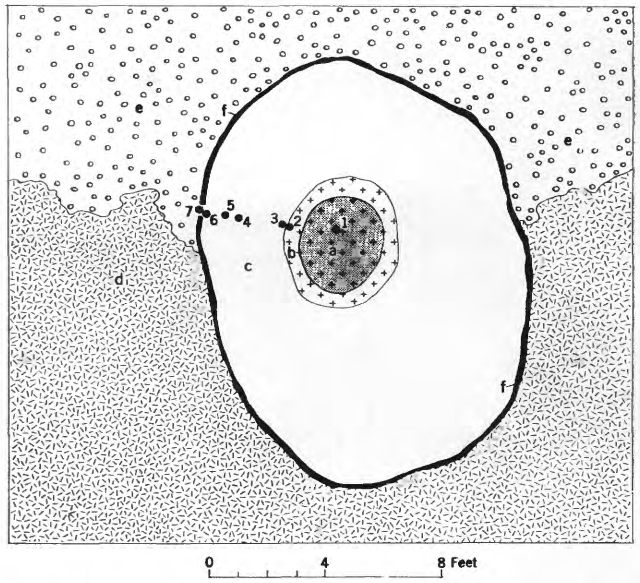


FIGURE 47.—Relations of kaolinitic clay and bauxite surrounding a boulderlike core of nepheline syenite in a residual bauxite deposit. Partly kaolinized nepheline syenite core (*a*) grading into completely kaolinized syenite (*b*) that retains no relict texture, is surrounded by light-colored bauxite and bauxitic clay containing much kaolinitic clay (*c*). The boulderlike body is in a residual deposit of granitic-textured bauxite (*d*) overlain irregularly by pisolitic bauxite (*e*). A thin limonitic layer (*f*) separates the light-colored kaolinized bauxite of the core from the unkaolinized bauxite outside. Numbers show the locations of specimens 1–7, photomicrographs of which appear in plates 12 and 13.

The second thin section (pl. 12*B*) is from the kaolinitic outer part of the hard rock core. The original texture of the nepheline syenite is not preserved. The kaolinite is mostly in flakes and masses that appear somewhat contorted.

The third thin section, representing the rock immediately adjacent to the second, is from the inner part of the broad, light-colored zone of bauxite and kaolinitic clay (fig. 47*c*) surrounding the central core. It is composed predominantly of gibbsite partly replaced by kaolinite (pl. 12*C*). Like the kaolinite in the second thin section, the gibbsite appears contorted and apparently has undergone flowage. In the less disturbed parts the shapes of relict feldspar crystals can be recognized in the microcrystalline gibbsite aggregates.

The fourth thin section (pl. 12*D*) was cut from the same layer, about 2 feet outside the third specimen. Microcrystalline gibbsite aggregates preserve the relict structures of the original feldspar laths. Pseudomorphs of leucoxene after skeletal sphene crystals are scattered through the rock. A few spaces between the relict feldspar laths contain an iron-stained "amorphous" substance, probably cryptocrystalline gibbsite, but most of the interspaces are filled with kaolinite in light-gray fine-grained masses. At one end of the thin section the kaolinite masses are separated from microcrystalline gibbsite aggregates by a lining of minute gibbsite crystals that jut out into the kaolinite; these also line open cavities.

In the fifth thin section 3 inches from the fourth the formation of crude pisolites from the granitic-textured rock is illustrated (pl. 13*A*, *B*). The most primitive forms consist of microcrystalline gibbsite pseudomorphous after feldspar fragments, surrounded by a thin envelope of brownish cryptocrystalline gibbsite, and an outer lining of tiny gibbsite crystals, like those in the fourth thin section. Other pisolites contain groups of light-brown oolites and fragments in cryptocrystalline gibbsite, also lined with tiny gibbsite crystals. The space surrounding the pisolites is commonly occupied by kaolinite masses in which tiny curved vermicular crystals of the same mineral are found.

The sixth thin section (pl. 13*C*) from the outer part of the light-colored layer (fig. 47*e*) is similar to the fifth, but the pisolites are more abundant and smaller; both pisolites and interspaces contain a greater proportion of the cryptocrystalline form of gibbsite; and the light-gray kaolinite masses are confined to irregular veins and cavities between the pisolites. Many are lined with tiny gibbsite crystals as in the two preceding slides. Dark-brown leucoxene and a black opaque mineral, possibly ilmenite, occur in irregular blebs in the bauxite.

The seventh thin section, immediately adjacent to the sixth, is from the limonitic layer (fig. 47*f*) surrounding the boulderlike mass and separating it from dark-colored granitic-textured bauxite (fig. 47*d*). In this outermost thin section (pl. 13*D*) the bauxite is broken into fine fragments and oolites rimmed with the cryptocrystalline gibbsite. The larger pisolites contain microcrystalline gibbsite masses, some of which are recognizable as relict feldspar crystals. Kaolinite occurs in some of the interspaces but is badly obscured by the iron staining. The limonitic layer, averages about 2 centimeters in thickness and completely envelops the "boulder." Such layers are associated with nearly all the boulderlike cores. The limonitic bands cut across kaolin veinlets and gibbsitic bodies, obscuring some of the relationship between the aluminous rocks. They normally are located at the limit of porous bauxitic rock, where it abuts much less porous bauxitic and kaolinitic rock, therefore circulating waters containing iron in solution probably deposited iron oxides along the edge of zones of sharply decreased porosity. This may have taken place at a comparatively recent date, possibly at the same time the ferruginous banding of some of the bauxite was produced (fig. 48).

FIGURE 48.—Ferruginous banding of bauxite by ground water. Fluctuation of ground water has left narrow subparallel brownish-red bands in the bauxite seen in section in a cut. Photograph by A. L. Jenke.

The following relations can be summarized from the seven thin sections described above and from field observations:

1. In the central part of the "boulder" nepheline syenite has been partly altered to kaolinite and siderite.
2. Toward the outer edge of the kaolinitic part the texture of the original nepheline syenite has not been preserved.
3. The contact with the inner edge of the kaolinized gibbsitic part is sharp.
4. Both the kaolinitic and gibbsitic rock have been distorted at their contact in a manner resembling flowage.
5. Relict structures of gibbsitized feldspars and of concretionary pisolites are nearly effaced by kaolinization.
6. The proportion of kaolinite decreases outward.
7. The limonitic envelope is situated at the inner edge of porous bauxite and separates kaolinized from unkaolinized bauxite.

KAOLIN-BAUXITE TRANSITION

Several series of chemical analyses to study the gradation from unaltered nepheline syenite to bauxite were made a few years ago by R. C. Cross, chief chemist for the Alcoa Mining Co. Cross and the company have

kindly permitted the writers to reproduce three of these suites of analyses. Most of them were taken from the transition in boulderlike cores found in the working faces of Saline County mines. Careful analysis of samples taken at small intervals of the transition, such as has been done by Cross, shows that the change from clay to bauxite is locally abrupt, and the gradation is not as regular as formerly supposed. Considering the secondary relation of kaolin to bauxite as shown in the thin sections described in the foregoing section, this is what might be expected.

The first series of analyses were run on saw cuttings from a block of clay and bauxite, 2 by 3 inches in cross section. The block, placed in a mitre box, was sectioned with a hacksaw blade, parallel to the planes of similar lithology. The samples are consecutive and each represents an approximate one-eighth-inch cut from the face of the block. The total thickness of the block was about 3 inches. The table below shows the abrupt transition from clay to bauxite.

The analyses show that the soda, potash, and lime present in the original nepheline syenite have been largely leached out in both the clay and the bauxite. The relative content of manganese oxide, on the contrary, has been increased particularly in the bauxite.

Partial analyses of specimens collected in sequence across decomposition boulders in the Neilson and Davis underground mines near Bauxite are given in the tabulation below. The samples were taken at 1- to 6-inch intervals from the core outward. Only the percentage of silica, total iron as ferric iron oxide, and titania are given, but the grade of the bauxite or clay can be approximated by examination of the silica content, where the iron oxide is low.

Chemical analyses of the clay–bauxite transition in a 3-inch block taken at one-eighth-inch intervals

[Analyst, R. C. Cross, Alcoa Mining Co., Bauxite, Ark.]

Sample	Rock	Al_2O_3	SiO_2	Fe as Fe_2O_3	TiO_2	Ignition loss	Na_2O	K_2O	CaO	MnO
1	Clay	38.14	43.13	1.69	1.85	14.52	0.10	0.06	0.16	0.35
2	do	37.60	42.42	2.00	2.95	14.13	.13	.05	.15	.57
3	do	44.56	30.56	1.50	2.30	20.02	.11	.04	.16	.75
4	Bauxite	51.83	17.68	1.57	2.45	25.18	.11	.07	.15	.96
5	do	51.65	19.40	1.50	2.50	24.49	.10	.06	.16	.14
6	do	52.95	16.83	1.50	2.25	25.51	.06	.11	.15	.64
7	do	53.90	15.50	2.12	1.14	25.77	.08	.09	.13	1.27
8	do	55.30	12.22	1.43	2.04	27.63	.11	.08	.12	1.06
9	do	56.40	9.29	1.69	2.10	29.12	.09	.07	.10	1.14
10	do	57.54	7.47	1.69	2.10	30.10	.04	.01	.09	.96
11	do	58.85	4.27	2.00	2.15	31.63	.02	.03	.09	.96
12	do	60.20	2.41	1.81	2.03	32.18	.03	.04	.09	1.21

Partial analyses of a series of samples from a hard core of unaltered nepheline syenite outward to high-grade bauxite, in the Neilson mine, stope 5A, crosscut 4, NW¼NW¼ sec. 26, T. 2 S., R. 14 W.

[Analyst, R. C. Cross, Alcoa Mining Co., Bauxite, Ark.]

Sample	Distance from core (inches)	Lithologic description	SiO_2	Fe as Fe_2O_3	TiO_2
1	(1)	Hard unaltered nepheline syenite.	56.84	1.75	0.50
2	6	Excentric siderite occurrence	14.80	46.15	.55
3	12	do	25.58	28.55	.75
4	18	Typical clay	43.13	2.00	1.10
5	24	Clay	43.00	2.00	1.15
5A	30	do	43.00	2.00	1.15
5B	32	do	42.67	2.25	1.10
6	34	do	42.87	1.90	1.10
6A	36	Bauxitic clay	30.35	1.45	1.20
6B	38	do	38.06	1.35	1.15
6C	40	do	27.36	1.55	1.25
6D	42	Bauxite	15.86	1.60	1.35
7	44	Bauxitic clay	30.08	1.55	1.35
7A	45	do	29.68	1.55	1.50
8	46	do	21.76	1.70	2.00
8A	47	Bauxite	5.18	1.90	1.65
8B	49	do	3.44	1.60	1.45
8C	55	do	.93	1.70	1.45
8D	61	do	1.32	1.60	1.30
8E	67	do	.86	1.55	1.35

[1] At core.

Partial analyses of a series of samples from a hard core of nepheline syenite outward into high-grade bauxite, in the Davis mine, drift 3, SE¼NW¼ sec. 22, T. 2 S., R. 14 W.

[Analyst, R. C. Cross, Alcoa Mining Co., Bauxite, Ark.]

Sample	Lithologic description	SiO_2	Fe as Fe_2O_3	TiO_2
1	Hard nepheline syenite boulder core	55.36	4.25	1.20
2	Slightly weathered concentric shell surrounding nepheline syenite boulder	52.00	4.30	1.25
3	Second concentric shell around boulder; clay phase starts 1 inch from sample 2	49.82	4.70	1.20
4	Early phase of clay, 2 inches from sample 3	46.04	1.85	1.30
5	Clay phase, 2 inches from sample 4	41.76	2.90	1.60
6	Abrupt change to bauxite, 1 inch from sample 5	8.34	1.55	2.30
	Bauxite:			
7	1 inch from sample 6	5.43	1.40	2.25
8	1½ inches from sample 7	6.65	1.40	1.95
9	1½ inches from sample 8	4.09	1.35	2.05
10	2 inches from sample 9	3.29	1.35	2.10
11	3 inches from sample 10	6.41	1.10	1.85
12	6 inches from sample 11	2.37	1.30	2.10
13	6 inches from sample 12	2.58	1.40	1.90
14	6 inches from sample 13	2.12	1.45	1.85
15	6 inches from sample 14	1.76	1.50	2.00
16	1 foot from sample 15	1.73	1.85	1.80

In the sequence from the Davis mine, the change from clay in sample 5 to bauxite in sample 6 within the space

of 1 inch, and an accompanying decrease in silica from more than 40 percent to less than 10 percent, is no more abrupt than the change shown in the first of the three tables for which the samples were taken at a much closer spacing.

RELATION TO OVERLYING SEDIMENTS

Nearly all the type 1 deposits are overlain unconformably by silty to sandy carbonaceous clay and brown or light-gray to white micaceous sand of the Saline formation. Tongues of bauxite and clay are interbedded with these sediments adjacent to bauxite deposits. The sediments normally have a flatter dip than the surface of the bauxite deposits and pinch out against them.

RELATION TO OTHER TYPES OF DEPOSITS

Throughout large areas the basal bed of the Saline formation is a conglomerate of bauxite boulders in a bauxite or clay matrix. Downslope the clay matrix commonly is carbonaceous. These rubble beds of bauxite in the basal Saline are described in more detail under type 4 deposits, on page 133. In places they merge downward into type 1 deposits so gradually that it is impossible to detect any boundary between the two.

Patches of granitic-textured bauxite in place beneath the fragmental kaolinitic underclay of type 2 deposits were noted in the Rummel and Alford ore bodies in Pulaski County and the Harris ore body in Saline County. Similar granitic-textured bauxite patches and kaolinitic decomposition boulders merged with pisolitic bauxite beneath the upslope part of type 2 deposits in the Rauch Estate and Rauch Owned mines in Pulaski County and in the Elrod mine in Saline County.

MINES

Type 1 deposits have provided all or most of the ore extracted in the following mines: African Camp, Alexander Hill, Annie, Bertha, Bertha Extension, Cargill group, Cleveland, Cleveland-Evans, Davis, Ella, Globe 28, Granite Branch, Johnson, Julia, Lantz, Lone 7th, Maggie, Martin group, Mary, Maud group, Mine 14, Mittie, Neilson, Norton, Old Globe, Ozark 24, Ozark 28, Pruden, Pruden Extension, Section 10, Section 14, Section 15, Section 16, Section 26, Smith, Spring Hill, Steam Shovel, Stringtown, Tank and Washer, all in Saline County.

TYPE 2. DEPOSITS IN THE BAUXITE-KAOLIN FACIES OF THE BERGER FORMATION

DISTRIBUTION

Type 2 deposits flank the Pulaski, Bryant, and Saline nepheline syenite hills. The locus of their distribution is the buried upslope edge of the marine sediments of the Midway group where they thin out against hills of igneous rock (pl. 7). From this sinuous line encircling the hills the deposits extend downslope across the Midway surface as much as a mile in Saline County and as much as three-eighths of a mile in Pulaski County. They extend up the weathered nepheline syenite surface to the upper edge of the Berger formation, of which the bauxite bodies and their associated kaolinitic clay deposits constitute an apron-like local facies adjacent to the nepheline syenite rocks.

UNDERLYING ROCKS

The deposits and their enclosing kaolinitic envelope lie on the unevenly weathered kaolinitic surface of the nepheline syenite and included pendant rocks; on the Wills Point formation; and in a few places on shoreward beds of the Kincaid formation where the Wills Point is absent above it, either owing to erosion before deposition of the Berger, or possibly because of nondeposition.

RANGE IN ALTITUDE

In Pulaski County, bauxite in type 2 deposits is found throughout a vertical range of about 355 feet. Outcrops adjacent to the principal pit mines reach altitudes between 280 and 295 feet. The altitude of the deposits decreases in a south-southeasterly direction in accordance with the regional dip of the Berger formation with which they are associated. The deepest bauxite, 60 feet below sea level, has been recorded in the Cole deposit, the southeasternmost in the Pulaski district.

In Saline County the deposits have a vertical range of 620 feet. The Harris, Hardy, and Elrod ore bodies along the northwest slope of the Bryant nepheline syenite hill, in places reach an altitude that ranges from 360 to 380 feet above sea level. At the northwest end of the Saline nepheline syenite hill type 2 deposits, such as that worked in the Poodle mine, reach an altitude of about 300 feet. The deposits lie at progressively lower altitude south-southeastward as in Pulaski County. The deepest bauxite, 240 feet below sea level, has been recorded in the Long–Bell deposit, the southernmost known in the bauxite region.

SHAPE AND RELATION TO THE POST-MIDWAY EROSION SURFACE

All the deposits are lenticular and grade outward into kaolinitic clay. Their shape apparently depends upon the volume and grade of bauxitic colluvium that moved and accumulated downslope before and during their formation, upon the configuration of the subsurface valleys in which the material was deposited, and upon the amount of active fluviatile erosion during transportion and deposition. These factors are discussed in the section on origin. In some broad, shallow subsurface valleys the deposits are laterally and irreg-

ularly elongate and form a continuous blanket along the slopes and minor tributary valleys. Examples are the Ratcliffe deposit in Pulaski County and the Harris and East Bauxite deposits in Saline County. Those flanking the northwest side of the Bryant hill and the west side of the Saline dome are continuous along the slopes for more than a mile. In all these deposits the colluvial detritus that accumulated originally probably contained a considerable amount of high-grade bauxite deposited by mass wasting, perhaps in part by mudflow, from type 1 deposits on the higher slopes.

In long, narrow tributary valleys the bauxite deposits are elongate and lobate in plan along the sides of the valleys, their long axis almost parallel to the trend of the valley. Plate 25 shows a group of deposits of this type in secs. 16 and 21, T. 1 S., R. 12 W., Pulaski County. The centers of the valleys usually do not contain minable bauxite. A few of the smaller valleys are filled with bauxite and centers of the wider valleys are filled with kaolinitic clay that contains scattered fragments of bauxite and kaolin.

The stripped surface of a type 2 deposit, in the Section 35 mine, Saline County, is shown in figure 61. These bauxite bodies do not have as steep surface slopes as some of the type 1 deposits. In many type 2 deposits the upslope parts dip from 4°–6° toward the valley. Dips of more than 8° are rare but have been recorded in several Pulaski County bodies. A maximum dip of 8° was noted in the upslope part of the deposit underlying the Confederate Home property at Sweet Home, one of 9° in the E. A. Dixon deposit; 11° in the South Heckler deposit, and 11½° in the Harrison deposit; the last three mentioned are all in the Jennings Lake area. These dips are controlled by steep slopes on the underlying post-Midway erosion surface.

THICKNESS

Bauxite of minable grade in type 2 deposits commonly reaches 20, but rarely exceeds 30 feet in thickness. The average thickness of minable bauxite in these bodies is generally between 12 and 14 feet. The greatest thickness recorded by the Federal drilling program in a type 2 deposit was 43 feet of bauxite averaging 43.7 percent available alumina, in the East Bauxite deposit in Saline County. Greater thicknesses have been reported in some company drill holes, for example: 62 feet that averaged 45.5 percent of available alumina in a drill hole in the Dixie No. 2 mine, Pulaski County; and 48 feet of bauxite that bottomed in ore and averaged more than 53 percent available alumina in an Alcoa drill hole in sec. 20, T. 2 S., R. 14 W., Saline County. In these cored sections, it is not known whether all or only part of the bauxite belongs to a type 2 deposit. The section in the Dixie drill hole almost certainly contains bauxite of alluvial deposition in the upper part, as stratified bauxite has been recorded from nearby parts of the same mine.

BAUXITE-KAOLIN FACIES IN CROSS SECTION

The bauxite-kaolin facies in vertical section includes all the rock lying between the post-Midway erosion surface below, and the overlying clastic and carbonaceous beds of the Wilcox group. The upper surface is irregular because the Wilcox sediments tongue into the upper part of the bauxite-kaolin facies at a low angle. A typical vertical section through a type 2 deposit includes three principal lithologic units: a kaolinitic

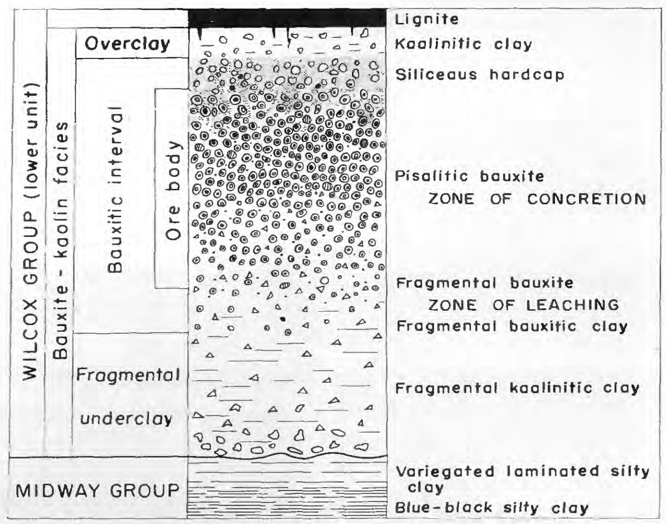


FIGURE 49.—Diagrammatic section of a type 2 deposit.

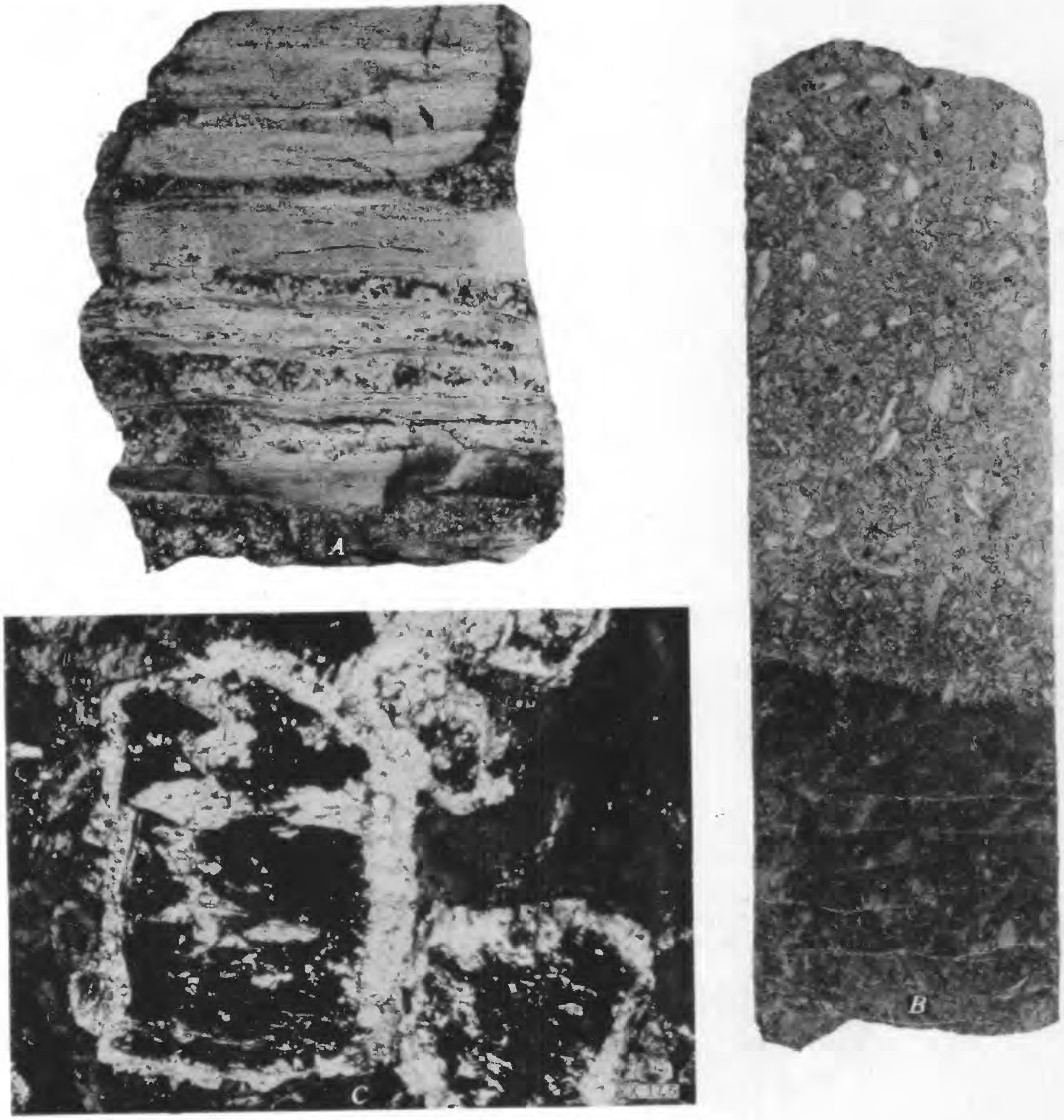
EXPLANATION OF PLATE 9

FRESH AND WEATHERED IGNEOUS ROCKS

A, Gray fine-grained feldspathic rock cut by parallel veins of coarse gray quartz syenite. An original shale of Paleozoic age apparently has been altered to feldspar and biotite. Hand specimen from an outcrop near Bauxite, Saline County. Natural size.

B, Pulaskite, showing the effects of early Tertiary weathering. The rock is dark gray and fresh below, light gray and kaolinitic above. Sawed face of core specimen (AB–1136–1) from USBM drill hole 1136, depth 287 feet, F. T. Sipes property, near the NE cor. sec. 15, T. 1 S., R. 12 W., Pulaski County.

C, Photomicrograph showing details of kaolinization of rock in figure *B*. Whitish areas are remnants of unaltered feldspars; dark-gray areas within these are largely kaolinite; outside are mostly feldspar; black areas are holes in thin section. Weathering emphasizes zonation of feldspars. Crossed nicols.



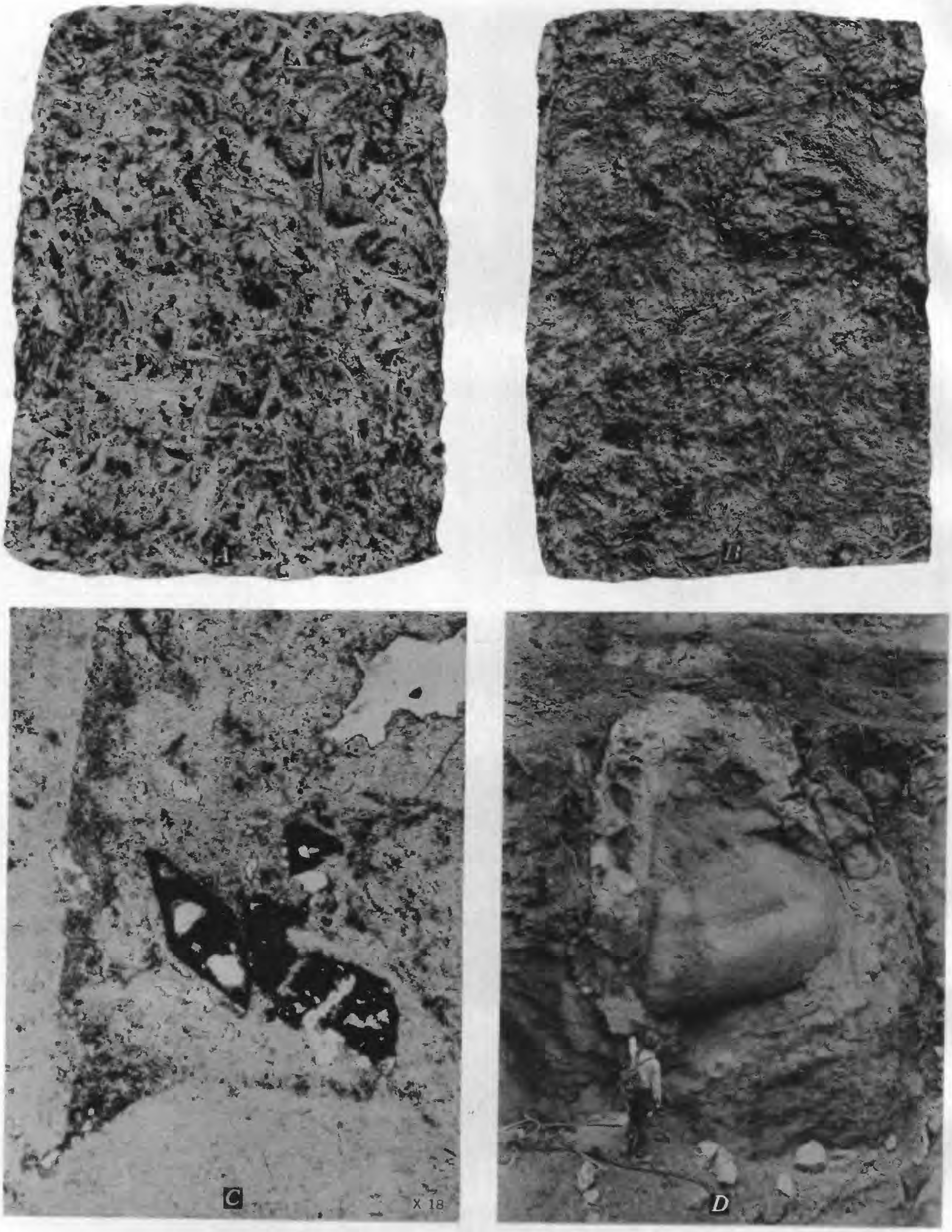

C
X 18
D

PLATE 10

NEPHELINE SYENITE AND GRANITIC-TEXTURED BAUXITE

A, Gray nepheline syenite showing typical arrangement of white feldspar laths. Hand specimen (AB–201–1) from quarry on east side of Arch Street Pike in the NE¼ sec. 28, about 3 miles south of Little Rock. Natural size.

B, Tan porous granitic-textured bauxite ("sponge ore") derived from a coarsely crystalline variety of nepheline syenite and still retaining relict texture of parent rock. Hand specimen (AB–72–1) from west part of Section 15 mine. Chemical analysis given on page 110. Natural size.

C, Photomicrograph showing anatase pseudomorphous after sphene in granitic-textured bauxite. Anatase appears black in the photograph. Most of the granular material is microcrystalline gibbsite which also lines cavities in the titaniferous crystals. Gibbsite pseudomorphous after feldspar appears at bottom and left edges of the photograph. Darker areas are iron stained; lightest areas are holes in the section. Thin section (AB–80–3) from specimen shown in figure 14 and plate 11*D*. × 18

D, Large kaolinitic decomposition boulder in the Section 26 mine. Inner part of kaolinized nepheline syenite in concentric shells, one of which forms rounded smooth surface at center, is surrounded by a light-colored layer of kaolinized bauxite and kaolinitic clay. Contact with darker bauxite outside is somewhat abrupt and marked by a narrow (very dark) limonitic layer.

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PLATE 11

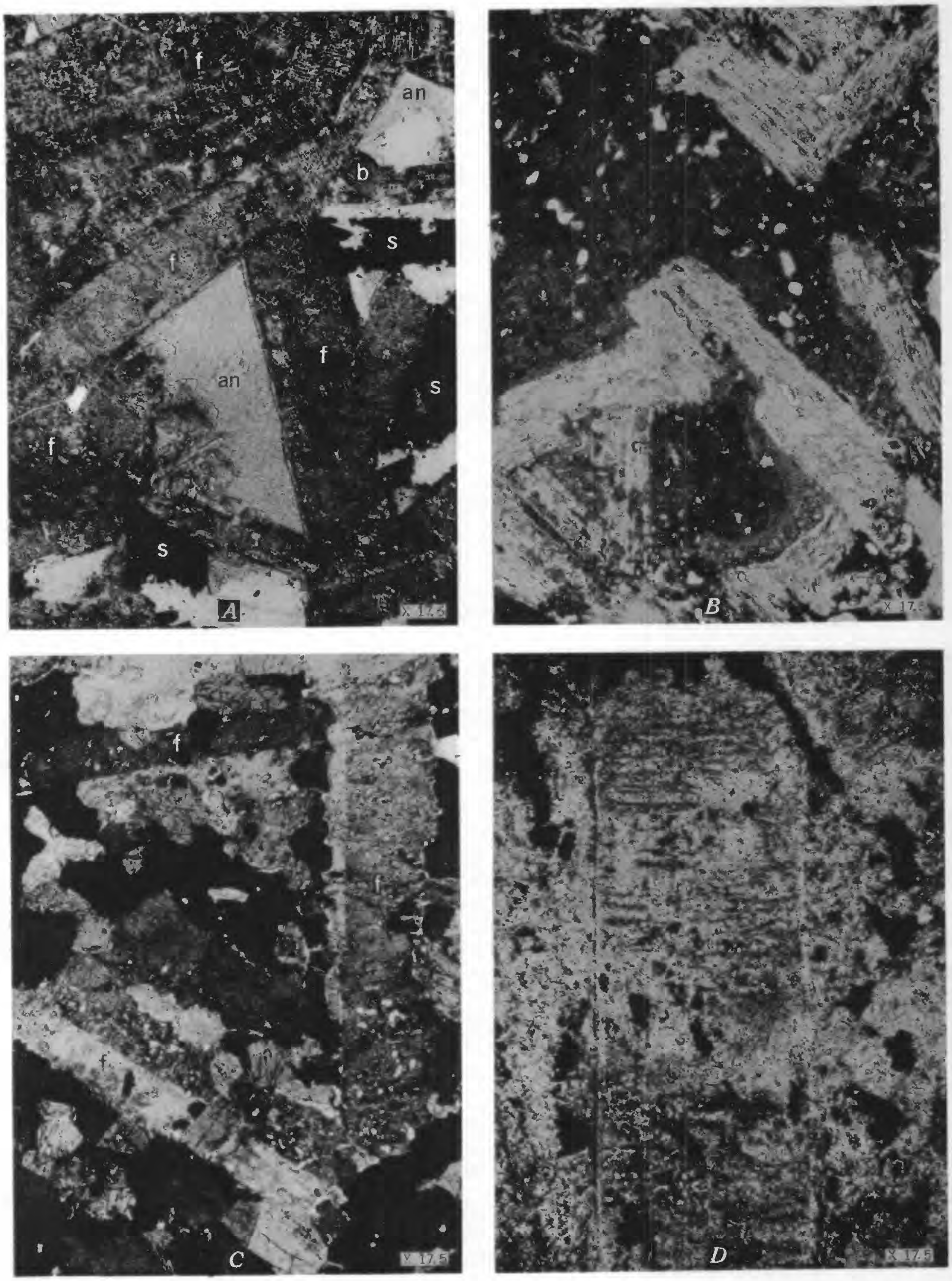
PHOTOMICROGRAPHS OF NEPHELINE SYENITE AND GRANITIC-TEXTURED BAUXITE

A, Gray nepheline syenite. Thin section showing nearly opaque laths of microperthitic feldspar (*f*) enclosing translucent wedge-shaped bodies of analcine (*an*) that have replaced nepheline, and scattered crystals of biotite (*b*) and sphene (*s*), partly torn in sectioning; lightest areas are holes in slide. Chip sample (AB–201–11b) from quarry on Arch Street Pike, 3 miles south of Little Rock, Pulaski County. Chemical analysis on page 61; spectographic determination given on page 61. × 17.5

B, Tan granitic-textured bauxite. Thin section (AB–111–2) from specimen showing light-gray translucent areas of microcrystalline gibbsite that have replaced feldspar laths; dark nearly opaque areas of cryptocrystalline gibbsite stained with iron oxides; and white pore spaces. × 17.5

C, Gray coarse porphyritic nepheline syenite. Thin section showing large microperthitic feldspar cysytals (*f*) full of small inclusions in a coarse ground-mass predominantly of orthoclase, together with nepheline and small amounts of sodic plagioclase, aegerine, sphene, and apatite. Chip sample (AB–310–1b) from road cut 0.6 mile east of Bauxite, Saline County. Crossed nicols. Chemical analysis given on page 61; spectrographic determination given on page 61. × 17.5

D, Feldspar lath replaced by microcrystalline gibbsite in granitic-textured bauxite. Both lath and groundmass are gibbsite; black areas are holes in rock. Note preservation of feldspar cleavage. Thin section from specimen (AB–80–3) shown in figure 14. Crossed nicols. × 17.5


f
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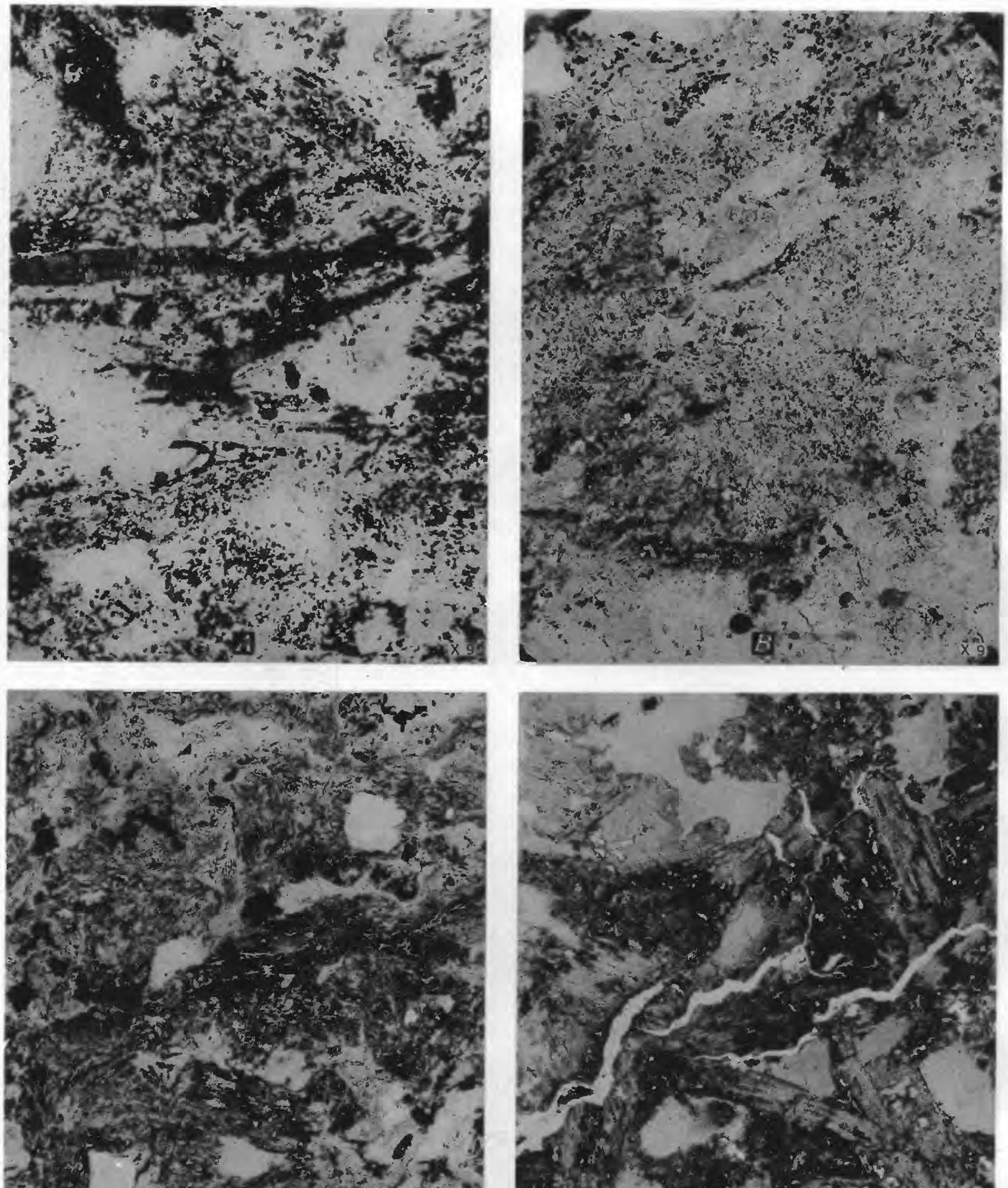
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PLATE 12

TYPE 1 DEPOSIT: PHOTOMICROGRAPHS OF THE ROCK SEQUENCE IN A KAOLINIZED DECOMPOSITION BOULDER

A, Partly kaolinized nepheline syenite at core. Lightest areas are kaolinitic masses; medium-gray areas are partly altered feldspar; scattered dark-gray grains and narrow wedges are siderite; black spots are anatase and possibly altered biotite. × 9.

B, Pseudofragmental kaolin near outer part of central core. The confused mass is composed almost entirely of kaolinite (light gray to gray) with some scattered siderite (dark gray) and blebs of anatase (black). × 9.

C, Gibbsitic rock 1 inch beyond that shown in the preceding figure. The rock is composed largely of gibbsite (fairly dark gray) which appears to have replaced feldspar laths, but the granitic texture has been disturbed and the bauxite distorted by flowage. Kaolinite (light gray) fills the pore spaces and locally replaces the gibbsite. Black spots are anatase and opaque iron and titanium minerals. × 9.

D, Granitic-textured bauxite with interspaces filled by kaolinite. In this specimen, collected 2 feet outside that shown in figure *C*, the relict granitic texture of the gibbsite pseudomorphous after feldspar is preserved almost intact. Medium-gray areas are gibbsite, darker where stained by ferric iron; light-gray material in cavities is kaolinite; white areas are cracks in section. × 9.

PLATE 13

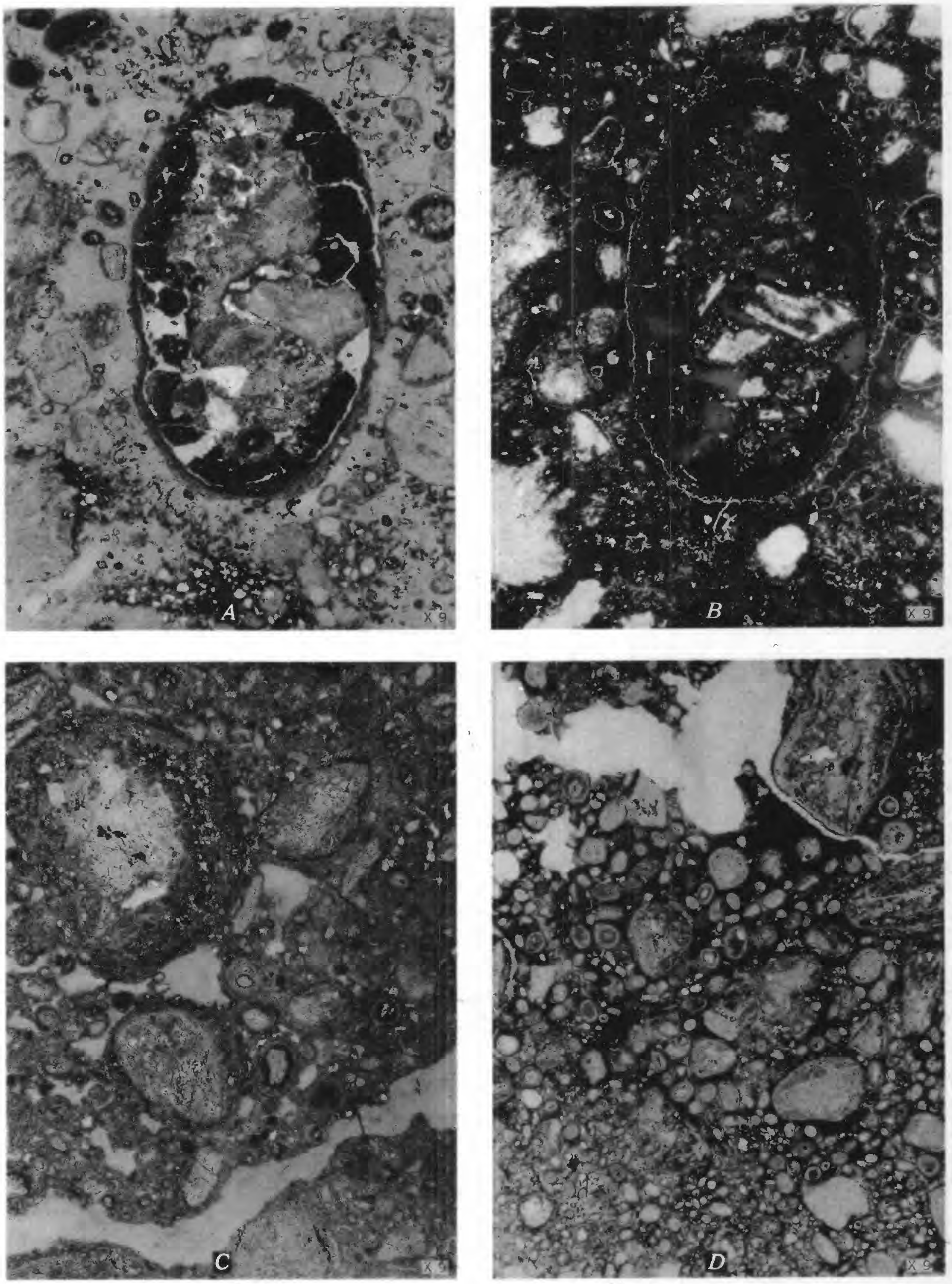
TYPE 1 DEPOSIT: PHOTOMICROGRAPHS OF THE ROCK SEQUENCE IN A KAOLINIZED DECOMPOSITION BOULDER—CONTINUED

A, Group of primitive pisolites in a matrix of secondary kaolinite. This section illustrates the formation of pisolites from granitic-textured bauxite by the envelopment by rind structures of fragments and masses of microcrystalline gibbsite. One large ellipsoid is composed of a conglomeration of bauxite fragments, oolites, and small pisolites. Many pisolites are cryptocrystalline and ferruginous (dark) toward the outer margin. The light-gray matrix is kaolinite. Note that kaolinite has not entered the large compound pisolite, which contains empty cracks and cavities (white). × 9.

B, Same section between crossed nicols. Microcrystalline gibbsite, and scales appear white; kaolinite, cryptocrystalline gibbsite, and iron-stained areas are dark. Note the layer of tiny gibbsite crystals that appear as a white thread around some pisolites. These crystals project outward into kaolinite masses. × 9.

C, Pisolitic bauxite containing cavities and cracks filled with kaolinite. In this section, collected still farther away from the core of the boulder, the concretionary bauxite structures are better developed than in the preceding thin section. More cryptocrystalline gibbsite is present. All pore spaces are filled with kaolinite (light gray). Because opposite sides of the large veinlet across the lower part of the photograph do not match, it seems likely that at least part of the kaolin was formed at the expense of bauxite by resilication and did not merely force the opposite sides of a crack apart, particularly as no bauxite fragments can be seen in the kaolin within the veinlet. × 9.

D, Pisolitic bauxite with ferruginous staining from the limonitic band surrounding the borderlike mass. The outermost specimen shows no secondary kaolinite. Pisolites and oolites are well developed; the cryptocrystalline form of gibbsite, much of it stained red by ferric iron, occupies interspaces, outer parts of pisolites, and entire oolites. × 9.


A
X 9
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X 9
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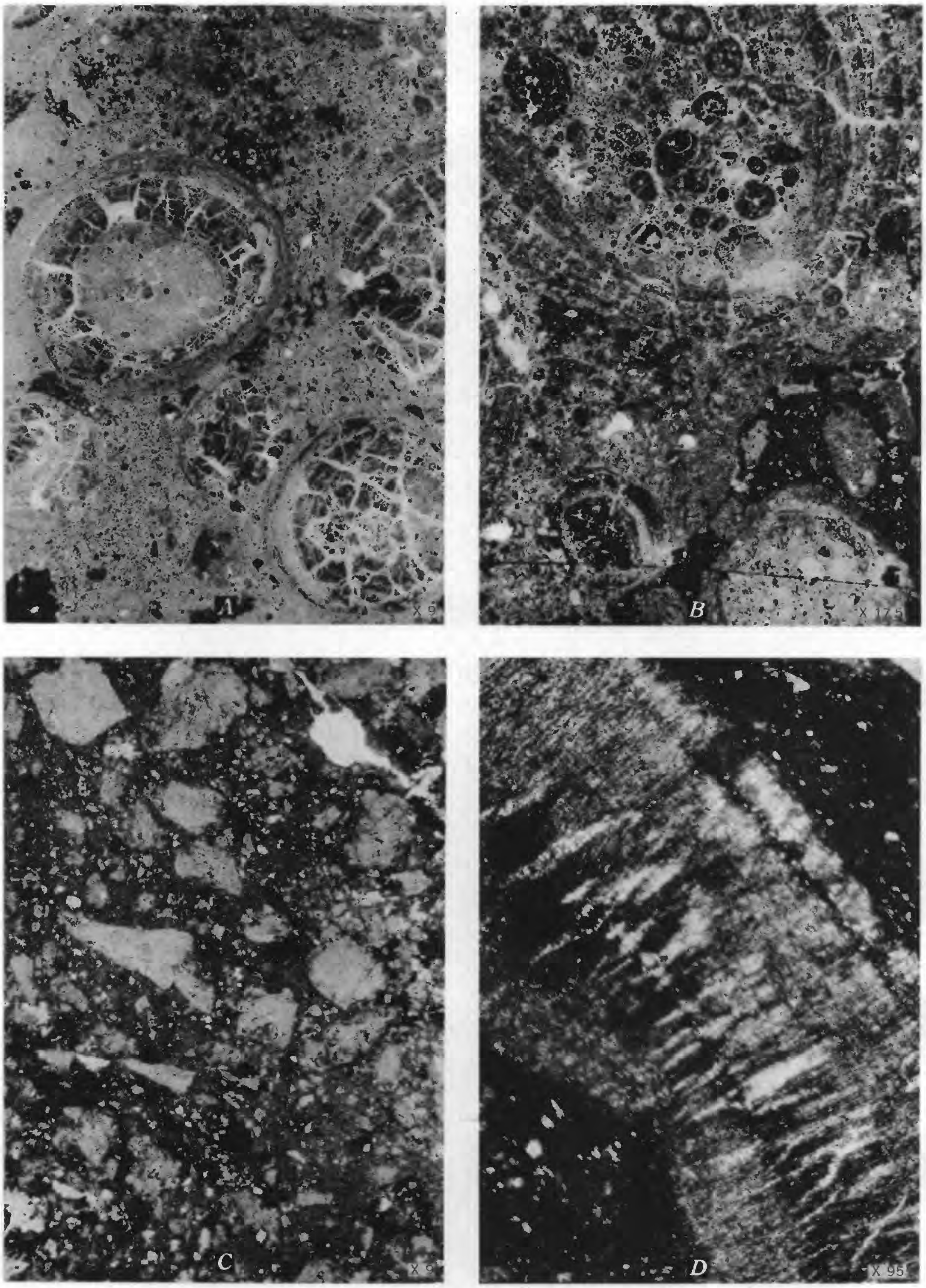
A
X 9
B
X 175
C
X 9
D
X 95

overclay that grades downward to the bauxitic material, which in turn overlies gradationally a fragmental kaolinitic underclay. Each of these units contains many different and characteristic rock types. The important ones are shown in the columnar section below (fig. 49).

The characteristics of bauxite deposits in the bauxite-kaolin facies of the Berger formation are well shown in the northern part of the Woodyardville area, in secs. 35 and 36, T. 1 N., R. 12 W., and secs. 1 and 2, T. 1 S., R. 12 W., Pulaski County. This area is considered the typical example for type 2 deposits because here many of the relationships were first determined. In it are the Cheatham, Dixon-Nelson, McClain-Burks-Nelson, Dixon, Vinson-Raines, and Woodyardville deposits, and the Dixon clay area which includes a small bauxite body known as the Vick deposit (pl. 17). This group of deposits is shown in the diagrammatic plan and cross sections on plate 15 in which the relations have been generalized. The descriptions that follow are characteristic of the bauxite-kaolin facies throughout the bauxite region.

The cross sections in plate 15 illustrate the normal distribution of bauxite and kaolinitic clay in valleys which drain the lower slopes of the nepheline syenite and the fringing Midway sediments. The bauxite deposits normally are located on the slopes at either side of the valley and die out toward the valley centers. Fragmental clayey detritus fills the centers of valleys, in places to a depth of 60 feet. Similar fragmental kaolinitic clay beneath the bauxite deposits usually ranges from 10 to 20 feet in thickness, but reaches a maximum of 30 feet.

Chemical zonation of the bauxite deposits from low silica at the center to high silica at the margin, corresponds to the lithologic gradation from bauxite to kaolinitic clay. The lowest silica content generally occurs in the middle or lower part of the pisolitic bauxite. This chemical zonation, however, does not coincide exactly with lithologic zonation, but generally cuts it at a low angle. The slight divergence between the two is shown in the three diagrammatic cross sections in plate 15. This divergence is most apparent in the upslope part of the pisolitic bauxite, which normally terminates in a low-grade siliceous bauxite or hardcap.

A moderate disparity in chemical composition exists between rocks of the same type from two deposits, even where lithologic specimens from the two localities appear identical. The difference in large part is due to secondary introduction of silica and ferrous iron oxide after the bauxite had formed, which has partly changed the chemical composition without materially altering the appearance of the rock, except for subtle differences in color. Chemical analyses, for this reason, are indispensible in determining grade of ore.

Vertical distribution of rock types in a normal type 2 deposit, and comparison of descriptive terms based on lithologic and chemical criteria

Lithologic		Chemical		Available alumina (percent)
Kaolinitic overclay		Kaolinitic clay		0
Hardcap	Bauxitic clay	Bauxitic clay		<24
		High silica bauxite		24-32
Pisolitic bauxite		Bauxite	High iron bauxite and bauxitic clay	>32
Fragmental, oolitic, or textureless bauxite		High silica bauxite		24-32
Fragmental, oolitic, or textureless bauxitic clay		Bauxitic clay		<24
Fragmental kaolinitic underclay Fragments coarse at base		Kaolinitic clay		0

Classification of rocks from the bauxite-kaolin facies according to their chemical composition, therefore will not necessarily agree with a classification on a lithologic

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EXPLANATION OF PLATE 14

TYPE 2 DEPOSIT: PHOTOMICROGRAPHS OF PISOLITIC BAUXITE AND FRAGMENTAL BAUXITE AND CLAY

A, Simple pisolites, entire and fragmentary. Brown pisolites in a tan bauxite matrix. Networks of cracks in the pisolites are best developed in the parts composed of concentric layers. Note the two small remnant segments of pisolites at lower center and left. Thin section (AB–16050–1) from core specimen. × 9.

B, Compound pisolite. Bauxite oolites in the interior of a large pisolite and the surrounding accretionary layers of the rind cut by a network of cracks are shown. The brownish cryptocrystalline gibbsite matrix has opaque areas, probably largely of iron oxides. Thin section (AB–17132–1) of specimen from Ratcliffe mine in Pulaski County. × 17.5.

C, Fragmental bauxite. Grayish-tan translucent bauxite fragments composed of microcrystalline gibbsite in a darker tan to brown iron-stained gibbsitic matrix. Scattered black areas are mostly iron oxides surrounding siderite grains; white areas are holes in the slide. Thin section (AB–7162B–1) from below pisolitic bauxite in USBM drill hole 7–162B, depth 116.5 feet, in the Finnegan deposit, Pulaski County. × 9.

D, Gibbsite replacing part of a kaolinite crystal in fragmental underclay. A large gray accordionlike cleavage book of kaolinite lies in surrounding darker appearing kaolinitic matrix. Tiny whitish gibbsite crystals line cavities between cleavage plates and stringy bodies of gibbsite ramify through central part of crystal. Thin section (AB–16052–5) from core specimen in figure 50*F*. Crossed nicols. × 95.

basis. Normal discrepancies between the lithologic and chemical classifications in a vertical section through a type 2 bauxite deposit are shown in the preceding table. Boundaries between the chemical and lithologic units are gradational, although lines are used to separate them in the columns of the table.

The chemical classification in the table is based on the proportion of silica to alumina, modified by the amount of impurities, and expressed as available alumina. The cutoffs are the same as those given earlier, in the section on classification of Arkansas bauxite. High-iron bauxite appears where introduction of secondary siderite has modified the grade in the middle and lower parts of the bauxite and bauxitic clay.

In order to permit a comparison of chemical analyses with careful lithologic descriptions, selected partial logs of several drill holes in type 2 deposits, in Pulaski and Saline Counties, are shown below.

Partial log of USBM drill hole 9–046. NE¼NW¼ sec. 36, T. 1 S., R. 14 W.

[Altitude at collar, 521.4 feet]

Depth (feet)	Lithologic description	Analyses (percent)						
		Al_2O_3	SiO_2	Fe as Fe_2O_3	TiO_2	Ignition loss	Insoluble	FeO
	Berger formation (bauxite-kaolin zone):							
205. 9–206. 4	Kaolinitic clay, light-creamy gray, containing lighter colored vertically elongate fragments and carbonaceous flecks; a few pisolites at base	38. 3	42. 8	2. 0	1. 6	14. 4	0. 9	0. 5
206. 4–207. 4	Pisolitic bauxite hardcap; matrix, light-creamy gray; pisolites gray, soft, forming 15 to 20 percent of rock	46. 0	28. 7	1. 4	2. 6	20. 6	. 7	. 4
207. 4–208. 4	Pisolitic bauxite, grayish tan, hard; pisolites gray and tan, with same hardness as matrix; scattered patches of kaolinite	52. 4	17. 6	1. 7	2. 2	25. 2	. 9	. 2
208. 4–209. 4	Pisolitic bauxite, grayish tan, hard, as above, scattered kaolinite and pyrite patches	52. 9	14. 0	2. 2	2. 2	26. 1	2. 6	. 4
209. 4–211. 4	Pisolitic bauxite, tan, fairly hard, locally mealy; pisolites break with and from matrix and constitute 40 percent of rock; scattered pyrite crystals	56. 0	9. 3	2. 4	2. 4	28. 4	1. 5	. 3
211. 4–213. 4	Pisolitic bauxite, tan, as above	57. 8	5. 9	2. 6	2. 4	30. 1	1. 2	. 5
213. 4–215. 4	Pisolitic bauxite; gray, tan, and reddish-brown pisolites in a soft tan porous matrix; locally matrix-free; a few large orange bauxite fragments	59. 3	3. 7	1. 5	2. 8	31. 7	1. 0	. 5
215. 4–217. 2	Pisolitic bauxite, as above, but crystalline siderite in cavities	50. 0	2. 6	11. 5	2. 8	30. 9	2. 2	9. 8
217. 2–219. 2	Pisolitic bauxite; hard tan matrix contains many cavities filled with crystalline siderite	49. 1	2. 8	13. 0	2. 6	30. 7	1. 8	12. 3
219. 2–221. 2	Pisolitic bauxite; as above	42. 6	3. 6	19. 4	3. 1	30. 2	1. 1	18. 2
221. 2–223. 2	Pisolitic bauxite mottled tan and green, fairly soft; pisolites smaller than above	52. 0	4. 4	10. 7	2. 6	29. 5	. 8	8. 8
223. 2–227. 7	No recovery	-----	-----	-----	-----	-----	-----	-----
227. 7–229. 7	Pisolitic bauxite; rich tan hard matrix locally greenish; pisolites brown and gray, soft, some hollow inside, consists 15 to 20 percent of rock; sideritic	49. 2	5. 5	11. 9	3. 4	28. 2	1. 8	10. 2
229. 7–231. 7	Pisolitic bauxite; as above, but pisolites grading out at base	51. 8	5. 2	10. 8	2. 8	28. 8	. 6	10. 2
231. 7–232. 7	Bauxite, moderately hard; a few scattered oolites and fragments, siderite pellets common	53. 7	6. 5	8. 1	2. 4	28. 5	. 8	7. 4
232. 7–233. 7	Bauxite; as above	49. 7	12. 7	9. 2	3. 2	24. 5	. 7	7. 4
233. 7–235. 7	Bauxitic clay, mottled tan and bluish green; contains siderite pellets	44. 1	25. 6	8. 1	2. 6	18. 6	1. 0	6. 6
235. 7–238. 7	Kaolinitic clay, bluish green, with bauxitic clay and kaolin fragments, many siderite pellets and grains	40. 3	26. 0	11. 3	3. 4	16. 6	2. 4	9. 3
238. 7–240. 7	Kaolinitic clay, gray to reddish-brown, sideritic	38. 2	42. 4	4. 1	. 8	13. 5	1. 0	3. 7
	Basement rock:							
240. 7–249. 5	Kaolinitic clay, residually derived from nepheline syenite	36. 4	41. 6	5. 0	1. 0	12. 1	3. 9	3. 9

Partial log of USBM drill hole 19–192. NW¼NE¼ sec. 21, T. 1 S., R. 12 W., Pulaski County

[Altitude at collar, 342.6 feet]

Depth (feet)	Lithologic description	Al_2O_3	SiO_2	Fe as Fe_2O_3	TiO_2	Ignition loss	Insoluble	FeO
	Berger formation (bauxite-kaolin zone from 256.4 to 293.3 feet):							
251.9–256.4	Lignite, brownish black, hard, woody	(1)	(1)	------	------	------	------	------
256.4–258.1	Bauxitic clay, light creamy tan, pisolitic, soft; pisolites are white with black rinds, dark gray with white rims, or rarely black; scattered tan bauxite fragments; lignite fragments at top	41.9	36.2	1.8	2.5	16.8	0.8	0.5
258.1–260.0	Pisolitic bauxitic clay, grayish tan as above, scattered large pisolites and pebbles; pisolites abundant and look like those above, but many have gray semiliquid centers; matrix creamy, oolitic; kaolin veining	47.4	27.5	1.2	2.3	20.5	1.1	.5
260.0–260.6	Siliceous pisolitic bauxite, gray; pisolites as above, but some have black and red cherty centers; numerous horizontal sheets of white kaolinite	51.6	19.1	1.5	2.8	24.3	.7	.6
260.6–262.3	Pisolitic bauxite, gray, hard; more red and black pisolites than above, some compound; kaolinite patches; a little crystalline siderite	54.4	12.4	2.2	3.3	27.2	.5	1.1
262.3–263.1	Pisolitic bauxite, tan firm; pisolites mostly red or black with tan rinds, a few compound; matrix softer than above, oolitic, sideritic; numerous cavities	55.8	6.7	4.0	3.3	29.4	.8	3.1
263.1–264.5	Pisolitic bauxite, as above	56.2	6.1	4.0	2.9	30.0	.8	2.9
264.5–265.1	Pisolitic bauxite, harder than above and more sideritic	54.6	5.8	5.9	3.0	29.7	1.0	4.6
265.1–267.1	Pisolitic bauxite, tan hard; pisolites abundant, average 6 mm. across, mostly dark gray to black, lighter outward, with thin tan rinds; matrix oolitic, cavernous, with siderite in brown grains and oolites	51.6	3.8	10.2	3.1	30.4	.9	8.7
267.1–269.1	Pisolitic bauxite, as above	52.1	4.5	9.4	2.9	30.3	.8	8.2
269.1–271.1	Pisolitic bauxite, tan hard; pisolites gray to bluish, mostly hard but a few soft, 4 to 6 mm. across, comprising 25 to 35 percent of the rock; matrix tan to pinkish, with scattered kaolinite and rusty patches	54.6	3.9	7.2	3.0	30.4	.9	6.1
271.1–272.9	Pisolitic bauxite, as above	54.7	4.4	6.7	3.1	30.3	.8	5.7
272.9–274.7	Pisolitic bauxite, as above, but pisolites large, hard and brownish black to dark gray; much brown crystalline siderite at 274.2	45.1	3.3	18.0	3.0	29.8	.8	15.2
274.7–276.6	Bauxite, pinkish buff, soft, clayey or mealy; pisolites few, poorly formed with soft to liquid gray centers; white kaolinite streaks	47.7	4.9	13.5	3.3	29.7	.9	11.2
276.6–277.6	Bauxitic clay, light buff to grayish downward, firm, locally sideritic; sporadic large gray soft pisolites	39.0	21.4	13.6	3.0	21.8	1.2	11.7
277.6–278.6	Kaolinitic clay, tannish gray, firm; siderite pellets common	30.4	31.7	16.3	2.7	17.9	1.0	14.7
278.6–280.6	Kaolinitic clay, light gray to white, firm, sideritic	28.1	30.0	20.0	2.6	18.2	1.1	16.8
280.6–282.6	Kaolinitic clay, mottled reddish brown and gray; siderite in scattered tan pellets	29.8	33.0	17.4	2.3	16.6	.9	13.1
282.6–287.5	Kaolinitic clay, mottled, as above	29.5	32.0	18.9	2.0	16.2	1.4	14.9
287.5–288.5	do	26.9	31.5	21.7	1.9	16.9	1.1	18.7
288.5–292.3	Kaolinitic clay, gray, faintly mottled with reddish-brown, firm, semiplastic to plastic, highly sideritic	28.5	32.4	19.6	1.8	16.2	1.5	17.3
292.3–293.3	Siderite layer, varicolored with merging tan, purple, red and gray; hard, dense, oolitic	(1)	(1)	------	------	------	------	------
	Wills Point formation:							
293.3–295.3	Silty clay, mottled red and gray, plastic	36.3	49.4	4.8	.6	7.5	1.4	.3
295.3–296.2	Silty clay, horizontally banded khaki-colored and gray; grayer downward; boundary vague	22.5	63.2	2.9	.6	7.8	3.0	.4
296.2–299.5	Silty clay, black, with numerous angular white fragments of kaolinized feldspar	22.2	55.0	4.5	1.5	7.7	9.1	.5
299.5–300.3	Silty clay, khaki-colored and gray, fragmental; mixture of silty clay and decomposed nepheline syenite fragments	22.3	49.3	2.5	2.1	7.5	16.3	.6
300.3–301.3	Fragmental clay debris; gray silty clay and decomposed nepheline syenite fragments	(1)	(1)					
301.3–303.7	Fragmental clay debris, as above; grades downward	------	------	------	------	------	------	------
	Kincaid(?) formation:							
303.7–306.9	Fragmental nepheline syenite debris; partly decomposed feldspar fragments, white rounded clay balls, and many large siderite pellets	------	------	------	------	------	------	------

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[1] Not analyzed.

The minor elements in the bauxite, hardcap, and kaolinitic underclay have been determined by spectrographic methods in a few samples. Those from type 2 deposits are tabulated below. The minor elements have been discussed earlier, in the section on the chemical constituents of Arkansas bauxite.

Spectrographic determination of minor elements in bauxite and clay samples from type 2 deposits, in percent

[Analyst, K. J. Murata]

Element	1	2	3	4	5	6	7
	Bauxite	Hard-cap	Bauxite	Hard-cap	Bauxite	Under-clay	Under-clay
Ti	0.9	1.5	1.0	1.2	1.0	0.7	1.4
Mn	.2	.01	.1	.2	.08	.2	.4
Zr	.1	.08	.1	.2	.09	.08	.2
Ca	.1	.1	.1	.1	.1	.1	.08
Mg	.06	.04	.04	.02	.05	.1	.04
Nb	.03	.02	.04	.07	.05	.04	.1
Y	.04	.02	.01	.02	.02	.009	.02
Sr	.003	.02	.004	.008	.002	.004	.03
Cr	.01	.02	.006	.003	.006	.007	.01
La	--------	.007	--------	.02	--------	.01	.03
V	.009	.01	.005	.005	.007	.01	.008
Ga	.009	.004	.005	.007	.005	.006	.006
Ba	.01	.004	.001	.001	.0009	.002	.002
B	.004	.003	.003	.002	.003	.003	.002
Pb	--------	--------	--------	.007	--------	.001	.003
Cu	.002	.002	.002	--------	.002	.002	.003
Mo	--------	--------	.003	.004	.004	--------	--------
Sc	.0009	.0009	.0007	.0004	.0007	.0009	.0007
Be	--------	.0002	--------	.0002	--------	--------	--------

Looked for but not found: Sn, Ag, Bi, Sb, As, Tl, Ge, In, Co, Ni, Ta, and P.

1. Poorly pisolitic tan bauxite containing fine siderite (specimen AB-3019-1) from USBM drill hole 3-019, depth 267 feet, South Ironton deposit, W. A. Dreher property, in the NW¼SE¼ sec. 14, T. 1 S., R. 12 W., near Ironton, Pulaski County.
2. Pisolitic bauxite hardcap with liquid-filled pisolites (specimen AB-6127B-1) from USBM drill hole 6-127B, depth 278 feet, Bates deposit, in the NW¼NE¼ sec. 21, T. 1 S., R. 12 W., Pulaski County.
3. Tan pisolitic bauxite with crystalline siderite (specimen AB-16048-1) from USBM drill hole 16-048, depth 455.2 feet, East Bauxite deposit, International Paper Co. property, in the SE¼NW¼ sec. 31, T. 2 S., R. 13 W., Saline County.
4. Tannish-gray poorly pisolitic siliceous bauxite (specimen AB-16052-1) from USBM drill hole 16-052, depth 451.9 to 452.2 feet, East Bauxite deposit, International Paper Co. property, in the SW¼NW¼ sec. 31, T. 2 S., R. 13 W., Saline County.
5. Poorly pisolitic light tan bauxite containing siderite and chlorite (specimen AB-16052-2) from USBM drill hole 16-052, depth 473.0 to 473.1 feet.
6. Tannish-gray bauxitic underclay (specimen AB-16052-3) from USBM drill hole 16-052, depth 480.5 to 480.6 feet.
7. Dark-brownish-gray fragmental kaolinitic underclay (specimen AB-16052-5; fig. 50*F*) from USBM drill hole 16-052, depth 488 feet.

The principal lithologic subdivisions of the bauxite-kaolin facies are discussed in more detail on the pages that follow.

FRAGMENTAL UNDERCLAY

Most of the clay below the bauxite and in the valley centers has a gray kaolinitic matrix of fine clay- to silt-sized particles. It contains a jumble of fragments of white or light gray kaolin, light tan to reddish bauxitic clay and bauxite, and grains of other altered and detrital minerals, and siderite pellets. Most of the fragments range from 0.5 to 10 millimeters in diameter, but some are several centimeters across. They usually are subangular, but a few are well rounded and have polished surfaces. In the lower part of the unit, the fragments have a notable parallel alinement at most localities.

A small part of the detrital material is from a recognizable source: dark-gray or greenish-gray fragments that preserve relict textures of the pendant rocks of Paleozoic age; hard white to pale-green bodies which apparently are kaolinized remnants of former cleavage fragments of feldspar; less altered feldspar grains; black metallic subhedral to euhedral grains, commonly 0.1 to 0.5 millimeters across, of ilmenite some of which X-ray analysis shows has partly altered to anatase, and less commonly to magnetite; and in some places, tan pseudomorphs of leuxocene (anatase) after sphene, as much as 5 millimeters long. Small carbonaceous flecks and wisps also are found locally.

At the base of the underclay large kaolinized fragments of the underlying rock are generally present. These include recognizable pieces of kaolinized nepheline syenite and of varicolored laminated clay from the upper part of the Wills Point formation. The heavy minerals, evenly scattered through the gray fragmental kaolinitic clay, are a little more concentrated at the base. The clay is stained and mottled irregularly a dull red to yellowish brown by iron oxides at and near the base. This mottling is common immediately overlying the laminated and stained top part of the Wills Point formation.

Bauxitic fragments are absent at the base of the fragmental clay. In the central parts of valleys where bauxite deposits do not occur, the bauxitic fragments usually are found about 10 feet above the base to well above the middle of the unit. In the upper third or quarter of the unit where the bauxite merges with kaolinitic overclay, the fragments cannot always be distinguished, but gibbsite in all but the top several feet of the section is indicated by chemical analyses. Where the fragmental clay underlies bauxite bodies, the clay grades upward without any visible break into bauxitic clay.

Small white, tan, or pink pellets and aggregates of siderite are scattered abundantly through the fragmental clay, particularly in the lower part. They are similar to those found in the kaolinitic clay derived in place from the nepheline syenite and from the Wills Point formation.

In thin section, many fragmental clay specimens are seen to consist of kaolinite in flakes, structureless masses, and groups of wormlike crystals. In some sections an iron-stained clay makes up the matrix in which the fragments are imbedded. The bauxite fragments are composed chiefly of microcrystalline gibbsite aggregates, in the upper parts of the underclay. Locally minute radiating crystal aggregates as well as single grains of siderite are scattered through some of the kaolinite masses. An accordionlike crystal of kaolinite contains spaces lined with minute gibbsite crystals and is cut by tiny threadlike gibbsite masses, that appear to have replaced part of the kaolinite (pl. 14*D*). A sawed face of the core of fragmental clay

(specimen AB–16052–5) from which it came is shown in figure 50*F*.

Also recognizable in some thin sections of fragmental clay are shale fragments, mica flakes, and decomposed feldspar crystals. The fragments have a nearly parallel orientation, particularly toward the base of the unit. Siderite pellets are spherulitic in structure and between crossed nicols show a well-defined spherulitic cross. Concentrations of siderite grains range from 0.01 to 1.0 millimeter in diameter. They are common along kaolinite veinlets that cut the clay matrix and fragments. Dark-brown irregular masses of leucoxene and iron oxides are common, as well as black opaque subhedral crystals of ilmenite, some of them skeletal.

In a few places upslope from the buried edge of the Midway sediments, the fragmental underclay contains tiny radiating aggregates of hydrous mica that have formed within some of the kaolinite masses. The hydrous mica was found in the fragmental clay near the base of the bauxite-kaolin facies in USBM drill hole 1–023, between the Dreher-Junkin-Herrod bauxite deposit and the nearby edge of the Midway sediments, in Pulaski County; also beneath the Grubbs-Hawkins deposit, Saline County, in Alcoa drill hole X–262 (fig. 5*D*). As this mineral is known elsewhere only in kaolinite fragments deposited within the Wills Point formation, or in kaolinized nepheline syenite immediately beneath the same formation, its presence in the lower part of the fragmental kaolinitic clay may indicate that some of the clay was formed and deposited during Wills Point time.

LITHOLOGIC CHARACTER OF BAUXITE INTERVAL

The bauxite deposits in the bauxite-kaolin facies can generally be separated into three lithologic zones from base to top and, to a lesser extent, from downslope to upslope end. The lower zone contains bauxite which is fragmental, sparsely oolitic, or claylike in texture; a middle concretionary zone contains pisolitic bauxite; and an upper zone, mainly restricted to the upslope part of the deposit, contains siliceous, indurated bauxite, in which crude, soft or hollow pisolites in places give the rock a vesicular appearance. This last, known as the hardcap, usually contains too much kaolinite to be used for ore; it is discussed in a separate section below. The distribution of the three lithologic types and their relation to the main chemical subdivisions based on silica content is shown in the three diagrammatic cross sections in plate 15.

The texture of the lowermost bauxite zone coincides with that of the underclay below it, and that of the kaolinitic clay at the same stratigraphic level a little downdip. If the clay nearby is fragmental, the bauxite also is fragmental; if the clay is almost textureless, so is the bauxite. The clay, however, is nowhere oolitic. Oolites are found generally in the upper part of this lowermost bauxite zone and continue upward into the matrix of the pisolitic bauxite. Beneath a part of the North Heckler deposit in Pulaski County, a pisolitic texture persists downward through the bauxitic clay into the upper part of the kaolinitic underclay.

Fragmental bauxite (pl. 14*C*) is dark tan to cream colored, and is of a mealy consistency. It contains bauxite and bauxitic clay fragments, 2–20 millimeters across, a little larger in average size than those in the clay surrounding the deposits. Large fragments of bauxite with distinguishable granitic or pisolitic textures are not uncommon. Fragments of gray kaolinitic clay are rare and usually are surrounded by a rind of soft tannish bauxitic clay.

In cross section this fragmental to textureless bauxitic zone is wedge shaped. Fragmental bauxite constitutes more than half the thickness of the ore, generally not more than 10 feet, in those parts of the deposits that lie toward the valley centers. It thickens downslope and grades toward the valley center into fragmental bauxitic clay. It thins upslope and grades into overlying bauxite. A complete gradation occurs downward through bauxitic clay to the fragmental underclay.

The zone of concretion in type 2 deposits is similar to that in type 1 deposits, but the differences are constant and distinct. Pisolites are smaller, generally ranging from 4 to 8 millimeters, and the red-stained matrix with vermicular structures of the type 1 deposits is lacking. In the lower part of the concretionary zone the pisolites are small, poorly formed, and sparsely scattered through the soft mealy tan matrix. These pisolites are soft and gray inside; many have viscous centers, bluish gray to bluish black, and have a high alumina content. The matrix, commonly oolitic, breaks away easily from the thin brittle rinds.

Upward the pisolites are larger harder, and more compact. They have a brown to gray subvitreous interior that breaks with a conchoidal fracture and they are surrounded by concentrically layered tan rinds. Mixed with the pisolites are sparse soft angular to subrounded fragments of bauxite and bauxitic or kaolinitic clay enclosed in concentrically banded rinds. The pisolites and pebblelike fragments are scattered through a matrix that is soft and mealy and light tan at the base, dark tan to brown in the upper part, and increasingly harder upward. In some deposits the pisolites in the central part of the concretionary zone are hard, almost vitreous, with red to black centers; locally they occur in loose aggregates. As a rule the silica content of the bauxite is lowest in the lower half of the concretionary zone, but commonly the ferrous iron content due to siderite is high there. Sawed sections of cores of

pisolitic bauxite from the concretionary zone are shown in the photographs in figures 16 and 50*D*.

In thin section most of the bauxite in type 2 deposits appears to be made up of the cryptocrystalline form of gibbsite, which is brownish and opaque in the matrix and in the fine-grained pisolites, and is dark between crossed nicols. Microcrystalline gibbsite showing moderate birefringence is limited to the network of cracks that cut the pisolites and parts of the matrix (pl. 14*A*, *B*) and to aggregates within sparsely scattered fragments enclosed in rinds and derived from the residual deposits upslope. A few of the fragments retain a granitic texture. The microcrystalline gibbsite aggregates are common in fragmental bauxite in the basal part of the deposits, but the enclosing bauxitic matrix appears isotropic between crossed nicols. Siderite is generally in groups of subhedral to anhedral grains filling cavities, or scattered through the matrix and, rarely, in the outer zones of pisolites. Kaolinite is rare in bauxite of ore grade and usually appears as contorted masses of fresh-looking wormlike crystals filling veinlets and cavities in the matrix. Cavities and pore spaces locally contain crystals of gibbsite, chlorite, pyrite, and siderite, usually in that order where they occur together. Dark-brown leucoxene (anatase) and black and brown opaque minerals, including ilmenite and ferric iron oxides, are scattered through the rock in specks, blebs, and small shapeless masses. The dark metallic minerals apparently are not as common as in the fragmental underclay, but the titania content is about the same.

Minerals that have been identified by means of X-ray examinations of pisolitic bauxite specimens from the East Bauxite deposit are given in the tabulation below.

Minerals identified by X-ray analysis in pisolitic bauxite from drill holes in the East Bauxite deposit

Analyst, J. M. Axelrod, Heavy-mineral separation and optical examination by M. L. Lindberg]

Minerals	1a	1b	2a	2b
	Light-medium	Heavy	Light	Heavy
Gibbsite	×	×	×	×
Chlorite	×	×	×	×
Siderite	×	×	×	×
Ilmenite	------	×	------	×
Anatase	×	×	------	×
Rutile	------	×	------	------
Zircon	------	×	------	×
Unidentified opaque minerals	------	×	------	×

1a. Pisolitic bauxite cut by a siderite vein (specimen AB-16048-1), from lower half of concretionary zone in USBM drill hole 16-048, depth 455.2 feet, about 200 feet *southwest of drill hole 16-050.* Bromoform floats and bromoform sinks; methylene iodide floats only.
1b. Same as sample 1a but methylene iodide sinks only.
2a. Pisolitic bauxite (specimen AB-16050-1; pl. 14*A*), from middle part of concretionary zone in USBM drill hole 16-050, depth 449 feet, near the center of the SE¼ NW¼ sec. 30, T. 2 S., R. 13 W., Saline County. Bromoform floats only.
2b. Same as sample 2a, but bromoform sinks only.

Near the top of the concretionary zone the pisolites are sparse and commonly have gray centers. Some have the interior filled with white kaolinite or are rimmed with this material. Kaolinite veinlets are common in the matrix between pisolites in the upper part of some deposits and in places form horizontal sheets (fig. 50*C*). There is a gradation upward within 1 or 2 feet, into a hardcap or through pisolitic bauxitic clay into a kaolinitic overclay, and an accompanying and exceedingly gradual color change from tan to light gray or nearly white. Chemical analyses of silica

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EXPLANATION FOR FIGURE 50

Core specimens of pisolitic and kaolinitic clay from type 2 deposits (natural size). *A*, Kaolinitic overclay. Sawed face of core specimen (AB-10148-1) from USBM drill hole 10-148, depth 152.1 feet, Lewis Treadway property, SE¼NE¼ sec. 8, T. 1 S., R. 12 W., near Berger, Pulaski County. Chemical analysis given on page 129. *B*, Hard pisolitic bauxitic clay. Matrix resembles hardcap and contains pisolites, many of which are hollow, giving the rock a vesicular aspect. Note halos around dark carbonaceous flects and some pisolites. Sawed face of core specimen (AB-18231-1), from the Brown deposit, USBM drill hole 18-231, depth 245.6 feet, NE¼SE¼ sec. 15, T. 1 S., R. 12 W., near Ironton, Pulaski County. Chemical analysis on page 128. X-ray determination of mineral constituents given on page 128. *C*, Veins of kaolinitic clay in hard brownish pisolitic rock. Note light diffusion zone of kaolinite surrounding veins, and local destruction of pisolitic texture within veins. Sawed face of core specimen (AB-612-1) from Alcoa drill hole C-612, depth 202.5 to 207.5 feet, NW¼NW¼ sec. 20, T. 2 S., R. 14 W., Saline County. *D*, Debris of whitish kaolinitic and grayish gibbsitic fragments on brownish-gray pisolitic bauxite. Bauxitic fragments above unconformity are composed of microcrystalline gibbsite; pisolitic bauxite below, mostly of cryptocrystalline gibbsite. "Available alumina" content is 18,2 percent in debris and 55.2 percent in pisolitic bauxite. Sawed face of core specimen (AB-16037B-1) from the East Bauxite deposit, USBM drill hole 16-037B, depth 380.2 feet, SE¼NE¼ sec. 36, T. 2 S., R. 14 W., Saline County. *E*, Gray fragmental underclay. Gray kaolinitic areas are slightly finer grained and more sideritic than white kaolinitic areas. Black dots are tiny siderite spherulites. Sawed face of core specimen (AB-262-1) from Alcoa drill hole X-262, depth 412 feet, NW¼SE¼ sec. 36, T. 2 S., R. 14 W., Saline County. *F*, Brownish-gray fragmental underclay composed mostly of kaolinite flakes and masses, and a small amount of gibbsite. Sawed face of core specimen (AB-16052-5) from USBM drill hole 16-052, depth 488 feet, East Bauxite deposit. See photomicrograph (pl. 14*D*) and spectrographic analysis (p. 124)

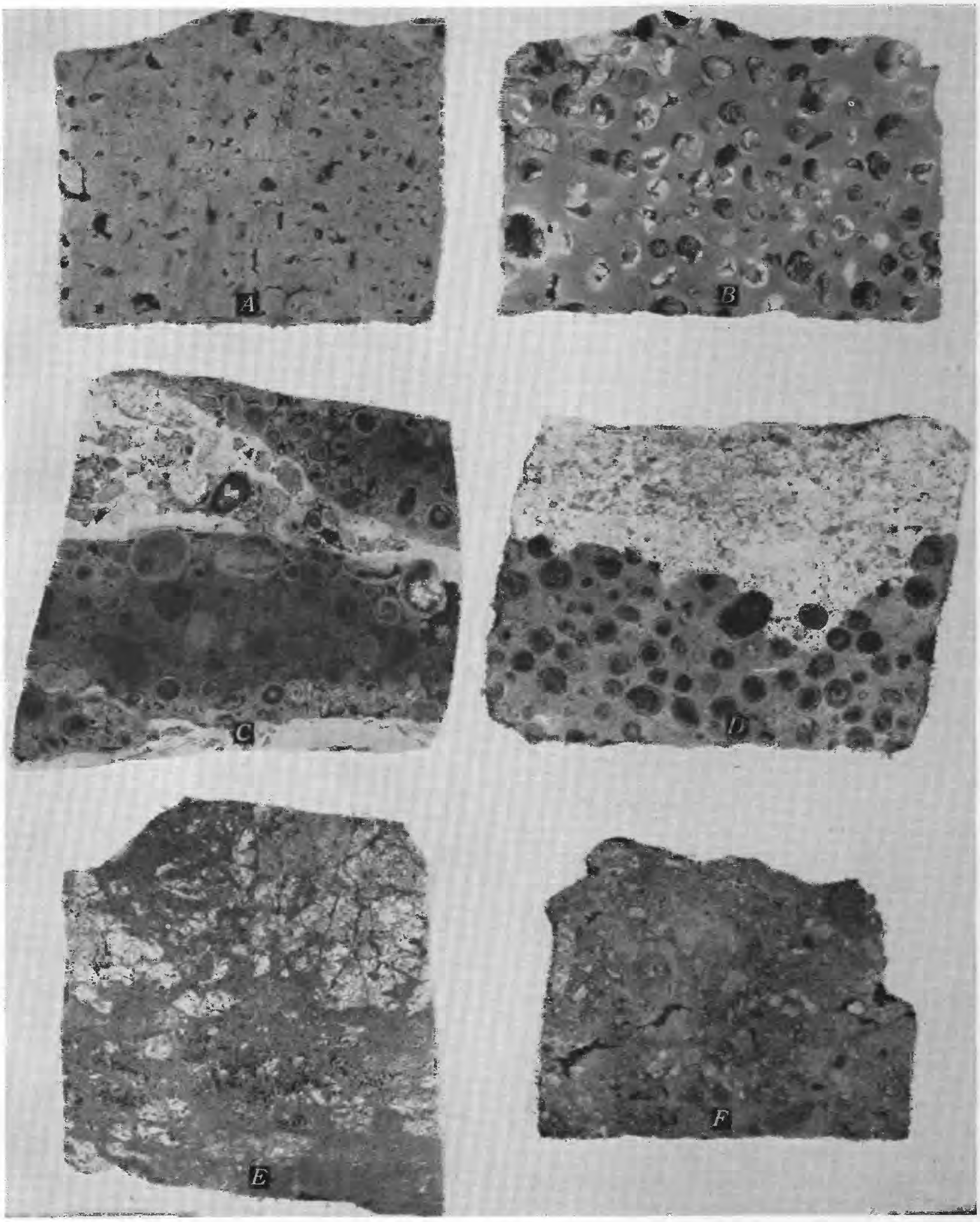

FIGURE 50.

content, however, show that the change is relatively abrupt.

Pisolitic bauxite constitutes more than 50 percent of type 2 deposits. In the middle and upslope parts of these deposits the pisolitic material is more than half the thickness of the ore. The thickest sections of ore in type 2 bodies are composed almost entirely of pisolitic bauxite. The bauxite in the concretionary zone thins downslope and toward the valley center. It grades upslope as well as upward into bauxitic clay.

HARDCAP

The pisolitic bauxite is overlain gradationally by bauxitic to kaolinitic clay. In places this material can be distinguished from pisolitic bauxite only by chemical analysis, but generally it has a pale-grayish washed-out color that contrasts with the rich tan of higher grade bauxite.

Along the upslope edges of most type 2 deposits, and covering the greater part of some of the deposits, the high-silica material that looks like bauxite is indurated and forms a resistant capping over the ore as much as 3 feet thick. If these ore bodies are stripped in preparation for mining it is necessary to remove this covering to reach the ore below. In underground mining, on the other hand, the hardcap forms an excellent roof.

In the most typical form of hardcap the matrix is hard and the pisolites soft. The matrix ranges in appearance from a dense, porcellaneous, cherty-looking material to a brittle gray clay. Most of the pisolites have soft interiors; commonly they are filled with a thick gray to dark-gray muddy fluid. The rinds are softer than the matrix, but are a little more firm than the centers. On drying, these pisolites commonly crack and disintegrate leaving cavities that give the rock a vesicular appearance. Fragments are rare in the hardcap and where present are usually large, well rounded, and polished. They consist of a hard, impervious material surrounded by a concretionary rind. Small smooth flat to round pebbles of microcrystalline gibbsite are scattered through the matrix.

The specimen in figure 50*B* from a drill hole in the Brown deposit has the typical vesicular appearance of much of the hardcap, although it came from just above a lignite layer in the middle of the bauxite-kaolin facies. Residues of pisolites that partly fill the cavities can be seen in the matrix. In another drill-core specimen from the top of the bauxite in the Bates deposit, the matrix has been entirely replaced by kaolinite but the pisolites appear intact and are composed of hard opaque gibbsite. The chemical analyses of cored specimens from which the two specimens were taken are as follows:

Chemical analyses of core specimens in Pulaski County drill holes from which hardcap specimens were taken

[Analyses, U. S. Bureau of Mines field laboratory at Little Rock, Ark.]

	Percent 1	Percent 2
Al_2O_3	44.1	44.2
SiO_2	31.4	16.9
Fe as Fe_2O_3	1.8	10.3
TiO_2	2.7	2.6
Ignition loss	19.3	25.2
Insoluble	.5	.8
FeO	.7	8.6

1. Pisolitic bauxite hardcap, from USBM drill hole 6–127B, depth 276.9 to 278.9 feet, Bates deposit, NW¼NE¼ sec. 21, T. 1 S., R. 12 W. (specimen AB–6127B–1).
2. Hardcap with bauxite pebbles, from USBM drill hole 18–231, depth 244.1 to 246.1 feet, Brown deposit, NE¼SE¼ sec. 15, T. 1 S., R. 12W. (specimen AB–18231–1; fig. 50*B*).

In thin sections cut where the pisolites are least altered, they appear much like those in the normal pisolitic bauxite—brown opaque bodies crossed by veinlets. Some of the veinlets contain microgranular gibbsite: others contain kaolinite. The centers of some of the pisolites are missing. Cavities also occur filled with kaolinite in structureless masses and tiny wormlike cleavage books, accompanied by small amounts of iron oxides, or pyrite. The matrix is a mixture of kaolinite and a fine-grained isotropic substance, presumably cryptocrystalline gibbsite. Tiny fragments of kaolinite cleavage books, oolitic bodies resembling the pisolites, and in places granular and angular fragments of finely crystalline gibbsite occur throughout the matrix. Small opaque areas probably are titanium and iron oxides, or pyrite.

The two illustrated hardcap specimens were submitted to optical and X-ray examination after heavy mineral and magnetic separations were made. X-ray analysis revealed the following mineral constituents.

Minerals identified by X-ray analysis in specimens of hardcap from Pulaski County

[Analyst, J. M. Axelrod, Heavy-mineral separations and optical examination by M. L. Lindberg]

Mineral	1a Light	1b Heavy	2a Medium	2b Heavy
Gibbsite	×	------	×	×
Kaolinite	×	------	×	------
Siderite	------	------	------	×
Pyrite	------	×	------	(?)
Ilmenite	------	×	------	×
Anatase	------	×	×	×
Rutile	------	×	------	------
Zircon	------	------	×	×
Unidentified black opaque minerals	------	------	×	×

1a. Pisolitic bauxite hardcap, from USBM drill hole 6–127B, depth 278 feet, Bates deposit, NW¼NE¼ sec. 21, T. 1 S., R. 12 W. (specimen AB–6127B–1). Bromoform floats only.
1b. Same as 1a, but methylene iodide sinks only.
2a. Hardcap with bauxite pebbles, from USBM drill hole 18–231, depth 245.6 feet, Brown deposit, NE¼SE¼ sec. 15, T. 1 S., R. 12 W. (specimen AB–18231–1; fig. 50*B*). Bromoform sinks, methylene iodide floats.
2b. Same as 2a, but methylene iodide sinks only.

In a few places bauxitic clay unconformably overlies the bauxite (fig. 50*D*). The hardcap locally contains pebbles high in alumina, in areas adjacent to alluvial (type 3) deposits that overlie the type 2 deposits. Some pebbles are pale tannish gray and fine grained. They resemble pebbles derived from rocks of Paleozoic age in the region. Others are recognizable reworked fragments of granitic-textured and pisolitic bauxite. A dark-brown ferruginous pebble of this sort was found in a light creamy-gray matrix, from a drill hole in the Dixon deposit, Pulaski County. A thin section of this dark pebble shows a faint pisolitic structure and a network of veinlets filled with microcrystalline gibbsite.

OVERCLAY

The type 2 deposits are covered by as much as 15 feet of kaolinitic clay. Throughout the upslope parts of the bauxite bodies, where hardcap is present, the thickness of the overclay rarely exceeds 3 feet. In places, however, bauxitic clay extends upward to the overlying lignite or gray silty clay bed. Kaolinitic clay is thickest in the downslope parts of the deposits. The contact between the underlying bauxitic clay or hardcap and the overclay is gradational but within a short vertical distance.

The clay is thin upslope and usually has a fragmental appearance. It is filled with light or dark yellowish- to brownish-gray fragments, angular or subangular, as much as 20 millimeters long; and contains abundant rounded subspherical tan bodies that resemble pisolites (fig. 50*B*). In many places the overclay contains flecks and wisps of carbonaceous matter. Most of the fragments and bodies are oriented vertically and are surrounded by a halo of lighter colored cream or gray clay. Many of the bodies appear carbonaceous and are almost crescent shaped. In thin section they apparently are composed of kaolinite associated with carbonaceous matter. The groundmass likewise is made up of kaolinite in masses and tiny wormlike crystals.

A specimen (AB-10148-1) exhibiting the texture commonly seen above the hardcap is shown in figure 50*A*; it is from a drill core in the Treadway deposit, Pulaski County. A chemical analysis of this specimen made by the U. S. Geological Survey follows:

Chemical analysis of overclay from the Treadway deposit, Pulaski County [1]

[Analyst, C. M. Warshaw. The sample contained organic matter that could not be determined accurately]

Oxide	*Percent*
Al_2O_3	38. 61
SiO_2	42. 31
Fe_2O_3	. 51
FeO	. 65
MgO	. 00
CaO	. 02
Na_2O [2]	. 01
K_2O [2]	None
TiO_2	1. 91
P_2O_5	. 08
CO_2	None
SO_3	. 65
MnO	. 001
Cr_2O_3	. 025
BaO	None
Ignition loss minus SO_3	14. 96
Total	99. 74

[1] Cored sample from USBM drill hole 10-148, depth 152.1 feet, on property of Lewis Treadway, in the SE¼NE¼ sec. 8, T. 1 S., R. 12 W., Pulaski County (fig. 50 *A*).

[2] Na_2O and K_2O determined with flame photometer by W. W. Brannock.

RELATION TO OTHER BERGER SEDIMENTS

In any single section the bauxite-kaolin facies is usually overlain by lignite or carbonaceous clay as much as 20 feet thick. In some deposits carbonized root remnants extend downward from the lignite into the overclay for several feet. A 10-foot lignite log was found near the top of the pisolitic bauxite in the Young mine, Saline County (fig. 63). Generally the contact between the kaolinitic clay and lignite is sharp. Less commonly the overlying bed is a gray or greenish-gray silty clay. Where the overlying beds can be traced updip, they wedge out into the upslope continuation of the bauxite-kaolin facies. Downslope the kaolinitic overclay fingers into other clastic and carbonaceous beds of the Berger formation. These beds are contemporaneous in deposition with the upper part of the bauxite-kaolin facies. This relationship is illustrated in figure 7. In the Woodyardville area, the bauxite bodies occur on three separate levels or benches (pl. 17). The low deposits are overlain by massive lignite beds that wedge out updip in the overclay of the bauxite bodies upslope. This feature can be seen in the diagrammatic cross sections in plate 15.

RELATION TO OTHER TYPES OF DEPOSITS

The deposits or mines in which remnants of type 1 are beneath type 2 deposits have been listed on an earlier page.

In many of type 2 deposits the pisolitic bauxite of the concretionary zone is truncated above by a lignite bed, commonly associated with gray silty clay and overlain by another bed of bauxite. Typical examples of this relationship are the Ratcliffe, Birnbach No. 1, Glidewell, and Rummel deposits, all in Pulaski County. Wherever this has been observed, the overlying bauxite has on examination proved to be of sedimentary origin. It is stratified, gravelly, moderately to well sorted, or crossbedded. Where this relationship exists, the normal section of the type 2 deposit has been truncated and a type 3 deposit laid down above it.

No occurrence is known of the truncation of type 2 deposits by conglomeratic (type 4) deposits. In the Section 28 and Young mines in Saline County, types 2 and 4 deposits occur in the same stratigraphic section separated by as much as 60 feet of clastic and carbonaceous beds of the Berger formation.

MINES

Deposits in the bauxite-kaolin facies of the Berger formation constitute a large part of the bauxite in the region. They contain more than half of the remaining ore reserves. Except for the large high-level deposits on the Saline dome, most of the bauxite shown in the subsurface map of the region (pl. 2) is of this type.

In Pulaski County type 2 deposits have provided the bulk of the ore mined in the Berger, Berger No. 100, Bierman, Brown-Ratcliffe, Burks-Nelson, Buzbee, Dixie Nos. 1–3, England shaft, Heckler, Hoekstra, McGuire, North England, Nutt-Bailey, Old Rauch, Penzel-Coe, Pulaski, Ratcliffe, Ratcliffe (Dulin), Ratcliffe Lease, Rauch, Rauch Estate, Rauch Extension, Rauch Leased Rauch Owned, Rauch Property, Reichardt Extension, Rummel, Sherrill, Sherrill-England, Sweet Home, Vick, Vinson-Hoffman, Weiss, Westminster Church, Willie Thomas, Winn, and Wright mines.

In Saline County this type of deposit has provided most of the ore in the Alexander No. 1, Bryant, Covington, Elrod, Fletcher-Hudspeth-Harris, Hogue-Fletcher, Hurricane Creek, Martin shaft, Northern, Poodle, Quapaw, Ramsey, Rowland, Section 17, Section 28, Section 35, Stuckey, Whitley, and Young mines and possibly also in the Bizzell, Canal No. 2, Fletcher, and Townsend mines.

TYPE 3. BEDDED DEPOSITS IN THE BERGER FORMATION

DISTRIBUTION

Alluvial deposits of Berger age are associated with type 2 deposits chiefly in Pulaski County. They are best developed along the southeast edge of the Pulaski high. Upper bauxite beds of this type have been found in the Bruton, Fourche Bayou, Ratcliffe, W. A. Ratcliffe, Birnbach No. 1, Glidewell, Finnegan, Reichardt, Brown, Hollenberg, Alford-Ross, and Rummel deposits, which are distributed along a southwestward-trending band from sec. 17, T. 1 N., R. 11 W. to sec. 21, T. 1 S., R. 12 W. In Saline County, a bed of bauxite conglomerate overlain by Berger sediments forms an apron overlapping the downslope part of the Hurricane Creek deposit and parts of the Bailey and Tindall deposits, in sec. 18, T. 2 S., R. 13 W. Bauxite gravel filling channels, probably representing alluvial deposition during Berger time, has been noted in the lower part of the Fletcher deposit and in the middle part of the bauxite mined in the Midwest mine. The Saline County bauxite gravel deposits, however, do not form separate workable beds as do several of those in Pulaski County.

UNDERLYING ROCKS

The typical alluvial deposits in the Berger formation truncate and rest upon type 2 deposits and finger downslope into clastic and carbonaceous sediments. The normal sequence of rocks that lie progressively beneath a type 3 deposit from the upslope to the downslope ends is bauxite, siderite rock, lignite, and gray silty to sandy clay, as is shown in the diagrammatic section in figure 51. Well-bedded bauxite rests on siderite rock and crossbedded bauxite on lignite in the Rummel shaft mine (fig. 27*C*). Stratified bauxite overlies a wedge of gray silty clay that contains a lignite layer near the top, in the Ratcliffe open-pit mine (pl. 16). The type 3 deposit overlies and truncates pisolitic bauxite of type 3 deposition at all these places. A bed of kaolinitic or bauxitic clay underlies the bauxite in some type 3 deposits.

SHAPE AND RELATION TO THE UNDERLYING SURFACE

The deposits fill ancient channels, small swamps, and depressed areas. They are lobate or tongue shaped in plan, lenticular in cross section, and nearly always smaller than the type 2 deposits with which they are associated. As a rule they extend farther downslope than the underlying type 2 deposits but dip at a low

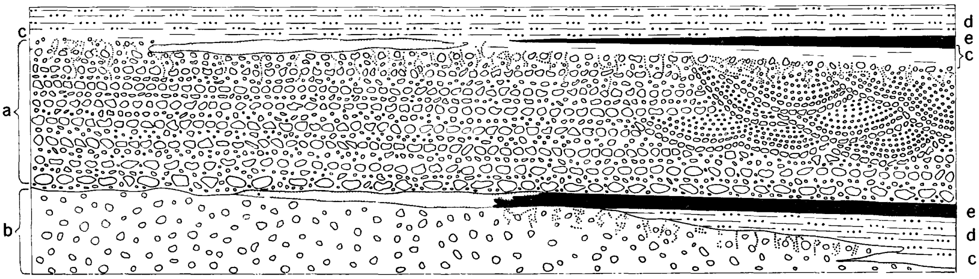

FIGURE 51.—Generalized cross section of a type 3 deposit. Stratified and crossbedded bauxite (*a*) of a type 3 deposit unconformably overlies pisolitic bauxite (*b*) of a type 2 deposit; bauxite in both deposits is overlain by kaolinitic clay (*c*). Encroaching sediments of the Berger formation include gray silty to sandy clay (*d*) and lignite (*e*) that grades upslope into a lens of sideritic rock (shown by light tone). Kaolinitic veining beneath lignite and kaolinitic clay in the upper part of both bauxite deposits is indicated by dotted pattern.

angle. They have about the same dip as the clastic and carbonaceous sediments that overlie them, and usually a gentler dip than the underlying type 2 deposits.

THICKNESS

Beds of well-sorted bauxite gravel reach 10 feet or more in thickness. The thickest bed on record is the upper bauxite bed in the Birnbach No. 1 ore body, Pulaski County. A company drill hole in the middle of this body cut 18 feet of stratified bauxite with an average grade of 47.2 percent available alumina.

LITHOLOGIC CHARACTER OF THE BAUXITE

The chief detrital constituents of type 3 deposits are brown, black, red, white, and gray pisolites and pebbles of bauxite. They range from large rounded to subangular grains and granules, about 2 millimeters in diameter, to small cobbles, that reach 10 centimeters in length. Subspherical pisolites, a few millimeters across are the most common. They are generally in layers that are 1 to 5 centimeters thick and moderately well sorted. Nearly all the pisolites and pebbles are hard and cherty and break with a conchoidal fracture. The larger ones lack an outer rind and are distributed through the rock so that they touch one another. This distribution is further evidence of their transportation and redeposition. The soft tan rinds that surround so many concretionary bodies in types 1 and 2 deposits were probably worn off as the pisolites and pebbles were transported.

Examination under the microscope shows that the pisolites are composed of an opaque dark brown substance that probably is chiefly cryptocrystalline gibbsite, as corroborated by chemical and X-ray analysis and also by differential thermal analysis. The pisolites are cut by a network of veinlets and cracks that extend inward from the edge as shown in the photomicrograph, figure 25*D*. Some of these veinlets contain microcrystalline gibbsite, others kaolinite. A few of the smaller pebbles, usually smooth and ellipsoidal, are composed of a microcrystalline aggregate of gibbsite.

The interstices between pisolites and pebbles contain many small brownish subangular to subrounded grains of "amorphous" gibbsite, and a few nearly spherical bodies some of which appear to be oolites, about 0.5–2.0 millimeters across. They usually are surrounded by a transparent or faintly brown-stained crystalline gibbsite matrix.

The three principal cementing materials are finely crystalline gibbsite, granular siderite, and kaolinite in masses and wormlike crystals. They apparently formed in the order named, although whether the kaolinite or siderite was first is not always indicated. Probably the two were contemporaneous. Study of hand specimens and thin sections from different parts of the stratified bauxite bed in the Ratcliffe deposit has shown the principal relationship. Gibbsite coats many of the pisolites, in some places forming well-defined tabular crystals (fig. 24 *D*) and in others forming a finely crystalline groundmass around the "amorphous" grains between pisolites (fig. 25*D*). A hand specimen from the Dixie Lease mine (fig. 25*A*) shows a rock containing crystalline gibbsite cement that was cut by later kaolinite veins. The kaolinite cuts pisolites and gibbsitic matrix, surrounds torn-off fragments of the earlier

matrix in places, or has been inserted between pisolite and matrix. In other places siderite in interlocking subhedral to anhedral grains fills cavities, many of which are lined with gibbsite crystals and masses of microcrystalline gibbsite. In a few places tabular gibbsite crystals are enclosed within siderite grains.

Gravel- and sand-filled channels were seen in the Fletcher mine, within the lower bauxite bed and only a few feet above the surface of the Wills Point formation, as shown in figure 52. One of the uppermost channels, 15–20 feet wide, was lined with lignite as much as an inch thick. Within an individual lens, as seen in cross section, the waterworn bauxite detritus is limited to about the same grain size. X-ray and optical examination of the heavy mineral fraction in clean black cherty pebbles from a lens of cemented gravel showed the minerals listed below.

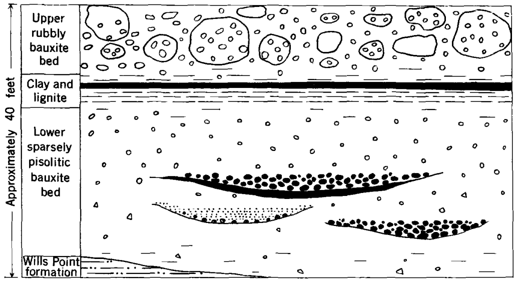

FIGURE 52.—Diagrammatic sketch of channels filled with bauxite, sand, and gravel in the Fletcher mine, Saline County. The vertical section represents about 40 feet.

Minerals identified by X-ray analysis in black cherty pebbles from the Fletcher mine, Saline County

[Analyst, J. M. Axelrod. Mineral separations and optical examination by M. L. Lindberg. Specimen AB-60-1]

Minerals	1	2	3
	Medium	Medinm-heavy	Heavy
Gibbsite	×	×	×
Boehmite	×	-----	-----
Hematite	-----	-----	×
Maghemite	-----	-----	×
δFe_2O_3 (unknown mineral)	-----	-----	×
Siderite	×	-----	×
Ilmenite	-----	-----	×
Anatase	-----	×	×
Rutile	-----	-----	×
Zircon	-----	-----	×
Unidentified opaque minerals	×	×	×
Staining matter	×	×	×

1. Material with about the same specific gravity as bromoform.
2. Bromoform sinks, methylene iodide floats.
3. Methylene iodide sinks.

The minor elements in three specimens of bauxite from these gravel deposits, including the pebbles from the Fletcher mine just referred to, were determined by spectrographic methods and are given in the table below. The results of the spectrographic work were discussed earlier in the section on the chemical characteristics of Arkansas bauxite on pages 96–99.

Spectrographic determination of minor elements in bauxite from type 3 deposits, in percent

[Analyst, K. J. Murata]

Element	1	2	3
Ti	1. 4	1. 5	0. 2
Ca	. 1	. 2	. 3
Zr	. 08	. 2	. 1
Ba	. 06	. 1	. 02
Sr	. 02	. 09	. 05
Mn	. 01	. 06	. 05
Nb	. 02	. 08	. 02
Mg	. 03	. 03	. 05
Cr	. 03	. 02	. 004
V	. 02	. 02	. 007
Y	. 006	. 02	. 01
Ga	. 009	. 009	. 01
B	. 009	. 009	. 003
La	-----	-----	. 02
Mo	. 002	. 005	. 002
Ni	. 004	. 005	-----
Pb	. 001	. 001	. 0007
Be	-----	. 0007	. 002
Sc	. 0009	. 001	. 0004
Cu	. 001	. 001	-----
Co	-----	. 002	-----

Looked for but not found: Sn, Ag, Bi, Sb, As, Tl, Ge, In, Ta, and P.

1. Stratified bauxite composed of oolites and pisolites in a gibbsitic matrix (specimen AB-11-1; figs. 24*D*, 25*D*), from the Harley mine, Pulaski County.
2. Firmly cemented dark-brown to black hard cherty-looking pisolites and pebbles (specimen AB-28-2; fig. 24*C*), from a crossbedded bauxite gravel in the Reichardt mine, Pulaski County.
3. Black cherty bauxite pebbles (specimen AB-60-1) from a bauxite gravel lens in the Fletcher mine, Saline County.

HARDCAP

The upper part of the bauxite gravel deposits contains scattered white to dark-gray, hard masses of kaolin, which are about the size of the bauxite pebbles. They are concentrated at the top and are less abundant downward. The kaolin is best developed in the bauxite gravel beneath a kaolinitic clay bed which is in turn overlain by a lignite bed, as shown in the diagrammatic sketch (fig. 51). The kaolin fills cavities between tiny veinlets within the hard pisolites and pebbles. Locally, small patches of the gibbsitic matrix are replaced by kaolinite, but this is a minor phenomenon.

Gibbsite pebbles occur in a hard cellular bauxitic to kaolinitic matrix much like the hardcap over type 2 deposits. A specimen of this material from USBM drill hole 18–231 in the Brown deposit is illustrated in figure 50*B* and has been described in the section dealing with type 2 deposits, page 128. This specimen was found above a lignite layer at the base of a type 3 deposit, and probably was formed by the resilication of

soft bauxitic material by ground-water solutions that moved freely through the gravel. Chemical analyses of pebbles and matrix from USBM drill holes in the vicinity of drill hole 18–231 are given in the table below. Under the microscope the pebbles are seen to consist chiefly of microcrystalline gibbsite and minor amount of kaolinite and siderite. The matrix is composed of kaolinite and small scattered microcrystalline gibbsite aggregates. Minerals identified by X-ray methods in a sample from drill hole 18–231 have been listed in the table on page 128.

Chemical analyses of bauxite pebbles and bauxitic matrix, in percent, from drill holes in the Brown deposit, Pulaski County

[Analyses by U. S. Bureau of Mines field laboratory, Little Rock, Ark.]

	Pebbles		Matrix
	1	2a	2b
Al_2O_3	61. 5	55. 7	44. 6
SiO_2	4. 0	14. 1	27. 7
Fe as Fe_2O_3	1. 3	1. 3	4. 6
TiO_2	. 8	. 7	1. 5
Ignition loss	31. 4	27. 1	20. 2
Insoluble	1. 0	1. 1	1. 4

1. Gray hard bauxite pebble from USBM drill hole 5–119, depth 258.8 feet, R. L. Brown property, NE¼SE¼ sec. 15, T. 1 S., R. 12 W., Pulaski County.

2a. Grayish-tan hard bauxite pebble from USBM drill hole 5–126, depth 263.4 to 267.0 feet, J. E. Maughn and T. A. Dillaha property, NW¼SE¼SE¼ sec. 15, T. 1 S., R. 12 W., Pulaski County.

2b. Same drill hole and depth interval as sample 2a, but from the gray hard pisolitic bauxitic clay matrix only.

A bed of hard dark bauxite pisolites containing some pebbles of the same material enclosed in a firm gray kaolinitic matrix overlies pisolitic bauxite of type 2 deposition in the Kramer Extension deposit. The two bauxite beds are separated by about 3 feet of pisolitic bauxitic clay. Chemical analyses of the matrix and pisolites in the table below show the difference in composition. In this specimen the secondary kaolinitic matrix is unusually low in titania.

Chemical analyses of pisolites, rinds, and kaolinitic matrix of gray pisolitic and pebbly bauxite from a drill hole in the Kramer Extension deposit, in percent

[Analyses by U. S. Bureau of Mines field laboratory, Little Rock, Ark. Samples selected and prepared by F. A. Hildebrand]

	Pisolites			Matrix	Pisolites and matrix
	1	2	3	4	5
Al_2O_3	59. 8	59. 9	57. 6	42. 6	51. 0
SiO_2	2. 9	3. 0	6. 0	40. 0	19. 8
Fe as Fe_2O_3	1. 7	2. 2	1. 6	1. 2	1. 4
TiO_2	3. 2	3. 7	3. 2	. 5	4. 1
Ignition loss	31. 8	30. 1	30. 8	15. 5	22. 8
Insoluble	. 6	1. 1	. 8	. 2	. 9
FeO	. 6	. 9	. 7	. 2	. 3

1. Gray hard pisolitic to pebbly bauxite in USBM drill hole 5–317, depth 311.7 to 311.9 feet, Lou Ella La Pierre property, in the SE¼SW¼SW¼ sec. 16, T. 1 S., R. 12 W., Pulaski County; analysis of selected pisolites only.
2. Same 0.2-foot core as sample 1; hard interiors of other selected pisolites only.
3. Same pisolites as sample 2; analysis of rinds only.
4. Gray kaolinitic matrix of the same 0.2-foot core.
5. Analysis of the entire core from 311.7 to 312.9 feet.

In places the top of the bauxite gravel beds contains enough granular siderite to constitute an indurated ferruginous capping. In the east-central part of the Ratcliffe pit, this capping probably formed a short distance upslope from lenticular lignite beds that overlie the bauxite and kaolinitic clay as shown in figure 51.

Overclay.—The kaolinitic clay above type 3 deposits does not differ from the clay overlying type 2 deposits. The kaolinitic clay does not exceed 5 feet in thickness and averages 1 to 2 feet.

RELATION TO THE ENCLOSING DEPOSITS

The downslope parts of the bauxite gravel deposits generally overlie, finger laterally into, and underlie the clastic and carbonaceous beds of the Berger formation, but are separated from them by a gray kaolinitic clay bed containing bauxite pebbles and fragments. Stratigraphically the gravel deposits occur from about 60 feet below to within a few feet of the top of the formation.

MINES

All the ore worked in the Dixie Lease, Dorough, England pit, Harley, Keenzel, Morgan, Reichardt shaft, and Thorpe mines and part of the ore in the Dixie No. 2, Ratcliffe, and Rummel mines was bauxite of fluviatile deposition. These mines are all in Pulaski County.

TYPE 4. CONGLOMERATIC DEPOSITS AT OR NEAR THE BASE OF THE SALINE FORMATION

DISTRIBUTION

Deposits of bauxite boulders and finer bauxite and clay detritus are found in several parts of the Saline dome, mostly on the middle and lower slopes. They form a thick bed locally, at the base of the Saline formation (fig. 53). The rubble deposits are large and of high enough grade to be of commercial importance in secs. 11, 15, 28, 33 and in the NE¼ sec. 24, T. 2 S., R. 14 W. Owing to the spotty nature of the ore and the low grade of most of the bauxitic material, the limits of these basal Saline sediments are only incompletely known.

UNDERLYING ROCKS

The most extensive type 4 deposits are at the base of the Saline formation, and overlie the eroded surface of the Berger formation. They grade upslope into the rubbly part of the residual type 1 deposits, from which the detrital constituents are largely derived (fig. 53). Similar but smaller lenticular conglomerate beds tongue into the Saline sediments overlying type 1 deposits. In a few places on the higher slopes of the nepheline syenite hill the bauxite rubble fills channels that have been cut into the weathered residual rock. A remnant of one of these, in the western part of the Section 15 mine, is shown in figure 54.

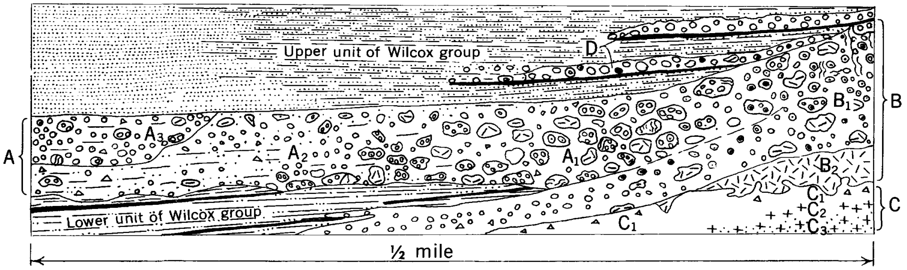

FIGURE 53.—Generalized cross section of a type 4 deposit. The conglomerate bauxite and clay bed (A) lies at the base of the upper unit of the Wilcox group below dark carbonaceous clay interlaminated with sand. It overlies unconformably gray sandy to silty clay and lignite of the lower unit of the Wilcox group. Some parts are mostly a coarse bauxite rubble (A_1); others contain considerable clay and some sand (A_2), and there are also channels filled with bauxite fragments and pisolites in a clay or bauxitic clay matrix (A_3). Bed (A) grades upslope into the upper part of a type 1 deposit (*B*) of which pisolitic and vermicular bauxite of the zone of concretion (B_1) and granitic-textured bauxite of the zone of leaching (B_2) are shown. These overlie structureless or fragmental kaolinitic clay (C_1) that grades downward through kaolinized nepheline syenite (C_2) into fresher rock (C_3). Small rubbly lenses (D) similar to the basal bed of the upper unit of the Wilcox group (A) finger out into higher sediments of the Wilcox group.

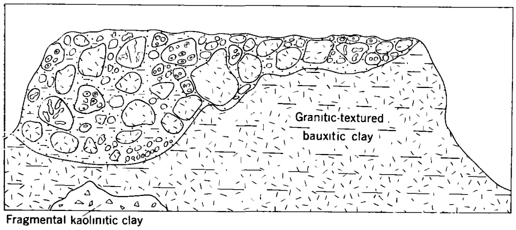

FIGURE 54.—Bauxite boulder conglomerate of Saline age overlying granitic-textured bauxitic clay.

SHAPE AND RELATION TO THE UNDERLYING SURFACE

The basal contact of a type 4 deposit is always an unconformable one. On higher slopes the bauxite rubble is confined to narrow channels cut in the weathered nepheline syenite rocks. On the middle slopes it overlies type 1 deposits in poorly defined patches that merge with the residual bauxite. The tendency of adjacent bauxite blocks to cement together, even though separated by an erosional break, is a characteristic of bauxite that can be noted in present day stockpiles and waste dumps.

Along the break in slope where the weathered residual surface of the nepheline syenite is overlain by the upper edge of the Berger formation the bauxite boulders are piled in a jumble of large blocks within a bauxite or clay matrix, and it is here that the type 4 deposits are minable. The bauxite and clay extend outward as much as a mile in a lobate blanket over the Berger surface.

THICKNESS

In the Fletcher mine the upper rubble bed has an average thickness of about 15 feet and the maximum known minable thickness is 18 feet. The upper bed in the nearby Townsend mine is 14 feet thick. In the Midwest mine the upper bauxite bed is 18 feet thick, but the lower part of it may have been deposited in Berger time. These mines are all at or near the upslope edge of the Berger formation. Thicker deposits of lower grade material have been reported farther out on the Berger surface. As much as 30 feet of bauxite and clay was logged in company drill holes in the basal bed of the Saline formation in parts of sec. 28. In one Alcoa drill hole in this area, 26 feet of low-grade bauxite, determined by chemical analysis, was present.

LITHOLOGIC CHARACTER OF THE BAUXITE

Where the alluvial deposits mantle the slopes and cover residual deposits, they consist of a rubble of medium- to large-sized blocks, many of which are irregular and angular. The largest blocks exceed 4 feet across. They are composed of the lithologic varieties of bauxite that are found in the residual deposits. Single blocks contain several varieties, including boulders of kaolinized nepheline syenite. The matrix that surrounds the boulders is bauxitic, some of it a high-grade bauxite, where the alluvial deposits fringe or lie a short distance downslope from extensive residual bauxite deposits. The matrix in the upper part of the alluvial bauxite beds, just beneath the clastic Saline sediments, and also farther out on the surface of the Berger formation, generally contains considerable clay and sand.

Several specimens from the conglomeratic upper part of the bauxite in the Midwest open-pit mine were collected and studied by M. I. Goldman and the writers, by means of thin sections and chemical analyses (fig. 55) In one corner of the pit the upper few feet of bauxite rubble has a dark carbonaceous clay matrix and merges upward with the carbonaceous sand of the Saline formation. It grades laterally, as well as downward, into rubbly bauxite with a bauxitic matrix. Chemical

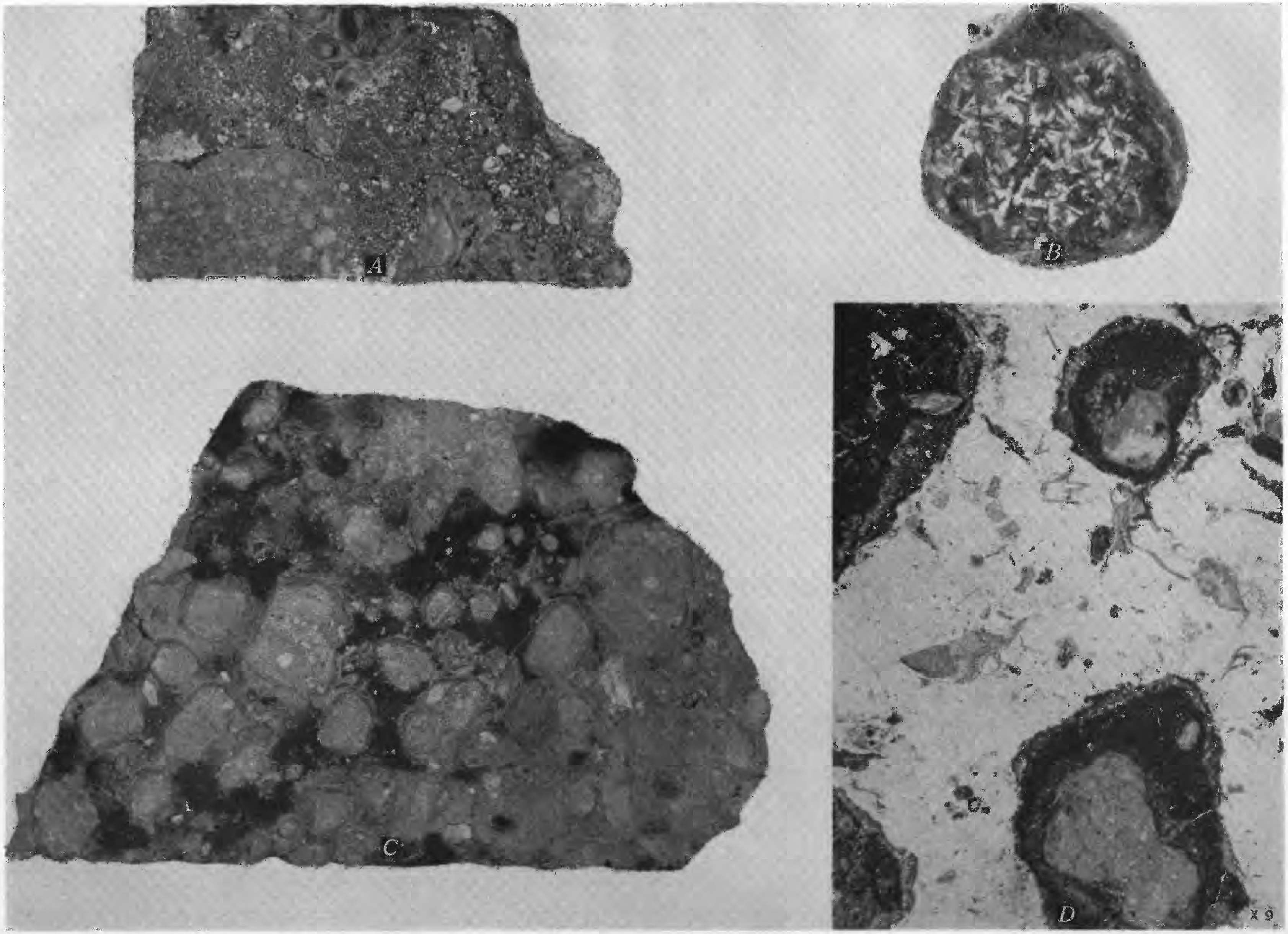

FIGURE 55.—Specimens of bauxite rubble from type 4 deposits in Saline County. (*A–C* natural size). *A*, Pisolitic bauxite pebbles in matrix of fine bauxite grains. Hand specimen (AB-89-10) from upper part of upper bauxite bed in the Midwest mine. Chemical analysis given in table 12. Spectrographic analysis given on page 136. *B*, Granitic-textured bauxite and fragment of pisolitic bauxite enclosed within a single rind. Relict feldspar crystals preserved as white microcrystalline aggregates of gibbsite. Sawed face of specimen (AB-250-2) probably from stockpile at Lignite. *C*, Rubble of pinkish bauxite fragments in black carbonaceous clay matrix. Note fragmentary appearance of individual pieces. Sawed face of hand specimen (AB-89-2) from top of upper bauxite bed in the Midwest mine. *D*, Photomicrograph of specimen shown in *C*. In thin section the kaolinitic matrix appears light; medium gray bodies are mostly plant fragments; darker ones are bauxite and carbonaceous border, edged with a thin kaolinitic layer. × 9.

analyses of the rubble, cobbles, and matrix are given in table 12.

The specimens listed in the table vary greatly in composition. The boulders retain about the same gibbsite or kaolinite content as similar-appearing rock in place in the type 1 deposits upslope. The matrix ranges in composition from a highly gibbsitic rock to a kaolinitic clay with carbonaceous staining.

TABLE 12.—*Chemical analyses of bauxite cobbles and clay matrix from the conglomeratic upper bauxite bed in the Midwest mine, in percent*

[Analyses by U. S. Bureau of Mines field laboratory, Little Rock, Ark.]

	1	2	3a	3b	4	5	6
Al_2O_3	58.0	38.5	37.3	31.6	46.4	51.7	55.7
SiO_2	3.9	37.1	25.4	32.4	6.4	6.0	.7
Fe as Fe_2O_3	1.3	3.5	13.0	15.5	14.5	8.8	5.9
TiO_2	.8	1.4	2.7	1.9	2.6	2.8	3.4
Ignition loss	35.7	18.8	21.1	18.2	29.7	30.2	32.5
Insoluble	.3	.7	.5	.4	.4	.5	1.8
FeO	.2	.6	10.2	14.0	12.0	6.4	4.4

1. Gray granitic-textured bauxite from a cobble (specimen AB-89-1) collected at the top of the bed, immediately below brown carbonaceous sand. The cobble was coated with a film of pyrite and enclosed in a carbonaceous clay matrix, which were removed before analyzing.
2. Black carbonaceous clay matrix from a bauxite conglomerate containing reddish and tan pisolitic pebbles (specimen AB-89-2; fig. 55*C*), from the top of the bed.
3a. Brown matrix containing a few small white fragments of a bauxitic rock (specimen AB-89-6) that surrounds a large kaolinized nepheline syenite boulder in the southeast corner of the Midwest pit.
3b. Predominantly white fragments from the same matrix.
4. Orange-red sideritic granitic-textured bauxite debris (AB-89-6a) from the same locality as sample 3.
5. Hard brittle chertlike bauxitic rock (specimen AB-89-8) irregularly mottled dull red and grayish tan, that surrounds bodies of brown pisolitic bauxite with indistinct boundaries, immediately below the bauxite conglomerate with carbonaceous matrix, at the north end of the east wall of the pit.
6. Tan bauxite rubble containing grayish tan pisolitic pebbles and cobbles in a fine bauxite matrix (specimen AB-89-10; fig. 55*A*) collected at or near the top of the upper bauxite bed, near the center of the west wall of the pit

One of the specimens shown in table 12 (AB-89-10) also was examined spectrographically, and the minor elements are shown in the tabulation below. The results of the spectrographic work have been discussed in the section of this report on the chemical features of Arkansas bauxite. The concentration of minor elements in this sample, except for manganese, is slightly higher than was determined in three samples from type 1 deposits. Too few samples have been examined, however, to draw any conclusions as to secondary concentration of the minor elements by bauxitization and by later processes.

Spectrographic determination of minor elements in a sample of bauxite rubble from the Midwest mine, Saline County, in percent

[Analyst, K. J. Murata]

Element	Percent	Element	Percent	Element	Percent
Ti	1.8	Ba	0.04	Ga	0.008
Zr	.2	Sr	.03	Mo	.002
Ca	.2	La	.02	B	.002
Mg	.09	Y	.02	Cu	.001
Nb	.08	Cr	.02	Pb	.001
Mn	.05	V	.01	Sc	.0006

Looked for but not found: Be, Ni, Co, Sn, Ag, Bi, Sb, As, Tl, Ge, In, Ta, and P.

In thin section the granitic-textured rock, sample 1 in table 12, is almost entirely an aggregate of microcrystalline and finely crystalline gibbsite that has replaced interlocking feldspar crystals of an original nepheline syenite rock. Many small cavities are empty. Scattered through the rock are small euhedral black opaque grains, some as skeleton crystals, most of which appear to be ilmenite, also several tiny pyrite grains. There is considerable brown staining.

The conglomeratic rock containing pebbles and a thin section cut from the same specimen are shown in figure 55*C*, *D*. The matrix, sample 2, table 12, is composed of fine kaolinite flakes stained light brown by carbonaceous matter. A few scattered macerated plant fragments exhibit a distinct cellular structure. Some small angular fragments are composed of finely crystalline gibbsite without rinds. The interior of the pinkish-tan pebbles is composed of microcrystalline gibbsite patches of different sizes, including the opaque cryptocrystalline variety. The pebbles have a broad dark brown-stained border of material similar to that in the interior and also contain fresh-looking finely crystalline gibbsite aggregates enclosed by black opaque bodies and scattered specks probably of iron sulfides and carbonaceous matter. The outer edge of this border is light brown to grayish and contains white translucent masses of tiny contorted wormlike crystals of kaolinite filling cavities and pore spaces. In several of the pebbles the gibbsitic interior forms a meshwork and the spaces between are filled with kaolinite similar to that in the outer rim. The kaolinite crystals within the pebbles are lighter colored, larger, and fresher looking than the brown-stained kaolinite in the matrix. A few patches of these white kaolinite crystals fill cavities, indicating that they formed later than the matrix.

The matrix rock (table 12, samples 3a and 3b) has a detrital appearance in thin section. The groundmass is composed of fine kaolinite mixed with scattered fine crystals and microcrystalline aggregates of gibbsite, and fragments and sections of accordionlike kaolinite crystals, as much as 0.15 millimeter in width. Clear translucent patches of kaolinite finger irregularly into the surrounding matrix and appear to be secondary. Brown to gray spherulites and grains of siderite, as much as 2.0 millimeter in diameter, are scattered through the rock. They have formed in place and several have grown into and through gibbsite aggregates. The dark opaque minerals are sparsely distributed and the recognizable ones include dark-brown patches of leucoxene (anatase), black subhedral grains of ilmenite, and several grains of pyrite.

In contrast to the specimens with kaolinitic matrices is the low-silica bauxite (table 12, sample 6; fig. 55*A*), in which pebbles and cobbles of pisolitic bauxite are

enclosed in a matrix of fine grains, oolites, pisolites, and angular fragments of bauxite. The pisolitic bauxite in the pebbles appears soft and porous. In thin section it consists of brownish opaque cryptocrystalline gibbsite, containing tiny cavities and veinlets lined with a thin coating of microcrystalline gibbsite. A variety of fragments in the matrix is composed of white to grayish translucent finely crystalline to microcrystalline gibbsite aggregates, and the tan cryptocrystalline form. The fragments are cemented with gray ramifying grains of siderite which also fill many of the pore spaces within the larger pebbles. The siderite is oxidized and stained dark brown, particularly within the matrix. A small cavity lined with siderite is filled with fine gibbsite crystals. The dark minerals include illmenite and anatase.

Variety is the rule in the lithologic composition of a type 4 bauxite deposit. The specimens and sections that have been described give a general idea of several of the rock types. Each detrital fragment and block records the history of the rock from which it was derived. Secondary minerals that formed after the bed was deposited include siderite, kaolinite, and gibbsite.

The basal Saline formation generally contains more clay and sand away from the source of the detritus, as indicated in figure 53. In several drill hole sections logged by the Geological Survey in sec. 28 T. 2 S., R. 14 W., most of the bed is made up of kaolinitic or bauxitic clay. However, channels and pockets within the bed are filled with high-grade rubbly bauxite.

The bed is extensive opposite the southwest slope of the Saline dome. It covers most of the W½ sec. 28 and the E½ sec. 33 and extends into the SW¼SW¼ sec. 34. It spreads out as a blanket above the Young, Sutton, and West Cargill deposits, all of which are type 2 ore bodies. The bed is about 20 to 60 feet higher in the section than the bauxite-kaolin facies, and the stratigraphic interval between is occupied by carbonaceous and clastic beds of the Berger formation. In the eastern part of sec. 28 the bed probably grades upslope into the large type 1 deposit that contains the Ozark 28 and Globe 28 mines, but drilling information is not available to confirm or deny this assumption.

Throughout most of the area where the basal Saline overlies the Berger formation the Saline contains low-grade bauxite, usually having an average analysis comparable to bauxitic clay. Where the bed overlies the Young mine of the Crouch Mining Co., it is composed of hard bauxite pebbles and cobbles in a clay matrix. The mine superintendent L. W. Richards, informed the writers in October 1948 that a concentrate of abrasive-grade bauxite can be derived by washing clay from the hard pebbles and cobbles in the middle 8 feet of the 14-foot bed. About a ton of water served to clean a ton of the raw bauxite. If other parts of this extensive bed contain a large amount of similar rock, the application of simple washing methods may add materially to the commercial importance of these alluvial (type 4) deposits.

RELATION TO OTHER SEDIMENTS OF THE SALINE FORMATION

The manner in which the conglomeratic bauxite and clay beds grade upward into the brown sand and silty carbonaceous clay of the Saline formation has been described. Downslope the rubble beds grade and finger laterally into sand and carbonaceous clay beds similar to those that overlie the deposits. Where this lateral change takes place they lie deeply buried, hence the details of the passage from one type of rock to the other are not known—only its occurrence is known from drill-hole information.

Where the Saline formation fringes the upland of Paleozoic age in the vicinity of the town of Benton, a conglomerate facies is composed principally of siliceous pebbles and cobbles derived from the rocks of Paleozoic age. This facies is described in the stratigraphic section of this report. These conglomerate beds are equivalent to those of the type 4 deposits. The pebbles and cobbles record the increased erosional activity that marked the early part of Saline time.

MINES

This type of deposit has been mined, at least in part, as an upper bed in the Childress, Fletcher, Gray, Midwest, and Townsend mines in Saline County.

ORIGIN OF THE DEPOSITS

The origin of bauxite has engaged the attention of geologists for more than a hundred years. It now is generally agreed that bauxite forms as the product of weathering under conditions that accompany a tropical or subtropical climate, but relatively little is known of the sequence of chemical and physical changes that take place. Bauxite deposits have been divided into two main categories: those derived from the weathering of igneous rocks and their residual clays, the lateritic bauxite; and those derived from clay weathered from limestone, the terra rossa bauxite. The Arkansas deposits, with modifications, belong to the first category.

HISTORICAL REVIEW OF THE THEORIES ON ORIGIN

The probable origin of the Arkansas deposits has been discussed by several writers, notably Williams (1891), Branner (1897), Hayes (1901), Mead (1915), Bramlette (1936), and Goldman and Tracey (1946). The theories advanced for the genesis of Arkansas

bauxite fall into the same three groups under which Harder (1930, p. 86–104) has classified those advanced for bauxite in general as follows: chemical sedimentation, weathering in place, and detrital deposition.

The geologists who wrote the early reports on the Arkansas deposits all recognized the close association of the bauxite and the nepheline syenite, but attributed the origin of the bauxite to hot waters charged with aluminum salts that emanated from the nepheline syenite. In this they followed European geologists such as Coquand (1870–71), Meunier (1889), Collot (1887), and Augé (1888), who had suggested a hot-water origin for the French bauxite deposits many of which are associated with limestone. Some of the ideas of the early European writers were briefly reviewed by Branner (1897, p. 294–297).

Williams (1891, p. 125) states that the waters of the Tertiary sea penetrated to the still highly heated igneous rocks, dissolving their constituents in different proportions. The waters came to the surface in hot springs where excess matter precipitated as a basic hydrate of aluminum and iron, whereas the more soluble salts of the alkalis remained in solution. The pisolites probably were formed by agitation of the bubbling hot water. Williams (1891, p. 124) suggested as an alternative that the bauxite was formed by the decomposition of a bed of clastic material derived principally from the nepheline syenite, but considered this probability to be less likely.

J. C. Branner (1897, p. 294–297) suggested that the hot springs discharged directly into the marginal waters of the Tertiary sea. Here the aluminous salts were precipitated, and the pisolites were formed by agitation of the waves and nearshore currents. He attributed the boulderlike form of some masses of pisolitic bauxite to the action of storm waves on the principal bed of bauxite that possibly was exposed at low tide. Branner stated that none of the bauxite was formed in place by alteration of another rock. It should be pointed out, however, that neither Branner nor Williams had seen the granitic-textured variety of bauxite, uncovered when mining operations began later in Saline County.

Hayes (1901, p. 461–466) recognized that part of the bauxite has a granitic texture similar to that of the nepheline syenite and he considered this evidence for the derivation of part of the bauxite as an alteration product of the igneous rock. But he postulated that the alteration was caused by the action of hot waters from the nepheline syenite that deposited a gelatinous precipitate in the bottom of an overlying salt or highly alkaline body of water, probably not directly connected with the sea. The granitic-textured bauxite formed as a metasomatic replacement of the nepheline syenite, and boulders of it were mixed with the chemically precipitated pisolitic form, by currents within the water body.

The writers cited above were all aware of the earlier statements of Liebrich (1892) on the probable origin by decomposition of basaltic igneous rock of the bauxite deposits of the Vogelsberg Mountains near Giessen, Germany. But they did not consider that weathering could satisfactorily account for the Arkansas deposits. Liebrich, who in part was quoting the work of Streng, stated that all the bauxite in the Hessian fields was derived from igneous rock, but that the process that resulted in the formation of the pisolitic variety was complex and as yet unknown.

So far as the writers have been able to determine, the first to suggest that bauxite is derived from the weathering of igneous rock was Dieulafait (1881). The presence of titanium and vanadium in tiny amounts in many bauxite deposits led him to suspect such an origin. He reasoned that during the weathering of a granite, for example, a sand is formed of undecomposed quartz, feldspar, and ferromagnesian minerals, but part of the feldspar is also decomposed, leaving an essentially aluminous and ferruginous residue. This residue, he believed, is transported by wind action and parts of it are deposited in nearby basins in sufficient concentration and quantity to constitute bauxite deposits.

The work of Max Bauer (1898) on weathered rocks from the Seychelles Islands demonstrated that the rock called laterite consists essentially of a mixture of gibbsite and hydrous iron oxides, with or without quartz, and is derived in place from the alteration of feldspar and ferromagnesian minerals of the original igneous rock. He noted that this material was similar to the bauxite from the Vogelsberg Mountains in Germany.

One of the most enlightening reports on the origin of bauxite deposits by weathering in place and also by subsequent transportation and redeposition, was that of Lacroix (1913) on the laterite deposits of French Guinea and their associated alteration products. Lacroix showed by means of chemical analyses and microscopic study the characteristics of residual deposits on nepheline syenite, gabbro, diabase, and peridotite, as well as the alluvial deposits derived from them. He mentioned the Arkansas deposits in a footnote (p. 344) stating that he had visited the Granite Mountain area in Pulaski County briefly and had noted the similarity of the pisolitic bauxite there to the zone of concretion at Gaya, French Guinea. He apparently believed that the Arkansas deposits were the products of weathering like those in Africa, though he did not state so directly.

Mead (1915, p. 44–54) first clearly demonstrated that the residual deposits in Saline County are the product of subaerial weathering of the nepheline syenite

and are not chemical sediments. He based his argument on the following evidence:

1. An obvious genetic relationship between the bauxite and nepheline syenite because of their similar distribution.
2. The apparent gradation from nepheline syenite through kaolinized nepheline syenite to bauxite, observed wherever a fresh cross section is available.
3. Preservation of the granitic texture in parts of the bauxite and kaolin, and also of feldspar shapes replaced by gibbsite within pisolites.
4. Irregular surface at the base of the bauxite which could have been produced only by weathering.
5. Presence of kaolinized decomposition boulders of nepheline syenite that occur within and grade outward to bauxite.
6. The wide vertical range of distribution of the deposits.
7. High porosity of the bauxite.
8. Presence in the bauxite of the same heavy accessory minerals that are found in the nepheline syenite.
9. The apparent chemical gradation between the unaltered nepheline syenite through the kaolinized phase to the bauxite.

Mead concluded that the nepheline syenite was altered first to kaolin and later to bauxite, and that the porous structure of the kaolinized phase of the nepheline syenite was essential to the alteration of kaolin to bauxite. The oolitic or pisolitic texture of the bauxite formed in place from the granitic or amorphous types of bauxite. Deposits that formed in place from the nepheline syenite show evidence of downward secondary concentration of alumina in that the upper part is gradationally higher in silica upward.

Mead likewise called attention to the small detrital deposits that occur as lenses interstratified with the Tertiary sediments. The lenses, he said, originated on the nepheline syenite surface but were removed from their place of origin by Tertiary streams. Drill-hole cores showed that they have the same heavy accessory minerals as the residual bauxite deposits and the nepheline syenite.

Behre (1932) noted that lignite commonly overlies bauxite in the Arkansas mines and asked if the humic waters in the swamps where the lignite was formed might not have been instrumental in the alteration of the nepheline syenite to bauxite, as kaolin forms under such conditions. Ross (1943, p. 232) stated that swampy conditions would have been ideal for the formation of both siderite and kaolin but suggested that the genetic relation of the bauxite to the kaolin beds be given intensive study.

Bramlette (1936, p. 25–31) believed that the bauxite was formed chiefly from the weathering of the nepheline syenite as well as other surface rocks and that bauxitization took place in a single period during early Wilcox time. The process was controlled by the character of the bedrock and favorable climatic, topographic, and ground-water conditions. Like Mead, Bramlette believed, that kaolin formed as an intermediate stage in the process and added that variations in the texture and mineral composition of the altered nepheline syenite probably accounted for the uneven surface of the underclay and for the irregular "horses" of clay within the bauxite. He suggested also that most of the original iron in the bauxite was leached in the ferrous state and carried downward and precipitated in the zone of abundant spherulites of siderite in the kaolinized nepheline syenite. The siderite now present in the bauxite, he believed, entered from above at a later time, doubtless associated with the rising base level and water table and the swampy conditions that accompanied the deposition of the Wilcox sediments. He said that in several places, for example the Ratcliffe mine in Pulaski County, the upper part of the bauxite was resilicified through the leaching of some of the aluminum hydroxide from this zone.

As the result of field studies that accompanied the drilling programs described in this report, evidence indicates a widespread secondary kaolinization or silicification of parts of the Arkansas bauxite deposits. Goldman and Tracey (1946) in a preliminary paper have presented data indicating that the residual bauxite of Arkansas formed directly from fresh nepheline syenite and that the kaolin was introduced later. Additional data in confirmation of this hypothesis have been presented in the section on type 1 deposits in the present report and will be discussed in the pages that follow.

Goldman (1949) also revived the earlier idea of Passarge (1895) and of Holland (1903) that some microorganism participated in the formation of the bauxite by utilizing silica and by preventing silica in solution from combining with bauxite. Knibbs (1928, p. 18) remarked that any theory that introduces a living agency is supported by the well-substantiated fact of the occurrence of bauxite in hot wet climates. But Vageler (1933, p. 129), who had a wide acquaintance with tropical soils, believed that there are no "laterite bacteria."

BAUXITIZATION AND KAOLINIZATION

Some geologists consider the thick layer of kaolin that lies between the fresh nepheline syenite and the bauxite of Arkansas indicates that the formation of kaolin was an intermediate stage in the process of bauxitization. The complete gradation between the bauxite and the kaolin as postulated by Mead is a strong argument in favor of this concept.

The writers of this report maintain that the assumed gradation is irregular, and in many places does not exist. Chemical analyses of samples taken at intervals as little as an eighth of an inch apart have been cited

(p. 118) to show that the change in some places is abrupt, in others uneven; thin sections have been described wherein kaolin fills pore spaces in the bauxite or cuts it in veinlets; photographs have been presented and mine faces described that indicate some of the kaolin was formed in and from bauxite. There is a widespread and complete gradation from nepheline syenite to kaolin, and nowhere is bauxite in place in direct contact with nepheline syenite. But in the upper well-drained parts of residual (type 1) deposits where bauxite is in contact with kaolin, the identifiable kaolin is later than the bauxite.

This relation indicates that these deposits were affected by a period of kaolinization which followed that of bauxitization. It does not mean that kaolin and bauxite were not formed contemporaneously, nor does it mean that no bauxite was formed from kaolin. On the contrary, evidence presented in this report shows that kaolinization was a dominant weathering process during Wills Point time and that some kaolinitic clay formed in Kincaid time. The weathered upper part of the Wills Point formation consists largely of kaolinitic clay throughout large areas. Moreover, evidence indicates that gibbsite directly replaced kaolinite to form part of the bauxite in low-level colluvial (type 2) deposits. The processes that resulted in the formation either of bauxite or of kaolin apparently continued independently of one another and their operation depended upon the chemical and physical conditions that prevailed at any locality at a particular time.

Most students of weathering and soil formation agree that a tropical or subtropical climate is necessary for the formation of bauxite. Kaolinite forms in a temperate climate, but it also is a characteristic product of weathering under tropical or subtropical conditions. Deep kaolinitic weathering that resulted in the formation of great masses of kaolin apparently is more characteristic of tropical than of temperate regions.

Campbell (1917, p. 72, 123) believed that alteration of crystalline rocks took place before laterite or bauxite could form. He suggested that they were partly altered to kaolinite or sericite before lateritization. Campbell says:

> If a rock has not been rendered porous or permeable by rain water in the zone of permanent saturation, it will not in the tropics undergo material change in the zones above.

This comment concerned the description by Lacroix (1913, p. 271) of the fresh condition of igneous rock in French Guinea in almost immediate contact with bauxitized material containing practically none of the original mineral constitutents.

Harrison (1934, p. 37–38) proved, however, by recalculation of chemical analyses of thin layers of fresh to weathered rock, that the mineral that was first set free by weathering of the feldspar in basic igneous rocks of British Guiana could neither be a hydrous aluminum silicate nor a sericitic mica. He said, moreover,

> The microscopic observations in each case I have studied indicate that *the mineral of first and direct formation from the plagioclase feldspars is gibbsite* [the italics are Harrison's].

Figure 56*A*, *B* shows a sawed section of weathered diabase boulder from Hope quarry on the Demerara River, about 70 miles south of Georgetown, British Guiana. This locality is one of the first investigated and described in considerable detail by Harrison (1911, p. 120, 353; 1934, p. 21–27) in his study of the katamorphism of igneous rocks under tropical conditions. The specimen was collected by E. C. Harder and sent to C. S. Ross of the U. S. Geological Survey.

The inner core of the boulder is unweathered diabase composed, according to Harrison, of 50 percent plagioclase (labradorite) containing alkali-feldspar and interstitial micropegmatite, 42 percent augite, and 4.5 percent ilmenite and titaniferous magnetite. Minor constituents, in decreasing order, are enstatite, biotite, olivine, and quartz. The outer crust is a mixture of gibbsite and hydrous iron oxides and relatively unweathered titanium minerals. Gibbsite is well defined in a narrow layer immediately adjacent to the unaltered diabase, where it forms small white microcrystalline masses visible in the photograph.

Within 1 to 2 millimeters the rock is altered from completely fresh diabase to ferruginous bauxite. Examination in thin section of the zone of contact discloses feldspar completely fresh at one end and partly altered to microcrystalline gibbsite at the other. The alteration took place from the outside toward the center and also along cleavage cracks. Iron oxides and scattered gibbsite scales surround remnants of ferromagnesian minerals. There is no evidence of kaolinite or of sericite.

Many of the commercial bauxite deposits in British Guiana, however, are separated from the underlying fresh rock by a hundred feet or more of residual clay (Harder, 1949, p. 902).

Teixeira (1942, p. 160) noted the sharpness of the contact between the bauxite and the fresh rock throughout a large area in the Poços de Caldas region Brazil, and noted boulders of nepheline syenite with bauxitic alteration rims similar to the diabase boulder from British Guiana. In other places Pinto (1938, p. 25) found a few inches to several feet of clay and kaolinitic nepheline syenite between the bauxite and the fresh rock.

It is interesting that of the three regions in the world where bauxite is formed from nepheline syenite rocks, in two of them—the Los Islands off the coast of French

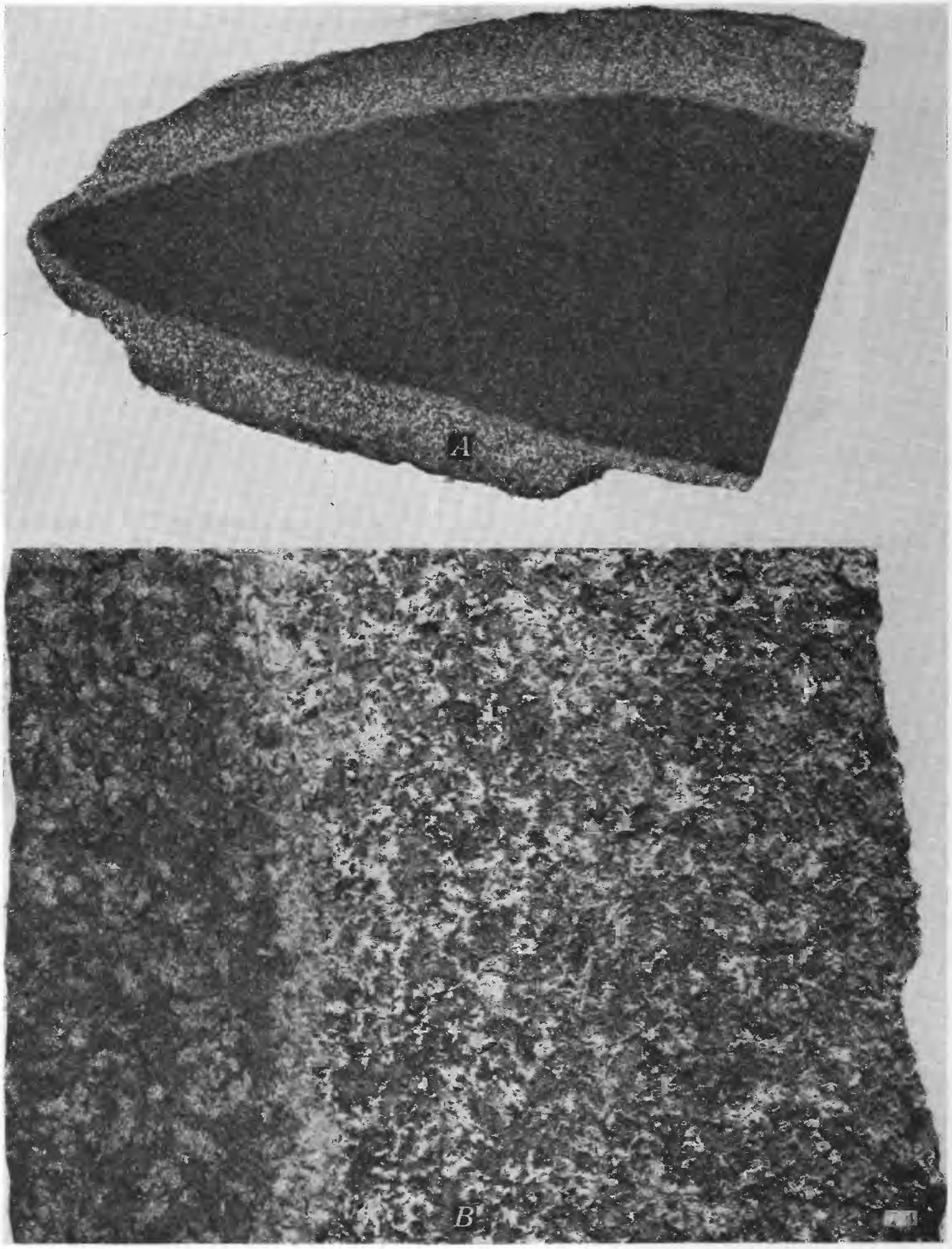

FIGURE 56.—Weathering of diabase to bauxite in British Guiana. *A*, Block of diabase, the outer rim of which is weathered to ferruginous bauxite composed essentially of microcrystalline gibbsite and iron oxides. From Hope quarry near Christianburgh on the Demerara River, British Guiana. Half natural size. *B*, Enlarged view of the bauxitic rim showing the characteristic "spice bread" texture. The white patches are nearly pure gibbsite and the darker reddish-brown parts are gibbsite and iron oxides. × 4.

West Africa and the Poços de Caldas region of Brazil—bauxite lies in contact with the fresh igneous rock from which it was formed. Kaolin also has formed from nepheline syenite in those same regions.

Harrison (1934, p. 9) concluded that under tropical conditions, the weathering of basic and intermediate rocks, at or close to the water table under conditions of nearly perfect drainage, is accompanied by the almost complete removal of certain minerals. These minerals are silica, calcium, magnesium, potassium, and sodium leaving an earthy residuum of aluminum trihydrate (in its crystalline form of gibbsite), limonite, and a few unaltered fragments of feldspars; in some cases secondary quartz and other resistant minerals, originally present in the rock are left in the residuum. Harrison called this process "primary laterization." In this report the first stage of the process is called "bauxitization." According to Harrison it commonly is followed by one of resilication, gradually resulting in the formation of vast masses of lateritic earths or argillaceous laterite, which in the tropics so frequently cover wide areas of basic and intermediate rocks. Harrison and Lacroix noted that under tropical conditions certain acidic rocks, such as aplite, pegmatite, granite, and granite-gneiss do not undergo primary lateritization but weather instead to clay, or to quartziferous impure kaolin. But, according to Harrison, lateritic earth and even pot clay may undergo desilication, with the formation of concretionary and surficial masses of bauxite.

FACTORS THAT CONTROLLED THE WEATHERING PROCESS

Bauxite and bauxitic clay have been found associated with and are believed to have been derived from a wide variety of rocks and their weathering products in many parts of the world. These rocks include nepheline syenite, phonolite, syenite, trachyte, granite, pegmatite and aplite dikes, diorite, gabbro, basalt, diabase (dolerite), metavolcanic rocks, gneiss, several varieties of schist, phyllite, slate, arkose, limestone, and sedimentary clay. Whether bauxite or kaolin will form at any given place in the tropics depends upon many factors, such as the ratio of precipitation to evaporation, the prevailing temperature, the porosity of the source rock, elevation above sea level, which affects climate, position with regard to topography and drainage, relation to the water table, and the pH and humus content of the water passing through the rock.

CLIMATE

Most geologists who favor a weathering-in-place origin for bauxite have suggested that this takes place in warm tropical regions that have alternating wet and dry seasons. This theory is well established in the geologic literature on the Indian, African, and Australian lateritic deposits. Infiltrating water is believed to remain in the rock interstices throughout wet monsoon periods and drain away during the dry periods, thus giving full play to chemical weathering. Studies made by soil scientists in widely separated equatorial regions, however, indicate that it may be continuous moisture, rather than alternating wet and dry periods, that leads to the formation of bauxite and high-alumina laterite.

Sherman (1949, p. 342) has presented evidence to show that in the Hawaiian Islands, soils with high-alumina content as compared to silica form in areas of considerable rainfall. He cites a soil with the composition of bauxitic clay derived from volcanic ash and formed under 273 inches of rain per year.

An examination of stratigraphic evidence in the Arkansas bauxite region leads to the conclusion that a change from a climate of alternating wet and dry seasons to one of continuous moisture may have ushered in the period of bauxite formation; and that a return to seasonal dryness may have ended this period. Evidence that during late Midway time a strong seasonal fluctuation of rainfall was in effect, is indicated by the graded bedding present in the dark-gray silty clay of the Wills Point formation. Presumably the coarser silty material was deposited by streams entering the Midway sea during wet periods, and the finer material settled gradually to the bottom during dry seasons.

Similar evidence of seasonal variation is found locally in the dark chocolate-brown silty to sandy clay in the lower part of the Saline formation. Brown silt and clay laminae alternate with very thin layers of white micaceous clayey quartz sand—presumably evidence of seasonal fluctuation in deposition on a flood plain.

The Wills Point formation was deposited before bauxitization began and probably all the Saline formation was deposited after it had ceased. The Berger formation, however, whose deposition coincided with at least part of the period of bauxitization, shows little evidence of seasonal variation. On the contrary, the abundant lignite, siderite beds, and the general greenish-gray color of the sediments indicate that it was chemically weathered during deposition in a swampy environment. The bauxite apparently was formed where silicate rocks rich in alumina stood above the permanently saturated areas.

TOPOGRAPHY AND DRAINAGE

Free movement of water through the rock for a long period resulted in the formation of bauxite. Continuous movement is possible only in topographically elevated well-drained areas. Many residual bauxite deposits in the Arkansas field are at the crests of ridges or on fairly steep slopes. Comparatively few are in

the bottoms of valleys. Normally the lower slopes and bottoms of valleys are occupied by kaolinitic clay. the kaolin appears to have formed in the lower poorly drained areas at the same time that bauxite formed on higher, well drained slopes.

A study of the profiles and sections through the bauxite shows that comparatively little steepening of surface slopes has taken place. Erosion has resulted in truncation of the upper parts of the deposits, and deposition on the lower parts, so that the slopes of the present surface of the bauxite are gentler than when they first formed.

In Arkansas residual (type 1) bauxite deposits that rest on kaolinized nepheline syenite dip 10° to 15° basinward throughout large areas. Upslope dips more than 15° are the general rule. The maximum recorded slope on the surface of the bauxite is 42° (fig. 34), and the slope of the base of the bauxite in places probably is greater.

Steep slopes permitted free movement of ground water deep in the coarse-grained igneous rock. This assumption is borne out by the association of the thickest known residual deposit (about 43 feet normal to the slope) with the steepest slope (fig. 34).

POROSITY OF SOURCE ROCKS

A loose coarsely porous rock will permit the free movement of water through it, therefore if such a rock is at or near the surface in the zone of aeration, rainwater falling upon it will move downward uninterruptedly. In this rock, according to Mohr (1933, p. 18), the water movement is intermittently downward, even if the rainfall is less than evaporation. Most of the source rocks on the nepheline syenite hills in the Arkansas bauxite region were sufficiently porous, either because of cavity space in the interstices or because of joints and cracks, to insure adequate circulation. Mead (1915, p. 51), while postulating that the alteration of kaolin resulted in the formation of the bauxite, suggested that it was an open spongy texture that permitted and controlled the change from kaolin to bauxite. He added that where the clay had an impervious texture it was not altered.

The enormous amount of leaching that can be done by tropical rain falling on a coarsely porous rock, as compared to its almost complete lack of effect on an impervious one, explains in part why in Arkansas the bauxite deposits were concentrated around the masses of igneous rock and why deposits are absent or scarce and highly siliceous on the surface of the fine sediments of the Midway group.

ALTITUDE

Bauxite deposits of late Tertiary to perhaps Recent age, weathered principally from igneous rocks or their residual clays, are found at altitudes from a few tens of feet to about 4,700 feet. In British Guiana and Surinam, in French West Africa (including French Guinea and the Los Islands), and in Madagascar and the Seychelles Islands, the formation of bauxite apparently has taken place in relatively low areas where the maximum relief does not exceed a few hundred feet, but it also has been reported at an altitude of 2,200 feet in British Guiana. In Gold Coast and Nyasaland, bauxite and laterite occur in deposits capping high tablelands and plateaus 1,000 to 2,000 feet above the surrounding lowlands (Harder, 1949, p. 896). In peninsular India many similar tablelands and plateaus are capped by laterite containing bauxite deposits that range in altitude from 3,000 to 4,700 feet and, less commonly, from 1,000 to 3,000 feet. In the planalto of Poços de Caldas, Brazil, extensive deposits of bauxite are found in rolling country at altitudes that range from 3,900 to 4,400 feet. Whether the more elevated occurrences have been uplifted since the bauxite was formed is not known. There must be an altitude above which bauxite cannot form—an altitude where the temperature becomes too low and conditions of weathering more like those in temperate climate are produced, which would result in podsolization, rather than lateritization of the soil.

As some of the low-level deposits in the Arkansas bauxite region are now as much as 240 feet below sea level, it seems likely the hills upon which most of the bauxite formed were several hundred feet higher in early Eocene time than they are now. The summits of the Saline and Pulaski nepheline syenite hills probably stood at least 700 feet above sea level when the bauxitic weathering took place.

EFFECT OF TEMPERATURE

Mohr (1933, p. 15) has explained the role of temperature in the formation of tropical soil in controlling the relationship between macroflora and microflora. The macroflora synthesizes organic materials from water and carbon dioxide of the air leaving a residue known as humus. The bacterial microflora breaks down the humus the macroflora builds up.

The macroflora grows at temperatures between 0°C (32°F) and 45°C (113°F) and has its optimum growth at 25°C (77°F). Besides air and water the macroflora needs vigorous irradiation. The microflora, given full aeration in the soil, does not function efficiently below 10°C (50°F); it has its optimum growth probably between 35° and 45°C (95° and 113°F); and can live in temperatures as high as 80°C (176°F). Microflora not only needs air and water but sufficient warmth.

The activity of the macroflora in building up humus in the soil is shown in figure 57, curve *A* taken from

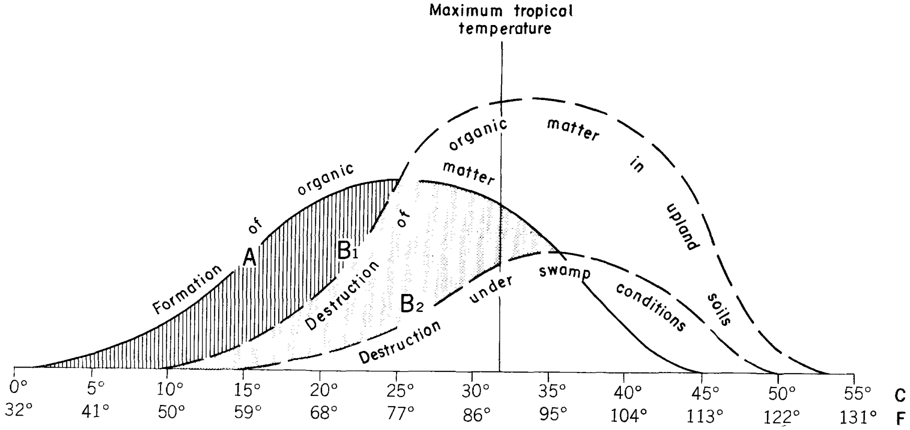

FIGURE 57.—Formation and destruction of organic matter in tropical regions, plotted against temperature. Slightly modified after Mohr.

Mohr (1933, p. 15). The activity of the microflora in destroying this humus is shown in curve B_1 in the same figure. The vertical solid lines in the diagram show where, under conditions of full aeration, the formation of humus is in excess of its destruction. Mohr believes that 25°C (77°F) is the critical temperature above which humus is destroyed faster than it is formed and none can exist. At this and higher temperatures water moving in well aerated soil above the water table carries little organic matter in solution.

Where the soil contains insufficient air a different condition prevails. The bacterial microflora is anaerobic and sluggish in its activity. Thus organic matter is much less rapidly broken down into carbon dioxide and water. The decreased activity of these bacteria in destroying organic matter is shown in figure 57, curve B_2. The area of combined dashed and solid vertical lines represents the range of conditions under which more organic material accumulates than is broken down by anaerobic bacteria. The temperature above which all humus is destroyed (about 35°C) is higher than the average maximum temperature of present moist tropical regions (about 32°C or 90°F) marked by the single vertical line; all swamp waters and marsh soils, therefore, contain organic matter.

IMPORTANCE OF ORGANIC MATTER IN GROUND WATER

Why so much attention has been paid in the preceding paragraphs to the formation and destruction of humus in the soil will be evident if one considers the brief statement regarding the chemistry of weathering in tropical regions, made by Mohr (1933, p. 17–18) and translated from the Dutch by Pendleton, as follows:

> The silicic acid of minerals is relatively most easily soluble in pure water (rainwater); the presence of dissolved salts, or carbonic acid, or of organic materials decreases the solubility.
>
> Kaolin, which is hydrous aluminum silicate, the basis of all that is called clay, also moves in pure water; it does not move in water containing salts, or carbonic acid, or organic materials.
>
> Iron oxide and alumina (aluminum oxide), on the contrary, are insoluble in pure water and in salt solutions, but go into solution as soon as the water contains humous organic materials, or strong acids.
>
> From this it follows that as the leaching occurs with water that has no organic materials, in the long run the free silicic acid and even the kaolin disappear, but iron oxide and alumina remain. Leaching with humous waters, on the contrary, results finally in products rich in silicic acid but free from iron and alumina.

Bauxite is formed, therefore, when under tropical conditions rainwater moves continuously through a porous aluminous rock. Kaolin is formed when the same rock is acted upon by water containing dissolved organic matter, or strong acids.

WATER TABLE

The importance of the water table in the formation of bauxite follows from the statements above. Given a high temperature, continuous precipitation, and a porous rock, the water in the zone of aeration above the capillary fringe of the water table will consist of pure or nearly pure rainwater moving downward. Also, the coarser the rock, the less the upward extent of the capillary fringe. Under such conditions bauxite will form. Below the water table, however, in the zone of saturation some organic matter and dissolved salts are in solution. Here kaolin will form.

MacLaren (1906) was one of the first to recognize

the importance of the water table in controlling rock weathering. But he believed that a lateritic crust is built up chiefly by materials carried in solution by ascending water in the capillary fringe, and that this crust, therefore, is not the direct product of the decomposition of a rock in place, but a replacement of the decomposition product.

Campbell (1910, p. 436; 1917, p. 121) contended that laterite and bauxite were never formed in the zone of permanent saturation, otherwise deposits of these materials would commonly be found in thicknesses of more than a hundred feet. Kaolin, on the other hand, forms in this zone and accumulates in such thicknesses. Campbell believed that laterite is formed in the zone of intermittent saturation, that is, in the zone of seasonal fluctuation in the water table and its capillary fringe. Such an environment, in peneplaned regions, according to Pendleton and Sharasuvana (1946, p. 433), gives rise to laterite in the original definition of Buchanan (see p. 72), but this rock has been shown by Fox (1936) to be a mixture chiefly of hydrous iron oxides and lithomarge (kaolinitic clay). Mohr concluded that layers through which ground water moved downward part of the time and upward at other times would be more enriched in silica than those layers where only downward percolation of rainwater occurred.

Fox (1927, 1932, p. 26–35, figs. 4–8) has shown that in peninsular India bauxite is formed as segregations in soft porous "laterite" well above the water table in basaltic plateaus. The ground-water level is marked by a bed of laminated siliceous lithomarge, 6 to 20 feet thick, underneath which kaolinized basalt grades downward into the unaltered rock. Apparently the lithomarge was formed in the zone of fluctuation of the water table and is about equivalent to the siliceous laterite that is found in peneplanes in low equatorial regions.

Harrison (1934, p. 27–28) believed that aluminous laterite is not a product of surface weathering, but is characteristic of the level coincident with or slightly above the water table. In British Guiana, he found, weathered crusts from the surface are higher in silica than lateritic crusts nearer the unweathered rock.

Goldich (1948) reemphasized the importance of the water table in controlling the formation either of bauxite or of kaolin. In speaking of the "transitional" clay layer between the bauxite and the parent rock he said:

> The clay layer is a normal product in tropical regions where weathering has progressed deep enough and where physical conditions permit establishment of a permanent water table. In this zone kaolin minerals—endellite, halloysite, and kaolinite—develop either by direct crystallization or by silication of aluminum hydroxide. The establishment of a permanent water table in a deep weathering profile marks the end of the cycle of laterization and a physical-chemical change of conditions favoring gibbsite development to those favoring clay minerals.

A review of the copious though scattered literature on the genesis of bauxite leads to the conclusion that the formation of bauxite is dependent upon the behavior of certain elements in aqueous solution. Goldschmidt (1937, p. 665) has divided the field of elements into three parts according to ionic potential (ionic charge divided by ionic radius). He describes the behavior of these groups of elements in solution as follows:

> Substances with low ionic potential, such as sodium, calcium, and magnesium, remain in true ionic solution in the process of weathering and transportation; those with intermediate ionic potential are precipitated by hydrolysis, their ions being associated with hydroxyl radicals from aqueous solutions; and substances with still higher ionic potential form anions containing oxygen and usually again soluble to give true ionic solution.

A modified version of Goldschmidt's diagram of the three groups of elements is given in figure 32. How closely this concept agrees with results, of the relative concentration or depletion of the elements in bauxite determined by spectrographic analysis, has been discussed in the chemical features of Arkansas bauxite on pages 96–99.

TIME

The weathering of igneous rock in a tropical climate is slow, even under optimum conditions. Many present day plateaus capped by laterite and bauxite have been uplifted and exposed to weathering since early in the Tertiary period. Bramlette (1936, p. 29) believed that the period of bauxitization in Arkansas may have lasted in early Wilcox time for 1,000,000 years, or longer—the Eocene epoch is estimated to have lasted about 13,000,000 years. Our present knowledge that bauxite continued to form during the deposition of the Berger formation, the lowest of the Wilcox group, possibly extends the overall period of bauxitization. But the stratigraphic relations described earlier in this report indicate that the time interval represented by the unconformity between the Wills Point and Berger formations was shorter than was believed heretofore. Evidence also indicates that the low-level deposits buried beneath the Berger were formed during only part of the period of bauxitization.

SUMMARY

Bauxitization takes place if the following conditions are satisfied:

1. A warm humid climate of continuous moisture, in which rainfall considerably exceeds evaporation most of the time.
2. A high temperature, probably exceeding 77°F most of the time, provides an environment in which the microflora can

destroy humus faster than the macroflora can manufacture it. (Ground water rich in humic organic material or strong acids deposits silica and kaolin and takes alumina and iron oxides into solution.)

3. Pure rainwater acts upon a porous aluminous rock, preferably coarse grained, that will permit free movement of water.
4. This rock is located in a topographically elevated well-drained place, but not so far above sea level that a temperate climate and conditions more favorable for podsolization will prevail.
5. The rock is above the level of the permanent water table.
6. The conditions listed above last for a long period of time.

The field relations of the Arkansas bauxite deposits indicate that these conditions were met, as far as can be determined. Evidence of deposition of the sediments of the Berger formation under chemically reducing conditions indicates a continuously moist climate during at least part of the period of bauxitization. A continuously high temperature is indicated by the subtropical faunas of the formations of the Midway group and the floras of the Wilcox group. The source rocks are mostly coarse grained igneous rocks, particularly high in alumina. The bauxite that formed in place is all located on topographically elevated parts of the region. These were well drained, and probably stood above the level of the water table until the later Tertiary sediments encroached upon them.

ORIGIN OF TYPE 1 DEPOSITS

The residual bauxite deposits on the higher slopes of the nepheline syenite hills probably for the most part were formed directly by the bauxitization of fresh igneous rock. At the same time that bauxite formed on well-drained slopes and spurs, kaolin formed in valleys and in other poorly drained places on the surface of the nepheline syenite. Kaolinitic clay within the bauxite deposits, however, and kaolinized nepheline syenite underneath the residual bauxite formed mostly after the period of bauxitization ended, rather than as an intermediate stage in the derivation of bauxite from nepheline syenite. The following are the principal criteria that favor the direct genesis of bauxite from fresh rock.

1. Bauxite is derived directly from fresh igneous rock in subtropical to tropical regions, notably the Los Islands off French West Africa, parts of British Guiana, and the planalto of Poços de Caldas, Brazil.

2. In Arkansas, from the end of the period of bauxitization during the Eocene epoch to the present time, climatic conditions favoring the formation of kaolin rather than bauxite have been in effect. One would, therefore, expect to find evidence of kaolinization following bauxitization as the normal sequence.

3. Bauxite deposits were covered by Eocene sediments. The ground-water level doubtless rose as the sediments were deposited, and the bauxite deposits were brought beneath the water table. This introduced a new set of conditions under which kaolinization was favored.

4. Observations have consistently shown the secondary relationship of kaolin to bauxite within the type 1 deposits. These observations have been described earlier in this report and are supported by a large mass of data.

5. In granitic-textured bauxite the minute details, such as cleavage planes, in feldspar laths of the original nepheline syenite are often preserved in the microcrystalline gibbsite pseudomorphs. This indicates direct alteration of the feldspar to gibbsite, rather than an intermediate kaolinitic stage, as alteration to kaolinite forms structureless masses and wormlike crystals within the feldspar lath and tends to obliterate its structures.

Much of the kaolin between the residual bauxite deposits and the fresh igneous rock was doubtlessly formed later than the bauxite. This may have been, as suggested by Goldich (1948), the result of the establishment of a permanent water table and subsequent weathering beneath it. But the fact that residual nepheline syenite boulders within the bauxite bed were also kaolinized after the bauxite formed indicates that a separate and later period of kaolinization occurred probably as the Eocene sediments covered the deposits.

Bauxite deposits arrived at their present state through many complex changes, the most important of which are listed below. They are in the order of their occurrence, although two or more of these changes were taking place simultaneously.

1. Bauxitization of the nepheline syenite resulted in the formation of granitic-textured bauxite that contains microcrystalline gibbsite as the main product. The place where this process occurred has been termed the zone of leaching.

2. Breaking down and further changes in the granitic-textured bauxite resulted in the formation of pisolites and other concretionary structures and the change from microcrystalline to cryptocrystalline gibbsite. This took place in what is called the zone of concretion.

3. Extreme consolidation of some of the pisolites was accompanied by the change of the gibbsite to boehmite and the iron oxide to a magnetic form. This occurred only locally in the zone of concretion and apparently was, at least in part, a process of dehydration.

4. Migration of the gibbsite in solution took place, followed by crystallization and deposition in cracks and fissures within pisolites and bauxite matrix. This apparently happened several times, even after bauxitization had ceased and kaolin was introduced.

5. Kaolin was produced chiefly by weathering of the nepheline syenite beneath the bauxite, following a rise in the water table that accompanied the deposition of the Eocene sediments. Some of the silica released by this weathering process went into resilication of part of the bauxite. Kaolin veins, irregular kaolinitic bodies, and kaolinized residual nepheline syenite boulders within the bauxite deposits were all formed at this time. Siderite was also introduced under these conditions.

LEACHING

The changes listed above are taken up in more detail below. The first part of the bauxitization process resulted in the formation of bauxite that preserves to some degree the original texture of the nepheline syenite. The silicate minerals in the parent rock were leached; silica, together with sodium, potassium, calcium, and magnesium were removed, as also were barium and strontium, and to some extent the rare earths yttrium and lanthanum; and hydrous oxides of aluminum, iron, and titanium were left. These elements were concentrated by the leaching process as were a few of the rarer elements in the nepheline syenite. Chromium, niobium, and gallium were concentrated in a greater proportion than aluminum. Molybdenum, zirconium, titanium, vanadium, and manganese were also concentrated, but less so than aluminum.

The principal end product was the microcrystalline form of gibbsite, derived chiefly from alteration of feldspar. This is reported as the first mineral to form from the weathering of feldspar in nepheline syenite or basic igneous rocks in equatorial regions, such as West Africa (Lacroix, 1913, p. 337;), Madagascar (Lacroix, 1923, p. 100), and British Guiana (Harrison, 1911, p. 355; 1934, p. 37). Part of the gibbsite was formed in the interspaces between relict feldspar crystals from nepheline, analcime, and other silicate minerals. Hydrous iron oxides were derived chiefly from the weathering of the ferromagnesian silicates and also from magnetite which, though present in the nepheline syenite, has not been identified among the heavy minerals in granitic-textured bauxite. Titanium oxide, in the form of anatase, was derived from the alteration of sphene and part of the ilmenite in the original rock.

The zone of leaching moved gradually downward, encroaching on the fresh nepheline syenite as weathering progressed. Had there been no further chemical change, mechanical disintegration, or removal by erosion of the bauxite formed initially in this zone, the alumina in these deposits would still be in the form of microcrystalline gibbsite preserving the nepheline syenitic texture. However, further changes, resulting in the formation of concretionary structures, took place in the upper part of the bauxite and gradually encroached downward on the granitic-textured bauxite. Moreover, at a later time when conditions favored the formation of kaolin, some of the granitic-textured bauxite especially at the base of the deposit was converted to kaolin by resilication.

CONCRETION

Formation of the concretionary forms of bauxite began with the breaking down of the granitic-textured rock into finer material. Disintegration of many microcrystalline gibbsite masses in the shape of relict feldspar crystals took place in this process and was accompanied by a gradual enlargement of the ferruginous interspace areas. Many geologists believe that the so-called amorphous form of aluminum hydroxide is a colloid, and that concretionary structures such as pisolites are of colloidal origin. Although X-ray examination showed a crystalline structure in both forms of gibbsite in Arkansas bauxite, the X-ray pattern of the form which appears isotropic under the microscope is weak and indistinct, suggesting that it is not well crystallized. It is possible that the cryptocrystalline form of gibbsite may have resulted from crystallization of a former colloid, originally derived from the microcrystalline material.

Rinds surround and seal off single fragmentary gibbsite pseudomorphs after feldspar, groups of these fragments, and bodies of matrix that consisted largely of iron-stained, cryptocrystalline gibbsite containing scattered microcrystals of gibbsite (fig. 55*B*). Concretionary bodies that formed around tiny nuclei apparently grew no larger than oolites. Where oolites or small pisolites already had formed in parts of the matrix, the sealing off of groups of these concretions by rinds has resulted in the formation of compound pisolites.

Material within many of the pisolites was consolidated, as evidenced by concentric cracks now filled with siderite between some pisolites and the surrounding matrix. The network of radial, concentric, and irregular cracks that cuts many of the pisolites and their outer concentric layers is likewise evidence of shrinkage.

Large bodies also were enclosed by rinds of cryptocrystalline gibbsite. These include pebble- to small boulder-sized blocks of granite-textured bauxite (the so-called sponge ore) that resisted the tendency to disintegrate and were sealed off from the finer material adjacent to them. Some of these bodies remain even at the top of the deposits. Blocks of bauxite with pisolitic and vermicular structure were enclosed in rinds and thus separated from the surrounding concretionary rock. The late stage of the process in the upper part of the deposits was one of continual breaking up and reconsolidating of the rock with a partial

destruction of some of the pisolites that had formed. As old passages were filled and new ones opened, so old pisolites were partly leached, leaving only fragments of the once concentric structures (pl. 14*A*).

The effect of the concretionary process was to consolidate the bauxite, to redistribute the constituents, and locally to raise the alumina content. It is not known whether there was a general upward migration of iron or alumina, such as has been reported in many bauxite and laterite deposits. Subsequent introduction of ferrous iron and its partial oxidation in surface deposits has masked the distribution of the primary iron oxide in the bauxite. The brick-red color of much of the pisolitic bauxite in type 1 deposits probably was caused by part of the original iron in the bauxite because it apparently is related to the vermicular structures. No evidence was found of an iron crust (cuirasse de fer) having formed over the residual deposits, such as is characteristic of many of the Indian and African laterites. Later kaolinization also has masked the original distribution of the alumina in the bauxite. The titania as anatase was widely and finely disseminated by the concretionary process and apparently has been somewhat concentrated locally.

FORMATION OF BOEHMITE AND MAGNETIC IRON OXIDE

Minor products of the concretionary process appear to have been boehmite and a magnetic iron mineral (magnetite or maghemite), which have been found within some of the harder pisolites.

Boehmite commonly is associated with gibbsite in bauxite deposits the world over, and many European deposits are composed chiefly of boehmite. J. de Lapparent (1936a, p. 2), after finding the best formed crystals of boehmite within pisolites beneath carbonaceous beds in Pereille (Ariege), France and in Ayrshire, Scotland, believed that long exposure to water containing humic matter in solution caused the crystallization of boehmite. He also said that gibbsite forms above the water table, boehmite at the water table, and diaspore below it (De Lapparent, 1936b). Hüttig and Wittgenstein (1928) converted gibbsite to boehmite in the laboratory in 24 hours at a temperature of 370°C and a pressure of 20 atmospheres. This led De Weisse (1948, p. 141) to suggest that the same change takes place in nature at a relatively low pressure owing to the weight of the sediments that covered a bauxite deposit. Goldich and Bergquist (1948, p. 99–100), on the other hand, suggest that boehmite may be formed in lateritic soil as a metastable phase and that it is transformed to gibbsite, the change being retarded in an acid chemical environment.

The presence in Arkansas of boehmite only in pisolites in the zone of concretion indicates that it may have formed from gibbsite through some process of aging and consolidation of the pisolites. The magnetic iron commonly associated with it may have influenced its formation.

MIGRATION OF Al^{+++} IN SOLUTION

Crystalline gibbsite fills cracks cutting across the earlier structures of the bauxite. These crystals indicate solution of hydrous aluminum oxides and redeposition after the bauxite had formed. Similar veinlets in Georgia bauxite and kaolin deposits were briefly described by Allen (1945, p. 273–274). Crystallization of nearly all the gibbsite that fills veinlets and cavities in the Arkansas deposits appears to have generally preceded the introduction of kaolinite, but in at least one place it followed kaolinite that fills a cavity near the top of the bauxite. Gibbsite crystals that line the cavities and protrude outward into masses of kaolinite may have formed at the time the kaolinite was introduced.

The gibbsite was deposited by circulating ground water and crystallized along cracks and cavities that permitted circulation of the solutions through the less permeable rock.

FORMATION OF KAOLIN BODIES

The beginning of Saline deposition was accompanied by a gradual change in the climate of the bauxite region. Rainfall probably increased somewhat and was limited to shorter, more violent periods, separated by drier periods. Active erosion took place during early Saline time, and rock from both the Paleozoic upland and from the residual bauxite deposits on the nepheline syenite hills was stripped off and redeposited downslope.

The chocolate-brown carbonaceous clay and interbedded sandy layers of the Saline formation encroached higher and higher on the nepheline syenite hills, and the residual bauxite deposits gradually were buried. The level of the water table rose, following the rising base level of the sediments. Bauxite deposits that once were in well-drained areas were brought beneath the water table. The ground water underneath carbonaceous beds contained dissolved organic matter and became acid. Much of the silica dissolved in the ground water was deposited as kaolin in the upper part of the bauxite deposits. The acid water worked its way through the homogeneous concretionary parts of the deposits and the extremely porous granitic-textured bauxite and attacked the fresh nepheline syenite beneath.

Kaolin was also formed by the resilication of the bauxite, that bordered the igneous rock, but not in large quantities. This resilication was accomplished by means of excess silica derived from the silicate minerals of the nepheline syenite during the kaolinization

process. As would be expected, the conversion from bauxite to kaolin resulted in an increase in volume that caused squeezing and local flowage of both bauxite and kaolin where the two are in contact. The resilication and the irregular penetration of silica, resulted in a fragmental-appearing texture in the kaolin adjacent to the bauxite. It was accompanied by movement of kaolin into cracks, cavities, and pore spaces in the bauxite.

Allen (1948, p. 1307) has emphasized that veins of clay minerals cutting bauxite do not prove resilication, particularly where clay overlies bauxite, because migration of clay minerals has occurred at many deposits not associated with bauxite. This brings up the question as to how much of the kaolin in the bauxite was formed by migration of kaolinite in solution and how much by the introduction of silica and alteration of the bauxite. It seems likely that both may have taken place simultaneously, as Mohr has suggested that silica and kaolin behave alike under the same ground-water conditions. Field evidence reviewed earlier indicates that the kaolin veins and bodies in type 1 deposits are clearly later than the bauxite, and most of them cut it from beneath. If the source of much of the kaolin were the weathering of the nepheline syenite, kaolinite and silica would have been liberated and could have moved in solution. Examination of the kaolin veins has shown that they widened at the expense of bauxite, not by pushing apart the bauxite, but irregularly by alteration of the bauxite along the side of the vein. This indicates that resilication of gibbsite to form kaolinite played an important part in the formation of the kaolin immediately bordering the bauxite.

INTRODUCTION OF SIDERITE

Organic acids are effective in the solution of ferrous iron compounds (Clarke, 1924, p. 535) and contribute to swamp waters the material from which bog-iron ores are formed. The ground water that caused kaolinization of the bauxite was also charged with ferrous iron and carbon dioxide which were deposited as granular siderite, in the bauxite. Siderite, a late mineral, filled most of the small open cavities in the pisolitic bauxite.

Siderite was also formed within the kaolin adjacent to the bauxite. Here it is mostly spherulitic and has a radiating structure inside and one or two concentric layers outside, or is in veinlets having a minute comb structure.

ORIGIN OF TYPE 2 DEPOSITS

Type 2 deposits, contained in the bauxite-kaolin facies at the upslope edge of the Berger formation, probably formed largely in place from weathering of a colluvium of bauxitic and kaolinitic detritus above the water table. The following three processes, listed in chronologic order, essentially determined the present shape, size, and distribution of the bauxite deposits.

1. Deposition of the colluvial apron.
2. Bauxitization of parts of the colluvium above the water table.
3. Gradual burial of the apron, accompanied by kaolinization of much of its upper part.

The colluvial apron was a clay fanglomerate—an accumulation of weathering products derived mostly from the nepheline syenite slopes farther uphill. The detritus came to rest along the break in slope where the steeply dipping weathered surface of the nepheline syenite is lapped by the nearly flat-lying sediments of the Midway group. The colluvial detritus rests, therefore, partly upon deeply kaolinized and bauxitized nepheline syenite and partly upon weathered residual clay of the Wills Point formation, and in a few places on truncated weathered beds of the Kincaid formation.

PRE-WILCOX WEATHERING AND EROSION

Wedges of relatively fresh detritus in the Midway sediments indicate that no appreciable kaolinization of the nepheline syenite masses took place during Kincaid time, a period of active erosion. This was followed in Wills Point time by a period of less active degradation accompanied by chemical weathering and widespread kaolinization of the igneous rocks.

Immediately following the retreat of the Midway sea a stream pattern, already established on the higher slopes of the nepheline syenite hills, was extended outward onto the Midway surface. The sediments of the Wills Point were channeled deeply in some places; the lip of this formation was stripped from some of the larger drainage channels, though generally not from the small valleys. The eroded surface then was weathered profoundly and a soil profile was established.

DEPOSITION OF THE COLLUVIAL APRON

Following this period of relative inactivity, erosion on the higher slopes and deposition in the valleys began, eventually resulting in the formation of a peripheral apron of fragmental clay surrounding the base of the nepheline syenite hills. The 10 to 30 feet of gray fragmental clay that now underlies the bauxite deposits probably was deposited in a few places before the complete withdrawal of the Midway sea. Evidence for deposition in Midway time is the alteration of part of the kaolinite to hydrous mica in the lower few feet of the fragmental kaolinitic clay, observed at several localities near the edge of the Wills Point formation or immediately overlying it. Hydrous mica is a characteristic alteration product of kaolin within or covered by Wills Point sediments, but not of kaolin on the higher slopes. Formation of this micaceous mineral probably was aided by the fixation of potassium in sea water.

The gradual accumulation of the colluvial apron continued during and following the withdrawal of the Midway sea and later accompanied the deposition of the carbonaceous and arenaceous sediments of the Berger formation, as described on pages 41–44. Several processes of mass wasting contributed to its formation, probably including soil creep, slump, mudflow, and landslides.

A climatic change to continuous moisture under tropical or subtropical conditions, probably resulted in the formation on the upper slopes of the nepheline syenite of a thick weathered mantle of bauxite, of which the type 1 deposits are the residue. Fragments of bauxite were added to the mass accumulating downslope, which had up to this time been receiving an almost entirely kaolinitic detritus. Probably at no time in any large area was the accumulating colluvium composed entirely of bauxite. Both bauxite and kaolin were formed in the deposits upslope, bauxite on the ridges and slopes and kaolin in the valleys. The probable composition of the material originally contributed to the colluvial apron can best be determined by examining cores of fragmental clay taken near the centers of small lateral valleys and in between bauxite deposits. The material near the middle of these clay deposits, 50–60 feet thick, is composed chiefly of kaolinitic clay in which are finely disseminated gibbsite and small angular bauxite fragments, indicating that for the most part the average chemical composition is similar to bauxite clay.

The movement of bauxite downslope in quantity probably did not begin until beds of lignite, gray silty clay, and sand of the Berger formation started to build up from the deeper parts of the basin toward the upper slopes of the nepheline syenite hills. The parts of the colluvial apron deposited at this stage came to rest at the change of grade formed by the intersection of the weathered nepheline syenite slope and the flat-lying contemporaneous surface of the lignite or silty clay bed of the Berger formation. The locus of deposition therefore moved gradually upslope as later beds of the Berger formation progressively covered the peripheral apron of bauxite and fragmental clay.

BAUXITIZATION OF PARTS OF THE COLLUVIUM

The type 2 bauxite deposits were formed during and after the deposition of the colluvial apron and before their burial beneath the later sediments of the Berger formation. For the following reasons it is believed that these bauxite deposits were formed in place by weathering above the water table of the bauxitic to kaolinitic colluvium.

1. Type 2 deposits have a comparatively uniform lithologic and chemical zonation which is similar in all parts of the bauxite region (pl. 15).
2. They are commonly ranged along brows and slopes of ridges, similar to type 1 deposits. Thus they are usually in a topographic position where they would most likely have been above the water table and well drained.
3. Such deposits grade toward the valley center into kaolinitic clay containing scattered fragments of bauxite. For this reason it seems unlikely that a large part of the kaolinitic clay has formed in place by the resilication of a mass of bauxite. If this had happened each deposit and each fragment of bauxite would be a remnant unaffected by resilication.
4. The bauxite fragments and pebblelike bodies within the bauxite deposits and also within the kaolinitic clay are generally composed of microcrystalline gibbsite, whereas the bauxite pisolites and matrix in the deposits are made up essentially of cryptocrystalline gibbsite. This suggests that they do not have precisely the same origin.
5. In the bauxitic and kaolinitic underclay individual kaolinite flakes under the microscope commonly are seen to contain scattered microcrystalline gibbsite grains. In one accordionlike kaolinite crystal, microcrystalline gibbsite after kaolinite was observed (pl. 14*D*). This would appear to be evidence in support of Harrison's conclusion that bauxite can form from clay (Harrison, 1934, p. 10).

The chemical process by which parts of the colluvium were transformed into bauxite probably is the same as that which formed the type 1 deposits—that of hydrolysis. However, the rock acted upon was a semiporous mixture of clay and bauxite, rather than fairly fresh nepheline syenite. Much of the calcium, sodium, potassium, and magnesium and part of the silica already had been leached from this weathered nepheline syenite detritus in the colluvium.

Spectrographic analyses indicate that there is a greater concentration of certain elements normally precipitated by hydrolysis (fig. 32). These elements include chromium, molybdenum, scandium, titanium, vanadium, manganese, and yttrium. Their apparent concentration would lend confidence to the belief that this bauxite was formed by hydrolysis of an already weathered rock. On the negative side is the apparent lack of any increment in the content of aluminum, gallium, niobium, and zirconium and the increase in content of several substances of low ionic potential normally depleted by hydrolysis, such as barium, calcium, magnesium, and strontium.

Boron, the presence of which was not detected in the nepheline syenite or in type 1 bauxite deposits,

probably entered the type 2 deposits from the marine Paleocene sediments.

The part of the type 2 bodies that appears to be analogous to what has been termed the zone of leaching in type 1 deposits is the wedge-shaped downslope portion beneath the pisolitic bauxite. This retains about the same textures as the bauxitic and kaolinitic clay beneath and surrounding it. In places where fragments occur, they are composed of microcrystalline gibbsite. The matrix is semiopaque and composed largely of cryptocrystalline gibbsite, probably mixed with very fine grained kaolinite. It is only a minor part of most deposits, however.

The "zone of concretion," represented almost entirely by pisolitic bauxite, constitutes a large part of a type 2 deposit. The pisolites and other concretionary structures probably formed gradually in a fragmental to textureless bauxite matrix, in much the same manner as the type 1 deposits formed from the breaking down of granitic-textured bauxite. Pisolites were formed by the sealing off of small bodies of the fine-grained matrix and the gradual accumulation around them of rind layers. This was accompanied by a change of part of the remaining microcrystalline gibbsite to the cryptocrystalline form. Aggregates of microcrystalline gibbsite that remained unchanged were enclosed in concretionary rinds. Passages were opened and subsequently filled with aluminous material in the matrix between pisolites and fragments. Radial and concentric cracks were formed in most of the pisolites and these cracks and little fissures and cavities in the matrix later were filled with finely crystalline gibbsite, as in the type 1 deposits. As the initial form of bauxite in type 2 deposits was largely in a finely divided state, it was a suitable environment for the formation and growth of concretionary structures. This explains why so little of the "zone of leaching" is preserved in these deposits.

What caused the zonation commonly observed in the concretionary part of the deposits is not definitely known. In many places the soft pisolites with bluish viscous or pasty interiors near the base of this zone are similar in chemical composition to the red and black pisolites with hard chertlike interiors near the middle. The soft consistency and the grayish color of the pisolites near the top of the deposits, however, are due largely to secondary kaolinization.

Boehmite and magnetic iron oxide are associated in a few of the hard pisolites in type 2 deposits. As in type 1 deposits, boehmite probably formed from gibbsite as the result of a lengthy aging process.

INTRODUCTION OF KAOLINITE AND SIDERITE

The gradual burial of the bauxite deposits and the associated kaolinitic clay beneath the paludal sediments of the Berger formation was accompanied by the introduction and formation of kaolinite in their upper part. A gradual process first affected the downslope parts of the colluvial apron. As the sediments of the Berger increased, the locus of deposition moved upslope and the water table rose. The approximate position of the water table at the base of the slope at any given time was marked by the edge of a swamp in which lignite was accumulating.

Kaolin that covers bauxite deposits, particularly that which covers their downslope parts, probably was transported to its present position. A large amount of the kaolinite, however, was formed in place around and beneath the swamps. The evidence just presented on pages 120–130 shows that the kaolinite in bauxite deposits of type 2 was introduced principally from above. The bauxite was cut by vertical veinlets and horizontal sheets of kaolinite that replaced the bauxite. An excess of silica introduced along with the kaolinite combined with gibbsite to form additional kaolinite. Resilication of gibbsite played an important part in the formation of the hardcap and its overclay. Resilication took place particularly in bauxite not more than several feet below the bottom of the swamp.

Siderite was introduced at about the same time as the kaolinite. The acid humic waters that permeated the deposits at this time contained ferrous iron and carbon dioxide. These oxides were deposited in the form of crystalline siderite in most of the available cavities and pore spaces in the bauxite, and in a spherulitic form in the less pervious kaolin. Siderite generally appears to have formed a little later than secondary kaolinite in cavities where the two occur together. Both minerals probably formed earlier in the downslope parts of the colluvial apron and its bauxite deposits than in the upslope parts.

ORIGIN OF TYPE 3 DEPOSITS

The alluvial bauxite lenses, called type 3 deposits in this report, are composed essentially of reworked hard pisolites and pebbles derived principally from type 2 deposits and perhaps in part from type 1 deposits. This is indicated, in addition to other evidence, by similarity in the assemblage of heavy minerals and the content of minor elements in the deposits of both residual and alluvial origin.

The upslope part of a type 3 deposit generally rests directly upon a type 2 deposit, presumably the same one from which the sedimentary bauxite was largely derived. Stratification, size sorting, and crossbedding of the bauxite gravel indicate that the medium of deposition was flowing water. The bauxite alluvium was deposited by small streams that drained the slopes upon which residual bauxite deposits had formed or

were forming. The wedge of lignite and clay beneath the downslope part of most type 3 bodies indicates that they were deposited generally in swampy areas at the time that the type 2 deposits were partly covered by the encroaching Berger sediments. The lenses apparently have grown outward downslope as well as upward, while the base level of Berger deposition continued to rise.

The spaces between the pisolites and pebbles are filled with a softer oolitic bauxite that apparently was also derived from the deposits upslope. Other parts of the bauxite gravel are loosely consolidated, with almost no filling in the interspaces. Some of these voids were filled later by crystalline gibbsite that moved in solution and crystallized to form drusy coatings on pisolites, in cavities, and in veinlets.

The same sort of sediments that were deposited in a paludal environment over the type 2 deposits also covered the type 3 deposits. From the swamp waters kaolinite, siderite, and excess silica were introduced downward into the bauxite. Kaolinite apparently was deposited directly in veinlets and small masses where the rock was composed essentially of hard pisolites and pebbles with little or no binder. Resilication of bauxite to form kaolinite appears to have affected places where soft bauxite was packed between the hard material. In this manner rocks that resemble the hardcap of type 2 deposits were formed locally in the middle or lower parts of the alluvial lenses. Crystalline siderite also fills many of the voids in this bauxite, having been introduced in the same way as described for type 2 deposits.

Their close association with type 2 deposits indicates that the type 3 deposits formed within or shortly after the main period of bauxitization. But because they were deposited by water in channels and other low places and probably were quickly buried beneath additional sediments of the Berger formation, they were not in a favorable environment for further bauxitization. Their quality as to alumina, iron, and silica content, therefore, is controlled principally by the grade of the original material deposited and by the quantity and disposition of the kaolinite and siderite introduced after burial.

ORIGIN OF TYPE 4 DEPOSITS

The bauxite lenses in the lower part of the Saline formation were deposited during a later stage in the erosion cycle, after all the type 3 and most of the type 2 deposits had been buried beneath the Eocene sediments. In early Saline time nearly all the bauxite exposed to erosion was in the extensive type 1 deposits that mantled the Saline nepheline syenite hill and these were the source of the type 4 deposits. Either a moderate regional uplift or an increase in rainfall, more probably the latter, caused deposition of the boulder beds along the base of this hill. The same conditions caused the deposition of an apron of siliceous gravel along the edge of the Paleozoic upland. Also during early Saline time, the part of the Pulaski high that remained above the level of depositing sediments was stripped of most of its type 1 bauxite deposits and part of the kaolin that had formed upon it.

The conditions under which deposition in Saline time took place probably were not favorable for the weathering of rock to bauxite, possibly because the rains were seasonal and were separated by dry periods of long duration. The bauxite rubble, moreover, was generally deposited in poorly drained areas that were not favorble for bauxitization in place.

The grade of the bauxite, therefore, is dependent upon the degree of mechanical contamination of the alluvial material, which is mainly a function of the proximity of the transported rock to its source.

During and closely following the burial of these deposits siderite and kaolinite were introduced, but the amounts are minor in comparison with the volume of clay and sand mechanically mixed with the bauxite during transportation.

AGE AND DURATION OF BAUXITIZATION

The bauxite in the Arkansas deposits was all formed during a single long period of weathering. This period followed deposition of the marine sediments of the Wills Point formation and withdrawal of the Midway sea from the region; it probably closed before deposition of the continental Saline formation. The climatic conditions that favored bauxitization probably also affected a large part of the North American continent. Stratigraphic relations indicate that all the gibbsitic bauxite deposits in the south-central and southeastern United States formed about the same time (Bridge, 1950).

Uncertainty as to the geologic age of the Berger and Saline formations and their correct correlation with the standard geologic column for the Gulf Coast region allows some leeway in dating the period of bauxitization in Arkansas. Although it is possible that the Berger formation represents continental deposition during Midway time after the withdrawal of the sea from the Arkansas bauxite region, the Berger is lithologically similar to the Wilcox group in Mississippi and Alabama. It is possible, however, that the Saline formation belongs, not in the Wilcox group, but in the Claiborne (from which it now is believed that many supposed "Wilcox" fossil plants were originally collected) and that, as some petroleum geologists have suggested, Wilcox deposition did not extend as far north as central

Arkansas. The period of bauxitization, therefore, may have been entirely within Wilcox time, or it may have begun in late Midway time and ended in Claiborne time. Bauxitization therefore, definitely continued through the early Eocene but possibly may have started in late Paleocene time. Regional studies of the sediments along the northern fringe of the Gulf Coastal Plain from stratigraphic data now available would do much to lessen the uncertainty as to the limits of this period.

The relative ages of the four types of deposits within the Arkansas bauxite region deserve a brief comment. As the type 1 deposits lie on the upper slopes of the nepheline syenite hills in well-drained areas, they were the first to be formed and the last to be buried. For this reason, they probably were exposed to weathering throughout the period of bauxitization.

The type 2 deposits, on the other hand, were formed in a colluvial apron along the bases of these hills, derived in part from the type 1 deposits. As they were soon covered by the encroaching sediments, bauxitization must have taken place relatively rapidly during only a part of the time that this process was active. The bauxite in type 1 deposits, therefore, can be both older and younger than that in type 2 deposits.

Deposition of the two alluvial types of bauxite deposits probably took place with comparative rapidity. The relation of any of these alluvial deposits to the two residual types can be determined by its stratigraphic position in the enclosing sediments and by its field relations.

ECONOMIC GEOLOGY

DISCOVERY OF BAUXITE IN ARKANSAS

Bauxite in Pulaski County was first described by W. Byrd Powell (1842) in a short report on the geology of Fourche Cove and the immediate vicinity. Powell, not realizing its true nature, referred to the rock as an "amygdaloid." However, his descriptions of the types of "amygdaloid" (p. 11–13), in some places "resembling a mass of peas, each of which is solid jasper," in others "earthy and more or less friable," and at one place like "a sponge, with its fibres encrusted with the red oxides of iron," leave no doubt that he was referring to bauxite. Moreover a catalog and map in the report (p. 21, map), indicating the localities at which he collected rock specimens, show that some of them came from outcrops now known to be bauxite.

D. D. Owen (1860, p. 70), state geologist of Arkansas from 1857 to 1860, also mentioned pisolitic outcrops in Pulaski County, in secs. 4 and 9, T. 1 S., R. 12 W., in which there had been several small prospects dug in search of gold and other metallic ores. He said that the rock in the NE¼ sec. 9 "is a ferruginous amygdaloid of rather a peculiar character. The amygdules are very globular, so that the rock has the appearance of peastone, the cavities being mostly empty." These and several other similar outcrops also were mentioned by J. Lesley (1860, p. 159–162), who made a detailed topographical and geological survey of the Fourche Cove. Apparently neither of these men suspected the true identity of the rock.

J. C. Branner, state geologist of Arkansas from 1887 to 1893, was the first to identify bauxite in Arkansas. This was in June 1887, and the locality was along the road from Little Rock to Sweet Home, about a mile south of Fourche Bayou. Between this point and Sweet Home, slightly more than a mile farther south, bauxite from nearby outcrops was used to surface the road. Four years passed between Branner's recognition of bauxite in Arkansas and the publication of his preliminary description of the deposits. In the interim, the first description of bauxite as such in the United States identified in a small deposit in Floyd County, Ga., was published in a brief note by Nichols (1888, p. 905). Branner announced his discovery and described all the known outcrops, covering an estimated area of 640 acres in Pulaski and Saline Counties, in a preliminary report to the Governor of Arkansas, dated January 7, 1891. This was printed by the local newspapers the following day and also appeared in the 3d to 6th biennial reports of the Bureau of Mines, Manufacturing, and Agriculture of the State of Arkansas, 1894 to 1901. He also published a short article telling of the occurrence, in the American Geologist (Branner, 1891, p. 181–183), and this was abstracted in several other scientific journals.

HISTORY OF MINING AND PRODUCTION

The discovery of the Arkansas bauxite deposits came several years after the invention of a practical commercial process for producing aluminum. The Hall-Herault process for the manufacture of aluminum by the electrolysis of alumina had been discovered in 1886 by two young men working independently, Hall in the United States and Herault in France. The Pittsburgh Reduction Co. was formed in 1888 to exploit Hall's process. Limited production of bauxite began in the Georgia field that same year but was mostly for chemical use. Another process, that permitted alumina to be produced cheaply from bauxite, was patented by K. J. Bayer in Germany in 1888 and in America in 1894. The Bayer process coupled with the Hall process provided the foundation on which the aluminum industry in the United States has been built.

Branner was confident that his announcement of the discovery of bauxite in Arkansas would evoke an im-

mediate interest from the producing companies (Ferguson, 1920, p. 46). The early demand for the ore was limited, however, and was satisfied by the deposits in Georgia, together with deposits found in Alabama in 1890. Branner tried to interest the Pittsburgh Reduction Co. and the Solvay process Co. in the Arkansas deposits but was not successful. No funds were made available by the State Legislature to the Arkansas Geological Survey after 1893, and Branner left to teach geology at Stanford University.

It was late in 1894 or early in 1895 when the first Georgia bauxite producers showed interest in the Arkansas deposits. The year 1895 was one of considerable activity in acquiring land, both in Pulaski and Saline Counties. The first mining company in the field was the Southern Bauxite Mining and Manufacturing Co. (Perry and Smith), which later changed its name to the General Bauxite Co. This company located its headquarters in the vicinity of the present town of Bauxite. In 1896 the company shipped 40 tons of ore for experimental purposes. This earliest production was reported to the writers in June 1945 by J. W. Lewellen of the Alcoa Mining Co., who is also the source for much of the information contained in the following paragraphs on the history of production.

In table 13 are listed the companies that have mined bauxite in the Arkansas bauxite region. The table was prepared from records available in U. S. Geological Survey, "Mineral Resources," the U. S. Bureau of Mines, "Minerals Yearbook," and publications of the Arkansas Geological Survey. The companies are arranged in chronological order of their first year of production, and annotations enable the reader to follow some of the changes of company names.

Bauxite from the Arkansas field was first produced commercially in 1898. E. Metznauer of Little Rock erected a small plant near Mabelvale for the manufacture of alumina and aluminum salts. After experimenting unsuccessfully with the high-silica bauxite, near Mabelvale which did not lend itself to processing by the soda method, Metznauer acquired a small property near Bauxite in the NE¼ sec. 15, T. 2 S., R. 14 W. About 358 tons of ore from this property was processed at the Mabelvale plant that year, and part of the alumina was converted to alum or some other salt. That same year the Illinois Chemical Co. built a small plant near Bauxite and started mining from an outcrop in the NW¼ sec. 16, T. 2 S., R. 14 W. During the first several years of production bauxite mined by all the operating companies was used in the manufacture of aluminum sulfate, or commercial "alum" (Hayes, 1901, p. 466).

In 1899 the Pittsburgh Reduction Co. joined the other Georgia-Alabama producers that had entered the Arkansas field. The company secured a property in the NE¼ sec. 16, T. 2 S., R. 14 W., and reportedly shipped 1,720 long tons of ore during the first year (Rothwell, 1900, p. 12).

In 1900 the Illinois Chemical Co. and E. Metznauer were the largest producers, the other two companies shipped only a few hundred tons each. This was the last year of production for the Illinois Chemical Co.

The Pittsburgh Reduction Co. and the General Bauxite Co. built crushing and drying plants at Bauxite in 1901. During that year the two companies mined only 867 tons, the total Arkansas production. These companies increased their production in 1902 and Metznauer shipped about a hundred tons of ore before leaving the business.

The completion, early in 1903, of the plants of the two principal companies brought Arkansas to the fore as the leading producer of bauxite in the United States, a position still held. In that year the Saline mining district produced 25,713 long tons of bauxite, or 53.5 percent of the total United States production.

In 1904, the first bauxite from the Pulaski mining district, about 550 long tons, was mined by Fred Berger (American Bauxite Co.) from a deposit on the Arch Street Pike near what is now known as the Berger Spur. This company produced slightly more than 5,600 tons from 1904 to 1906, for the manufacture of refractory brick. The process for which Berger held a patent used calcined bauxite and a small amount of plastic fire-clay binder. The Arkansas production for 1904 was nearly the same as for the preceding year and was 54.0 percent of the total for the United States.

In the summer of 1905 the General Bauxite Co. sold its Arkansas holdings to the Pittsburgh Reduction Co. In 1906 the Republic Mining and Manufacturing Co., another Georgia producer, bought the interest of Berger's American Bauxite Co. In 1907, the Pittsburgh Reduction Co. changed its name to the Aluminum Co. of America and the company increased its plant facilities. During this period Arkansas production mounted gradually.

However, world-wide depression that year brought production to a halt by mid-November and it was not resumed until September 1908.

After the 1907 depression, production rose rapidly and the 1909 tonnage was almost three times that of

1908. The mining interests of the Aluminum Co. of America in 1909 took the name American Bauxite Co. This had no connection with Berger's earlier company of the same name. From 1910 to 1914 the increase in production was gradual and several new companies came into the region. The Globe Bauxite Co. began mining operations in 1912. They located at Chemical Spur in Saline County and later extended their activities to Pulaski County. The Norton Co. erected a calcining plant in 1913 at Bauxite and purchased ore for the the manufacture of abrasives. After 1918 the company mined bauxite sporadically from its single property in the Saline mining district. The National Bauxite Co. formed by several officials of the defunct General Bauxite Co. had acquired property in Arkansas in 1907, and at the beginning of 1914 produced bauxite in the Pulaski mining district, about a mile southeast of Berger. After 1916 the National property was operated by the E. I. du Pont de Nemours Co.

World War I brought a sudden demand for bauxite and United States production was greatly augmented. The output in Arkansas rose from 195,247 tons in 1914 to 562,892 tons in 1918, an increase of 288 percent. During this period Arkansas produced 90 percent of the domestic supply. A general cancellation of orders followed the signing of the Armistice, but by the middle of 1919 the demand again increased, and the production in 1920 was greater than that for any previous peacetime year. Also in 1919 South American bauxite began to be imported in some quantity into the United States.

Near the end of 1920 and early in 1921 the demand for bauxite decreased sharply and all the Arkansas mines were closed by March 1921. In June a few mines reopened and production continued on a limited basis. The E. I. du Pont de Nemours Co. mined no bauxite after 1921.

The demand for ore was normal through 1922 and in 1923 increased markedly. The Arkansas bauxite region shipped 493,880 tons that year despite an increase in United States imports from 23,656 tons in 1922 to 119,020 tons in 1923. The Southern Bauxite Co. operated a deposit in the Saline district in 1922.

From 1924 through 1929 Arkansas production was reasonably steady, generally 300,000–350,000 tons per year. Most of the ore was mined by underground methods following the opening of the first underground mine in 1924 by the American Bauxite Co. That same year the Superior Bauxite Co. shipped bauxite for chemical use from a property near the Southern Bauxite Co. mines. Between 1925 and 1927 the Dixon Bros., D. B. Hill, and J. P. Wright, produced some ore apparently all from a single deposit in Pulaski County that lies on the line between secs. 35 and 36, T. 1 N., R. 12 W. In 1928 the Dixie Bauxite Co. began mining operations near Sweet Home and in 1929 started working the first vertical shaft mine in the bauxite region.

The American Bauxite Co., the principal producer in the Arkansas field, changed its name early in 1930 to The Republic Mining and Manufacturing Co. of Delaware, and the old Republic Mining and Manufacturing Co. of Georgia that had been operating in the Pulaski mining district, was incorporated into the new company. The new Republic Mining and Manufacturing Co. was the largest producer during the thirties and early forties. The Kalbfleisch Corp. entered the Arkansas field in 1930 and worked the old Globe and Superior pit mines in secs. 25 and 26, T. 2 S., R. 14 W. Later in the thirties, and in the forties, the same company, under the name American Cyanamid and Chemical Corp. was one of the principal producers in the bauxite region. The Crouch Mining Co., a subsidiary of the General Abrasive Co., began mining operations in 1931 from the England shaft mine in Pulaski County; then in 1940 switched operations to the Young shaft mine in Saline County, the deepest mine in the bauxite region.

Several new producers were active in the bauxite region during the middle thirties. The Crawford Bauxite Co., 1933, produced ore from a shaft mine in the Saline district, about a mile northeast of Mount Olive. The Pulaski Bauxite Co. also produced some ore in 1936 and 1938 from the J. P. Wright property in sec. 36, T. 1 N., R. 12 W., Pulaski County. The Standard Bauxite and Chemical Co. sank a shaft in the northeast corner of section 17, T. 2 S., R. 14 W., and this property was operated by the West Bauxite Mining Co. in 1936 and by the Arkansas Bauxite Corp. which also operated two other properties in the Saline district. A wet process activating plant was installed at West Bauxite jointly owned with Max R. Miller Co. In 1940 the Arkansas Bauxite Corp. sold most of its interests to the American Cyanamid and Chemical Corp. The Porocel Corp. erected a plant in 1938 near Berger and in 1939 produced activated bauxite by means of a new dry process. Ore was purchased from other companies, mostly from American Cyanamid and Chemical Corp. Porocel Corp. also bought the West Bauxite activating plant.

Arkansas production increased in 1939 and 1940, but did not reach the 1923 level. Early in 1941 another new company, the Dulin Bauxite Co., started mining operations in Pulaski County and began construction of a calcining plant at Sweet Home. World War II brought

TABLE 13.—*Chronological list of the companies that have mined bauxite in the Pulaski*

Mining company	District	1896	1897	1898	1899	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912	1913	1914	1915	1916	1917	1918	1919	1920	1921
Southern Bauxite Mining and Manufacturing Co.	Saline																										
General Bauxite Co.	do.	X			X	X	X	X	X	X	X																
E. Metznauer	do.			X	X	X		X																			
Illinois Chemical Co.	do.			X	X	X																					
Pittsburgh Reduction Co.	do.				X	X	X	X	X	X	X	X															
American Bauxite Co. (Fred Berger)	Pulaski									X	X	X															
Republic Mining and Manufacturing Co. (of Georgia).	do.												X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Aluminum Co. of America	Saline												X	X													
National Bauxite Co.	Pulaski																			X	X	X					
American Bauxite Co.	Saline														X	X	X	X	X	X	X	X	X	X	X	X	X
Norton Co.	do.																								X		
Globe Bauxite Co.	Sal., Pul.																	X	X	X	X	X	X	X	X	X	X
E. I. du Pont de Nemours Co.	Pulaski																						X	X	X	X	X
Southern Bauxite Co.	Saline																										
Superior Bauxite Co.	do.																										
J. P. Wright	Pulaski																										
Dixon Bros.	do.																										
D. B. Hill	do.																										
Dixie Bauxite Co.	do.																										
Republic Mining and Manufacturing Co. (of Delaware).	Sal., Pul.																										
Kalbfleisch Corp., Inc.	Saline																										
Crouch Mining Co., Inc.	Pul., Sal.																										
Crawford Bauxite Co.	Saline																										
American Cyanamid and Chemical Corp.	Pul., Sal.																										
Standard Bauxite and Chemical Co.	Saline																										
West Bauxite Mining Co.	do.																										
Arkansas Bauxite Corp.	do.																										
Pulaski Bauxite Co.	Pulaski																										
Consolidated Chemical Industries, Inc.	Sal., Pul.																										
Dulin Bauxite Co.	Pul., Sal.																										
Reynolds Mining Corp.	Sal., Pul.																										
Sweet Home Bauxite Co.	Pulaski																										
Victory Bauxite Co.	do.																										
Hardin and Prewitt Bauxite Co.	do.																										
Sweet Home Mining Co.	do.																										
P. C. Upton	Pul., Sal.																										
Aluminite Mining Corp.	Pulaski																										
Arkansas Bauxite Stripping Co.	Saline																										
Clarke Bauxite Co.	Pulaski																										
Fourche Mountain Mining Co.	do.																										
S. E. Evans Construction Co.	Saline																										
Maner Graham	do.																										
Hull-Macke Bauxite Co.	do.																										
Hurricane Creek Mining Co.	do.																										
Jackson and Squire	Pul., Sal.																										
Kenark Mining Co.	Pulaski																										
Osage Bauxite Co.	Saline																										
Roy Prewitt	Pulaski																										
Pulaski Mining Co.	do.																										
Schafer and Haire Bauxite Co.	Saline																										
E. G. Schoffner, Receiver	Pulaski																										
Taff, Fleming, Dryden, and McWorkman.	Saline																										
Wells Mining Co.	Pulaski																										
Leydig and Fleming	Saline																										
Porter Dewitt Construction Co.	do.																										
Midwest Mines Co.	do.																										
Vaughn and Hurley	Pulaski																										
Macke Mining Co.	Saline																										
Verne McMillen, Receiver	Pulaski																										
Mrs. Leila L. Bentley, Receiver	do.																										
Alcoa Mining Co.	Sal., Pul.																										

and Saline mining districts from 1896 to 1949, showing the years of reported production

1922	1923	1924	1925	1926	1927	1928	1929	1930	1931	1932	1933	1934	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	Remarks
																												Changed name to General Bauxite Co.
																												Sold most of interests to Pittsburgh Reduction Co.
																												Changed name to Aluminum Co. of America.
																												Sold out to Republic Mining and Manufacturing Co.
X	X	X	X	X	X	X	X																					Combined with later American-Bauxite Co.
																												Mining interests later became American Bauxite Co.
																												Formed by officials of General Bauxite Co.
X	X	X	X	X	X	X	X																					Became Republic Mining and Manufacturing Co.
	X																				X	X	X	X				Bought abrasive ore from 1913 to present.
X	X	X	X	X	X																							
																												Succeeded National Bauxite Co. in Arkansas.
X	X	X	X	X																								
		X	X	X	X	X	X	X																				
			X	X																								
				X																								
				X	X																							
						X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X						
								X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X					Changed name later to Alcoa Mining Co.
								X	X																			Later became American Cyanamid and Chemical Corp.
									X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	Subsidiary of the General Abrasive Co.
											X	X	X															
												X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
												X																
														X														Mined for Arkansas Bauxite Corporation.
													X	X	X	X	X	X										Worked Standard Bauxite and Chemical Co. property.
														X		X												Associated with J. P. Wright & Co.
																X	X											
																			X	X	X	X	X	X	X	X	X	
																				X	X	X	X	X	X	X	X	
																				X	X	X						Roy Prewitt and associates.
																				X	X							
																				X	X							
																				X	X							
																					X							See Hurricane Creek Mining Co.
																					X	X						Went into receivership shortly after mining started.
																					X	X						P. C. Upton and associates.
																					X							
																					X	X						Roy Prewitt and associates.
																					X							
																					X							
																					X	X						Name later changed to Macke Bauxite Co.
																					X	X						P. C. Upton and associates.
																					X	X						
																					X	X						
																					X	X						
																					X							
																					X	X		X	X	X	X	Associated with Dulin Bauxite Co.
																					X	X						
																					X	X						Appointed receiver for Aluminite Mining Corp.
																					X	X						
																					X	X						
																					X							
																					X							
																						X						Operated by Porter Dewitt Construction Co.
																					X	X						
																						X	X					
																						X						Succeeded E. G. Shoffner.
																						X						Succeeded Verne McMillen.
																							X	X	X	X	X	New name for Republic Mining and Manufacturing Co.

on an increase in production that would have been thought impossible a few years earlier. The production of crude bauxite from the Arkansas mines increased from 991,481 long tons in 1941 to 7,053,028 long tons in 1943, then dropped to about half this figure in 1944. A modified Bayer-process alumina plant, the largest in the world, designed to handle bauxite of an average grade of 50 percent alumina and 13 percent silica, was constructed at Hurricane Creek. The Metals Reserve Company, a branch of the Federal Government, set up a sliding price schedule based on $4 per dry ton for ore of this quality. The War Production Board allocated priorities to stimulate bauxite producers. A total of 32 producing companies operated in the bauxite region during this period. Most of these companies were selling ore to the Metals Reserve Company for stockpiling and for use in the two large Government-owned alumina plants at Hurricane Creek, Ark., and Baton Rouge, La. On December 31, 1943 there were 79 separate mining operations in progress at the same time in the bauxite region.

Since World War II the production, which fell to slightly more than a million tons in 1945, gradually increased to more than a million and a half tons in 1948. On April 15, 1945 the Republic Mining and Manufacturing Co. changed its name to the Alcoa Mining Co. Eight companies in 1949 operated 19 mines (table 13) in the region, and are listed below:

Alcoa Mining Co.
American Cyanamid and Chemical Co.
Consolidated Chemical Industries, Inc.
Crouch Mining Co., Inc.
Dulin Bauxite Co., Inc.
Norton Co.
Pulaski Mining Co.
Reynolds Mining Corp.

The Reynolds Mining Corp. among other properties acquired the holdings of the Pulaski Mining Co. Owing to labor difficulties in two major producing companies, however, production fell off during the year. Consolidated Chemical Industries, Inc. and Norton Co. mined no ore but continued buying ore or using bauxite already in stockpiles.

In the table below Arkansas bauxite production is shown for all the years that the bauxite region has been actively engaged in mining. Most of the data have been taken from "Mineral Resources of the United States," published by the U. S. Geological Survey and the "Minerals Yearbook" published by the U. S. Bureau of Mines. The figures for 1907–9 have been revised, in accordance with unpublished data from the U. S. Bureau of Mines, to eliminate the production from other States shown in combination with them in early volumes of "Mineral Resources."

Arkansas bauxite production, in long tons, as shipped

Year	Production	Year	Production
1896	40	1924	327, 630
1897	------	1925	296, 320
1898	633	1926	371, 570
1899	5, 045	1927	303, 830
1900	3, 445	1928	361, 236
1901	867	1929	351, 054
1902	4, 645	1930	315, 273
1903	25, 713	1931	186, 697
1904	25, 748	1932	89, 779
1905	32, 956	1933	142, 179
1906	50, 267	1934	145, 764
1907	58, 942	1935	219, 791
1908	33, 703	1936	354, 943
1909	101, 531	1937	402, 195
1910	110, 406	1938	293, 280
1911	122, 183	1939	361, 256
1912	117, 299	1940	423, 283
1913	169, 871	1941	813, 545
1914	195, 247	1942	2, 391, 596
1915	268, 796	1943	6, 348, 478
1916	375, 910	1944	2, 788, 019
1917	506, 556	1945	988, 877
1918	562, 892	1946	1, 049, 125
1919	333, 490	1947	1, 186, 726
1920	481, 279	1948	1, 430, 688
1921	124, 850	1949	1, 232, 883
1922	266, 790		
1923	493, 880	Total	27, 649, 001

The quantities shown in the table are for bauxite "as shipped" and show actual tonnages of material shipped, part of which already had been treated in intermediate processing plants. Bauxite is shipped in several forms in which the moisture content varies considerably—crude, dried, activated, calcined, and sintered—depending upon the use for which the material is intended. The table, therefore, does not give an accurate picture of mine production, and the total is less than the actual total output of crude bauxite. These are the only figures available, however, that cover the entire span of production from 1896 to 1949.

Only since 1940 are figures available on the amount of crude bauxite produced at the mines. These figures and those for dried bauxite equivalent, representing the weight of the bauxite after drying, are shown in the table below.

Production of crude bauxite from mines in Arkansas, 1940–49, in long tons, from U. S. Bureau of Mines, "Minerals Yearbook"

Year	Crude bauxite	Dried bauxite equivalent
1940	[1] 497, 586	[1] 428, 471
1941	991, 481	856, 196
1942	2, 852, 051	2, 459, 906
1943	7, 053, 028	6, 036, 490
1944	3, 173, 008	2, 695, 317
1945	1, 061, 911	910, 049
1946	1, 288, 764	1, 050, 347
1947	1, 368, 693	1, 153, 563
1948	1, 649, 926	1, 395, 341
1949	1, 287, 358	1, 094, 924
Total	21, 223, 806	18, 079, 604

[1] Unpublished data, courtesy of the U. S. Bureau of Mines.

It is possible to estimate the total crude production for the years before 1940. The U. S. Bureau of Mines "Minerals Yearbook" (figures for 1938), revised in 1939, has calculated the dried bauxite equivalent of bauxite shipped from Arkansas from 1934 to 1939. By converting these figures to the amount of crude bauxite produced and, the dried bauxite equivalent being taken as 85 percent of the crude, a ratio of 1:1.2 for bauxite "as shipped" to crude bauxite for the 6-year period is indicated. Similarly, if unpublished Bureau of Mines figures on dried bauxite equivalent shipped, 1920–39 are used, a ratio of 1:1.18 of bauxite "as shipped" to crude bauxite is indicated. If these ratios are taken as typical of the entire period of production before 1940, a total production of 10.6–10.8 million long tons of crude ore is indicated for 1896–1939. Added to the total crude bauxite production shown in the preceding table, this amounts to an estimated total crude production from the Arkansas bauxite region of about 32 million long tons through 1949.

BAUXITE MINES AND MINING

During the first few years of production the opening of a mine in the Arkansas bauxite region was a comparatively simple operation. As most of the mining was limited to outcrops, stripping of only a few inches to a few feet of soil was required. Charges of blasting powder placed in drill holes generally about 15 feet deep broke down the bauxite face sufficiently to permit the ore to be loaded into wagons by pick and shovel. Some of the bauxite was loosely consolidated and required little or no blasting. Granitic-textured bauxite was separated from pisolitic, grades were segregated, and limonitic blocks discarded by hand sorting. These simple mining methods have been described by Hayes (1901, p. 471–472), Struthers (1904, p. 276–277), and Berger (1904, p. 607).

By 1911 stripping had reached a depth of 40–50 feet at the Maggie mine near Bauxite, but this apparently was the extreme depth (Phalen, 1912, p. 926–927). Steam shovels were already being used in stripping, but actual mining was done by hand methods owing to the variable character of the ore and strict requirements for metal grade. In the large strip pits of the American Bauxite Co. near Bauxite, the ore was mined in benches, shoveled into mine cars, and conveyed to a railroad operated from mines to mill.

Through World War I and the early twenties surface-mining methods were used exclusively. The amount of overburden that had to be stripped in order to expose the ore reached a maximum of 80 feet before 1927 (Cash and Von Bernewitz, 1929, p. 231). Several writers have described the separate steps required to prepare the deposits in the vicinity of Bauxite for mining (Allen, 1925; Anon., 1927; Cash and Von Bernewitz, 1929; Shiras, 1923, 1931). These five steps are listed as follows:

1. Bulk stripping with 60- to 70-ton steam shovels and the removal of overburden in 1–3 benches depending upon the thickness.
2. Secondary stripping with 20- to 36-ton shovels of the caterpillar type or by wheeled scrapers, which follow the contours of the bauxite, and removal of all but 18 inches to 3 feet of overburden.
3. Ripping and breaking up of the clayey hardcap by means of heavy road machines, and removal of this waste.
4. Cleaning out small irregularities and channels on the ore surface by hand pick-and-shovel work.
5. Sweeping of the ore surface with steel brooms, which improved the grade of the ore by lowering the average silica content by as much as 1 percent.

Generally, 7 percent of silica was the maximum content permitted for metal-grade ore. The bauxite exposed in the mine face was broken up by low-strength dynamite or powder placed in holes 6–20 feet deep. Ore of irregular grade, because of clay pockets, was mined by hand; that of uniform grade was produced by steam shovel.

Increased stripping costs, owing to the exhaustion of most of the shallow ore, led to the introduction of underground mining methods. Early in 1924 the American Bauxite Co. completed a 4,000-foot haulage adit to open the Davis underground mine and extracted bauxite from depths of 70 to 180 feet. Other mines of this type were later exploited in nearby deposits. In the late twenties and early thirties about 60 percent of the bauxite mined in Arkansas was produced by underground methods (Allen, 1925; Branner, 1935; Shiras, 1931).

The underground mining method that has become a generally standard system for the bauxite region is to drive two parallel entries, 30 to 50 feet apart, to the end of the ore body, with crosscuts every 200 feet or more. Breast stopes are driven normal to or at angles as low as 45° to the entries, on 30- to 50-foot centers. They are extended along the base of the ore to the edge of the ore body. Headings between the stopes divide the ore into a series of pillars. At least a foot of bauxite is left as a roof. The ore is mined by a room and pillar system, the outer parts first, then retreating and caving toward the entries.

The first vertical-shaft mine, a timbered shaft, the Dixie No. 1, was opened in 1928 north of Sweet Home in the Pulaski mining district. One- to three-compartment shafts have been sunk in many mines since, where water or quicksand in the overburden is not a problem.

During World War II a reinforced concrete circular drop shaft, with an inside diameter of 6 feet and a depth of 122 feet, was sunk to open the Rowland mine near Bryant. Five 2-inch pipes within the 8-inch shaft wall contained the compressed air lines and electric wires for the mine.

In the forties, circular steel-lined concrete-grouted shafts came into use in the bauxite region. They are most practical in loosely consolidated ground, free from large boulders, where quicksand and water in the overburden are a problem (MacPherson, 1945, p. 9–10). The first and one of the deepest of these is the 310-foot shaft, 75 inches in diameter at the Young property of the Crouch Mining Co. in Saline County. These shafts are drilled from a 70-foot derrick by means of a technique used by the Layne-Arkansas Co. of Stuttgart, Ark. This method has been described in some detail by MacPherson.

The improvement of earth-moving equipment during the thirties and the necessity for exposing the largest volume of ore in the shortest time at the outset of World War II led to a new emphasis being placed on strip-mining. This also has the advantage of greater recovery of the ore in place—generally between 85 and 90 percent. According to MacPherson (1945, p. 7) three types of equipment were used during the war in stripping operations: tractor-drawn scrapers of 6–15 cubic yards capacity; power shovels loading into large-capacity diesel trucks; and walking-type draglines employing buckets of 1- to 10-cubic yard capacity. Cleaning of the ore surface was as described on page 159. Cleaning did not have to be as thorough because improvements in the Bayer process embodied in the Hurricane Creek alumina plant and its associated sinter plant permitted use of bauxite of a higher silica content than heretofore (13 percent average). Stripping was generally confined to depths less than 80 feet, but reached 125 feet in part of one of the large pits near Bauxite.

TABLE 14.—*The mines of the Arkansas bauxite region listed alphabetically, with information as to mining district, type, general*

Mine name	Number on map (pl. 1)	District	Type of mine	Approximate location
African Camp	67	Saline	Open pit	SE¼NE¼ sec. 15, T. 2 S., R. 14 W
Alexander Hill	64	do	do	SE¼SW¼ sec. 15, T. 2 S., R. 14 W
Alexander No. 1	(†)	do	Underground (VS)	SW¼SW¼ sec. 35, T. 1 S., R. 14 W
Alexander No. 2	85	do	do	See Gates mine
Annie	(†)	do	Open pit	NW¼NE¼ sec. 16, T. 2 S., R. 14 W
Area *A*		do	do	*See* Remarks
Area *B*		do	do	do
Area *C*		do	do	do
Berger	44	Pulaski	do	W½SW¼ sec. 4, T. 1 S., R. 12 W
Berger No. 100		Saline		*See* Cargill mine.
Berry-Mayhan	(*)	Pulaski	Open pit	SW¼NE¼ sec. 2, T. 1 S., R. 12 W
Bertha	104, 105	Saline	Underground	NW¼SW¼ sec. 26 and NE¼SE¼ sec. 27, T. 2 S., R. 14 W
Bertha Extension	106	do	Open pit	N½SE¼ sec. 27, T. 2 S., R 14 W
Bierman	27	Pulaski	Underground (VS)	NW¼SE¼ sec. 2, T. 1 S., R. 12 W
Bizzell	76	Saline	Open pit	SE¼SE¼ sec. 11, T. 2 S., R. 14 W
Brown-Ratcliffe	7	Pulaski	Underground (VS)	NE¼SE¼ sec. 24, T. 1 N., R. 12 W
Bryant	48	Saline	do	SW¼SW¼ sec. 35, T. 1 S., R. 14 W
Burks-Nelson	23	Pulaski	Open pit	SE¼SW¼ sec. 36, T. 1 N., R. 12 W
Buzbee	(*)	do	do	SW¼SE¼ sec. 4, T. 1 S., R. 12 W
Canal No. 1	69	Saline	do	S½SE¼ sec. 10 and NW¼NE¼ sec. 15, T. 2 S., R. 14 W
Canal No. 2	70	do	do	SE¼SE¼ sec. 10, T. 2 S., R. 14 W
Cargill (north shaft)	95	do	Underground (VS)	SW¼SW¼ sec. 24, T. 2 S., R. 14 W
Cargill (Southern)	94	do	Open pit	SW¼SW¼ sec. 24, T. 2 S., R. 14 W
Cargill (south shaft)	97	do	Underground (VS)	NW¼NW¼ sec. 25, T. 2 S., R. 14 W
Cargill (Superior)	98	do	Open pit	do
Childress	81	do	Underground (VS)	NW¼NE¼ sec. 24, T. 2 S., R. 14 W
Church	(†)	do	Open pit	SW¼NW¼ sec. 15, T. 2 S., R. 14 W
Cleveland	93	do	do	NW¼SW¼ sec. 24, T. 2 S., R. 14 W
Cleveland (Southern)	96	do	do	SE¼SW¼ sec. 24, T. 2 S., R. 14 W
Cleveland-Evans	87	do	do	SE¼NW¼ sec. 24, T. 2 S., R. 14 W
Consolidated (Gates Lease)	85	do	Underground (VS)	*See* Gates mine
Covington No. 4	79	do	do	NE¼SE¼ sec. 12, T. 2 S., R. 14 W
Covington No. 5	80	do	do	SE¼SE¼ sec. 12, T. 2 S., R. 14 W
Crosscut No. 23	56	do	Underground	NE¼NE¼ sec. 21, T. 2 S., R. 14 W
Dan Rauch	39	Pulaski	Open pit	*See* Rauch Extension mine
Davis	63, 63a	Saline	Underground	NW¼, W½NE¼, NE¼SW¼, and NW¼SE¼ sec. 22, T. 2 S., R. 14 W.
Dixie Lease	14	Pulaski	Open pit	SE¼SE¼ sec. 24, T. 1 N., R. 12 W
Dixie No. 1	16	do	Underground	NE¼NE¼ sec. 25, T. 1 N., R. 12 W
Dixie No. 2	2	do	Underground (VS)	S½NW¼ sec. 19, T. 1 N., R. 11 W
Dixie No. 3	24, 25	do	Combined	NE¼SE¼ sec. 35 and NW¼SW¼ sec. 36, T. 1 N., P. 12 W

See footnotes at end of table.

Since the war, the greater proportion of bauxite mined has come from open pits. Nearly all the large Alcoa underground mines have closed. Several of the smaller producers, however, have continued to mine chiefly by underground methods. The Reynolds Mining Corp. while keeping the average grade of the bauxite entering the Hurricane Creek plant at about 14 percent silica and 50 percent alumina, by blending, is utilizing rock containing as high as 30 percent silica, or as low as 35 percent alumina where the iron content is high. Ore of high-silica content does not lend itself to mining by underground methods as it disintegrates in roof and pillars. The company in 1949 was stripping bauxite to a depth of 125 feet in their large Section 35 mine and planned later to go as deep as 175 feet. According to O. C. Schmedeman, formerly vice-president and chief geologist of the company (personal communication, November 1949), open-pit methods in this particular area permit a recovery four times greater than would be possible by underground methods, as only one of several bauxite layers is thick enough to mine underground.

There are still many deposits in the region that lie at depths too great to mine economically by present stripping methods. As the shallower deposits are depleted, emphasis will again shift to underground mining.

The mines of the Arkansas bauxite region are all listed in alphabetical order in table 14. The list is as complete as possible and contains all published names and those used by operating companies of the past decade. It probably omits names of some of the older mines. The type of mine, approximate location, period of activity by decades, and other information are given for each mine. As the naming, particularly of open-pit mines, is haphazard and is subject to change in some cases, different names for the same mine are indicated by cross reference.

location, principal operating company, periods of activity, so far as known, and operating status as of July 1, 1949

Principal operating company	Periods of activity					Status on July 1, 1949	Remarks
	Before 1910	1910–19	1920–29	1930–39	1940–49		
Alcoa Mining Co					X	Operating	
do					X	Not operating	New area stripped in 1949.
Consolidated Chemical Ind., Inc				X		Abandoned	Now part of Reynolds' Section 35 pit mine.
do							Now part of Reynolds' Section 24 property.
American Bauxite Co	X	X				Abandoned	
Republic Mining and Manufacturing Co.			X	X			Old name for surface workings around Davis mine.
do			X	X			Old name for pit mines in secs. 14 and 15.
do			X	X			Do.
do	X	X				Abandoned	See also North England mine.
American Cyanamid and Chem. Corp							
do					X	Not operating	
Republic Mining and Manufacturing Co.		X	X	X	X	Abandoned	Formerly was small open-pit mine.
Alcoa Mining Co						Not operating	Stripped but never mined.
Consolidated Chemical Ind., Inc					X	do	
S. E. Evans Construction Co				X		Abandoned	Opened and mined by Arkansas Bauxite Corp.
Dulin Bauxite Co					X	do	
Osage Bauxite Co					X	do	Now part of Reynolds' Section 35 pit mine.
Pulaski Mining Co					X	do	
Reynolds Mining Corp					X	do	
Republic Mining and Manufacturing Co.					X	do	Named in 1924 when drainage canal was dug, but not operated until later.
do					X	do	
American Cyanamid and Chem. Corp				X	X		Underground part of Cargill (Southern) mine.
do			X	X	X		Former pit mine of Southern Bauxite Co.
do				X	X		Underground part of Cargill (Superior) mine.
do			X	X	X		Former pit mine of Superior Bauxite Co.
Hull-Macke Bauxite Co					X	Abandoned	Now part of Reynolds' Section 24 property.
Republic Mining and Manufacturing Co.				X		Not operating	A continuation of the Steam Shovel mine.
American Cyanamid and Chemical Corp.				X	X	Abandoned	Also mined by Hurricane Creek Mining Co.
do			X	X	X	do	Former pit mine of Southern Bauxite Co.
Hurricane Creek Mining Co				X	X	do	Opened by American Cyanamid and Chem. Corp.
American Cyanamid and Chem. Corp							
Reynolds Mining Corp					X	Operating	Shafts of the Hurricane Creek mine group.
do					X	Abandoned	
do				X		do	Part of Davis mine; portal at Maggie mine.
American Cyanamid and Chem. Corp							Originally owned by Republic Mining and Manufacturing Co.
Republic Mining and Manufacturing Co.			X	X	X	Abandoned	Oldest underground mine in bauxite region.
Clarke Bauxite Co					X	do	
Dixie Bauxite Co			X			do	Also known as Hoekstra mine.
do			X	X	X	do	First shaft mine in bauxite region.
do					X	do	Included Dixon and Pulaski pit mines.

TABLE 14.—*The mines of the Arkansas bauxite region listed alphabetically, with information as to mining district, type, general*

Mine name	Number on map (pl. 1)	District	Type of mine	Approximate location
Dixon	25	Pulaski	Open pit	NE¼SE¼ sec. 35, T. 1 N., R. 12 W
Dollar	41	do	do	NW¼NW¼ sec. 9, T. 1 S., R. 12 W
Dorough	9	do	do	NW¼SE¼ sec. 24, T. 1 N., R. 12 W
Drury	5	do	do	*See* Ratcliffe mine.
East Maud	107	Saline	do	SE¼SE¼ sec. 22, SW¼SW¼ sec. 23, and NE¼NE¼ sec. 27, T. 2 S., R. 14 W.
East Neilson	99	do	do	SE¼SW¼ sec. 23, T. 2 S., R. 14 W
East Ozark	91	do	do	NW¼SE¼ sec. 24, T. 2 S., R. 14 W
Ella	60	do	do	S½NE¼ sec. 22, T. 2 S., R. 14 W
Elrod	49	do	do	NW¼NW¼ sec. 2, part of NE¼NE¼ sec. 3, T. 2 S., R. 14 W
England (outcrop)	43	Pulaski	do	SW¼SW¼ sec. 4, T. 1 S., R. 12 W
England (open pit)	12	do	do	SE¼SE¼ sec. 24, T. 1 N., R. 12 W
England (shaft)	42	do	Underground (VS)	SW¼SW¼ sec. 4, T. 1 S., R. 12 W
Fletcher	74	Saline	Open pit	SE¼SW¼ sec. 11, T. 2 S., R. 14 W
Fletcher 40	74	do	do	*See* Fletcher mine
Fletcher-Hudspeth-Harris	129	do	do	NW¼NE¼ sec. 9, T. 2 S., R. 14 W
Gates	85	do	Underground (VS)	NW¼NE¼ sec. 24, T. 2 S., R. 14 W
Globe	103	do	Open pit	NW¼SE¼ sec. 26, T. 2 S., R. 14 W
Globe 28	114, 115	do	Underground (VS)	SE¼NE¼ sec. 28, T. 2 S., R. 14 W
Granite Branch	61	do	Open pit	E½NW¼ and W½NE¼ sec. 22, T. 2 S., R. 14 W
Gray (east pit)	86	do	do	NE¼NE¼ sec. 24, T. 2 S., R. 14 W
Gray (west pit)	83	do	do	NW¼NE¼ sec. 24, T. 2 S., R. 14 W
Gray Property	82	do	do	*See* Midwest mine
Hamp Smith	118	do	do	*See* Smith mine
Harley	13	Pulaski	do	SE¼SE¼ sec. 24, T. 1 N., R. 12 W
Harris	(†)	Saline	Underground (VS)	*See* Alexander No. 1 mine
Harris	129	do	Open pit	*See* Fletcher-Hudspeth-Harris mine
Heckler	35	Pulaski	Underground (VS)	NE¼SW¼ sec. 9, T. 1 S., R. 12 W
Hoekstra (shaft)	16	do	Underground	*See* Dixie No. 1 mine
Hoekstra (open pit)	17	do	Open pit	NE¼NE¼ sec. 25, T. 1 N., R. 12 W
Hoekstra-Dobbs-Illing	18	do	do	do
Hogue-Fletcher	53	Saline	do	NW¼SW¼ sec. 2, and NE¼SE¼ sec. 3, T. 2 S., R. 14 W
Hurricane (Nos. 1 and 3)	78	do	Underground (VS)	E½SW¼ sec. 12, T. 2 S., R. 14 W
Johnson	58, 59	do	Open pit	NW¼SE¼ and NE¼SW¼ sec. 22, T. 2 S., R. 14 W
Julia	57	do	do	SW¼NW¼ and N½SW¼ sec. 22, T. 2 S., R. 14 W
Keenzel	11	Pulaski	do	SW¼SE¼ sec. 24, T. 1 N., R. 12 W
Lantz	55	Saline	do	N½NW¼ sec. 15, T. 2 S., R. 14 W
Little Ratcliffe	4	Pulaski	do	*See* Ratcliffe (Dulin) mine
Lone 7th	121	Saline	do	NW¼SE¼ sec. 16, T. 2 S., R. 14 W
Maggie	56	do	do	NE¼NE¼ sec. 21, T. 2 S., R. 14 W
Martin	(†)	do	do	W½SE¼ sec. 15, T. 2 S., R. 14 W
Martin	46	do	Underground (VS)	SW¼NW¼ sec. 35, T. 1 S., R. 14 W
Mary	62	do	Open pit	NE¼NW¼ and NW¼NE¼ sec. 22, T. 2 S., R. 14 W
Maud	107, 108	do	do	*See* Middle and East Maud mines
McDonald	84	do	Underground (VS)	NE¼NE¼ sec. 24, T. 2 S., R. 14 W
McGuire	45	Pulaski	Open pit	NW¼NE¼ sec. 8, T. 1 S., R. 12 W
Metznauer	(†)	Saline	do	NW¼NE¼ sec. 15, T. 2 S., R. 14 W
Middle Maud	108	do	do	NW¼NE¼ sec. 27, and SW¼SE¼ sec. 22, T. 2 S., R. 14 W
Midwest	82	do	do	NE¼NE¼ sec. 24, T. 2 S., R. 14 W
Mine 14	73	do	do	SE¼NE¼ and NE¼SE¼ sec. 14, T. 2 S., R. 14 W
Mittie	(†)	do	do	E½SW¼ sec. 15, T. 2 S., R. 14 W
Morgan	8	Pulaski	do	NW¼SE¼ sec. 24, T. 1 N., R. 12 W
Neilson	100	Saline	Underground	SW¼SW¼ sec. 23, W½ and NE¼ sec. 26, E½NE¼ sec. 27, T. 2 S., R. 14 W.
North England	44	Pulaski	Open pit	NW¼SW¼ sec. 4, T. 1 S., R. 12 W
Northern	(*)	Saline	do	SW¼NE¼ sec. 13, T. 2 S., R. 14 W
Northern (Nos. 8 and 9)	(*)	do	Underground (VS)	SE¼SW¼ and SW¼SE¼ sec. 7, T. 2 S., R. 13 W
Norton	68	do	Open pit	SW¼NE¼ sec. 15, T. 2 S., R. 14 W
Nutt-Bailey	(*)	Pulaski	Underground (VS)	SW¼NE¼ sec. 21, T. 1 S., R. 12 W
Old Calumet	103	Saline	Open pit	*See* Globe mine
Old Crouch	42	Pulaski	Underground (VS)	*See* England (shaft) mine
Old Dixie No. 2	1	do	do	*See* Dixie No. 2 mine
Old Globe	103	Saline	Open pit	*See* Globe mine
Old National	33	Pulaski	do	*See* Old Rauch mine
Old Rauch	33	do	do	SW¼NE¼ sec. 9, T. 1 S., R. 12 W
Ozark 24	89, 90, 92	Saline	do	NE¼SW¼ sec. 24, T. 2 S., R. 14 W
Ozark 28	112, 113	do	Underground (VS)	NE¼SE¼ sec. 28, T. 2 S., R. 14 W
Patricia No. 1	84	do	do	*See* McDonald mine
Penzel-Coe	28	Pulaski	do	NE¼SW¼ sec. 2, T. 1 S., R. 12 W
Poodle	126	Saline	Open pit	NW¼NW¼ sec. 16, T. 2 S., R. 14 W
Pruden	122	do	do	SE¼NW¼ and SW¼NE¼ sec. 16, T. 2 S., R. 14 W
Pruden Extension	123	do	do	S½NW¼ sec. 16, T. 2 S., R. 14 W

See footnotes at end of table.

location, principal operating company, periods of activity, so far as known, and operating status as of July 1, 1949—Continued

Principal operating company	Periods of activity					Status on July 1, 1949	Remarks
	Before 1910	1910–19	1920–29	1930–39	1940–49		
Dixon Bros				×		Abandoned	See also Dixie No. 3 mine.
E. G. Shoffner, Receiver					×	do	
Dixie Bauxite Co					×	do	
Alcoa Mining Co							Supplied ore to Drury plant.
Republic Mining and Manufacturing Co.	×	×	×	×	×	Not operating	
do					×	do	
American Cyanamid and Chem. Corp				×	×	Abandoned	
American Bauxite Co	×	×	×			do	
Republic Mining and Manufacturing Co.					×	Operating	Now part of Reynolds' Section 35 pit mine.
American Cyanamid and Chem. Corp					×	Abandoned	
Dulin Bauxite Co					×	do	
Crouch Mining Co				×	×	do	
Reynolds Mining Corp				×	×	Operating	Opened by Arkansas Bauxite Co.
American Cyanamid and Chem. Corp							
S. E. Evans Construction Co					×	Abandoned	Also mined by Leydig and Fleming.
American Cyanamid and Chem. Corp				×	×	Not operating	Now part of Reynolds' Section 24 property.
Globe Bauxite Co	×	×	×	×		Abandoned	
American Cyanamid and Chem. Corp				(?)	×	do	East and west shafts.
American Bauxite Co	×	×	×			do	
Jackson and Squire					×	Not operating	Now part of Reynolds' Section 24 property.
do					×	do	
Midwest Mines Co							
Republic Mining and Manufacturing Co.							
Dulin Bauxite Co					×	Abandoned	
American Cyanamid and Chem. Corp							Now part of Reynolds' Section 35 pit mine.
S. E. Evans Construction Co							
American Cyanamid and Chem. Corp				×	×	Abandoned	
Dixie Bauxite Co							
Reynolds Mining Corp					×	Abandoned	
Jackson and Squire					×	do	
Maner Graham					×	do	
Reynolds Mining Corp					×	do	Shafts of the Hurricane Creek mine group.
American Bauxite Co		×	×	×		do	
do		×	×			do	
Prewitt and Hardin					×	do	
Republic Mining and Manufacturing Co.		×	×	×	×	do	
Dulin Bauxite Co							
Alcoa Mining Co						Not operating	Stripped but not mined.
American Bauxite Co	×	×	×	×		Abandoned	
do	×	×	×	×		do	
Schaeffer and Haire					×	Not operating	Part of Reynolds' Section 35 mine area.
American Bauxite Co		×	×	×		Abandoned	
Republic Mining and Manufacturing Co.							
Arkansas Bauxite Corp				×	×	Abandoned	Opened and mined by Crawford Bauxite Co.
Arkansas Bauxite Stripping Co					×	do	
E. Metznauer	×					do	One of the earliest pit mines.
Republic Mining and Manufacturing Co.		(?)	×	×	×	do	
Midwest Mines Co					×	do	Now part of Reynolds' Section 24 property.
Republic Mining and Manufacturing Co.			×	×	×	Not operating	
American Bauxite Co		×	×			Abandoned	Later mined as Section 15 mine.
Roy Prewitt					×	do	
Republic Mining and Manufacturing Co.				×	×	do	
American Cyanamid and Chem. Corp					×	do	Probable site of original Fred Berger mine.
Reynolds Mining Corp					×	do	
do					×	Operating	Shafts of the Hurricane Creek mine group.
Norton Co		×	×	×	×	Not operating	
Dulin Bauxite Co					×	Operating	
Superior Bauxite Co							
Crouch Mining Co							Southeast shaft.
Dixie Bauxite Co							
American Cyanamid and Chem. Corp							
Du Pont de Nemours Co							Opened by National Bauxite Co.
American Cyanamid and Chem. Corp		×	×			Abandoned	
do				×	×	do	
do				×	×	do	
Crawford Bauxite Co							Now part of Reynolds' Section 24 property.
Dulin Bauxite Co					×	Abandoned	
Republic Mining and Manufacturing Co.					×	do	
do			×	×	×	Not operating	
do					×	do	Stripped but very little was mined.

TABLE 14.—*The mines of the Arkansas bauxite region listed alphabetically, with information as to mining district, type, general*

Mine name	Number on map (pl. 1)	District	Type of mine	Approximate location
Pulaski	24	Pulaski	Open pit	NW¼SW¼ sec. 36, T. 1 N., R. 12 W
Pulaski (Hoekstra)	17	do	do	*See* Hoekstra pit mine
Pulaski (Sherrill)	15	do	do	*See* Sherrill mine
Quapaw (north pit)	51	Saline	do	SE¼NE¼ sec. 3, T. 2 S., R. 14 W
Quapaw (south pit)	52	do	do	NE¼SE¼ sec. 3, T. 2 S., R. 14 W
Ramsey	128	do	do	SE¼NE¼ sec. 9, T. 2 S., R. 14 W
Ratcliffe	3, 5	Pulaski	do	SE¼NE¼ and NE¼SE¼ sec. 24, T. 1 N., R. 12 W
Ratcliffe (Dulin)	4	do	do	SE¼NE¼ sec. 24, T. 1 N., R. 12 W
Ratcliffe Lease	6	do	do	NE¼SE¼ sec. 24, T. 1 N., R. 12 W
Rauch	36	do	Underground (VS)	NE¼SW¼ sec. 9, T. 1 S., R. 12 W
Rauch Estate (pit)	38	do	Open pit	do
Rauch Estate (shaft)	37	do	Underground	do
Rauch Extension	39	do	Open pit	SE¼NW¼ sec. 9, T. 1 S., R. 12 W
Rauch Leased	34	do	do	SE¼NE¼ sec. 9, T. 1 S., R. 12 W
Rauch Owned	32	do	do	NW¼NE¼ sec. 9, T. 1 S., R. 12 W
Rauch Property	31	do	do	do
Reichardt	30	do	Underground (VS)	NW¼SW¼ sec. 2, T. 1 S., R. 12 W
Reichardt Extension	29	do	Open pit	N½SW¼ sec. 2, T. 1 S., R. 12 W
Republic	39	do	do	*See* Rauch Extension mine
Rowland	47	Saline	Underground (VS)	NE¼SE¼ sec. 34, T. 1 S., R. 14 W
Rummel	(*)	Pulaski	do	NE¼SE¼ sec. 21, T. 1 S., R. 12 W
Schaeffer and Haire	46	Saline	do	*See* Martin underground mine
Section 10	54	do	Open pit	S½SW¼ sec. 10, T. 2 S., R. 14 W
Section 14	71, 72	do	do	NW¼ and W½NE¼ sec. 14, T. 2 S., R. 14 W
Section 15	65	do	do	S½SW¼ sec. 15 and SE¼SE¼ sec. 16, T. 2 S., R. 14 W
Section 16	120	do	do	E½SW¼ and SW¼SE¼ sec. 16, NE¼NW¼ sec. 21, T. 2 S., R. 14 W.
Section 17	124	do	do	SE¼NE¼ and NE¼SE¼ sec. 17, T. 2 S., R. 14 W
Section 26	101, 102	do	Underground	SW¼NW¼ sec. 26, T. 2 S., R. 14 W
Section 28	117	do	Underground (VS)	NW¼SW¼ sec. 28, T. 2 S., R. 14 W
Section 35	(*)	do	Open pit	S½SW¼ and SW¼SE¼ sec. 35, T. 1 S., R. 14 W
Sherrill	15	Pulaski	do	NE¼NE¼ sec. 25, T. 1 N., R. 12 W
Sherrill-England	15a	do	do	NE¼NE¼ sec. 25 and SE¼SE¼ sec. 24, T. 1 N., R. 12 W
Smith	118	Saline	do	E½NW¼ and NW¼NE¼ sec. 21, T. 2 S., R. 14 W
South England	43	Pulaski	do	*See* England outcrop mine
South Maud	110	Saline	do	*See* West Maud Extension mine
Southern Acid and Sulphur	111	do	Underground (VS)	NW¼SW¼ sec. 27, T. 2 S., R. 14 W
Spring Hill	119	do	Open pit	W½NW¼ sec. 21, T. 2 S., R. 14 W
Standard	125	do	Underground (VS)	NE¼NE¼ sec. 17, T. 2 S., R. 14 W
Standard 80	(*)	do	do	E¾S½ sec. 1, T. 2 S., R. 14 W
Steam Shovel	(†)	do	Open pit	SW¼NW¼ sec. 15 and SE¼NE¼ sec. 16, T. 2 S., R. 14 W
Stringtown	66	do	do	SW¼SE¼ sec. 15, T. 2 S., R. 14 W
Stuckey	127	do	do	NE¼SW¼ and NW¼SE¼ sec. 9, T. 2 S., R. 14 W
Superior	98	do	do	*See* Cargill (Superior) mine
Sweet Home	3	Pulaski	do	*See* Ratcliffe mine
Do	20	do	do	SW¼NE¼ sec. 25, T. 1 N., R. 12 W
Tank	(†)	Saline	do	NE¼NE¼ sec. 16, T. 2 S., R. 14 W
Thorpe	10	Pulaski	do	NE¼SE¼ sec. 24, T. 1 N., R. 12 W
Townsend	75	Saline	do	SW¼SE¼ sec. 11, T. 2 S., R. 14 W
Townsend 40	75	do	do	*See* Townsend mine
Ulmer	77	do	do	SW¼SW¼ sec. 12, T. 2 S., R. 14 W
Vick	(*)	Pulaski	Underground (VS)	SW¼SE¼ sec. 35, T. 1 N., R. 12 W
Vinson-Hoffman	(*)	do	do	W½NE¼ sec. 2, T. 1 S., R. 12 W
Washer	(†)	Saline	Open pit	NW¼NE¼ sec. 22, T. 2 S., R. 14 W
Weiss	26	Pulaski	do	SE¼NW¼ sec. 2, T. 1 S., R. 12 W
West Elrod	50	Saline	do	NE¼NE¼ sec. 3, T. 2 S., R. 14 W
West Maud	109	do	do	NE¼NW¼ sec. 27, T. 2 S., R. 14 W
West Maud Extension	110	do	do	SW¼NE¼ sec. 27, T. 2 S., R. 14 W
West Ozark	88	do	do	NW¼SW¼ sec. 24, T. 2 S., R. 14 W
Westminster Church	21	Pulaski	do	E½SE¼ sec. 25, T. 1 N., R. 12 W
Whitley	(*)	Saline	Underground (VS)	NW¼SE¼ and S½SE¼ sec. 12, T. 2 S., R. 14 W
Willie Thomas	22	Pulaski	Open pit	W½SE¼ sec. 25, T. 1 N., R. 12 W
Winn	40	do	do	SW¼NW¼ sec. 9, T. 1 S., R. 12 W
Wright	24	do	do	*See* Pulaski mine
Do	19	do	Underground (VS)	SW¼NE¼ sec. 25, T. 1 N., R. 12 W
Young	116	Saline	do	NE¼SW¼ sec. 28, T. 2 S., R. 14 W
Do	117	do	do	*See* Section 28 mine

*Unnumbered mines opened after completion of field mapping, July 1945, not shown on map, plate 1. (VS) indicates vertical shaft.

location, principal operating company, periods of activity, so far as known, and operating status as of July 1, 1949—Continued

Principal operating company	Periods of activity					Status on July 1, 1949	Remarks
	Before 1910	1910–19	1920–29	1930–39	1940–49		
Pulaski Bauxite Co				×		Abandoned	Later became part of Dixie No. 3 mine.
Reynolds Mining Corp							
do							
American Cyanamid and Chem. Corp					×	Abandoned	
do					×	do	
Arkansas Bauxite Stripping Co					×	do	Very little mining because of high iron content.
Republic Mining and Manufacturing Co.			×	×	×		Underground workings at north end.
Dulin Bauxite Co					×	Abandoned	Part of Ratcliffe pit area.
do					×	Operating	Do.
American Cyanamid and Chem. Corp				×	×	Abandoned	
do					×	do	
do					×	do	
do					×	Not operating	Continuous with Rauch Estate pit mine.
do					×	Operating	
do					×	Abandoned	
Fourche Mountain Mining Co					×	do	
Dulin Bauxite Co					×	do	
do					×	do	
American Cyanamid and Chem. Corp							
Taff, Fleming, Dryden, & McWorkman					×	Abandoned	
Pulaski Mining Co					×	Not operating	Now owned by Reynolds Mining Corp.
Schaeffer and Haire							
Republic Mining and Manufacturing Co.				×	×	Not operating	
do			×	×	×	Operating	
do					×	do	
do					×	do	
do						Not operating	Partly stripped but not mined.
do				×	×	do	Older pit workings, inclines to Neilson.
do					×	do	
Reynolds Mining Corp					×	do	
do					×	Abandoned	
do					×	Operating	
Republic Mining and Manufacturing Co.		×	×	×	×	Abandoned	
American Cyanamid and Chem. Corp							
Republic Mining and Manufacturing Co.							
Southern Acid and Sulphur Co				×		Not operating	
Republic Mining and Manufacturing Co.					×	Abandoned	
Arkansas Bauxite Corp				×		do	
Reynolds Mining Corp					×	Operating	
American Bauxite Co		×	×			Abandoned	See also Church mine.
Republic Mining and Manufacturing Co.						Not operating	Stripped but not mined.
Reynolds Mining Corp					×	Abandoned	
Superior Bauxite Co							
Republic Mining and Manufacturing Co.							
Sweet Home Bauxite Co					×	Abandoned	
American Bauxite Co	?	×				do	
Dulin Bauxite Co					×	do	
American Cyanamid and Chem. Corp				×	×	do	Opened by Arkansas Bauxite Corp.
do							
Reynolds Mining Corp					×	do	
Dulin Bauxite Co					×	do	Mined through Vinson-Hoffman shaft.
do					×	Not operating	
American Bauxite Co	×	×				Abandoned	
Victory Bauxite Co					×	do	
Alcoa Mining Co					×	Not operating	
Republic Mining and Manufacturing Co.			×	×	×	Operating	
do					×	do	
American Cyanamid and Chem. Corp				×	×	Abandoned	
Kenark Mining Co					×	do	
Reynolds Mining Corp					×	Operating	Shaft of the Hurricane Creek mine group.
Arkansas Bauxite Stripping Co					×	Abandoned	Opened by Vaughn and Hurley.
Aluminite Mining Corp					×	do	
J. P. Wright							See also Dixie No. 3 mine.
Wells Mining Co					×	Abandoned	
Crouch Mining Co					×	Operating	
Republic Mining and Manufacturing Co.							

†Unnumbered mines; sites obscured by later workings or not located.

USES AND GRADES OF ARKANSAS BAUXITE

Most of the bauxite mined in Arkansas has been for metallurgical purposes. Lesser amounts have been produced for the abrasive, refractory, chemical, oil-refining, and cement industries.

Bauxite mined in Arkansas before World War II averaged about 58 percent Al_2O_3 and 6.5 percent SiO_2 (MacPherson, 1945, p. 5). Metal-grade ore at this time generally was limited to ore containing less than 7 percent silica. Bauxite containing more than 7 percent silica was discarded or left unmined, except in some instances where it was used for chemical-grade ore. Deposits mined before the war were principally those near the surface and at high elevations. Large parts of these were comparatively low in ferrous iron, either through oxidation to ferric iron or because the original siderite content was not excessive.

Freshly mined bauxite contains 5–20 percent moisture depending upon its porosity (Mead, 1915, p. 39). This moisture averages about 15 percent and is in addition to the combined water in the hydrated minerals that comprise the rock. The freshly mined bauxite is known as wet or raw ore. Bauxite commonly is dried by heating it to temperatures that range from 100° to 140°C in rotary kilns. Much ore for chemical and for metallurgical use is prepared in this way. For other purposes the ore is calcined, that is, nearly all the combined water in the bauxite is driven off by heating it to fairly high temperatures (about 600°C). When heated to about 500°C the calcining is incomplete but the adsorptive properties of the rock attain a maximum. Highly adsorptive rock prepared in this manner is known as activated bauxite. Each of these types of bauxite, containing different amounts of water, has its own specific uses in several industries.

The specifications for Arkansas ore required for industry differ considerably, as shown in the following table (MacPherson, 1945, p. 5):

Grades of bauxite or product. After MacPherson

Industry	Form in which used	Percentage range in chemical content			
		Al_2O_3	SiO_2 <	Fe_2O_3 <	TiO_2 <
Alumina or aluminum	Wet or dried	48–60	18	13	4
Abrasive	Calcined [1]	80–85	8	8. 5	4. 5
Refractory	do	78–85	8	8. 5	4. 5
Chemical	Dried	52–60	13	2. 5	3
Cement	Wet	52–56	3. 5	15	4
Oil refining	Activated	75–80	10	9	4

[1] Calcined ores contain from 0.30 to 0.45 percent combined water.

A somewhat similar table was published by Thoenen and Burchard (1941, p. 35) for the prewar commercial grades of bauxite. It differs from the one reproduced above in the more rigid requirements for metallurgical-grade ore and, to a lesser extent, for chemical ore.

The bauxite used in the manufacture of alumina and aluminum generally is dried if it is to be shipped to an alumina plant outside the bauxite region, in order to reduce shipping costs. Bauxite processed at the local Hurricane Creek alumina plant is delivered wet. The improved Bayer process for the manufacture of alumina and the auxiliary lime-soda-sinter process to extract additional alumina from the red mud residue of the Bayer process settling tanks have been described by Gould (1945, p. 796–802). The Bayer and other processes for producing alumina from bauxite and the electrolytic process for the reduction of alumina to aluminum are described by Edwards and Mason (1930, v. 1, p. 124–335).

Fused-alumina abrasives are used in grinding and polishing steel and other metals, because of their properties of hardness, toughness, and mode of fracture (Knibbs, 1928, p. 121). They are sold under several trade names. Ore for the abrasive industry should be moderately low in silica, iron, and titania content. Upon the amounts of these impurities depend other properties, including color of the finished product and the amount of ferro-silicon formed (and removed) during processing. Once a satisfactory abrasive has been prepared, the problem becomes one of uniformity, in grain and color, in duplicating this product.

Some metallurgical grades of bauxite can be beneficiated to attain abrasive quality. Two simple processes have been used in Arkansas with some success. The first is employed where gibbsite is concentrated in hard pisolites in a soft clayey matrix. The ore is merely washed and screened to separate the hard pisolites from the soft clay. The second is applicable to soft crumbly bauxite low in silica but containing considerable siderite. This material is roasted in a gas flame to oxidize the iron which is then largely removed by magnetic separation.

Bauxite for refractory bricks or blocks is preferably low in silica and has a moderate iron oxide and titania content. The iron content depends upon the temperature at which the refractory will ultimately be used. High-alumina refractories, made chiefly from bauxite, bauxitic clay, diaspore, or high-alumina clay are much cheaper than fused alumina refractories. These high-alumina refractories contain at least 58 percent of alumina (Fox, 1932, p. 213). Great care has to be exercised during manufacture in adequately shrinking the bauxite by heating it to temperatures between 1,400° and 1,600°F, by properly grading the crushed preshrunk bauxite aggregate, by using the least possible quantity of bonding material (usually kaolin or bentonite), by pressing the crushed rock into blocks

with as few voids as possible, and by firing at an adequately high temperature (Knibbs, 1928, p. 93–100). If properly prepared, the bauxite and high-alumina blocks are highly refractory, retain considerable strength at high temperature, and are resistant to basic slags.

The principal requirement for bauxite used in the chemical industry is a low iron content (less than 2.5 percent of total iron expressed as Fe_2O_3). From this ore a number of salts of aluminum are prepared, notably aluminum hydroxide, sodium aluminate, aluminum chloride, aluminum sulfate, and commercial alum (Fox, 1932, p. 199–203). In recent years the use of Arkansas ore for chemical purposes has decreased somewhat; much of the chemical ore now comes from Georgia and Alabama deposits.

Activated bauxite is used in the oil refining industry for filtering, decolorizing, and desulfurizing certain petroleum products (Fox, 1932, p. 206). Highly adsorbent, it has the advantage over most similar agents, such as alumina or fuller's earth, because it is comparatively hard and is suitable for use in a granular form (Knibbs, 1928, p. 102). Some types of bauxite when activated are well suited for purifying gasoline, others for purifying kerosene, and still others for lubricating oil. Why this is so and what property or properties of bauxite govern its suitability, are at present unanswered questions. Bauxite suitable for thermal activation must have a high alumina content, a low iron content, the proper physical structure as to strength and resistance to attrition, and certain specific adsorptive and catalytic properties (King, Laughlin, and Gwyn, 1944, p. 239). Activated bauxite originally intended as an adsorbent for lubricating oil, was used chiefly during World War II in the catalytic alkylation of 100-octane gasoline. The ore treated in the plant of the Porocel Corp. at Berger, Ark., is first heated to temperatures between 250° and 350°F which leaves about 30 percent water in the rock. It is crushed and screened and then thermally activated by incomplete calcination at temperatures between 700° and 1,000°F depending upon the intended use. The company also produces activated bauxite impregnated with aluminum chloride, which is used as a catalyst in the isomerization of butane.

A small amount of bauxite is employed in the manufacture of aluminous cement, a calcareous hydraulic cement containing a little silica and a high percentage of alumina (Knibbs, 1928, p. 70). Although costly to manufacture and at present less in demand than heretofore owing to improvements in ordinary portland cements, aluminous cement is still preferred for some purposes because of its rapidity in setting and attaining full strength and its resistance to deterioration in sea water and in soils containing sulfate salts (Fox, 1932, p. 204–206).

During World War II, the War Production Board established three standard grades, based on the silica content of the bauxite:

1. Low silica, restricted, contains less than 7 percent silica. This ore was allocated for metallurgical and abrasive uses.
2. High silica, restricted, contains from 7 to 15 percent silica. This ore was allocated for sale to Government stockpiles for use in the modified Bayer process plants.
3. High silica, unrestricted, contains 15 percent or more silica. No restrictions were placed on this bauxite.

The Metals Reserve Company established a scale of prices, with penalties and premiums for alumina below and above 50 percent and for silica above and below 13 percent.

RESERVES

The first attempt to assess the reserves of the bauxite region was made by Hayes (1901, p. 468–470, pl. 61). He limited his estimates to what we know now as the residual or type 1 deposits associated with the Saline dome. The estimates were made from field observations and geologic inference as to the extent and thickness of the bauxite underlying Tertiary sediments. The total, which he itemized by areas, reached an aggregate tonnage as follows:

	Tons
Total amount estimated in outcrops	6, 601, 500
Total amount estimated under cover	43, 711, 200
Grand total	50, 312. 700

The estimate of Hayes was criticized as being grossly in excess of proved reserves. The rigid limits as to silica content of the ore in the early days, coupled with limited exploration, limited the known bauxite of commercial grade to a few million tons ahead of production. Hayes' estimate can now be reappraised after more than 40 years of mining in the Saline dome area, which has yielded nearly three-fourths the commercial bauxite produced in Arkansas. An approximate estimate of its total output through 1949 is between 24 and 26 million long tons of crude ore. It must be remembered also that all the ore in a bauxite deposit cannot be recovered. The proportion that can be extracted varies with mining methods used and may be as low as 50 percent or as high as 95 percent. Considering these facts, the lack of drilling data, and the relatively few exposures and mine workings available to him, Hayes' original assessment of the reserves in this area was a good overall estimate.

The total reserves of the bauxite region, in addition to the ore remaining in the area considered by Hayes, include ore bodies in type 2 deposits surrounding the Pulaski, Bryant, and Saline nepheline syenite hills, and in associated type 3 deposits in Pulaski County and

type 4 deposits in Saline County. The last two types account for a very small part of the total. A few thousand tons can also be accounted for in remnants of type 1 deposits in the Pulaski district.

Several appraisals of the total reserves of the United States, including those of Arkansas, have appeared in recent years. The principal prewar study, that of Thoenen and Burchard (1941) has been given in tables 1 and 2 of this report. The estimate was low, reflecting only the known reserves at that time.

A tabulation of reserves, as of 1944 while the government drilling was still in progress, was made by Bridge, Dorsh, and Weitz (1947, p. 223). This estimate was based in large part on the results of the Federal drilling program, including drill-hole information provided by all the operating companies. Data as to grade of ore were only approximate in most of the company information. For this reason, the writers believe that the tonnage estimates of Bridge, Dorsh, and Weitz are on the generous side for each average grade of Arkansas ore cited in their table (Bridge and others, 1947, p. 223). The figures probably represent more closely the total ore containing more than 32 percent available alumina that can be obtained by blending low-grade, high-silica and high-iron bauxite containing less than 32 percent available alumina with the adjacent high-grade ore.

The present estimates of the total reserves of the Arkansas bauxite region, given in table 15, are admittedly conservative. Whereas the tonnages of Bridge, Dorsh, and Weitz were computed at 20 cubic feet per ton, those in the table 15 were computed at 22 cubic feet per ton. Both ratios are reasonable: high-grade bauxite in places has a density of 23 cubic feet per ton; low grade, a density of 19 cubic feet per ton; the bauxite of highest density is that in which siderite fills the pore spaces. Between 40 and 50 percent of the total ore is believed to contain more than 6 percent of FeO.

TABLE 15.—*Bauxite reserves of Arkansas as of January 1950, by districts, in millions of wet long tons*

Mining district	Grade of ore [1]	Average content (in percent)		Reserves in deposits 8 feet or more thick				Reserves in deposits 5 feet or more thick			
		Al_2O_3	SiO_2	Measured	Indicated	Inferred	Total	Measured	Indicated	Inferred	Total [3]
Pulaski	1	59	6	(2)	(2)	(2)	0. 1	(2)	(2)	(2)	0. 1
	2	52	10	4. 3		0. 1	4. 4	5. 9		0. 2	6. 1
	3	50	9	6. 4	1. 5	. 2	8. 1	8. 8	2. 0	. 3	11. 1
Saline	1	59	6	(2)	(2)	(2)	4. 0–5. 5	(2)	(2)	(2)	5. 0–6. 3
	2	52	10	33. 9		. 6	34. 5	42. 1		. 7	42. 8
	3	50	9	14. 7	46. 9	1. 0	62. 6	18. 6	57. 9	1. 3	77. 8
Total	1	59	6	(2)	(2)	(2)	4. 0–5. 5	(2)	(2)	(2)	5. 0–6. 3
	2	52	10	38. 2		. 7	38. 9	48. 0		. 9	48. 9
	3	50	9	21. 1	48. 4	1. 2	70. 7	27. 4	59. 9	1. 6	88. 9

[1] Specifications:
Grade 1. Prewar—not more than 7 percent of SiO_2; not more than 3 percent of FeO.
2. War Production Board requirements—not more than 15 percent of SiO_2; not more than 6 percent of FeO; not less than 40 percent of Al_2O_3; and not less than 32 percent of available alumina.
3. Same as grade 2 but no restriction as to iron content. The tonnage listed under each specification is cumulative; that is, grade 2 includes grade 1, and grade 3 includes grades 1 and 2.

[2] Data not available for making separate estimates.

[3] Totals of reserves in deposits 5 feet or more thick include totals in deposits 8 feet or more thick.

The present estimate also excludes a large tonnage of bauxite mostly on the western side of the Saline dome, that is known from drillers' logs, but for which no information as to grade was available at the time the Bridge, Dorsh, Weitz estimate was made. Later information has indicated that most of this rock contains less than 32 percent available alumina. Lastly, the 6,642,000 tons produced from 1945 through 1949 and the estimated wastage that accompanied this production has been taken into account.

In the table 15, 70.7 million tons at the beginning of 1950 is believed to be a reasonable estimate of the ore in place, minable under the same emergency conditions that prevailed during World War II. Not all of this ore can actually be recovered, however. No table of recoverable bauxite reserves such as the one published by Bridge, Dorsh, and Weitz (1947, p. 224) is given here. Their table was calculated on a mined and dried basis on the assumption that 85 percent of the material in the ground can be mined where open-pit methods are used, 65 percent where underground mining must be employed, and that 15 percent of the weight is water lost on drying. If the same ratio of recoverable ore to ore in place used by Bridge, Dorsh, and Weitz is applied to the 70.7 million tons cited above, a total of about 46 million tons of recoverable ore on a mined and dried basis can be estimated to remain in the bauxite region.

Most of the reserves remaining in Pulaski County are in small deposits. In this county, as of January

1950, nearly all the deposits originally containing more than 500,000 tons of bauxite in place are being mined or have been almost completely exhausted. Only one ore body with known reserves slightly in excess of 500,000 tons in place has not yet been exploited. In Saline County, on the contrary, a major part of the reserves are in deposits that exceed one million tons of bauxite in place.

FUTURE PRODUCTION

The Arkansas bauxite region has yielded about 93 percent of the bauxite mined in the United States. Geologic studies have shown that the climatic conditions under which the bauxite formed were widespread in this country, though confined to a relatively limited part of geologic time. Bauxite formed, principally during Wilcox time, at many localities in the south-central and southeastern United States. Much of it has been dissipated by subsequent erosion and by further alteration.

Central Arkansas is the only known region in the United States where it can be demonstrated that bauxite formed in place from crystalline igneous rocks relatively high in alumina. This factor is believed to be the most direct cause of the concentration of our domestic ore in this region.

Any search for new important reserves in this part of the country, therefore, should be directed along two principal lines: (1) investigation of unexplored areas above or adjacent to the known buried hills of igneous rock, and (2) a search for other masses of igneous rock rock that were exposed to weathering during late Midway to early Wilcox time and have been protected from intense erosion since then. Nearly all the hitherto unexplored areas fringing the known masses of nepheline syenite have been investigated and a large tonnage has been discovered. The geophysical program of the U. S. Bureau of Mines and the sinking of 60 deep drill holes to explore the more deeply buried parts of the Little Rock igneous complex failed to disclose any additional large masses of nepheline syenite that protrude above the surface of the Midway sediments and hence were exposed to weathering during Wilcox time. Moreover, geologic investigations of the Midway and Wilcox contact in southwest Arkansas between the bauxite region and the Texas border by W. H. Monroe and L. W. Stephenson and geophysical traverses did not disclose any additional bauxite deposits or buried bodies of igneous rock.

The results of the wartime investigations strongly indicate that bauxite in central and southwestern Arkansas is limited to the known masses of nepheline syenite in Pulaski and Saline Counties. The writers believe that drilling in these counties already has discovered most of the significant bodies of ore, because nearly all the favorable areas have now been explored. Future drilling will no doubt discover additional deposits, for the most part near those already known. It is believed that the reserves of bauxite that remain to be discovered in these counties will not exceed 10 percent of the gross tonnage of those already known.

DESCRIPTION OF THE BAUXITE DEPOSITS AND MINES

Deposits and mines of the two main districts of the Arkansas bauxite region are described separately. The Pulaski and Saline mining districts are the two productive centers; the nonproductive area between them was also investigated. Each of these districts, for purposes of convenience in description, has been further subdivided into smaller areas delimited by prominent topographic features of the post-Midway erosion surface, but identified in name with geographic localities on the present land surface. Eight subdivisions are in the Pulaski mining district, 4 in the nonproductive area to the southwest, and 10 in the Saline mining district.

The bauxite deposits have been described in general from northeast to southwest because this was the general direction and sequence of the exploration work followed by the Federal drilling program. The U. S. Bureau of Mines report on the results of this drilling, published in 1948 (Malamphy and others 1948), followed the same general arrangement. In the U. S. Bureau of Mines report 14 half township maps and 77 detail maps give locations and numbers of all the holes drilled, except a few deep holes drilled to test the geophysical anomalies, and these are shown in an additional small scale map. The township maps show surface and subsurface contacts of the principal rock units as mapped by the Geological Survey. Chemical analyses of samples from the cores in the drill holes and brief lithologic descriptions that summarize detailed logs made by geologists are also given.

This publication has been designed to interpret and to supplement the data contained in the U. S. Bureau of Mines report. For each bauxite deposit drilled by the Federal Government reference has been made to the pertinent pages and location maps in the U. S. Bureau of Mines report. To avoid obscuring the ore body maps on the following pages the numbers of drill holes have been omitted, except for those used in the detailed cross sections, or mentioned in the text. The numbers of the other holes, if desired, can be found on the maps in the U. S.

Bureau of Mines report. Where possible, the names of bauxite deposits used in the U. S. Bureau of Mines report have also been used in this publication.

Much of the supplemental material in this report comes from drilling data provided by all the companies that have operated in the bauxite region from 1940 to 1950. This information, supplemented by field examination, has made it possible to give at least a brief description of each company-explored and developed deposit, as well as those investigated by the Federal drilling program. As a result, this is a comprehensive report on all known bauxite deposits in the central Arkansas region.

Detailed logs of the holes drilled by the Federal government in the bauxite region are on file in the office of the State Geologist at Little Rock, Ark., and in the library of the U. S. Geological Survey at Washington, D. C.

PULASKI MINING DISTRICT

The bauxite deposits that constitute the Pulaski mining district are associated with the Pulaski nepheline syenite mass (the Pulaski high). This has also been called the Granite Mountain district (Hayes, 1901, p. 454–459) and the Sweet Home area (Bramlette, 1936). The nepheline syenite rocks are exposed in an extensive outcrop on Granite Mountain (sometimes called Fourche Mountain), 2 to 5 miles south of Little Rock, in Pulaski County. Bauxite and kaolin rocks are limited to the eastern, southern, and part of the western flanks of this nepheline syenite mass. The eastern limit of the district is about 2 miles northeast of the town of Sweet Home. From here the scattered deposits form a sinuous band that trends about S. 35° W. for 8.7 miles; then bends sharply northward, trending about N. 10° W., 3.6 miles to the settlement of Berger. The total area along this strip is about 7 to 8 square miles.

The geologic locus of distribution of the deposits is the buried edge of the sediments of the Midway group where they wedge out against the nepheline syenite. Nearly all the ore bodies are within a quarter of a mile of this line, some lying over the nepheline syenite, others above the Wills Point formation, and several over the Kincaid formation in places where the overlying Wills Point formation was removed by erosion before deposition of the Berger formation.

Some of the bauxite deposits crop out at the surface along the edges of the nepheline syenite outcrop, but most of them are buried beneath an overburden of Eocene continental sediments (of the Wilcox group) that include sand, clay, and lignite beds. This overburden generally becomes progressively deeper southward and the southernmost buried deposit is covered by about 430 feet of continental beds.

For convenience in describing the deposits, the Pulaski mining district has been divided into eight geographical areas (fig. 58), as follows:

1. Picron Hill area. The easternmost extremity of the Pulaski nepheline syenite mass, including a single bauxitic outcrop and deposit in sec. 17, T. 1 N., R. 11 W.
2. Sweet Home embayment. A deep concave bow in the edge of the nepheline syenite, including the deposits in secs. 19, 20, and 30, T. 1 N., R. 11 W., and secs. 24 and 25, T. 1 N., R. 12 W.
3. Woodyardville area. A shallow embayment in the edge of the nepheline syenite, including the deposits in secs. 35 and 36, T. 1 N., R. 12 W. and secs. 1, 2, and 11, T. 1 S., R. 12 W.
4. Ironton area. Eastern flank of the buried southward extension of the nepheline syenite mass, including deposits in secs. 10, 14, 15, and part of sec. 22, T. 1 S., R. 12 W.
5. Jennings Lake area. Western flank of the buried southward extension of the nepheline syenite mass, including deposits in secs. 16, 21, and part of sec. 22, T. 1 S., R. 12 W.
6. Berger area. Western flank of the nepheline syenite mass, including the deposits in secs. 4, 8, 9, and the northern part of sec. 16, T. 1 S., R. 12 W.
7. Primrose Church basin. Includes deposits in secs. 3, 4, 9, and 10, T. 1 S., R. 12 W.
8. Echo Valley area. A single outcrop at the north edge of sec. 26, T. 1 N., R. 12 W.

PICRON HILL AREA

At its northeasternmost end in secs. 17 and 18, T. 1 N., R. 11 W., the Pulaski nepheline syenite mass is exposed in two separate outcrops of pulaskite. One of these passes through the southern part of the village of College Station and the other is exposed about a quarter of a mile to the northeast on the north slope of Picron Hill. The lower ground between these two exposures is covered with a thin veneer of sediments of the Saline formation. About midway between the two pulaskite exposures and on the east slope of Picron Hill and in the NE¼SW¼, sec. 17, is an exposure of low-grade bauxite several hundred feet across, the Bruton outcrop (pls. 1 and 2).

The post-Midway surface of the pulaskite between the two outcrops contains a subsurface valley that trends east-southeastward. The buried lip of the Wills Point formation lies about half a mile west of the bauxite outcrop and this lip bends around the end of the pulaskite hill in a sharp curve. The alluvial deposits of the flood plain of the Arkansas River, including Quaternary terrace deposits that fringe the nepheline syenite rocks, have been laid down unconformably on the rocks of Eocene age. Erosion before deposition of these sediments probably caused the scarcity of bauxite in this area.

The earliest exploration in this area was by the Republic Mining and Manufacturing Co. in several test pits dug on a rectangular grid in the bauxite

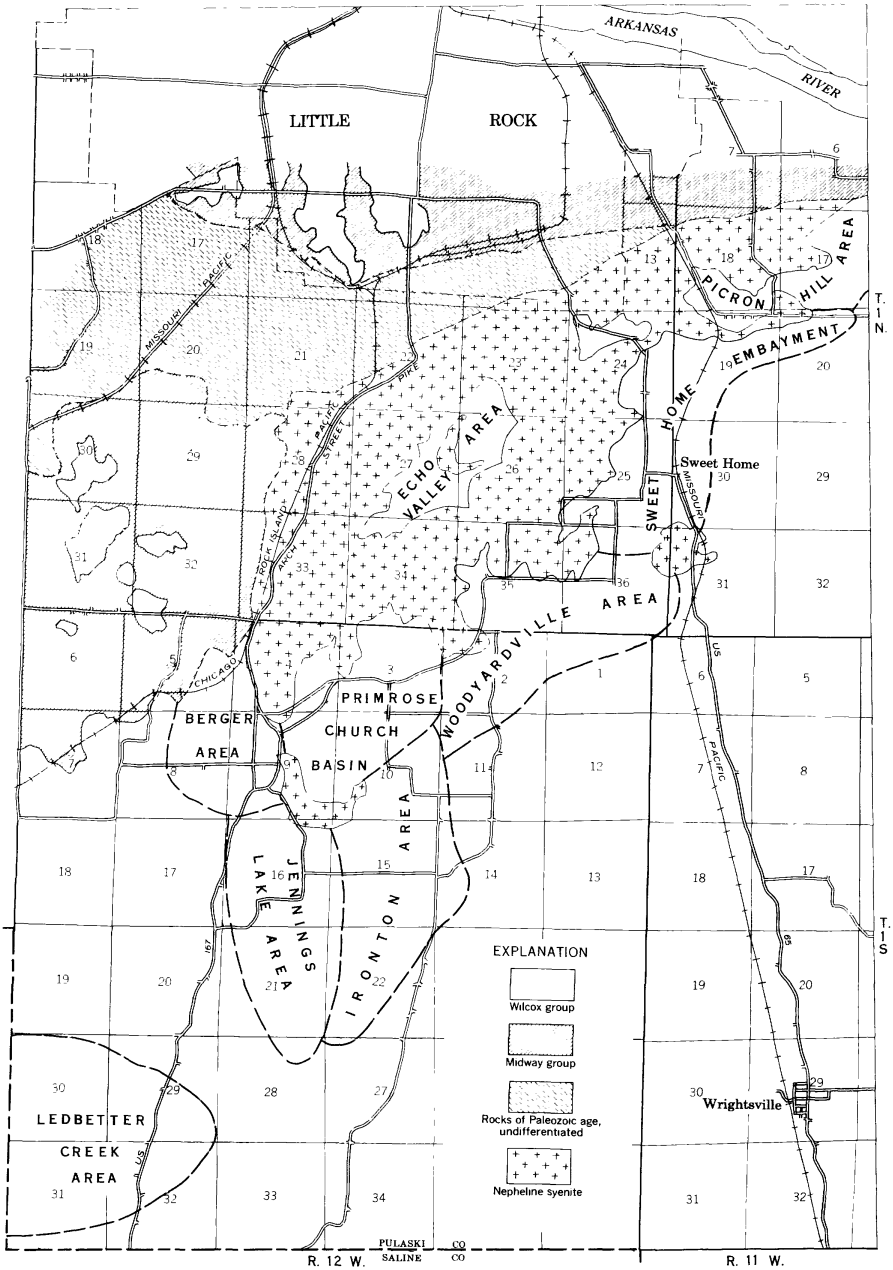

FIGURE 58.—Sketch map of the Pulaski mining district showing the areas into which it has been subdivided for the purpose of describing the deposits.

outcrop. The Federal drilling program disclosed the minor deposits described below.

BRUTON AND BRUTON EXTENSION DEPOSITS

Plate 2

The Bruton and Bruton Extension deposits (Malamphy and others, 1948, v. 2, p. 4–16, figs. 32, 33) lie in the SW¼ sec. 17, T. 1 N., R. 11 W., about 3 miles east-southeast of the central part of Little Rock and half a mile northeast of College Station. The deposits were prospected by 19 drill holes on Alcoa property and 23 on property of B. T. Harris to the east. The only minable ore lies at the south edge of the outcrop in a small body a few hundred feet long. The bauxite is pisolitic, yellow to tan, locally stained orange. It is hard in some places, soft and clayey in others. The upper part is pebbly with patches and stringers of kaolin and may be in part reworked. Cavities filled with siderite are in the lower part. Most of the bauxite is low grade. The overburden, 2 to 18 feet of gray clay, sand, and gravel, probably belongs to the Saline formation. The outcrop and minable bauxite are situated at the upslope end of a valley cut into the syenite and represent an accumulation of bauxitic colluvium (type 2 deposit) at the base of a steeper slope.

About 500 feet southeast of the ore body, in USBM drill hole 18–259E, about 12 feet of tan to brown pebbly pisolitic bauxite of Berger age (type 3 deposit) was found at a depth of 20 feet, lying above 1 foot of lignite and carbonaceous clay. A minable thickness of bauxite was not found in adjacent drill holes.

About 600 feet farther east, 8½ feet of low-grade bauxite (type 2 deposit) at a depth of 35 feet was found in USBM drill hole 18–271. The bauxite is soft and pisolitic but pebbly in the upper part. This deposit, delimited by offset holes to the west but not to the east, is too small to have any commercial interest.

SWEET HOME EMBAYMENT

A large irregular embayment in the margin of the nepheline syenite mass surrounds the town of Sweet Home. This embayment extends from an outcrop in the NW¼ sec. 20, T. 1 N., R. 11 W., west through sec. 19, and south across secs. 24 and 25, T. 1 N., R. 12 W. and thence south-southeast to an isolated nepheline syenite outcrop in the southwest corner of sec. 30, T. 1 N., R. 11 W. The mouth of the embayment is 2 miles wide along a northeast line, and the embayment is 1½ miles deep at right angles to this line. It is filled with sediments of the Wilcox group which slightly overlap the underlying sediments of the Midway group. The bauxite deposits are distributed in an arc along the buried edge of the Midway sediments, nearly parallel to the inner edge of the embayment.

The basement rock that forms the low sloping margin around the embayment consists principally of pulaskite. Several large roof pendants of metamorphic rocks of Paleozoic age, mostly gray quartzite and greenish altered shale, are in secs. 24, 25, and 36, T. 1 N., R. 12 W. Marine sediments of the Midway group rest on the basement rock, and most of them are covered by continental sediments of the Wilcox group. A poor exposure of clay of the Wills Point formation crops out near the center of sec. 25. From this locality the shoreward edge of the Midway sediments extends northward, beneath a covering of Wilcox continental sediments to a point near the center of the SE¼NE¼ sec. 24, T. 1 N., R. 12 W.; the Midway then trends eastward across the north half of secs. 19 and 20, T. 1 N., R. 11 W.

In general the buried post-Midway erosion surface of the nepheline syenite dips steeply to its contact with the surface of the Wills Point formation, which has a more gentle gradient. The bauxite-kaolin zone thins abruptly upslope from the buried Midway and nepheline syenite contact. Some of the largest outcrops of bauxite and bauxitic clay in the Pulaski mining district fringe the embayment.

Most of the bauxite in the deposits is pisolitic and appears to have been transported to its present position. The bauxite deposits are large accumulations, type 2 deposits as much as 60 feet thick, most of which have moved downslope as colluvium and have been deposited at the edge of the Berger formation, where they were further bauxitized.

Scattered on top of, or just downslope from the larger ore bodies are stratified, crossbedded, pebbly, or rubbly lenses of bauxite (type 3 deposits) that interfinger with gray silty clay and lignite of the Berger formation. Most of these lenses are small and of little or no importance commercially, but one at the south end of the Ratcliffe ore body, has provided all or part of the ore that has been mined in eight small mines.

The overburden in the area reaches a maximum of nearly 150 feet in thickness above the buried ore bodies and is composed of bauxitic and kaolinitic clay, lignite, lignitic clay, and gray silty to sandy clay of the Berger formation, overlain by brown silty to sandy clay, sand, and local gravel of the Saline formation. In the eastern part of the area, Quaternary terrace deposits, consisting of brown, red, and gray sandy to silty clay overlying gray to brown loose sand, cover the Eocene sediments.

The earliest exploratory work in the embayment probably was done by the Republic Mining and Manufacturing Co. which, according to "Mineral Industries 1917" was preparing in 1916 to open a mine near Sweet Home. In 1920 the company began strip-mining at the outcrop locality in sec. 24, T. 1. N., R. 12 W.

The second shaft mine in the bauxite region, the Dixie No. 2, was begun in 1928 on an eastern extension of the same deposit. During World War II 12 mining companies operated in this area.

FOURCHE BAYOU DEPOSIT

Plate 2

The easternmost deposit in the Sweet Home embayment, part of which was described by Malamphy and others (1948, v. 3, p. 5–16, fig. 36) as the Zuber deposit, lies in the SE¼NE¼ sec. 19 and the W½NW¼ sec. 20, T. 1 N., R. 11 W., a few tens of feet below the bed of Fourche Bayou (pl. 2). It was discovered in 1943 by the Jackson and Squire Construction Co., which drilled about 40 holes on the Childress property in sec. 20. In August 1944 a minable thickness of bauxite was reached in USBM drill hole 18–233D on the Hall property of the Dixie Bauxite Co., in sec.19. Further drilling showed that the new occurrence was part of the same deposit investigated by Jackson and Squire. The company stripped the overburden from part of the deposit on the Childress property in 1944. However, before actual mining began, waters from Fourche Bayou broke through and flooded the pit, so the mine was never operated.

The west end of the deposit was investigated by 32 drill holes spaced about 200 feet apart on a triangular grid, most of which were on the Hall property; one was drilled on the Zuber property south of Fourche Bayou in the SW¼NW¼ sec. 20.

The deposit trends east-northeastward. It is more than 1,900 feet long and 300 feet wide and had not been completely delimited at the end of the field work in 1945. The greater part of the deposit lies on the surface of the Wills Point formation near the base of a steep nepheline syenite slope and across a small subsurface valley that drained southward in early Eocene time. The ore body dips 5° E.

The bauxite is mostly light tan and pisolitic. The matrix is firm and contains considerable kaolinitic clay in irregular veinlets and masses surrounding the pisolites. The top 3 to 4 feet in places is pebbly, and contains pisolites with thin tan hard rims and black or brown cherty interiors; the pisolites in most of the deposit average a quarter of an inch in diameter. Locally there is a gray hard siliceous hardcap.

The iron content of the lower part of the deposit is fairly high, owing to siderite that occurs in brown to orange masses as much as 5 millimeters in diameter scattered through the bauxite.

The overburden ranges in thickness from 60 to 92 feet over the minable part of the deposit. Berger sediments that overlie the bauxite deposit range from about 5 to 40 feet in thickness. Lying on the eroded surface of the Berger formation is an upper unit of very fine to coarse, brown to colorless quartz sand, 57 to 71 feet thick, that in places grades laterally into brown or gray, silty clay. This is probably a Quaternary terrace deposit at the west margin of the Mississippi River alluvial plain.

RATCLIFFE DEPOSIT

Plate 16

The Ratcliffe deposit is the largest in the Pulaski mining district. It contains the North Dixie and Dixie Extension areas described by Malamphy and others (1948, p. 17–47, figs. 35, 37, 38). It lies at the northwest corner of the Sweet Home embayment; partly in sec. 19, T. 1. N., R. 11 W., and partly in sec. 24, T. 1 N., R. 12 W. It is on Highway 65 nearly a mile southeast of the city limits of Little Rock. The buried east end of the deposit is crossed by the Missouri Pacific Railroad. The ore body is broad, thick, and almost L-shaped. The long arm of the L is about 4,500 feet from east to west, and the short arm about 3,300 feet from north to south. The west end of the deposit crops out extensively along Highway 65. A smaller outcrop of bauxitic clay and low-grade bauxite north of the Dixie No. 2 mine is not directly connected with the ore body.

The deposit lies in an area where detritus has collected in considerable thickness since early Kincaid time. Several holes drilled through the bauxite-kaolin zone cut through as much as 70 feet of claystone conglomerate and fragmental clay, which apparently is part of the alluvial apron deposited along the flanks of Granite Mountain in Kincaid time. The Wills Point formation is present beneath the eastern part of the deposit. Elsewhere Berger fragmental clays lie directly upon debris of Kincaid age. A few feet of typical dark gray, khaki-colored, and red clay of Wills Point age was reached in USBM drill hole 18–331 north of the ore body and indicates that the Wills Point formation once extended farther shoreward but was partly stripped out before deposition of the Berger sediments.

The Ratcliffe ore body lies near the head of a subsurface valley, at the base of a steep syenite slope drained by a half dozen minor tributary valleys. It is thickest toward the upper end generally along the northern part of the ore body. C. Jessup of the Alcoa Mining Co. reported a maximum thickness of 42 feet of ore in the northern part of the Ratcliffe pit, and W. G. Hall of the Dixie Bauxite Co. called the writers' attention to a thickness of 60 feet of high-grade ore not far from the main shaft of the Dixie No. 2 mine. The highest grade bauxite occurred in these thicker areas. In the Dixie No. 2 mine the ore body dips to the south about 40 feet in 500.

The deposit is a composite of colluvial (type 2) bauxite locally overlain by alluvial (type 3) bauxite. The approximate areal distribution of both types is shown in plate 16. The bauxite in the lower body is pisolitic, massive, indurated in some places, soft and mealy in others, and rich tan to grayish tan. The pisolites average 6 millimeters in diameter and are fairly soft. The silica content is low in the center of the ore body; and high at the top and bottom or beneath lignite and clay lenses. The lower part of the bauxite contains a large amount of siderite locally in brownish to purplish granules and crystals.

The upper bauxite lens is bedded, in many places well sorted, and distinctly stratified (fig. 24); locally it is crossbedded. The largest area of stratified bauxite is at the southwest end of the deposit and extends for nearly 1,700 feet south-southwestward beyond the edge of the underlying colluvial ore body. At its north end, this lens of stratified bauxite rests directly upon the nonstratified bauxite (fig. 59), but a little farther south, in

FIGURE 59.—Ratcliffe mine, Pulaski County. Working face, October 1948, in southern part of Alcoa Mining Co. pit, looking northwestward. Harder 5-foot tapering bed at top below shacks is stratified bauxite; thicker bed below is massive pisolitic bauxite.

the southern part of the Ratcliffe pit a wedge of silty clay and lignite of the Berger formation separates the two beds. The upper part of the stratified bed is indurated and ferruginous. It is filled with hard cherty masses and veinlets of kaolinite, and grades upward into gray kaolinitic clay containing pebbles of hard pisolitic bauxite. The stratified bed in this part of the deposit has been mined in the southern part of the Ratcliffe pit, as well as in the Thorpe, Dorough, Morgan, Keenzel, England, Harley, and Dixie Lease pits (pl. 16).

Along the north border of the stratified lens described above, the surface of the deposit was cut by a channel 50–100 feet wide and a few feet deep, that extends northeastward across the deposit. This is shown in the sketch map and section (pl. 16). It was reported filled with lignite, probably of the Berger formation. Alluvial bauxite occurs also east of the Missouri Pacific Railroad tracks and in the area surrounding the Dixie No. 2 shaft.

Twelve mines in the Ratcliffe deposit, described briefly on the following pages, are shown on the sketch map (pl. 16) as of the early part of 1945.

Dixie No. 2 shaft mine (pl. 1, no. 2).—The eastern part of the Ratcliffe ore body has been mined by underground workings in the S½NW¼, the SW¼NE¼, and the N½SW¼ sec. 19, T. 1 N., R. 11 W. The mine has a vertical two-compartment shaft, 152 feet deep, and was originally worked on 2 levels, at 87 and 122 feet (Branner, G. C., 1935, p. 123). The ore body, which dips about 5° S. was mined by a series of overlapping levels.

The part of the deposit that lies in sec. 19 was discovered in 1928 by P. A. Dulin, and the shaft was started that year. Mining, which started in 1929, explored the northern part of the ore body where the bauxite reached a maximum thickness of 60 feet, and where the highest grade of abrasive ore was found. Until 1942 the mine produced only abrasive and chemical ore. The mine was connected by a switch with the Missouri Pacific Railroad where an oil-burning calciner and a dryer were installed. The calciner was dismantled in the fall of 1942 and high-grade metal ore was produced during World War II. During this time the southern part of the ore body was worked, in addition to bauxite that lay beneath caved areas where abrasive ore had already been mined. Toward the close of 1944 the mine was sold to the Dulin Bauxite Co., which produced some metal and abrasive ore in 1945 and 1946.

Much of the bauxite in this ore body, which is all pisolitic, contained 51 to 58 percent alumina and 3.3 to 7.9 percent silica. The iron content, reported as Fe_2O_3, generally ranged from 2 to 13 percent, most of which is ferrous iron. A large amount of bauxite high in iron content was left in caved areas below mined ore.

Drilling near the Dixie No. 2 mine.—Additional drilling was done by the Federal government to delimit that part of the Ratcliffe deposit that lies in sec. 19. Sixteen holes were drilled north of the Dixie No. 2 mine but no additional minable ore was found (Malamphy and others, 1948, v. 3, p. 42–47, fig. 38 under the title, "North Dixie deposit"). Fifty-eight more holes were drilled by the U. S. Bureau of Mines along the south side and at the east end of the deposit (Malamphy and others, 1948, v. 3, p. 17–41, fig. 37, under the title, "Dixie Extension deposit)." A minable thickness of bauxite was found in several of these drill holes, though some of it was high in ferrous iron.

Ratcliffe open-pit and underground mine (pl. 1, nos. 3, 5).—The Republic Mining and Manufacturing Co.

began open-pit mining in 1920 (U. S. Geol. Survey, 1921, p. 32) in the northwestern part of the ore body, on the W. A. Ratcliffe lease, SE¼NE¼ sec. 24, T. 1 N. R. 12 W. The mine was closed for a brief period toward the end of 1920 and in 1921 (U. S. Geol. Survey, 1922, p. 66), then was operated continuously until 1930 when Republic Mining and Manufacturing Co. merged with the American Bauxite Co. and the Saline County deposits only were exploited. In 1935 strip-mining was resumed and shortly afterward the eastern part of the Ratcliffe property was mined by means of underground workings that opened from the main pit. The underground mining was terminated in December 1942. During World War II pit-mining was greatly expanded, south of the Ratcliffe lease where stratified pebbly bauxite directly overlies massive pisolitic bauxite. Since the war mining has been continued by the Alcoa Mining Co.

The overburden that has been stripped ranges from less than a foot at the northwest end of the pit to nearly 50 feet at the southeast. The overburden above the underground workings ranges from 18 to 104 feet and averages about 65 feet.

The mine is connected by a small company railroad with the nearby Drury calcining plant of the Aluminum Ore Co., to whom the ore is sold. Much of the bauxite from the Ratcliffe mine has been used in the manufacture of abrasives because of its high quality.

The mine was called the Sweet Home mine in the U. S. Geological Survey "Mineral Resources" for 1929 and 1930 and in the U. S. Bureau of Mines "Minerals Yearbook" for 1936; also as the "Drury mine" in the "Minerals Yearbook" for 1945 to 1947, inclusive.

Ratcliffe (Dulin) open-pit mine (pl. 1, no. 4).—A small pit forms an alcove in the west edge of the Ratcliffe pit adjacent to Highway 65, in the southwest corner SE¼NE¼ sec. 24. The bauxite in this pit consisted of some lower grade ore left by the earlier mining operations and the ore was removed by the Dulin Bauxite Co. in 1944. This mine was called the Little Ratcliffe mine on a preliminary map (Bryson and Gordon, 1944).

Ratcliffe Lease open-pit mine (pl. 1, no. 6).—A small open-pit mine was operated by the Pulaski Mining Co. near the southwest corner NE¼NE¼SE¼ sec. 24, and forms a recess in the larger Ratcliffe pit. The overburden of Berger and Saline sediments, 30 to 70 feet thick, was stripped early in 1944. The pit was mined later in the same year at which time the Brown shaft mine was operating. The bauxite, part of the lower type 2 body, was pisolitic light tan to gray, somewhat clayey, but locally indurated. Many cavities in this part of the deposit contained well-formed purplish-brown siderite crystals as much as a quarter of an inch long. Additional stripping and mining were done by the Dulin Bauxite Co. in 1949.

Brown-Ratcliffe shaft mine (pl. 1, no. 7).—A lobe of bauxite at the south side of the Ratcliffe deposit, elongate in a north-northeasterly direction, was mined through a shaft sunk by the Dulin Bauxite Co. The shaft was 92 feet deep, with a timbered haulage compartment and manway, to the working level 84 feet below the surface. The mine was located principally on the properties of W. A. Ratcliffe and A. W. Brown in the NE¼SE¼ sec. 24. Early drilling was done by the Republic Mining and Manufacturing Co. before 1935. This part of the Ratcliffe deposit was not considered high enough grade to warrant exploration by the company before World War II. The Dulin Bauxite Co. began mining the ore in May 1944. The lease was surrendered in October 1945, and the ore was reported to be exhausted at that time.

The bauxite in this mine was pisolitic well indurated and light grayish-tan. The average grade was reported to be about 54 percent Al_2O_3, 8 percent SiO_2, 5.3 percent Fe_2O_3, including about 4 percent FeO. The bauxite was covered by 60 to 105 feet of overburden.

Thorpe open-pit mine (pl. 1, no. 10).—A small open pit 250 by 325 feet was mined by the Dulin Bauxite Co. on the property of Melissa Thorpe in the southeast corner of the NE¼SE¼ sec. 24, alongside of Highway 65. The 12 to 20 feet of overburden, mostly of the Saline formation, was stripped late in 1942, and the pit was operated at irregular intervals in 1943 and the first half of 1944.

All the bauxite mined in this pit was of the stratified ferruginous type, as much as 12 feet thick and overlying gray silty clay and lignite of the Berger formation. Part of the ore was treated at the nearby calcining plant of the Dulin Bauxite Co., and the rest of it was sold as crude ore to the Metals Reserve Company.

Dorough open-pit mine (pl. 1, no. 9).—An open pit at the west side of Highway 65 was operated by the Dixie Bauxite Co. on the Dorough lease in the SE¼NW¼ SE¼ sec. 24. The mine forms part of a single pit together with the Morgan mine of Prewitt Bauxite Co. immediately to the south. The bauxite crops out in the western part of the property. Dixie Bauxite Co. drilled 23 holes in August 1941. Overburden, as much as 24 feet thick, was stripped early in 1943, and the property was mined later that year.

Morgan open-pit mine (pl. 1, no. 8).—This mine was operated by Roy Prewitt (Prewitt Bauxite Co.) between April and November 1943, in the upslope part of the stratified deposit that overlies the main Ratcliffe deposit. The overburden apparently does not exceed 15 feet on this property. Most of the ore mined was

classified by the Metals Reserve Company as "high-silica restricted."

Keenzel open-pit mine (*pl. 1, no. 11*).—A small pit of irregular outline about 175 feet long by 100 feet wide, at the west side of Highway 65 and south of the Morgan mine, was operated by Hardin and Prewitt between December 1942 and February 1943. The bauxite mined was stratified, pebbly, and pisolitic. The overburden averaged about 6 feet, mostly sand.

England open-pit mine (*pl. 1, no. 12*).—The blanket of ferruginous stratified bauxite was also mined by the Dulin Bauxite Co. in a pit south of the Thorpe mine. The property was reportedly leased and stripped by the Dixie Bauxite Co. late in 1942, but was acquired by Dulin and mined in conjunction with the adjacent Harley pit in 1943 and 1944. The bauxite in this pit was crossbedded, low grade, and as much as 12 feet thick; the overburden ranged from about 6 to 15 feet in thickness. Not only the ore in this pit but that which lay beneath the road that separates it from the Thorpe pit has been mined out.

Harley open-pit mine (*pl. 1, no. 13.*)—A small open pit, the Harley mine, is contiguous with the England pit, which lies to the north. The Dulin Bauxite Co. began operations on this property late in May 1942, closed temporarily in November and December, then operated in 1943 and early 1944. The ore body is a southward continuation of the stratified bauxite lens that covers the southwestern part of the Ratcliffe deposit.

The grade of the bauxite is low and erratic. The bauxite pisolites are well sorted and interspaces are filled with masses of white kaolinitic clay and possibly halloysite. Secondary gibbsite crystals lining cavities between the pisolites have been collected from this pit (fig. 24*D*).

Dixie Lease open-pit mine (*pl. 1, no. 14*).—The southernmost of the group of pit mines located on the stratified southward extension of the Ratcliffe deposit is in the SW¼SE¼SE¼ sec.24. The mine was operated by the Clarke Bauxite Co., which acquired leases on two properties, the Hall or Dixie lease on the England property and the Dollar lease on the Stortz property. The company drilled 12 holes on the England property and 8 on the Stortz, disclosing an ore body 485 feet long and 165 feet wide, elongate in a north-northeasterly direction. The deposit was mined from September to November 1943, the ore was principally "high-silica restricted bauxite" according to the classification of the Metals Reserve Company.

SWEET HOME DEPOSIT

Plate 2

The second largest deposit in the Sweet Home embayment lies beneath the northern and western outskirts of the town of Sweet Home (pls. 1 and 2), mostly in the NE¼ sec. 25, T. 1 N., R. 12 W. The deposit is part of a colluvial blanket (type 2 deposit) resting on a weathered pulaskite slope that dips southeast. It can be divided into two principal parts: a large north ore body, elongate and irregularly lobate; and a smaller south ore body, subtriangular in outline. The long axes of the two ore bodies are nearly parallel and trend northeastward. The two bodies are connected and encircled by areas of low-grade bauxite and bauxitic clay. The downslope edge of both ore bodies extends across the Midway and nepheline syenite contact. Most of the deposit is buried beneath sediments of the Wilcox group.

The north ore body comes to the surface in a small outcrop at the southwest corner of the property of the Arkansas Confederate Home. From there it extends northeastward for about five-eighths of a mile through the NE¼NE¼ sec. 25. The bauxite in this ore body is pisolitic. Most of it is light tan, but part of it is gray or reddish. Some of the ore in the central part of the deposit is very high grade. This is surrounded by bauxite that is higher in silica and locally, in the lower part of the deposit, there are sideritic parts high in ferrous iron content. The maximum thickness of the minable bauxite is about 26 feet. Near the southwest end of the ore body, its upslope part dips 8° to the east-southeast, and its downslope part flattens to a dip of about 2°. Near the middle of the ore body the dip is 3°–4° SE. At the east end the bauxite dips 2°–3° E. The ore body is almost completely covered by the upper beds of the Berger formation, consisting principally of lignite, lignitic clay, and gray silty clay, with gray kaolinitic clay and tan bauxitic clay in the lower part just above the bauxite. These beds reach a total thickness of 42 feet on the south edge of the ore body beneath the Confederate Home property. The overlying Saline formation is composed largely of varicolored clay, loose sand, and gravel, with locally as much as 10 feet, of chocolate-brown silty carbonaceous clay at the base and has a maximum thickness of 41 feet. Both formations wedge out against the bauxite outcrop.

The south ore body lies beneath the western part of the town of Sweet Home in the SW¼NE¼ sec. 25. The outline of the minable part of this body forms a crude isosceles triangle with its base upslope and its apex downslope to the northeast. It is about 1,100 feet long from base to apex and 800–900 feet along the base. The enclosing envelope of low-grade bauxite and bauxitic clay comes to the surface in a curving outcrop, concave toward the ore body and a short distance southwest of it (pl. 2). The bauxite in the south ore body is pisolitic, in general higher in silica than much of the ore in the north ore body. Much of it is tan, but locally white, red, and gray varieties occur. The four color varieties

were in the western part of the ore body, that was mined by the Sweet Home Bauxite Co. The white variety was reported by Roy Prewitt, manager of the company, to be high in alumina, and the gray somewhat higher in iron than the red. The south ore body lies beneath overburden that ranges in thickness from a few feet at the south end, to about 20 feet at the north end of the base of the triangle, and 85 feet at the northeast end.

Confederate Home property.—The part of the Sweet Home bauxite deposit that lies beneath the 65-acre property of the State Confederate Home in the W½NE¼ sec. 25, T. 1 N., R. 12 W. was not mined during World War II although the extraction of the high-grade bauxite on this property was planned and a State Commission appointed to supervise the operation. The intended mining of this ore was halted before it began by cutbacks in Federal bauxite purchases during 1944.

In 1942, the property was prospected by the Dulin Bauxite Co., which drilled about 30 holes. In the latter part of 1943 the State Bauxite Commission enlisted the facilities of the U. S. Bureau of Mines to drill 227 holes on the property. Above the principal ore body the overburden reaches a maximum of 78 feet and averages 46 feet.

Sherrill–England open-pit mine (pl. 1, no. 15a).—The bauxite at the northeast end of the north ore body was being mined in the latter part of 1948 by the Reynolds Mining Corp. in its Sherrill-England pit, which lies at the east end of the Sherrill property (NE cor. sec. 25) and extends into the adjacent England property (SE cor. sec. 24). The presence of bauxite underlying the Sherrill property has been known for many years and several individuals and companies have drilled holes to prospect the deposit. Most of the ore under this property was considered too low in grade to mine before World War II. In the latter half of 1941 Reynolds drilled 87 holes on a rectangular grid spaced about 100 feet apart. The company developed the Sherrill-England mine in 1948 and began mining that year.

The bauxite in this mine is pisolitic and light grayish tan. The overburden is reported to range from 52 to 78 feet in thickness, of which the greater part consists of sediments of the Berger formation.

Sherrill open-pit mine (pl. 1, no. 15).—The central part of the Sherrill property was stripped by the Reynolds Mining Corp. in the latter half of 1942 and the property was mined in 1943 and 1944. The overburden in this part of the north Sweet Home ore body was reported to range from about 35 to 60 feet in thickness.

Dixie No. 1 shaft mine (pl. 1, no. 16).—The first mine in the Sweet Home deposit and likewise the first shaft mine in the bauxite region was located at the west end of the Hoekstra property, in the S½NE¼NE¼ sec. 25. The shaft sunk by P. A. Dulin was the No. 1 mine of the Dixie Bauxite Co., but was cited in Mineral Resources of the United States for 1929 (U. S. Geol. Survey, 1931, p. 489) as the Hoekstra mine (pl. 1, no. 16). The bauxite was reportedly of very high grade. The shaft and old workings are now covered by stripped overburden from open-pit operations of the Reynolds Mining Corp.

Hoekstra open-pit mine (pl. 1, no. 17).—The rest of the western half of the Hoekstra property was stripped and mined by the Reynolds Mining Corp. in 1943–44. The bauxite lay at a depth of 40 to 75 feet and reached a maximum thickness of about 26 feet. Most of the bauxite mined in this pit was pisolitic and hard, but along the east wall of the northern part of the pit the upper bauxite was observed to contain a mixture of light bluish-gray clay fragments and red weathered pisolites, probably a water-deposited detritus.

Hoekstra–Dobbs–Illing open-pit mine (pl. 1, no. 18).—These three properties were leased, developed, and mined by the Jackson and Squire Construction Co. during World War II. The part of the ore body mined lies across the line between the NE¼NE¼ and the SE¼NE¼ sec. 25, and the stripped area formed a common pit with the Hoekstra mine of the Reynolds Mining Corp. The leased tract was drilled by P. C. Upton and by Roy Prewitt, and later by Jackson and Squire. The mine was operated in 1943 and 1944.

The bauxite in this part of the deposit is pisolitic and contains considerable siderite, particularly in the lower part, which locally rendered the ore too low grade to mine. This part of the deposit is reported to lie beneath an overburden that ranged in thickness from about 50 to 75 feet.

Wright shaft mine (pl. 1, no. 19).—The northeastern part of the south ore body, immediately south of the Confederate Home property, was mined by underground workings of the W. T. Wells Mining Co. The bauxite, 50 to 70 feet below the surface of the ground, was reached by a vertical timbered shaft. Mining began in August 1943, and the lease on the mine was relinquished in June 1944, after suspension of mining operations. Most of the bauxite mined was classified as "high-silica restricted" by the Metals Reserve Company.

Sweet Home open-pit mine (pl. 1, no. 20).—The western part of the south ore body was mined by open-pit methods by the Sweet Home Bauxite Co. Stripping operations were begun in May 1942 south of the road. In May 1943, another pit was developed north of the first.

The bauxite mined in this part of the deposit was pisolitic and varicolored. The grade of the ore was low; most of it was classed as "high-silica restricted" bauxite by the Metals Reserve Company. The over-

burden in this part of the deposit ranges from a few feet to about 55 feet in thickness.

DEPOSITS IN THE NW¼ SEC. 30, T. 1 N., R. 11 W.

Two small deposits, one in the NW¼NW¼ sec. 30, and the other in the SW¼NW¼ sec. 30, lie beneath property owned by W. A. Ratcliffe and both are crossed by the Missouri Pacific Railroad tracks. They are associated with a buried hill of nepheline syenite (pulaskite) that stands a little apart from the main igneous mass (pl. 2). The top of this hill is exposed in a small flat outcrop of weathered pulaskite a few feet across, near the center of the SW¼NW¼ sec. 30, about 500 feet east of the railroad tracks. The outcrop is surrounded by alluvium.

The northernmost of the two deposits has been described by Malamphy and others (1948, v. 3, p. 48–64, fig. 39) under the title, "Ratcliffe deposits." It lies above the buried surface of the Wills Point formation which covers the slope of the nepheline syenite rock and fills the valley to the northwest of the hill. The deposit is a composite one. Most of the bauxite of minable grade consists of altered colluvial detritus that has been derived from the nepheline syenite hill and deposited along the east side of a small tributary valley that drains northward. The ore body is about 750 feet long, 200 feet wide, narrowly elliptical, and trends northeastward. Northwest of it and covering the downslope edge of the deposit is another bed of bauxite, most of which lies above lignite and carbonaceous clay. This bed is composed of hard brown bauxite pebbles and pisolites and dips slightly to the east. It has been derived from the north Sweet Home deposit, a lobe of which lies several hundred feet to the west. The small size of the ore body makes mining, under present conditions, somewhat doubtful.

The part of the deposit that contains bauxite of minable grade lies beneath overburden that ranges from 68 to 99 feet in thickness. This includes also the upper alluvial bauxite bed where it is 6.0 to 7.2 feet thick. The overburden includes an upper unit of brown silty clay, brownish sand and gravel, 52 to 69 feet thick. Apparently, this belongs in the Saline formation, except for the uppermost part which is Quaternary alluvium. The lower part of the overburden consists of gray silty clay, lignite, kaolinitic clay, and bauxitic clay of the Berger formation.

The second bauxite deposit was found in several drill holes that were described, along with many others, under the title, "Sweet Home clay deposit" by Malamphy and others (1948, v. 3, p. 65–84, fig. 40). It lies in the southwest corner of the SW¼NW¼ sec. 30, where Highway 65 bends southward from Sweet Home and parallels the Missouri Pacific Railroad. It is about 500 feet long and less than 200 feet wide; only one line of drill holes cut minable thicknesses of bauxite.

The bauxite lies a few feet above the weathered nepheline syenite on the south slope of the small buried hill mentioned above, and along a subsurface valley that drains directly eastward. Erosion along this valley at the south edge of the deposit probably accounts for its limited width. It is slightly higher in elevation at its east end than at the west. The lower and principal part of the deposit is pisolitic, and locally an upper pebbly bauxite bed is separated from the lower bed by a couple of feet of fragmental bauxitic clay.

FULLER SCHOOL DEPOSIT

Plate 2

The Fuller School deposit (Malamphy and others, 1948, v. 4, p. 9–31, fig. 43) is south of Sweet Home in the NE¼SW¼ and the central and northwest parts of the SE¼ sec. 25, T. 1 N., R. 12 W. It consists mostly of low-grade bauxite and bauxitic clay. Much of the bauxite has a high content of siderite, which at the surface is oxidized to limonite.

The deposit crops out along a small creek for nearly half a mile in a westerly direction. Two small ore bodies are within it, one south of, and the other southeast of the Fuller School. The edges of both bodies extend beneath the school grounds. Both have been stripped and mined outside the school property.

The deposit lies on the north slope of a small buried valley, that in early Eocene time drained eastward into a larger northeastward-trending valley. Weathered nepheline syenite, probably pulaskite, is in the bottom of the valley, but the Wills Point formation covers part of the flank and crest of the ridge to the north, cropping out north of the bauxite outcrop. The Wills Point does not exceed 15 feet in thickness in this area, and rests locally upon conglomerate of probable Kincaid age. Beneath the western part of the deposit the Midway sediments lie above dark-gray altered shale of Paleozoic age, but beneath the east end, the Midway sediments are absent and the fragmental underclay of the bauxite-kaolin zone rests directly upon decomposed nepheline syenite.

The Federal government drilled 73 holes in the deposit, most of which were spaced about 200 feet apart. The overburden in these drill holes reached a maximum of 43 feet, although over the minable part of the deposit it ranges in thickness from 30 to 68 feet.

Willie Thomas open-pit mine (pl. 1, no. 22).—In 1943 a pit mine was opened south of the Fuller School property after about 30 holes were drilled by Vaughn and Hurley. The road, known as the Sweet Home cutoff, was diverted to the south side of the pit and

part of the area occupied by the old road was included within the pit. The ore was mined by the Arkansas Bauxite Stripping Co.

The overburden in this pit was about 55 to 68 feet thick. Below about 15 feet of sand, gravel, and yellow clay is a clayey lignite bed, 4 to 7 feet thick. This lignite bed is underlain by a light-gray clay that weathers whitish, for a thickness of 40 feet or more. At the base the clay grades abruptly into a somewhat indurated pisolitic clay containing scattered hollow, soft, or hard, black pisolites, locally in aggregates. The main part of the bauxite lens is yellowish gray, the matrix hard, the pisolites mostly gray to pink. Hard sideritic parts are near the middle of the pisolitic bauxite interval, many of them in vertical tubelike bodies 1 to 2 inches across. The minable bauxite reached a maximum of 15 feet in thickness.

Westminster Church open-pit mine (pl. 1, no. 21).—A pit mine was opened by the Kenark Mining Co. at the east side of the Sweet Home cutoff on the Westminster-Thomas-Barner-Porter tract. Mining operations were begun here in the latter part of 1943 and continued until early in 1944. The bauxite in this part of the Fuller School deposit has a dip of about 5° to the southeast. It is pisolitic and light tan. Most of the bauxite mined in this pit was classified as "high-silica restricted." A small amount of "low-silica restricted" and "nonrestricted" bauxite also was mined.

The overburden in this pit consists mainly of gray silty clay and interbedded lignite of the Berger formation about 30 to 50 feet thick, thickening southeastward. On top of this about a foot of brown carbonaceous clay represents the basal bed of the Saline formation. A fossil plant collection (no. 9049) from this bed is listed in table 5. Between this bed and the surface is 10 feet of medium-grained sand.

OUTCROPS IN THE SW¼SW¼ SEC. 25, T. 1 N., R. 12 W.

Two bauxite outcrops are between a quarter and half a mile southwest of the Fuller School outcrop (pl. 1). The first is exposed in a knoll about a quarter of a mile north of a prominent pulaskite hill. The other outcrop, horseshoe-shaped, lies on the northwest slope of this hill at the southwest corner of sec. 25. Both outcrops were prospected and trenched many years ago by the Republic Mining and Manufacturing Co. They are surrounded by a thin veneer of sediments of the Saline formation.

These outcrops probably are remnants of extensive residual (type 1) deposits that once mantled the Pulaski nepheline syenite mass. The bauxite does not show a pisolitic texture, but is either dense or crudely granitic. The more easterly of the two outcrops is reported to have a high silica content, but the one at the southwest corner of the section contains very high-grade bauxite. Several specimens were collected by M. W. Ellis at the south end of this outcrop. Analyses of these specimens are given in the table below:

Analyses of bauxite samples, in percent, from south end of the southwestern outcrop in the SW¼SW¼ sec. 25, T. 1 N., R. 12 W.

[Analyses by U. S. Bureau of Mines field laboratory, Little Rock, Ark.]

Sample	Al_2O_3	SiO_2	Fe as Fe_2O_3	TiO_2	Ignition loss	Insoluble	FeO	Lithologic description of bauxite specimens
102	59.6	3.9	1.9	2.6	31.8	0.3	0.4	Nonpisolitic; texture dense to fragmental.
103	61.0	2.3	1.6	2.3	32.8	.2	.2	Crude granitic texture, poorly developed.
104	60.3	1.2	2.7	3.0	32.4	.4	.2	Dense, salmon red.
105	61.4	2.0	1.3	1.9	32.8	.6	.3	Do.

WOODYARDVILLE AREA

The deposits in the Woodyardville area, extend from the W½SE¼ sec. 36, westward through the SW¼ sec. 36 and the S½ sec. 35, T. 1 N., R. 12 W., and southwestward through the NW¼ sec. 1, and most of sec. 2, T. 1 S., R. 12 W., to the NW¼ sec. 11 (fig. 58). The land surface is gently rolling. The southeastern parts of the area, drained by Fish Creek, are swampy and flat, formed on terrace deposits at the west margin of the Arkansas River flood plain. To the north and west of this flat land are many low hills that fringe the southeast flank of Granite Mountain, cut in the more resistant sediments of the Saline formation.

Woodyardville lies 3 miles south of the city limits of Little Rock. A paved and graveled road, known as Dixon Road or the Sweet Home cutoff, passes along the north and west margins of the area, within a few hundred feet of the nearest bauxite deposits. This road joins Highway 65 at Sweet Home and Highway 167 a short distance south of Berger. From central Little Rock it is about 10 miles by road via Sweet Home and 9 miles via Berger to Woodyardville. Auxiliary all-weather gravel roads lead to or pass within a few hundred feet of every major bauxite deposit.

The Woodyardville area is bounded at the northeast by a pulaskite hill which crops out in the E½NE¼ sec. 36, T. 1 N., R. 12 W., and the W½NW¼ sec. 31, T. 1 N., R. 11 W. The area is bounded at the southwest by the narrow subsurface valley in the NE¼ sec. 10, T. 1 S., R. 12 W. that drains the Primrose Church

basin. It is separated from this basin in the W½ sec. 11 by a narrow, relatively steep sided basement ridge, the long axis of which trends about N. 10° W.

The basement rocks in the Woodyardville area consist of varieties of nepheline syenite, including pulaskite, tinguaitic border rocks, and nepheline syenite dikes; these are associated with altered shale and quartzite of Paleozoic age in roof pendants in the igneous rocks. Beneath the Wilcox sediments these rocks are partly covered by clay and debris of the Midway group. Most of the dike rocks and the largest masses of rock of Paleozoic age are in secs. 35 and 36, T. 1 N., R. 12 W.

The buried edge of the Midway sediments, where they wedge out on the igneous or metamorphic rocks, is in the shape of an arc irregularly concave to the southeast, that trends in a westerly direction across the southern part of sec. 36, then southwestward diagonally across sec. 2, T. 1 S., R. 12 W. The Wills Point formation laps over the underlying Kincaid formation for several hundred feet in most of the area, except beneath the Dixon deposit, where several gravel lenses of Kincaid age lie directly beneath the bauxite-kaolin zone.

The thickness of the bauxite-kaolin zone reaches 60 feet in places and its upper surface is relatively flat. The highly aluminous sediments of this zone thin out gradually basinward and its extent in this direction is poorly known, as drilling was limited to the vicinity of ore bodies.

Many buried valleys, both large and small, head in the nepheline syenite and extend downslope onto the surface of the Wills Point formation. They are approximately at right angles to the buried edge of the Midway sediments.

Most of the bauxite deposits in this area (pl. 17) lie either wholly or in major part on the Wills Point surface close to the edge of this formation, where it wedges out against the weathered nepheline syenite. Along this buried contact are three major deposits in the Woodyardville area, consisting of many ore bodies linked together by bauxite either of less than commercial grade or less than minable thickness. For convenience in description, however, the eastern one has been subdivided into the Cheatham, McClain-Burks-Nelson, Dixon-Nelson, and Dixon deposits; the central one, into the Woodyardville and Vinson-Raines deposits; and the southwestern one, into the Coe, Birnbach, and Glidewell deposits. In addition, the Reichardt deposit lies upslope entirely over weathered nepheline syenite (as do parts of the Dixon and Woodyardville deposits).

Nearly all of them are formed by residual alteration in valley-wall or valley-fill colluvial accumulations or a combination of both (type 2 deposits). The ore in the larger bodies usually lies along the walls of small shallow valleys and extends downslope—in several places across the valley floor and on the opposite slope. Much of the ore is pisolitic but part of it is fragmental and textureless, and the Cheatham deposit, near the east end of the area, contains a little pisolitic bauxite.

Several ore bodies, particularly those lying over the Wills Point formation in the western part of the area, have two layers of bauxite separated by a narrow wedge of siderite or lignite, and carbonaceous, bauxitic, or kaolinitic clay, which thickens downslope. In these bodies the upper bed is hard, pebbly to pisolitic, and stratified (type 3 deposit).

The bauxite deposits are covered by overburden ranging from several inches to about 325 feet thick and composed of lignite and gray silty to sandy clay of the Berger formation, brown silty to sandy carbonaceous clay and clayey sand of the Saline formation, and some surface sand.

Company exploratory work in parts of the area preceded that undertaken by the Federal project, and discovered at least three of the deposits. Small mines have been operated in the area intermittently since 1925. The earliest drilling appears to have been done by the Republic Mining and Manufacturing Co. and the Kalbfleisch Corp. Information from the company drilling aided geologists of the Federal drilling program in predicting the approximate trend of the buried edge of the Midway sediments before exploration of the area. The government drilling began in July 1942 and continued until about September of the following year.

CHEATHAM DEPOSIT

Plates 17 and 18

The easternmost ore bodies in the Woodyardville area are in the S½SE¼ sec. 36, T. 1 N., R. 12 W. on properties owned by R. E. Block, Earl Chambers, C. Cheatham, S. Cheatham, J. W. Hopper, Olaf Nelson, Sid Thomas, and Ella Thompson. These ore bodies are part of a large, irregular deposit linked together by low-grade bauxite or by bauxite less than 8 feet thick.

The bauxite in the Cheatham area was found by drill holes of the Republic Mining and Manufacturing Co. drilled on the Nelson property in 1938. From March to July 1943, 79 holes, most of them spaced about 200 feet apart, were drilled by the Federal project to delimit the bauxite in this tract.

The Cheatham deposit (Malamphy and others, 1948, v. 4, p. 48–72, fig. 45) lies athwart the buried edge of the Wills Point formation (pl. 17), where it thins out against the weathered nepheline syenite. It lies along a slope on the post-Midway erosion surface drained by three southwestward to southeastward-trending subsurface drainage systems. The relation of the deposit to this buried surface is shown on the subsurface map, plate 2.

The ore is thicker on slopes and over ridges, than in valley bottoms, indicating a residual origin for much of it. Three ore bodies are close enough that they probably can be mined as one. The northeastern, the first ore body, is about 400 feet long and less than 200 feet wide, and trends north-northeast; the minable bauxite reaches a maximum thickness of 14.2 feet in USBM drill hole 5–198. The second ore body is 200 feet southwest of the first, is subtriangular in outline, about 450 feet in a north-northwest direction and 400 feet in a south-southwest direction; the maximum known thickness of the bauxite in this body is 13.0 feet in USBM drill hole 5–150. The third and largest ore body is 200 feet west of the second and is continuous with the McClain-Burks-Nelson deposit to the west (pl. 17). This irregularly-shaped body is about 600 feet east to west and north to south. The ore reaches a maximum thickness of 13.2 feet in USBM drill hole 5–154.

The bauxite is tan or grayish-tan, nonpisolitic, either fragmental or textureless. In places the upper part of the bauxite is pisolitic. Brown granular siderite is common locally in the middle and lower parts of the deposits.

The bauxite is overlain by bauxitic clay, grading upward into kaolinitic clay at the top; these aggregate 4 to 10 feet in thickness. The ore is covered by overburden ranging in thickness from 74 to 116 feet and averaging 92 feet; this includes the bauxitic and kaolinitic clay mentioned above. The clastic and carbonaceous sediments of the upper part of the Berger formation are absent at the east edge of the deposit and reach 25 feet in thickness in the western part. Many drill holes penetrated a thick bed of lignite at the top of the Berger formation. The Saline formation ranges from 57 to 98 feet in thickness. Chocolate-brown silty to sandy carbonaceous clay, where present, is generally at the base; elsewhere the formation is composed mostly of loose sand and gray sandy clay. A persistent granule or pebble gravel bed is at or near the base, in places directly overlying the thick bed of lignite of the Berger formation.

MCCLAIN–BURKS–NELSON DEPOSIT

Plate 17

The McClain-Burks-Nelson deposit (Malamphy and others, 1948, v. 4, p. 32–47 and 73–78, figs. 44 and 46) is in the E½SE¼SW¼, E½NE¼SW¼, and W½NW¼SE¼ sec. 36, T. 1 N., R. 12 W. on properties of Jenny Burks, E. S. Dixon, Mrs. L. A. Miller, G. G. McClain, and Olaf Nelson. Part of the ore, on the Burks and Nelson properties, has been mined by the Pulaski Mining Co. (pl. 2, no. 21)

The deposit was prospected in 1938 by about 20 drill holes of the Republic Mining and Manufacturing Co.; in 1940, by 12 additional drill holes of the American Cyanamid and Chemical Corp; and later, by 16 holes of the Dulin Bauxite Co. The Federal drilling program drilled 50 holes to delimit the north end of the deposit.

The minable ore is in a narrow body, about 2,400 feet in length and about 600 feet in width at its widest part, trending S. 10° W. (pl. 17). The larger southern part of the body lies on the west slope of a southward-trending valley and dips about 3° SE. Near the north end a lobe about 750 feet long extends east-northeast up a tributary subsurface valley. Most of the deposit overlies weathered nepheline syenite but the deeper south end lies on the Wills Point formation which wedges out against the nepheline syenite. The basement rocks are overlain by a light-gray, fragmental, kaolinitic clay containing tiny pink to tan pellets and aggregates of siderite. The bauxite-kaolin zone has an average thickness of about 30 feet in this area.

Most of the bauxite in this deposit is pisolitic and tan or grayish-tan. The upper 4 to 6 feet is hard and the lower part is soft and crumbly.

The bauxite is overlain by as much as 8 feet of bauxitic and kaolinitic clay, particularly in the downslope or eastern part of the deposit. The overburden, including this clay, ranges in thickness from 63 to 96 feet thick in the part of the deposit north of the Burks-Nelson mine; in the southern part it ranges from 77 to 110 feet. The Berger formation has an average thickness of 19 feet and is composed largely of massive lignite interbedded with gray, silty clay. The lower part of the Saline formation is composed of chocolate-brown sandy to silty clay, 35 to 60 feet thick. This clay contains a few thin lignite seams and, throughout the central part of the ore body where this clay is thickest, the lower part is replaced by a lens of fine sand as much as 30 feet thick. The upper part of the Saline formation is composed of coarse-grained sand, locally grading into gray silty clay containing a few thin lignite beds and ranging in thickness from 15 feet across the north central part of the deposit to 40 feet across the southern part. A collection of fossil plants (loc. 9047) from the Saline formation in the Burks-Nelson mine is described in table 5, in the stratigraphic section.

Burks-Nelson open-pit mine (*pl. 1, no. 23*).—This mine was opened by the Pulaski Mining Co., a subsidiary of the Dulin Bauxite Co. Production, limited to the southern part of the deposit, began in August 1943, and continued in the early part of 1944. Stripping the comparatively narrow and deep open pit was difficult because lignitic clay at the west side of the pit acted as a lubricant and caused slumping of a sizeable mass of the overburden, in the early stages of mining.

The ore produced from this mine included "low

silica" and "high silica restricted," as well as a small amount of "unrestricted bauxite."

DIXON–NELSON DEPOSIT

Plates 17 and 18

The small Dixon–Nelson deposit (Malamphy and others, 1948, v. 4, p. 79–118, fig. 47, v. 5, p. 11–17, fig. 50) is connected to the McClain-Burks-Nelson and the Dixon deposits by less than 8 feet of ore-grade bauxite. It is on the E½NE¼NW¼ and the W½NW¼NE¼ sec. 1, T. 1 S., R. 12 W. on the properties owned by A. M. and A. L. Dixon and Olaf Nelson. In the reference cited it was described as part of the Dixon deposit and also as the Olaf Nelson deposit.

Eighteen holes were drilled on the Nelson property after USBM drill hole 1–061A cut through several feet of high-silica bauxite at a depth of 161 feet. At a later time, during delimiting of the Dixon deposit, an additional 15 holes were drilled in and around the western part of this ore body, spaced about 200 feet apart on a triangular grid. These were supplemented by 6 additional holes of the Reynolds Mining Corp.

The bauxite lies above the Wills Point formation which has a well-developed soil profile at the top in this area. The relation of this body to the adjacent deposits and to the post-Midway erosion surface are shown in plate 17. The ore body, as interpreted from drill-hole data, is probably about 900 feet long from east to west and as much as 300 feet wide. The thickest ore reached was 12.3 feet in USBM drill hole 1–207A and this included some material high in silica in the middle part. The bauxite is similar in general appearance to that in the adjacent bodies.

The bauxite of minable thickness lies from 143 to 158 feet below the surface and is immediately overlain by 2 to 6 feet of bauxitic clay that grades upward into kaolinitic clay. The Berger sediments above the bauxite-kaolin zone range from 45 to 53 feet in thickness. The Saline formation ranges in thickness from 90 to 106 feet. The lower part consists of chocolate-brown silty to sandy clay; the upper 58 to 77 feet is composed mainly of sand with a few clay or gravel layers.

DIXON DEPOSIT

Plate 17

The extensive Dixon deposit (Malamphy and others, 1948, v. 4, p. 79–118, fig. 47), composed of several closely spaced ore bodies, irregularly lobate, lies in the SE¼SE¼ sec. 35 and the SW¼SW¼ sec. 36, T. 1 N., R. 12 W., and in the N½NW¼ sec. 1, T. 1 S., R. 12 W. The southern and more deeply buried part of the deposit, drilled by the Federal project is on properties of Andrew M. Dixon, A. M. and A. L. Dixon, B. J. Birnbach, Willie Thomas, and L. M. Tling. The northern extension of this deposit crops out at the surface several hundred feet south of the Sweet Home-Berger road. The outcrop and the shallow ore adjacent to it have been worked by several small mines intermittently since 1925 (pl. 1, nos. 24 and 25).

Geologic information indicated the possibility of the occurrence of bauxite in the deeper southern part of the Dixon area and this was supported by data from USBM drill hole 2–100, which cut several feet of bauxitic clay near the west boundary of the Jennie Burks property. Exploration by the joint Federal project continued intermittently from January to May 1943 and the area was delimited by 118 drill holes. The bauxite was found to be continuous with that of the Dixie No. 3 mine to the north and the Dixon–Nelson deposit to the east.

The Dixon deposit lies in a broad, shallow valley on the post-Midway erosion surface that in early Eocene time drained southward (pl. 17). The Dixon No. 2 ore body is on the west slope of this valley; the other ore bodies are on the east side and in places reach its center.

The north end, in the NE¼SE¼ sec. 35 and the NW¼SW¼ sec. 36, rests on weathered rocks of Paleozoic age and on weathered pulaskite. The southern part of the deposit, in the SE¼SE¼ sec. 35, the SW¼SW¼ sec. 36, and in the N½NW¼ sec. 1, is almost entirely on sediments of the Midway group that wedge out against the igneous and the Paleozoic metamorphic rocks. Directly beneath the bauxite-kaolin zones under the northeastern part of Dixon ore body 1 and along the northwest margin of ore body 2 is gravel and kaolinitic debris of Kincaid age composed largely of pebbles derived from the rocks of Paleozoic age and associated igneous dike rocks. This was deeply kaolinized by weathering during early Eocene time when it was part of the post-Midway surface. Under the western and southern parts of ore body 1, and under the southeastern part of the ore body 2, this gravel of Kincaid age is covered by dark-gray silty clay of the Wills Point formation. Here the gravel appears much fresher because it was protected from post-Midway weathering by the overlying clay. The Wills Point formation thickens south-southeastward to about 30 feet beneath the southeast margin of the ore body 3. At the top of the formation is the normal weathered zone—khaki-colored in depressions and on gentle slopes on the post-Midway surface and red to white along buried ridges.

The bauxite is distributed in three principal ore bodies. The largest of these, ore body 1, is broadly L-shaped in outline, about 900 feet from north to south and 700 feet along the short arm of the L from west to

east. The smaller ore body 2 lies a short distance southwest of the ore body 1 and is separated from it by a thick vertical section of bauxitic and kaolinitic clay. The ore is distributed in a broadly curving arc, about 1,000 feet from its northeast to southwest ends with the 8-foot isopach and nearly 400 feet across at its widest part. Ore body 3, the smallest, lies south of ore body 1 and northwest of the Dixon-Nelson deposit, with which it is connected by bauxite less than 5 feet thick. It is about 600 feet long in a northwesterly direction, and 400 feet normal to this trend at its widest part. The thickest ore cut in each body was: 16.0 feet in ore body 1 in USBM drill hole 7–069; 18.3 feet in ore body 2 in USBM drill hole 7–097A; and 15.5 feet in ore body 3 in USBM drill hole 5–077. The dips of the ore bodies are fairly shallow and nearly parallel to the post-Midway erosion surface.

Most of the ore in the three bodies is pisolitic and grayish-tan to rich tan. The pisolites are abundant in the middle and upper parts, and most of them have hard cherty-looking centers. The pisolites near the base and top and along the edges of the ore have soft clayey to semiliquid centers and are sparsely distributed. The pisolites range from 3 to 30 millimeters across and average about 6 millimeters. Under the downslope end of the ore bodies 1 and 3 and the southwest end of the ore body 2 the pisolites are few, soft, and scattered, and some fragments of bauxite are tan and orange. In between the ore bodies 1 and 2 is a thick section of bauxitic clay through which are scattered many angular bauxite fragments. Similar clay lies immediately beneath and fringes all three ore bodies.

A siliceous hardcap of low-grade pisolitic bauxite or bauxitic clay, locally as much as 5½ feet thick, was found in places on top of the ore along the upslope parts of the ore bodies. The ore in many places is separated by only 1 to 2 feet of bauxitic or kaolinitic clay from the top of the bauxite-kaolin zone, but locally it is overlain by as much as 19 feet of clay bed.

Overburden above ore body 1 ranges in thickness from 40 feet to 100 feet; above ore body 2, from 42 to 102 feet; and above ore body 3, from 100 to 150 feet. The average thickness over the deposit is 92 feet.

The gray silty clay and lignite of the Berger formation ranges from 4 to 12 feet in thickness across the northern part of the drilled area and reaches a maximum thickness of 41 feet at the southeast end of ore body 3. The Saline formation ranges from about 39 feet at the north end of the drilled area to 98 feet at the southeast end of the deposit. It consists of varicolored clay, sand, and granule gravel where thin, and chocolate-brown silty to sandy clay and loose quartz sand in the deeper parts.

Wright open-pit mine (pl. 1, no. 24).—The earliest mining in the Woodyardville area was on the J. P. Wright property in the NW¼SW¼ sec. 36. Ore was shipped by Wright from this property in 1925–26. The mine was inactive until 1936 when it was operated by the Pulaski Bauxite Co. Production has been recorded for 1936 and 1938.

Dixon open-pit mine (pl. 1, no. 25).—Mining of the outcrop and shallow ore on the Dixon Bros. property in the NE¼SE¼ sec. 35 (pl. 2, no. 23) was begun in 1926. This operation was continued in 1926–27 by D. B. Hill. A sketch map by the Arkansas Geological Survey compiled in 1926 (Branner, G. C., 1928, p. 8) shows a single bauxite mine in this area under the name, Oliver and Hill Construction Co. According to P. A. Dulin, Jr. (personal communication, 1950), some ore was shipped about this time through the efforts of P. A. Dulin.

Dixie No. 3 mine (pl. 1, nos. 24, 25).—In 1941 the Dixon and Wright mines were acquired by the Dixie Bauxite Co. Production began that year from an underground mine in the southern part of the Wright property, developed by an incline from the old pit workings. A vertical shaft was also sunk but soon caved.

Late in 1942 stripping of the overburden from most of the remaining ore was begun, particularly on the Dixon property where most of the bauxite was less than 40 feet deep. The ore was mined by open-pit methods, supplemented by short underground workings. Operations at this mine terminated in 1943.

VINSON–RAINES DEPOSIT

By Miller W. Ellis

Plates 17 and 18

The Vinson-Raines deposit (Malamphy and others, 1948, v. 5, p. 18–46, fig. 51) underlies a relatively flat, partly wooded tract of land in fractional secs. 1 and 2, T. 1 S., R. 12 W. The deposit is on properties of B. J. Birnbach, L. M. Illing, and Willie Thomas, E. E. Raines, J. D. Stalworth, and A. M. Vinson.

Drilling by the Federal project on 400-foot centers to explore the area between the Dixon and Birnbach ore bodies and drilling by the Dulin Bauxite Co. in the SE¼NE¼ sec. 2, discovered the Vinson-Raines deposit. Eighty-four holes were drilled between September 1943 and early in 1944 by the Federal drilling program and 10 by the Dulin Bauxite Co. to investigate the deposit.

The deposit lies above sediments of the Midway group. The Kincaid formation in this area, penetrated in 14 drill holes, is composed of sandy limestone interbedded with black sticky clay and gray marl, laminated in places. Sand and gravel, derived mainly from the

metamorphic pendant rocks of Paleozoic age and partly from porphyritic or trachytic dike rocks, is abundant at the top and common in the lower part of the formation. The Wills Point formation, consisting of the typical dark-bluish gray silty clay, overlies the Kincaid formation; it is 24 to 71 feet thick in the drill holes that drilled through it.

The bauxite-kaolin zone ranges from 6 to 54 feet in thickness and averages about 30 feet. It is a valley fill of altered clay and bauxite fragments derived from the basement rocks upslope. The Vinson-Raines deposit, bifurcate and lobed in outline, formed along the brow and east slope of a low southeastward-trending ridge on the Wills Point surface and also along the south slope of a northeastward-trending ridge on this surface (pl. 18). It is connected by low-grade bauxite, several feet thick, to the nearby Woodyardville deposit.

The main ore body, as interpreted from the drill-hole data, is about 2,300 feet long, reaches slightly more than 300 feet in width, and trends about N. 45° W.; a branch about midway in the deposit extends about 1,100 feet to the northeast. The thickest ore, 19.5 feet in USBM drill hole 7–211, is near the upslope end.

Most of the ore is pisolitic bauxite. A vertical section through the ore is typical of a type 2 deposit. Above the ore is a hard, pisolitic bauxitic rock which ranges in chemical composition from high-silica to kaolinitic bauxite. This hardcap will form a competent roof rock for underground development and reaches a maximum of 5 feet along the upslope and updip edges of the ore body but thins abruptly downslope and downdip from the center of the body.

A maximum of 29 feet of bauxitic and kaolinitic clay covers the downslope parts of the deposit. The overburden ranges in thickness from 115 to 210 feet and averages about 145 feet. Clastic and carbonaceous beds of the Berger formation above the bauxite-kaolin zone are 24 to 64 feet thick, and include dark-greenish gray clay, lignite beds as much as 20 feet thick, and siderite layers. The Saline formation is 62 to 125 feet thick. Chocolate-brown silty to sandy-brown clay 38 to 102 feet thick, in the lower part in places grades laterally into sand, and is 2 to 97 feet thick in the upper part. Locally, the formation contains layers of gravel and lignite.

WOODYARDVILLE DEPOSIT

Plate 17

This deposit lies in the north-central part of sec. 2, T. 1 S., R. 12 W. and its northern tip extends into sec. 35, T. 1 N., R. 12 W. It was discovered and has been explored and mined largely by companies. Mines have been operated in it by the American Cyanamid and Chemical Corp., Consolidated Chemical Industries, Inc., the Dulin Bauxite Co., and the Victory Bauxite Co.

Drilling in 1930 by M. J. Childress on the Mayhan property, and in 1932–33 by J. C. Childress on the Berry property, found 4 to 14 feet of bauxite underlying 40–65 feet of overburden. Additional holes were drilled subsequently by several mining companies. The Federal project drilled 19 holes in the northern part of the deposit (Malamphy and others, 1948, v. 4, p. 19–135, in part, fig. 48; v. 5, p. 3, 9, 10, fig. 49).

The deposit is on the east slope of a broad pulaskite ridge and across a tributary eastward-trending ridge (pl. 17). South of this tributary ridge the deposit trends southeastward. Most of the ore lies above weathered pulaskite but part of the northern part of the body rests on a wedge of clay of the Wills Point formation into which is tongued a large amount of clayey feldspathic debris derived from the nearby syenitic rocks. The north tip, on the Vick property, rests on greenish-gray altered shale, part of a pendant of rock of Paleozoic age.

The workable part of the ore before mining was about 3,000 feet long along a line approximately N. 20° E. and slightly more than 1,100 feet wide at the central and widest part. It was gently curving in outline, concave northwestward. Most of the bauxite is pisolitic but in the downslope parts beneath the typical pisolitic bauxite as much as 5 feet of fragmental poorly pisolitic soft bauxite occurs.

According to available drilling records the ore lay beneath the 30 to 112 feet of overburden which includes the thick kaolinitic clay immediately above the deposit. In the USBM drill holes in the northern half of the deposit the carbonaceous and clastic beds of the Berger formation above the bauxite kaolin zone range from 23 to 39 feet in thickness and are composed largely of gray kaolinitic clay, brown carbonaceous clay, and lignite. The Saline formation in these drill holes ranges from 20 to 42 feet in thickness and is composed of chocolate-brown silty to sandy clay in the lower part and of gray to white clay and red and gray clayey sand in the upper part.

Weiss open-pit mine (*pl. 1, no. 26*).—Located on the Weiss property in the SW¼NE¼ sec. 2, this mine was developed by the Victory Bauxite Co., early in World War II. Twenty exploratory holes were drilled before strip-mining began in 1942. Production started in November 1942 and continued into March 1943.

The bauxite, moderately low in silica but with its middle and lower parts high in ferrous iron due to presence of siderite, was listed as high-silica bauxite by Metals Reserve Company. Part of the bauxite con-

sisted largely of pisolites cemented by amber-colored siderite crystals. A specimen of this rock is illustrated in figure 17.

This mine is in the shallowest part of the Woodyardville deposit. The overburden is reported to have ranged in thickness from about 30 to 45 feet. The mine has been abandoned since 1943.

Vick underground mine.—The northern tip of the deposit on the W. E. Vick property in the SW¼SE¼ sec. 35 was mined by the Dulin Bauxite Co. through the Vinson-Hoffman shaft. The U. S. Bureau of Mines drilled several holes prospecting for clay on this property in October 1943. Additional holes spaced about 200 feet apart were drilled by the Federal Government, to delimit the bauxite, and the ore was mined in 1947–48. Most of the bauxite was light-tan, pisolitic, but with few pisolites in the lower part. The bauxite lay beneath the 61 to 92 feet of overburden. The Berger formation above the bauxite-kaolin zone is 24 to 30 feet thick and contains a large amount of kaolin in the upper part. The Saline formation is 20 to 32 feet thick.

Vinson–Hoffman shaft mine.—This mine was opened by the Dulin Bauxite Co. to mine the ore on the properties of H. Hoffman, J. D. Richards (surface rights), and A. M. Vinson, in the fractional NW¼NE¼ and part of the SW¼NE¼ sec. 2.

American Cyanamid and Chemical Corp. drilled 13 exploratory holes on these properties and later Dulin drilled 14 more. Three were also drilled by the joint Federal project. A shaft was sunk and the mine began operating in 1946. Production continued until the close of 1948 or early in 1949.

The mine is in the northern part of the deposit where the bauxite was reported to be 10 to 14 feet thick. The upper part of the bauxite is pisolitic. The pisolites are hard with gray, red and brown to black vitreous interiors. The ore is softer below and contains orange and tan bauxite fragments in the lower part.

The overburden in this mine was 66 to 100 feet thick. The Berger formation above the bauxite-kaolin zone was recorded as 23 to 39 feet thick in 3 USBM drill holes. The Saline formation is 20 to 38 feet thick in these drill holes.

Berry–Mayhan open-pit mine.—This mine was developed by the American Cyanamid and Chemical Corp. on the H. J. Mayhan and Lud Berry properties in the SW¼NE¼ sec. 2, due south of the Vinson–Hoffman mine. The mine was opened in 1948 and produced until the early part of 1949.

The overburden on these properties is reported to range from 44 to 110 feet in thickness, increasing eastward. The Berger formation above the bauxite-kaolin zone apparently ranges from 16 to 46 feet in thickness and the Saline formation ranges from 28 to 70 feet.

Bierman shaft mine (pl. 1, no. 27).—This mine is located largely in the NW¼SE¼ sec. 2 on the Bierman property owned by Consolidated Chemical Industries, Inc. The company drilled 41 exploratory holes to investigate the deposit in the latter half of 1941 and a shaft was sunk in 1942. The mine was inactive during World War II and for several years later. Mining of low-silica bauxite was resumed in 1948.

Ore slightly more than 20 feet thick has been recorded in the central part of the property. The bauxite, mostly pisolitic, is low in silica but in places the middle and lower parts are high in ferrous iron, due to the presence of siderite.

The overburden ranges from 56 to 97 feet in thickness in this part of the Woodyardville deposit.

Penzel–Coe shaft mine (pl. 1, no. 28).—A vertical shaft was sunk by the Dulin Bauxite Co. in 1943 on the Penzel property in the NE¼SW¼ sec. 2 to mine the southwest end of the Woodyardville deposit on this property and the ore on the adjacent Coe property in the SW¼NW¼SE¼ sec. 2. Before mining, the two properties were prospected by 20 exploratory holes drilled by the company and a maximum thickness of 18 feet of commercial bauxite was recorded in the central part of the area. Operations in this mine continued until 1946.

Most of the bauxite was pisolitic and contained a firm light-reddish-brown material. As in other parts of the deposit, the iron content was locally high in the lower part of the ore. Between 80 and 111 feet of overburden covered the ore.

VICK DEPOSIT

Plate 17

The Vick deposit is a small one near the northeast corner of the SW¼SE¼ sec. 35, T. 1 N., R. 12 W., on property owned by W. E. Vick. It was discovered by company drilling during the thirties. The joint Federal project delimited the deposit by 8 drill holes spaced about 200 feet apart on a triangular grid. The U. S. Bureau of Mines also investigated the clay possibilities of a larger area that includes this deposit. In the published report (Malamphy and others, 1948, v. 4, p. 119–135, fig. 48) it is referred to as the Dixon clay deposit.

The bauxite body, a small type 2 deposit, probably does not exceed 350 feet in length or a maximum of 200 feet in width, and is elongate north-northwest. It lies across a contact of nepheline syenite and rock of Paleozoic age. The rock of Paleozoic age, recovered from the drill holes, is a grayish-green clay probably

derived from a shale, and is part of a large pendant that trends south-southwestward across sec. 35. The bauxite has accumulated near the base of a fairly steep slope on the east side of a southward-trending valley on the buried post-Midway surface.

Most of the ore is tan pisolitic bauxite. It is underlain downslope by tan fragmental bauxite grading downward into fragmental bauxitic clay above a sideritic fragmental underclay at least 15 feet thick. It also grades upward into fragmental bauxitic clay and further into fragmental kaolinitic clay, totaling 15 to 23 feet thick.

The overburden, including the clay cited above ranges from 34 to 60 feet in thickness. The Berger sediments above the bauxite-kaolin zone are 10 to 21 feet thick; the Saline formation is 16 to 20 feet.

REICHARDT DEPOSIT

Plate 2

This deposit is in the N½NW¼SW¼ sec. 2, T. 1 S., R. 12 W., on the L. Reichardt property, and extends northward into the S½SW¼NW¼ of the same section. It has been mined by the Dulin Bauxite Co. Thirteen holes were drilled on this property in 1938–39 by M. J. Childress for the owner. Subsequently 17 holes were drilled by the Dulin Bauxite Co. The drilling cut through 6 to 23 feet of commercial-grade bauxite beneath 30 to 82 feet of overburden.

The Reichardt deposit is on the south slope of the Pulaski nepheline syenite hill, most of it on the northeast side of a southeastward-trending valley on the post-Midway erosion surface (pl. 2). So far as is known, the bauxite-kaolin zone in this tract rests on weathered pulaskite. The deposit is bilobate in outline and is a composite of two types. The principal body, nearly 1,000 feet long and several hundred feet wide, and oriented about south-southeast, is a type 2 deposit composed principally of pisolitic bauxite. A lobate type 3 body of later sedimentary bauxite extends south-southwestward from the northern part of the type 2 deposit. Much of this transported bauxite downslope rests on lignite and silty clay of the Berger formation.

The pisolitic bauxite in the type 2 deposit is a light grayish-tan. Before mining operations began the upslope part of this ore body was a bed of bauxite rubble at least 3 feet thick. It contained abundant cobbles and boulders of granitic-textured bauxite as well as of pisolitic bauxite. This evidence indicates that part of the ore was derived from the erosion and transportation of a nearby type 1 deposit upslope, of which no vestige other than the transported rock now remains.

Reichardt shaft mine (*pl. 1, no. 30*).—The type 3 body in the southwestern part of the deposit was the first to be explored. Company drill holes here recorded 12 to 22 feet of bauxite at depths of 36 to 38 feet, overlying lignite and clay. A shaft was sunk and production commenced early in 1941. The mine operated until 1942, when it was abandoned and the collar buried beneath overburden stripped from nearby pit workings. The ore mined in this part of the deposit was principally a crossbedded and stratified gravel of hard cherty pisolites, a specimen of which is shown in figure 24*C*. As mentioned elsewhere in this report, local high concentrations of titanium minerals were reported in this mine.

Reichardt Extension open-pit mine (*pl. 1, no. 29*).—The type 2 bauxite body in this deposit was mined by means of an open-pit working, stripped late in 1942 and operated during 1943. At the close of that year the property was released to the owners. A photograph of the pit working, looking southeastward, has been published by Malamphy and others (1948, v. 1, fig. 1, lower photograph).

BIRNBACH DEPOSIT

By Elmer P. Kneedler

Plate 19

The Birnbach deposit (Malamphy and others, 1948, v. 5, p. 57–77, fig. 53) is about a mile south of Woodyardville on the road to Ironton. Most of it lies within the S½SW¼ sec. 2 and the N½NW¼ sec. 11, T. 1 S., R. 12 W., on properties of F. W. Beadle, B. J. Birnbach, G. R. Bressler, G. F. Gruver, J. L. Oberle, Mrs. D. Perry, G. J. Price, John Shook, and H. H. Wenzel. Delimiting holes were drilled also on adjacent properties owned by G. P. Elkins, W. F. Glidewell, W. C. Herrod, B. H. Hinson, N. C. Johnston, Mrs. C. Pierce, W. E. and Mrs. W. E. Rowe, Mrs. H. A. Thomas, and E. H. White. Bauxite was found in USBM drill hole 2–038, completed on August 25, 1942, in which was recorded 8.5 feet of ore at a depth of 172 feet. The deposit was delimited by 70 drill holes spaced about 300 feet apart, most of the holes were drilled between August and November 1942. Later, 33 holes were drilled by the Reynolds Mining Corp., information from which has been used in preparing the subsurface map, plate 19.

The deposit is almost elliptical, its longest dimension (about 3,500 feet) trending northeastward. The thicker parts, irregularly lobate in outline are made of three separate ore bodies linked together by thinner and lower grade bauxite. Ore body 1, the southwesternmost, has a crude trapezoidal outline about 1,200 feet long and 400 feet wide as interpreted from the drilling data. It is a composite body, elongate north-northeasterly. The western and southern parts are composed of two beds of bauxite separated by as

much as 4 feet of lignite and brown carbonaceous clay or gray silty clay, grading laterally into light-gray to bluish-gray sideritic kaolinitic clay. The lower bed, a type 2 deposit, reaches a maximum thickness of 12.4 feet of ore in USBM drill hole 7–023A, near the center of the body. The upper bed, a stratified (type 3) deposit, reaches a maximum thickness of 9.0 feet in USBM drill hole 5–058, at the south end of the body. The distribution of the two types of bauxite is shown in plate 19.

North-northeast of the first, ore body 2, is broadly spindle shaped in plan, elongate N. 45° E., about 800 feet long and nearly 500 feet wide. The thickest ore, in USBM drill hole 5–041, was recorded to be 15.1 feet thick including 3.8 feet of bauxitic clay in the lower part. All the bauxite in this body probably belongs to the type 2 classification.

Ore body 3, the northeasternmost, is club shaped in plan, about 1,500 feet long, about 800 feet wide in the broad southern part, and averages perhaps 250 feet wide along the narrower northeast extension. The southern part consists mainly of a type 2 bauxite deposit, for which a maximum thickness of 23 feet was recorded in a Reynolds drill hole (J–124). In this drill hole the type 2 bauxite is separated by 5 feet of lignite and silty clay from a higher bed of pebbly stratified bauxite, 18 feet thick. The upper bed, a type 3 deposit, extends northeastward beyond the type 2 deposit below. In most places it rests on several feet of lignite and silty clay that separate it from gray kaolinitic clay below. The relation of the two bauxite lenses is shown in plate 19.

Ore bodies 1 and 2 lie mostly on the west slope of a subsurface valley that curves south-southeastward to south-southwestward. They are separated by a low southward-trending Midway ridge from ore body 3, the thickest part of which lies in a small valley that in early Eocene time drained eastward.

The basement is probably pulaskite, the upper part of which where not covered by Midway sediments has been completely kaolinized. Two pendants of greenish-gray quartzite and altered shale, weathered to clay at the top, were discovered by drilling a short distance west of ore body 1 (pl. 2). Another pendant was reached at the bottom of USBM drill hole 2–111 southeast of ore body 3.

The bauxite-kaolin zone which includes the Birnbach deposit lies on sediments of the Midway group—in most places on the Wills Point formation. The trend of the deposit nearly parallels the trace of the buried Midway and nepheline syenite contact, which roughly delimits the northwest margin of the deposit. The shoreward facies of the Kincaid formation, a weathered clayey debris and pebbly gravel derived from the nepheline syenite and altered sedimentary rocks of Paleozoic age, is concentrated in tongues that extend up drainage channels on the nepheline syenite surface beyond the buried edge of the Wills Point formation. Beneath the deposit these rocks finger basinward into limestone beds, generally separated by layers of light-gray clay. Limestone was recorded in drill holes along the south and east edges of the tract. The greatest thickness of the Kincaid formation, 154 feet, was recorded in USBM drill hole 2–111. It consists of 122 feet of light-gray fossiliferous limestone with interbedded gray clay layers, overlying 32 feet of gray to green soft sandy debris derived mostly from pendant rocks of Paleozoic age.

The Wills Point formation consists of as much as 46 feet of blue-black silty clay, at the top with as much as 9 feet of varicolored clay laminated with gray or in solid colors. This weathering profile at the top is absent locally.

COE DEPOSIT

Plates 17 and 19

The Coe deposit (Malamphy and others, 1948, v. 5, p. 47–56, fig. 52) is composed of two small bauxite bodies in part of the W½SE¼ sec. 2. It is on properties of B. J. Birnbach, Sam Drain, L. A. Coe, and Hamilton and others. It lies about half a mile south-southeast of Woodyardville, mostly beneath wooded, swampy land in the Fish Creek drainage basin. It was discovered during the delimiting of the Birnbach deposit in USBM drill hole 2–113, drilled November 1942, in which 6.0 feet of commercial-grade bauxite was recorded at a depth of 120 feet. The deposit was delimited by 31 drill holes. Later in 1943 the Osage Bauxite Co. drilled 4 additional holes in the northern part of the deposit, information from which has been used in preparing part of plate 17.

The relationship of this deposit to the nearby Woodyardville ore body and to the post-Midway erosion surface is shown in plate 17 and its relationship to the Birnbach deposit in plate 19. The Coe deposit lies in a small drainage basin that slopes southeastward and is near the upslope edge of the Wills Point formation where the sediments wedge out against a clay derived from the weathering of nepheline syenite. The northern body, a type 2 deposit, is the larger; it is broadly spindle shaped, northerly elongate within the 5-foot isopach about 550 feet long (the northern tip not delimited), and is nearly 400 feet wide at its widest part. The bauxite of ore grade is principally grayish tan, pisolitic, and fairly well indurated in the upper part. The south body is about 500 feet long within the 5-foot isopach, elongate north-northwesterly and only a small area near the north tip, where the body is

composite, exceeds 8 feet in thickness. The south end of the south body is a type 2 deposit, overlain in the northwestern part by stratified bauxite which is a northeastward continuation of the stratified ore in the Birnbach ore body 3. The small size and spottiness of the Coe deposit renders its mining under any but emergency conditions, unlikely.

The overburden covering the north body ranges in thickness from about 107 to 137 feet, and above the south body ranges from 130 to 175 feet. The section of the Wilcox sediments that makes up this overburden is similar to that overlying the nearby Birnbach deposit.

The lower part of the bauxite-kaolin zone is composed of as much as 25 feet of gray kaolinitic fragmental clay containing small siderite pellets, and generally mottled red in the lower 5 to 10 feet. At the time the Birnbach deposit was drilled the characteristics of the upper part of the Wills Point formation and the basal Berger were not fully known, hence in some drill holes the lower part of the red-mottled underclay was mistakenly referred to the Wills Point and some points on the post-Midway erosion surface in the subsurface map (pl. 19) may be off as much as 5 feet vertically.

Bauxitic clay, a few inches to 7 feet thick, cream-colored or grayish-tan to tan, underlies the bauxite and also fringes the deposit laterally. Scattered through this clay are tan angular to rounded bauxite fragments. The bauxitic clay grades imperceptibly into the kaolinitic underclay below and, where present, into the bauxite above. The bauxite of the upper beds (type 3 deposits) in ore bodies 1 and 3 is composed of well-sorted transported pisolites of many colors.

Siderite in cavities and veinlets, or in single crystals, locally associated in veinlets with small crystals of pyrite, appears to be concentrated in the northwestern parts of the three ore bodies. The ore high in ferrous iron, where plotted with relation to the post-Midway erosion surface, lies in the upslope parts of valleys but not over ridges. A hardcap of pisolitic high-silica bauxite or bauxitic clay overlies the ore along valley flanks and terraces. In 23 drill holes the hardcap ranges in thickness from 1.4 to 6 feet and averages 2.7 feet. It is present in all three ore bodies but best developed in ore bodies 1 and 2, probably because so much of the upper part of ore body 3 is composed of highly sideritic stratified bauxite.

High-silica bauxite and bauxitic clay are overlain by kaolinitic clay from 1 to 23 feet thick, generally not more than 4 feet thick where it overlies hardcap. This overclay contains poorly formed pisolites in the lower part, yellowish to reddish siderite pellets, and scattered wisps and fragments of carbonaceous clay and lignite, particularly where the clay is overlain by lignite.

The overburden ranges in thickness from 73 to 265 feet, averaging about 170 feet above the minable ore. The Wilcox sediments above the bauxite-kaolin zone reach their greatest thickness, 324 feet, in USBM drill hole 7-017, east of orebody 3. The upper beds of the Berger formation above the bauxite-kaolin zone range in thickness from 13 to 154 feet, reaching their maximum thickness in the USBM drill hole 7-017. These upper beds include lignite, carbonaceous clay, and gray to bluish- or greenish-gray clay, silt, and fine sand. Locally the sand contains scattered black grains and particles that give it a "salt and pepper" texture. The lignite generally occurs in two distinct beds, each ranging in thickness from 2 to 36 feet. Other lignite beds are thin and lenticular.

The lower part of the Saline formation consists of the typical chocolate-brown silty to sandy carbonaceous clay, locally grading to brownish gray. It is interbedded, generally in the lower part, with as much as 90 feet of fine brown sand and sandy silt. Scattered seams of lignite, less than 2 feet thick in most places, are common. The upper part of the Saline formation consists chiefly of loose quartz sand, containing a few scattered lenses of yellow or gray plastic sandy to silty clay, some indurated ferruginous layers, and lenses of unconsolidated feldspathic gravel. In one drill hole much pyrite was recorded in one of the gravel layers. The thickness of the upper sandy part of the Saline formation ranges from 9 to 92 feet.

GLIDEWELL DEPOSIT

By William N. Laval

Plate 19

The Glidewell deposit (Malamphy and others, 1948, v. 5, p. 103–119, fig. 56) lies mostly within the SE¼NW¼ sec. 11, T. 1 S., R. 12 W., on properties of W. F. Glidewell, E. A. Robbins, and Mrs. M. D. Waller. Delimiting holes were drilled also on adjacent properties of L. A. Hudson, W. J. Price, John Shook, and K. O. Williams. The bauxite body was discovered in delimiting the Birnbach deposit. Four and six-tenths feet of ore-grade bauxite was recorded at a depth of 209 feet (USBM drill hole 6–255). Subsequently 43 holes were drilled to delimit the deposit.

The deposit, which is pear shaped in plan, consists of two distinct beds separated by as much as 2 feet of carbonaceous bauxitic clay. The lower and more extensive bed, a type 2 deposit, is composed of pisolitic and fragmental bauxite as much as 16 feet thick. It has been partly truncated by erosion and overlain by a type 3 deposit of gravelly bauxite as much as 7.3 feet

thick. The upper bauxite body, confined chiefly to channels, covers the northeastern and central parts of the lower body and is absent above the western and extreme northern parts and also along the margins.

The ore body is about 1,300 feet long and slightly more than 600 feet wide at its broadest part, oriented about N. 30° W. The thickest bauxite was recorded in USBM drill hole 5–409, in the north-central part, where the two beds aggregate more than 23 feet of ore-grade bauxite.

The bauxite-kaolin zone surrounding the Glidewell deposit lies on the Wills Point formation in a subsurface valley which trends southeastward to southward (pl. 19). The weathering profile at the top of the Wills Point formation consists of horizontally banded khaki-colored clay in most places; in several it is overlain by red- and gray-banded clay, and in one place at least, by light-gray clay. The gray fragmental underclay beneath the deposit ranges in thickness from about 9 to 20 feet. It contains a large amount of siderite, the FeO content ranging normally from 10 to 15 percent and locally as much as 35 percent. The basal 2 to 3 feet is a mottled red and gray kaolinitic clay filled with fragments of banded clay of the Wills Point formation many of which are as much as 4 inches across.

The upper bauxite bed is composed mainly of hard pebbly pisolites, about one-fourth inch in diameter. Most of it is a poorly sorted open-textured gravel, bound together by brown crystalline siderite, but the lower part has a matrix of gray bauxitic clay. Fragments of hard gray bauxite are fairly common. Along the southwest and south margins of the body the upper bed passes laterally into gray carbonaceous kaolinitic clay containing lignite fragments. The carbonaceous bauxitic clay or bauxite layer that separates the two bauxite beds is thickest in the north-central part of the ore body. Over the west slope of the subsurface valley the upper bed is represented by kaolinitic clay and the separating layer by black lignitic clay. Over the steeper east slope of the valley the separating layer contains much siderite and locally can be classed as a bauxitic ironstone.

A hardcap of 1 to 4 feet of gray dense pisolitic bauxitic clay covers the entire deposit. At the top of the sedimentary bed are cherty- or horny-appearing masses of kaolinitic rock and streaks of white kaolinite, associated locally with siderite. The lower half foot of hardcap is horizontally layered with sheets of white kaolinite. A kaolinitic overclay lies above the bauxitic clay capping.

The ore body lies beneath overburden that ranges from 208 to 275 feet in thickness and averages about 232 feet; this includes as much as 9.3 feet of hardcap and overclay at the base. The Berger sediments above the bauxite-kaolin zone range from 35 to 116 feet in thickness in two nearby delimiting holes at the southeast end of the deposit. Local high relief on top of the Berger indicates active post-Berger erosion before deposition of the Saline formation. Lignite beds 2–10 feet thick are interbedded with green or gray silty to sandy clay and brown carbonaceous clay in the lower 20 to 50 feet of the Berger formation above the bauxite-kaolin zone. In the upper part only thin lignite layers were recorded. The Saline formation ranges from 110 to 236 feet in thickness, filling depressions on the surface of the Berger formation. The chocolate-brown silty to sandy carbonaceous clay at the base ranges from 55 to 218 feet in thickness and is overlain by loose sand or clayey sand grading laterally into red, gray, or grayish-brown sandy clay ranging from 18 to 99 feet in thickness. Lignite stringers are common in the basal part.

IRONTON AREA

About 5 miles south of Little Rock, in secs. 10, 15 and 22, T. 1 S., R. 12 W., a buried ridge extends northward and southward from the east end of a large hook-shaped nepheline syenite outcrop. Along the east slope of this ridge, north and south of the village of Ironton, a group of bauxite bodies occurs sporadically, most of which are small but several are of moderate size. These deposits extend from the NE¼ sec. 10 to the SW¼ sec. 22 and also underlie part of the W½ sec. 14.

The buried ridge is bounded on the north by the Primrose Church basin. During early Eocene time this basin drained southeastward through a narrow valley in the NE¼ sec. 10. The south end of the ridge passes beneath sediments of the Midway group. Most of the ridge is composed of nepheline syenite, but in it are also several pendants of slate, phyllite, and quartzite of Paleozoic age, in the SW¼ sec. 14 and the E½ sec. 15. Some of the buried pendant rocks were a little more resistant than the surrounding nepheline syenite to early Eocene erosion. This resulted in the formation of a spur ridge of rock of Paleozoic age that trends about S. 50° E. and divides the arc of bauxite deposits into subequal segments. The east slope of the nepheline syenite dips steeply and is overlapped by sediments of the Wills Point formation, the surface of which dips somewhat less steeply eastward.

The buried nepheline syenite and Wills Point contact trends southward and slightly eastward to the end of the spur ridge, thence southwestward along the main ridge. In the NW¼ sec. 10, the upslope edge of the Wills Point formation lies at an altitude of about 65 feet above sea level, and in the SW¼ sec. 22 it reaches

100 feet below sea level at one place where pre-Berger erosion removed the sediments a short distance from their former limit.

Most of the bauxite deposits lie on benches on the nepheline syenite surface at or near the bases of steeper slopes. At the north end of this area they are at an average altitude of 140 feet above sea level, and at the south end they reach 60 feet below sea level. Three of the deeper bodies extend over the upper surface of the Wills Point. The deposits generally are either altered valley-flank accumulations (type 2), valley-fill (type 3), or a combination of both.

Most of the ore is pisolitic bauxite commonly underlain gradationally by a thin interval of slightly pisolitic to nonpisolitic bauxite. The ore bodies all thin out laterally into low-grade bauxite and bauxitic and kaolinitic clay. The bauxite-kaolin zone wedges out abruptly upslope against the nepheline syenite and more gradually downslope in the area lying east of the trace of the nepheline syenite and Wills Point contact.

The bauxite bodies in the Ironton area are covered by about 125 to 430 feet of overburden, the thickness of which increases from north to south. It is composed of lignite, lignitic clay, and silty to sandy gray clay of the Berger formation overlain by brown silty to sandy, carbonaceous clay and sand of the Saline formation.

All the deposits in this area were discovered by the Federal drilling program. A few exploratory holes had been drilled earlier by company drillers in and near the SE¼ sec. 10, without finding any bauxite.

The Finnegan deposit, although in line with the deposits of the Ironton area, lies within the Primrose Church basin and is described with the deposits of that area.

HEMPSTEAD DEPOSIT

Plate 2

The northern deposits in this area are small and offer little promise as potential ore bodies. The northernmost of these, the Hempstead deposit (Malamphy and others, 1948, v. 5, p. 127–131, fig. 58), lies beneath the western part of the line that separates the NE¼NE¼ and the SE¼NE¼ sec. 10, 1¼ miles north of Ironton. It was discovered during the investigation of the Dreher, Junkin, and Herrod bodies that lie a short distance to the south-southwest and explored by 12 drill holes.

Only two of the drill holes cut through a minable thickness of bauxite. In these drill holes pisolitic bauxite lies at a depth of 167 to 172 feet. The bauxite rests on a fragmental kaolinitic clay mantle above the weathered nepheline syenite surface which slopes steeply to the southeast (pl. 20). Downslope from the deposit the gradient of the nepheline syenite surface is more gentle.

The bauxite is overlain by as much as 10 feet of bauxite and kaolinitic clay. Above this overclay are carbonaceous and fine clastic sediments of the upper part of the Berger formation, averaging about 65 feet in thickness. They are overlain by chocolate-brown silty to sandy clay of the Saline formation, with a little lignite in the lower part and sandy at the top, aggregating about 105 feet in thickness.

DREHER–JUNKIN–HERROD DEPOSIT

Plate 20

The first bauxite found by the Federal drilling program was in USBM drill hole 1–022 on the George Dreher property, drilled on May 14, 1942. Later 36 holes, spaced 150 to 300 feet apart, were drilled to delimit the Dreher–Junkin–Herrod deposit (Malamphy and others, 1948, v. 5, p. 132–142, fig. 59) in parts of the SE¼NE¼, SW¼NE¼, and the NW¼SW¼ sec. 10, T. 1 S., R. 12 W.

The deposit consists of three separate bauxite bodies, the central one is the largest. The southern two are connected by a fringe of low-grade bauxite and bauxitic clay. The northern one, however, is separated from the central one by a narrow basement ridge. The subsurface map (pl. 20) shows their relation to subsurface contours drawn on the underclay beneath the bauxite deposits. They are small colluvial (type 2) bodies near the base of a steep nepheline syenite slope.

The bauxite is tan to grayish, pisolitic, with a mealy soft to moderately well indurated matrix. The pisolites, as much as 6 millimeters across, are abundant near the top of the bauxite but decrease in number with depth. Nonpisolitic bauxite at the base of each body grades downward into grayish-tan bauxitic clay. Gray fragmental kaolinitic clay, usually 10 feet or slightly more in thickness, lies between the bauxitic clay and kaolinized syenite below.

In the George Dreher bauxite body, the southernmost of the three, the bauxite is overlain by 1 to 8 feet of gray slightly sideritic kaolinitic clay, averaging about 4 feet in thickness. In the other two bodies the bauxite is overlain by 10 to 18 feet of gray plastic kaolinitic clay and bauxitic clay, averaging about 14 feet in thickness.

The overburden is composed of Wilcox sediments aggregating 125 to 180 feet and averaging about 135 feet in thickness above the George Dreher ore body and 165 feet above the Junkin and Herrod bodies. These beds consist of the following major units:

1. Gray silty clay with thick and locally massive lignite beds; 30 to 60 feet thick, averaging about 40 feet. These are the clastic and carbonaceous beds of the Berger formation.

2. Dark chocolate-brown carbonaceous silty clay and beds of brownish sand and scattered thin lignite layers, 75 to 100 feet thick, averaging about 80 feet; the carbonaceous clay member of the Saline formation.
3. An upper sequence of grayish sand and clay with some gravel; 10 to 20 feet thick, averaging about 15 feet. This sequence probably belongs mostly to the Saline formation but part of it may represent surface wash.

DREHER DEPOSIT

About 1,600 feet south of the George Dreher ore body (pl. 2) is a small deposit in the SW¼ sec. 10 on the property of W. A. Dreher (Malamphy and others, 1948, v. 6, p. 64–69, fig. 66). An estimated 16 feet of ore-grade bauxite was discovered in USBM drill hole 3–087 at a depth of 185 feet. This hole was drilled to prospect the area between the Dreher–Junkin–Herrod and the Sipes deposits. It was offset by others about 300 feet away, none of which recorded any bauxite, and later by additional holes about 175 feet away, two of which, one to the northwest and the other to the southeast, cut through about 2 feet of bauxite. The deposit is too small to be of commercial interest at the present time.

SIPES DEPOSIT

Plate 21

The Sipes deposit (Malamphy and others, 1948, v. 6, p. 70–80, fig. 67) lies mostly beneath the Franklin Sipes property in the NE¼NE¼ sec. 15. It is located three-eighths of a mile north of the Ironton store and about a mile east of Highway 167, from which it may be reached by good gravel road. It consists of two separate bauxite bodies at each side of a small northeastward-trending nose in the basement ridge. The bodies are connected across the ridge by bauxitic clay and low-grade bauxite. Thirty-four holes were drilled to investigate the deposit.

Both bodies rest on residual clay overlying nepheline syenite pulaskite (pl. 9*B*) and rocks of Paleozoic age and are about a quarter of a mile upslope from the buried edge of the Wills Point formation. The north ore body accumulated in a small valley along the contact of the nepheline syenite and the rocks of Paleozoic age and the south ore body at the base of a steep slope along the same contact. The upper surface of the deposit dips about 7° NE.

The bauxite of the Sipes ore bodies consists of a soft mealy tannish-gray or buff variety with pisolites making up 30–50 percent of the rock and a tan nonpisolitic type. In most of the drill holes the nonpisolitic bauxite was found to grade downward into tannish-gray bauxitic clay, underlain by bluish-gray fragmental clay. No high-silica hardcap, such as is common in many of the bauxite bodies in Pulaski County, is present on the Sipes deposit. However, the silica content is lower toward the middle of the ore body. Some parts are higher than others in ferrous iron content, which occurs principally in irregularly distributed granular siderite. Pellets of siderite are found in the bauxitic and fragmental underclays.

The overburden ranges in thickness from 211 to 283 feet and averages about 263 feet. Over most of the deposit a thin bed, about 2 feet thick, of carbonaceous clay or lignite lies at the top of the bauxite-kaolin zone, pinching out westward. The upper Berger sediments that overlie this bed consist of light-gray to gray silty to sandy clay with several thin interbedded lignite layers and a 20-foot interval of lignite and lignitic clay near the middle. The lower part of the Saline formation consists of about 140 feet of dark-brown to grayish-brown carbonaceous silty clay, with a few thin lignite seams near the top and bottom. The clay is interbedded with fine laminae of quartz and mica. The upper part of the Saline formation is composed of sand, silt, and sandy clay ranging in color from creamy white to yellowish brown, and gray, but has little lateral continuity. It ranges from 40 feet in thickness above the larger ore body to 75 feet above the smaller.

NORTH AND SOUTH IRONTON DEPOSITS

By Hal G. Stephens

Plate 21

The Ironton deposits (Malamphy and others, 1948, v. 6, p. 88–101, figs. 68, 69) are about 2 miles east of Highway 167 and about 6 miles south of the city of Little Rock. The North Ironton body is north and northeast of the Ironton church, beneath the properties of E. W. Dixon and D. F. Kumpe, in parts of the SE¼NE¼ sec. 15 and the SW¼NW¼ sec. 14. The South Ironton body lies a few hundred yards east and slightly south of the church, mainly under the properties of W. H. Dreher and W. R. Heasley in part of the N½SW¼ sec. 14.

The north body was discovered in USBM drill hole 3–018 and the south body in drill hole 3–019; both were drilled in August 1942. The discovery hole of the north body was drilled at the edge of the deposit and cut through only bauxite clay. Two weeks later USBM drill hole 5–001 was drilled about a thousand feet west of it and cut bauxite estimated to be 12 feet thick.

The North and South Ironton deposits are typical valley-fills with their upslope part each lying in the center of a broad shallow valley, the downslope part forming an apron along the slope. The bauxitic rock lies on gray kaolinitic underclay, the physiographic conformation of which is similar to that of the under-

lying basement rocks (pl. 21). A total of 36 holes were drilled to delimit the north deposit and 35 to delimit the south deposit; most of these were drilled 200–300 feet apart. Additional holes were drilled later by the Reynolds Mining Corp.

The basement consists of nepheline syenite and rocks of Paleozoic age. The latter occur in three pendants, one north of the north body, one between the two bodies, and the third south of the south body. Twenty-seven of the drill holes were bottomed in this type of rock, identified in the field principally as quartzite or hard metamorphosed shale.

The bauxite of the two Ironton ore bodies is gray to tan or buff, compact and hard at the top and generally firm throughout the section. In several drill holes the lower part was mealy and crumbly. Hard aggregates of granular siderite occur in both bodies but are not limited to any particular zone. Most of the bauxite is pisolitic, but the lower part of both bodies contains intervals in which the pisolites are small or absent. The bauxite grades downward into bauxitic clay, generally 3 to 4 feet thick, but locally reaches a thickness of 8 feet. Both bodies are enclosed in kaolinitic clay.

The overburden above the north ore body ranges in thickness from 256 to 285 feet and averages about 270 feet; above the south ore body the thickness ranges from about 264 to 305 feet and averages about 283 feet. The lower part of this overburden consists of carbonaceous and clastic sediments of the Berger formation from 25 to 90 feet thick. This is overlain by a dark brown sandy micaceous silt from slightly less than 100 to 190 feet thick. Thin lignite beds, sand, and buff-colored clay layers are common in this silt. The lower part consists of 20 to 50 feet of dark grayish-brown silty clay, which was recognized in most of the Ironton area. The uppermost part of the overburden is composed of 20 to 70 feet of sticky silty gray or yellow clay, interbedded in places with thin sand layers. This clay and the underlying silt represent the Saline formation.

BROWN DEPOSIT

By Richard C. Shelton

Plate 22

The Brown deposit (Malamphy and others, 1948, v. 6, p. 102–118, figs. 70) lies in parts of the SE¼ sec. 15 and the SW¼SW¼ sec. 14, T. 1 S., R. 12 W., on the properties of R. L. Brown, W. R. Heasley, J. E. Maughan, T. A. Dillaha, John and Eva Rose, and G. E. Spickes.

It was discovered in USBM drill hole 3–010, drilled August 27, 1942, from which was recovered a few feet of hard pebbly bauxite overlying a few inches of lignite and carbonaceous clay. The main part of the body was drilled several days later in USBM drill hole 3–012, redrilled as USBM 5–114A and the ore was recorded as nearly 10 feet thick at this point. The deposit was prospected by drilling 74 holes, most of which were spaced about 200 feet apart. Because the part of the body containing minable grade bauxite was found to be narrow, additional holes were drilled across it on 100-foot centers. The Reynolds Mining Corp. further prospected part of the deposit by drilling 15 holes.

The deposit lies in a small subsurface valley that in early Eocene time drained southeast from nepheline syenite and rocks of Paleozoic age on to the Wills Point surface (pl. 22).

The basement rocks are nepheline syenite and metamorphosed rocks of Paleozoic age and their residual weathered derivatives. Overlying the rock of Paleozoic age near the buried contact with the nepheline syenitic rocks, a soft, loosely consolidated mixture of green and white clay, siderite pellets, feldspar fragments, and small hard green, tan, and gray rock chips, probably Paleozoic, was found in a few of the drill holes. A maximum thickness of 76.3 feet of this material was recorded in drill hole 7–120. Although it does not appear to be residual, it is below the surface upon which the bauxite-kaolin zone was deposited, and it may represent a zone of deeper weathering along the contact. The mixture of fragments of decomposed nepheline syenite and rock of Paleozoic age may be the result not of transportation of the decomposed materials but of original intrusion of the rocks of Paleozoic age by the nepheline syenite.

The length of the bauxite body is nearly 2,000 feet in a northwesterly direction; the width locally exceeds 300 feet but is generally less. The upslope part dips southwestward about 5° and the downslope part much more gently. A maximum thickness of 21.3 feet of bauxite of 32 percent or more of available alumina was reached in USBM drill hole 5–124.

The bauxite consists of a pisolitic type 2 deposit overlain locally by a pebbly type 3 deposit. Along the southwest side of the Brown deposit the two types of bauxite are separated by a wedge of carbonaceous or highly sideritic silty clay as much as 3 feet thick. A small lobe (shown on pl. 22 as a separate body) near the head of the deposit and at its southwest side is composed of alluvial bauxite only and overlies gray carbonaceous clay containing a thin lignite layer.

The bauxite of most of the Brown deposit rests on 2 to 5 feet of light-grayish tan bauxitic clay, containing subangular dark-gray or orange clay fragments and a few small siderite pellets. This in turn rests on the typical light-gray fragmental kaolinitic underclay.

Two to five feet of bauxitic clay or high-silica bauxite

overlies the bauxite of ore grade in most of the drill holes. Pebbles of dark cherty high-alumina rock like those in the stratified bauxite below are scattered locally. Analysis of a pebble from USBM drill hole 7–118 showed that it contained 60.2 percent Al_2O_3 and 7.1 percent SiO_2. The pebble was in a 1-foot core sample that contained 49.9 percent Al_2O_3 and 17.0 percent SiO_2.

A high-silica bauxite hardcap was penetrated in six holes along the north side of the ore body—a hard gray bauxitic rock from which most of the pisolites have been leached.

Above the bauxitic rock is an average 5-foot interval of gray kaolinitic clay containing many fragments of gray clay and carbonaceous matter. At the top of this overclay in USBM drill hole 5–114A a root fragment about 5 inches long and three-sixteenths of an inch in diameter, carbonized and retaining its woody texture, was found in a vertical position in the core.

The overburden, including the upper part of the bauxite-kaolin zone, ranges in thickness from 224 to 291 feet and averages about 255 feet. Carbonaceous and clastic sediments of the Berger formation overlie the bauxite-kaolin zone and have an average thickness of 54 feet. These sediments consist principally of interbedded gray and green silty to sandy clay and lignite. Two principal lignite and lignitic clay beds extend over most of the deposit and range in thickness from 5 to 20 feet. The middle part of the overburden contains the carbonaceous clay member of the Saline formation, with an average thickness of about 118 feet. Thin seams of lignite are not restricted to any definite zone. The upper part of the overburden consists of sandy beds of the Saline formation averaging about 75 feet in thickness. Most of this sequence is composed of buff, tan, reddish brown, or yellow loose fine- to medium-grained fairly well rounded quartz sand, containing thin beds of pink, yellow, and gray sandy to silty clay, and locally a few fragments of lignite.

MAUGHAN DEPOSIT

Plate 22

The Maughan deposit (Malamphy and others, 1948, v. 7, p. 3, fig. 71; v. 10, p. 11–20) is a small type 2 bauxite body in the SW¼SE¼SE¼ sec. 15 on the property of J. E. Maughan, about 600 feet southwest of the Brown deposit and on the west slope of the same subsurface valley. About 30 holes were drilled to investigate this deposit, most of which were spaced approximately 200 feet apart.

The deposit, part of which lies over the Wills Point formation, dips northeastward about 3°. The bauxite is gray to tan, pisolitic, and most of it is well indurated.

The overburden ranges in thickness from 244 to 280 feet and averages about 256 feet. The section is similar to that overlying the Brown deposit.

NEWMAN–KENDRICK DEPOSIT

Plate 23

The Newman–Kendrick deposit (Malamphy and others, 1948, v. 8, p. 77–93, fig. 84) is in the NE¼ sec. 22 about three-fourths of a mile southwest of Ironton. The major part is on the property of H. E. Kendrick and Mrs. A. L. Newman. Bauxite was discovered in USBM drill hole 2–096C drilled January 1, 1943, and was later delimited by 58 drill holes.

This is a narrow, sinuous, colluvial deposit along a weathered nepheline syenite slope (pl. 23). Most of it lies upslope from the edge of the Wills Point formation, which thins out against the nepheline syenite (pl. 23). Two small valleys that drained eastward in early Eocene time contain the thickest bauxite.

The deposit is about 2,000 feet long and as much as 400 feet wide, elongate north-northeast; the ore of minable thickness, however, is not continuous for the entire length of the body. Bauxite of ore grade is distributed as in a typical type 2 deposit. Granular siderite is distributed irregularly through the bauxite, particularly in the lower part of the body. In several places the lower part is pisolitic and grades downward through gray pisolitic bauxite and pisolitic bauxitic clay to pisolitic kaolinitic clay which overlies fragmental kaolinitic clay. The ore is surrounded by an envelope of low-grade bauxite and bauxitic clay. In several drill holes along the upslope edge of the deposit 1 to 2 feet of siliceous hardcap was found above the ore.

The overburden above the ore ranges from 242 to 319 feet in thickness and averages 280 feet. The Berger sediments that lie above the deposit are 47 to 85 feet thick and average 68 feet. The lower 2 to 12 feet of these sediments consists of low-grade bauxite and high-alumina clay at the top of the bauxite-kaolin zone; the upper part is composed of lignite, gray silty clay, and greenish-gray sand. The chocolate-brown sandy to silty clay member of the Saline formation is 76 to 163 feet thick, averaging about 104 feet. Locally, where the member is thickest, the basal part is made up of loose quartz sand or brownish clayey sand, averaging about 63 feet in thickness. The upper member of the Saline formation, 87–126 feet thick and averaging 108 feet, is composed of white quartz sand containing beds of tan to gray sandy clay.

SMITH DEPOSIT

Plate 23

The Smith deposit (Malamphy and others, 1948, v. 8, p. 94–105, fig. 85) is located in parts of the NE¼SW¼ and the NW¼SE¼ sec. 22, on the properties of H. Y.

Smith and E. Kumpe. The deposit was discovered in USBM drill hole 2–144, drilled in February 1943, and delimited by 40 additional holes.

The deposit fills a small lateral valley on the post-Midway erosion surface at the base of a steep slope of nepheline syenite (pl. 23). The larger part lies on top of the Wills Point formation, near the edge where the Paleocene marine sediments thin out against the nepheline syenite (pl. 23).

The deposit is subtriangular, about 900 by 700 feet across, with the long dimension in an east-southeasterly direction. It dips about 6° SE. The bauxite is chiefly pisolitic, tannish gray to tan in color and grades downward into bauxite with fewer pisolites, much like that in the Newman–Kendrick deposit. Granular siderite is scattered through it, in the lower part. A hard siliceous capping as much as 2 feet thick covers most of the body. The ore is surrounded by low-grade bauxite and bauxitic clay. There is an underclay of fragmental kaolinitic clay. Bauxitic and kaolinitic clay as much as 6 feet thick overlie the ore body.

The overburden ranges from 327 to 373 feet in thickness and averages about 356 feet. It is similar to that of the Newman–Kendrick deposit.

COLE AND HOLLENBERG DEPOSITS

By Jack B. Collins

Plate 23

Two small deposits lie a short distance southwest of the Smith deposit. They are the southernmost in the Ironton area and the deepest in the Pulaski mining district. Because of their depth and relatively small size it is not likely that they will be mined under present economic conditions. The Cole deposit (Malamphy and others, 1948, v. 9, p. 3–8, fig. 86) is located in the SE¼SW¼ sec. 22 and the smaller Hollenberg deposit (Malamphy and others, 1948. p. 9–14, fig. 87) in the SW¼SW¼ sec. 22. Eighteen exploratory holes were drilled to investigate each deposit.

Both deposits are in small valleys on the post-Midway erosion surface, cut into the southeast slope of the buried nepheline syenite ridge and tributary to a larger drainage system southeastward (pl. 2). The bauxite occurs at breaks in slope on the sides and bottom of these valleys. The Cole deposit lies about 300 feet and the Hollenberg deposit 1,000 feet northwest and upslope from the buried edge of the Wills Point formation (pl. 23). The Wills Point formation is underlain by a relatively fresh gravel of nepheline syenite and feldspar fragments in a clay matrix, that locally grades to coarse sand and is calcareous in places, probably of Kincaid age. Locally the detritus extends upslope beyond the edge of the Wills Point formation. Between weathered nepheline syenite and the bauxite in the deposits is 10 to 20 feet of gray fragmental sideritic kaolinitic clay, bauxitic in the upper part.

The bauxite in both deposits is gray, buff, or red, pisolitic, or locally pebbly, and most of it is hard and brittle. Siderite is irregularly distributed through the bauxite in small crystalline masses filling cavities and pore spaces. Along the upper flanks of the Cole bauxite body are small masses of secondary kaolinite as much as 15 millimeters across, which are gray, hard, and cherty looking.

On the Hollenberg property two small lenticular bodies are connected by a thin sheet of bauxite, deposited mostly on the valley slopes. In the more northerly of the two, an upper bed of stratified pebbly (type 3) bauxite was found in USBM drill hole 10–129. It is separated from the lower colluvial (type 2) deposit by gray to buff hard porcellaneous clay. In the deposit on the Cole property the ore-grade bauxite is 17 feet thick in the valley bottom and thins gradually toward the north and east and abruptly toward the south and west. The body dips 2°–4° SW.

Bauxitic and kaolinitic clay, as much as 10 feet thick on the Cole property and 14 feet thick on the Hollenberg property, overlies the bauxite of minable grade.

The depth to the top of the bauxite-kaolin zone on the Hollenberg property ranges from 322 to 384 feet and averages 360 feet; on the Cole property it ranges from 354 to 380 feet and averages 363 feet. The thickness of the carbonaceous and clastic beds of the Berger formation in the lower part of this overburden ranges from 8 to 136 feet and averages 64 feet. The lower member of the Saline formation, a chocolate-brown silty, micaceous, carbonaceous clay containing much brown loose sand and interbedded thin lignite layers in the lower part, averages 189 feet in thickness. The upper member, of gray and brown sandy clay interbedded with loose brown sand, averages 107 feet thick.

JENNINGS LAKE AREA

The bauxite deposits described below are in secs. 16 and 21 and the west edge of sec. 22, T. 1 S., R. 12 W., Pulaski County (fig. 58). The land surface in the vicinity of Jennings Lake is rolling to flat and partly wooded; much of it is under seasonal cultivation. The deposits are within a mile of Highway 167, and are reached by all-weather roads.

They lie west of the crest of the buried ridge of nepheline syenite that extends southward from the large hook-shaped outcrop at the intersection of secs. 9, 10, 15, and 16 (pl. 2). The west slope of this ridge is cut by many subsurface valleys, most of which trend southwestward. The bauxite deposits are along the slopes of these valleys with a general southwesterly

elongation of the larger bodies and alinement of groups of smaller bodies. Most of them lie on the nepheline-syenite surface as much as three-eighths of a mile upslope from the edge of the Midway sediments, but several are on the Midway formation surface as much as a quarter of a mile downslope from the edge. The buried valleys that contain the deposits are tributary to a major drainage system that during early Eocene time passed between the Pulaski and Ledbetter nepheline-syenite hills.

The earliest prospecting in this area consisted of a few holes drilled by the Republic Mining and Manufacturing Co., in the S½ sec. 16, but although bauxite was recorded in several of them, apparently none of it was commercial. Wildcat drilling by the joint project, which was begun in July 1942, was done more systematically in 1943, after exploration of the Ironton area was virtually completed. The program early in 1943 was a triangular pattern of drill holes on 1,000-foot centers laid out to follow the buried edge of the Midway sediments. It was during this time that most of the ore bodies were discovered.

The bauxite in these bodies is nearly all pisolitic, as is characteristic of most other colluvial (type 2) bodies in the Pulaski district. In saddles near the south end of the nepheline-syenite ridge granitic bauxite was recorded in several drill holes and was believed to be in place. Also, in the Rummel deposit, the type 2 body is overlain by lignite and by a stratified or crossbedded type 3 bauxite deposit.

The ore bodies in this area lie at depths ranging from 95 to 450 feet below the surface. They are covered by sediments of the Wilcox group, including lignite, lignitic clay and gray-green silty to sandy clay of the Berger formation, overlain by brown carbonaceous silty to sandy clay and clayey sand of the Saline formation.

ALFORD–ROSS DEPOSIT

By Finis M. Sanford

Plate 24

The Alford–Ross deposit (Malamphy and others, 1948, v. 9, p. 54–95, fig. 89) is in the W½SE¼ sec. 21 and extends in several places into adjacent parts of secs. 21 and 28. Most of it is on properties of B. J. Alford, S. J. Jefferson, G. E. Naylor, J. H. Richmond, and F. L. Ross. Delimiting holes were also drilled on properties of Matt Bailey, C. E. Bennett, J. B. Burch, W. H. Dreyer, and Henry Rummel. The deposit is about 1 mile by gravel road east of Pratt's store, which is on Highway 167 about 9 miles from the center of Little Rock.

The ore was discovered in USBM drill hole 1–226, drilled May 26, 1943, in which 15.1 feet of bauxite was cut at a depth of 267 feet. About 140 holes were drilled between late May 1943 and early March 1944 to delimit the deposit.

The nepheline syenite rocks form a prominent southwestward-trending ridge beneath the Alford property. This is the south extension of the main subsurface ridge that separates the Ironton and Jennings Lake areas. The southwesternmost drill hole of the Alford-Ross group (USBM 17–048) bottomed at the west base of the ridge in a hard dense dark bluish-gray pulaskite. The feldspathoidal rocks, where they coincide with the post-Midway erosion surface, have been weathered to a residual kaolinitic clay to depths that reach 65 feet.

Sediments of the Midway group wedge out against the west slope of the ridge. They include typical clastic beds of the Kincaid formation, and blue-black silty clay of the Wills Point formation weathered at the top. In the northwestern part of the drilled area the Wills Point sediments slightly overlap those of the Kincaid, but in the southwestern part, as shown in plate 24, the debris extends upslope a short distance beyond the edge of the Wills Point formation.

The Alford–Ross ore body is irregularly trilobate in outline. The main part, oriented about N. 35° W., is slightly more than 1,900 feet long and has a maximum width of about 600 feet within the 5-foot isopach. Most of it lies diagonally across the west slope of the buried nepheline syenite ridge, but part of it is at the crest of the ridge, and two small lobes extend down gullies on the east slope. Another arm stretches about 1,200 feet S. 30° W. from the north-central part of the ore body, along the lower west slope of the ridge. The northwest and southwest ends of the body extend out a short distance over the buried edge of the Midway sediments. The rest of the ore body overlies the weathered nepheline syenite surface from which it is separated by a bluish-gray fragmental underclay as much as 17 feet thick. The underclay is fine grained, even textured, and compact in the upper part, but contains many angular gray to white clay fragments in the lower part.

Three different types of bauxite deposits contribute to the unusual shape of this ore body. Along the crest of the subsurface ridge the nepheline syenite has been altered in part to bauxite or bauxitic clay that exhibits a relict granitic texture (type 1 deposit), generally underlain, surrounded, or in places veined by kaolinitic clay, part of which also retains the texture of the original nepheline syenite (USBM drill holes 1–250, 5–204B, 5–205, and 7–199B). Granitic-textured bauxite reaches a maximum measured thickness of 13.4 feet in USBM drill hole 7–199B. This material at the summit of the ridge is not overlain by pisolitic bauxite, but rather by fragmental bauxite or bauxitic clay. A small accumulation of bauxite at the crest

of the ridge between the Alford-Ross and Rummel deposits (USBM drill holes 1–243 and 1–244B) is also of this type.

Downslope the type 1 deposit in the Alford–Ross body is overlapped by pisolitic bauxite and fragmental bauxite that has many of the normal characteristics of a type 2 deposit. Fragmental bauxite underlies pisolitic bauxite and patchy areas are near the base of the ore in the northeast-, east-central, and southeast parts of the ore body where fragmental detritus appears to be made up largely of material with a faint granitic texture.

Most of the bauxite in the deposit is gray to tan and pisolitic. The thickest ore in the deposit was recorded in USBM drill hole 3–272 which cut through 21.6 feet of pisolitic ore. In the northwestern part of the deposit the bauxite is clayey and sparsely oolitic. The oolites average about 1.6 millimeter in diameter and make up 10 to 15 percent of the rock.

In the northeastern part of the Ross property, several hundred feet northeast of the Alford–Ross deposit and almost the same distance west of the Rummel deposit, is a small boomerang-shaped (type 2) body composed largely of soft pisolitic bauxite, overlain at the northeast tip by a bed of stratified (type 3) bauxite. It is about 700 feet across the longest dimension within the 5-foot isopach. It rests mainly on small ridges at either side of a northwestward-trending gully on the post-Midway surface, and its concave side faces northwest.

Places where types 1 and 2 deposits are overlain by bauxite of alluvial deposition (type 3 deposits) are shown in plate 24. The best developed lens of this type covers the southwest lobe of the Alford–Ross ore body. The thickest stratified ore is 6.6 feet in USBM drill hole 3–291B, not counting an additional 2.7 feet probably of the same material that was lost in coring. In this drill hole only 0.7 foot of gray bauxitic clay was recorded between the upper bed and the ore of the type 2 deposit below. In others, nearly 19 feet of pisolitic bauxitic clay, kaolinitic clay, lignitic clay, and lignite were penetrated between the two ore layers.

The bauxite of minable grade is surrounded by an envelope of low-grade bauxite and bauxitic clay. Its thickness below the ore body averages 2.2 feet and above the ore body, 1.9 feet. Locally, a high-silica hardcap is as much as 2 feet thick containing secondary cherty-looking kaolinite in veins, stringers, and scattered masses. Above the bauxitic part of the deposit is a gray to white kaolinitic clay layer, the thickness of which ranges from 6 inches to 3 feet.

The overburden above the Alford–Ross deposit, including the bauxitic and kaolinitic clay mentioned above, ranges from 264 to 382 feet in thickness and averages about 315 feet. The smaller Ross deposit is covered by from 250 to 284 feet of overburden. The little type 1 body at the brow of the subsurface ridge is 223 to about 245 feet below the surface.

The Wilcox sediments above the bauxite-kaolin zone in the drilled area range from 185 to 430 feet in aggregate thickness. The carbonaceous and clastic beds of the Berger formation contain many stringers of reworked pisolitic kaolin and bauxite, particularly where they fringe the slopes of the buried nepheline syenite ridge. The Berger formation, including most of the bauxite-kaolin facies, is absent in places along the higher parts of the ridge, but over valleys the clastic and carbonaceous part reaches a maximum thickness of 150 feet. Lignite generally is distinctly bedded and thick in the lower part.

The lower brown clay member of the Saline formation contains stringers of woody lignite several inches thick, which are more abundant near the base. Along parts of the buried ridge the brown clay directly overlies kaolinized nepheline syenite or rocks of the bauxite-kaolin zone. The clay member ranges in thickness from 118 to 160 feet.

The upper part of the Saline formation in this area consists of fine- to coarse-grained loosely consolidated sand composed largely of angular to subangular quartz grains. The sand contains scattered lenses of gray and red-mottled sandy plastic clay. A 4- to 5-foot bed of this clay is usually at the base of the interval, overlain by a coarse clear water-bearing sand as much as 4 feet thick.

RUMMEL DEPOSIT

By Horace W. McGee

Plate 24

The Rummel deposit (Malamphy and others, 1948, v. 9, p. 15–52, fig. 88) is in parts of the E½ sec. 21 and the W½ sec. 22. It is on properties of Pauline Barron, Mrs. C. J. Pinkerton, Henry Rummel, E. L. Shackelford, and Lewis Treadway, about 9 miles by road south of the city of Little Rock. Part of the ore has been mined by the Pulaski Mining Co.

A bed of bauxite 18.1 feet thick was discovered in USBM drill hole 3–147, completed March 22, 1943. Subsequently, 125 holes were drilled to delimit the ore.

The deposit is irregular in outline, with its long axis trending about N. 40° E. Its maximum length within the 5-foot isopach is about 2,700 feet, and its width ranges from 120 to 700 feet. It has two small branches, one of which is L-shaped and extends northwestward from near the middle of the ore body. This branch has a maximum length of about 950 feet and ranges from 40 to 340 feet in width. The other branch extends southeastward across a saddle in the nepheline syenite

ridge for nearly 700 feet, and its width ranges from 250 to 270 feet.

The bauxite occurs as a lenticular blanket of weathered detritus lying for the most part on the northwest slope of the buried ridge of nepheline syenite, down to a little beyond the change of grade at its base. The thickest ore lies in a natural basin at the head of the drainage system, where the slope abruptly changes from steep to gentle. Some of the bauxite, with a granitic texture, remains in the place of its formation on the weathered nepheline syenite surface, along the top of the buried ridge.

Bauxitic clay, several feet thick, surrounds the bauxite, and locally where there are two or more layers of ore, it occurs as a separating layer. It overlies as much as 25.8 feet of gray fragmental sideritic kaolinitic underclay.

Most of the bauxite of ore grade, particularly in the downslope part, is pisolitic or is composed of reworked pisolites and constitutes a type 2 deposit. For this type of deposit a maximum of more than 24 feet of high-grade pisolitic ore was recorded in USBM drill hole 4–045B in the northeastern part of the deposit, overlain by an additional 8.4 feet of stratified (type 3) bauxite. In this part of the deposit the bauxite is hard, friable, high in iron content, and low in silica.

In the hook-shaped arm on the Treadway property the bauxite is soft and clayey and relatively low in iron and silica. A bauxitic clay layer as much as 4 feet thick is in the upper part of the bauxite in the eastern part of this small body. Pisolitic bauxite in the southwestern part of the deposit is soft to hard, friable, relatively high in silica, and low in iron. In one drill hole near the southwest end, a considerable thickness of granitic-textured bauxite was cut, the lower few feet of which is believed to be in place and to represent the root of a truncated type 1 deposit.

Beneath the pisolitic bauxite in the main ore body, along the slope of the main basement ridge, and also within the arm of the deposit that extends to the southeast, is a lenticular mass of clayey fragmental bauxite generally lower in silica than its appearance would indicate, as it resembles kaolinized nepheline syenite debris more than bauxite. It has a firm mealy or clayey matrix, soft and crumbly in most places, containing few to many fragments of orange or tan bauxite and white or gray kaolin. Many bauxite fragments have a recognizable granitic texture. Along the foot of the slope granitic-textured bauxite bodies, as much as 3 feet thick, were recorded in several drill holes (USBM 3–166, 3–181, 8–010, 8–011). They lie directly beneath pisolitic bauxite or separated from it by 1 to 2 feet of fragmental bauxitic clay, are underlain by bauxitic to kaolinitic fragmental underclay, and were not cut in offset holes drilled within 25 feet. They are interpreted as boulders along the outer downslope fringe of the fragmental bauxite mantle. Their presence here indicates that most of this detritus was derived from the erosion and transportation of bauxitic material from type 1 deposits higher on the basement ridge.

Stratified bauxite is distributed over the downslope parts of the deposit in two lenses (pl. 24) that possibly connect. This type 3 deposit has a maximum known thickness of 10.3 feet in USBM drill hole 1–212A. It is separated by 2.0 feet of lignite from the type 2 deposit below, 20.8 feet thick in this same drill hole. The sedimentary bauxite is thinly and flatly bedded in some places, as shown in a photograph taken in the underground mine (fig. 27); in others it is crossbedded. In the central part of the deposit the lignite dips to the northeast locally as much as 10°. Locally, the two bauxite beds are separated by a sideritic layer, shown in the photograph (fig. 27), that probably is a lateral extension of the lignite bed.

In one place, near the center of the mine workings accessible in October 1948, the lignite was underlain by several inches of tan bauxite sand. Discarded in early mining operations, the sand later was found to contain more than 60 percent Al_2O_3 and is one of the highest grade varieties of bauxite in the deposit. In one drill hole near the center of the ore body (USBM 1–218) are two separate lignite layers indicating at least three distinct periods of bauxite deposition.

Much of the siderite occurs in crystalline masses, lenticular layers, veinlets, and scattered grains. During the underground development of the deposit, the siderite bodies in the bauxite were not easily recognized until the mine face had been exposed to the air for several days. The red oxides that formed then, clearly outlined the parts containing high-iron content. Many of the oxides are small, elliptical, and scattered in a sort of polka-dot pattern. The greatest concentration is in the lower and middle parts of the deposit, rarely in the upper. Much of it is near the upslope part of the ore body, and is in the pervious bauxite layers.

Although the upper part of the bauxite is higher in silica than the middle part, a true hardcap was found only in the northwestern part of the deposit, where in several drill holes layers of hard siliceous bauxite, from a few inches to slightly more than 6 feet in thickness, were recorded. No kaolinitic overclay is above most of the ore; the bauxitic material is overlain by lignite. In the upslope parts of the deposit, however, the overclay locally reaches a thickness of 11.1 feet.

The sediments of the bauxite-kaolin zone are overlain by clastic and carbonaceous beds of the Wilcox group, ranging in thickness from 156 to 290 feet and averaging

223 feet. The carbonaceous and clastic beds of the Berger formation include a few hard layers of gray sideritic siltstone and average about 40 feet in thickness. In some upslope parts of the Rummel area they are absent, and the bauxite-kaolin zone is immediately overlain by the Saline formation. The average thickness of the brown clay member of the Saline formation is about 160 feet. The middle part of this member contains a large amount of loose fine-grained sand, locally as much as 100 feet thick, but in several drill holes no loose sand was reported. Thin lenticular beds of lignite, generally less than 2 feet thick, are scattered through this sequence and are common in the basal part. The upper sandy part of the Saline formation ranges from 24 to 135 feet in thickness and consists chiefly of loose fine- to coarse-grained quartz sand. Locally, the middle and lower parts of this sand contain lenses of gummy gray sandy clay, some of which is stained yellow, brown, or red. Lignite beds as much as 3 feet thick are found rarely in this part of the section.

Rummel shaft mine.—A shaft was sunk by the Pulaski Mining Co. in 1946 to develop the Rummel deposit. A small production was recorded that year and an increased output the following one. The ore was used by the abrasive and chemical industries. Early in 1948 a cave-in, apparently where crossbedded bauxite formed the roof of the mine, let a large amount of overburden into the workings southwest of the shaft. The soft muck oozed along drifts; then compacted and hardened, shrinking somewhat in the process. Operations were suspended in April 1948. Shortly afterward, the mine was bought by the Reynolds Mining Corp.

NUTT–BAILEY AND NUTT EXTENSION DEPOSITS

By John A. Jackson, James A. Cathcart and
Constantine N. Bozion

Plate 24

The Nutt–Bailey and the smaller Nutt Extension deposits (Malamphy and others, 1948, v. 8, p. 5–105, figs. 82 and 83) are in the central part of the NE¼ sec. 21 on the properties of the Dulin Bauxite Co., Pulaski Mining Co., Mrs. M. E. Hope, Mrs. G. P. Jackson, Mrs. C. J. Pinkerton, and Lewis Treadway. The properties belonging to the two mining companies formerly were owned by Andrew Nutt and Matt Bailey. An underground mine has been developed in the Nutt–Bailey deposit by the Dulin Bauxite Co. The mine is reached from Highway 167 by an improved gravel road.

The Nutt–Bailey deposit was first recorded in USBM drill hole 2–146 on February 22, 1943, in which was recovered 0.8 foot of low-grade bauxite at a depth of 310 feet. The Nutt Extension was discovered when USBM drill hole 2–149 cut 6.0 feet of commercial-grade bauxite at a depth of 151.5 feet. The area under discussion was originally investigated by drilling 104 holes on a triangular grid, most of them spaced about 200 feet apart. Later the U. S. Bureau of Mines drilled 115 holes between the others in order to delimit most of the ore by holes spaced about 100 feet apart.

Cross sections and several columnar sections along lines northeastward and northwestward through the Nutt–Bailey deposit appear on plate 24. The Nutt Extension and the east edge of the Nutt–Bailey deposits are also shown on this plate, which indicates their relation to part of the post-Midway surface and their position with respect to the nearby Rummel deposit.

The bauxite in the Nutt–Bailey ore body, like the Nutt Extension, a type 2 deposit, occurs as an irregularly shaped blanket, a large part of which occupies a southwestward-trending valley on the post-Midway erosion surface. Most of the ore body lies above Midway sediments that partly fill an earlier drainage channel cut into the weathered nepheline syenite surface. Within the 5-foot isopach the body is about 1,500 feet in length along a line oriented about N. 45° E.; the maximum width is about 1,200 feet. In the thick central part of the body, more than 30 feet of ore was recorded in 6 drill holes. The thickest ore was found in USBM drill hole 15–167B, in which 32.9 feet of low-silica pisolitic bauxite was cored.

The Nutt Extension ore body lies at a higher altitude on the weathered nepheline syenite surface, partly along the buried edge of the Midway sediments. It is broadly L-shaped, the long arm about 1,000 feet and trending N. 30° W., the short arm about 500 feet and trending N. 45° E. The thickest ore, 19.1 feet including a 2½-foot layer of high-silica bauxite 4½ feet below the top, was found in USBM drill hole 4–054A, where the two arms converge.

A section of the bauxite-kaolin zone and underlying sediments, with lithologic descriptions and chemical analyses, from USBM drill hole 19–192, drilled through a fairly thick part of the Nutt–Bailey deposit, has been given on page 123 in the discussion of type 2 deposits.

In the bottom of the subsurface valley is a debris of feldspar fragments in a white clay matrix believed to be mainly of Kincaid age, but at least the upper part of it is mixed in places with dark bluish-gray clay of the Wills Point formation. In several places, as shown in plate 24, the debris extends upslope beyond the edge of the overlying Wills Point, and just south of the deposit there is a small window of Kincaid debris in the post-Midway surface. The Wills Point is typically developed and the upper part was found to be weathered in all the drill holes that penetrated it. In the central part of the valley the weathered clay is khaki colored. The contact with the unweathered dark clay below is

sharp. The top part of the weathered zone is a banded, laminated or mottled, varicolored sideritic silty clay.

Between the soil profile on the post-Midway erosion surface and the overlying bauxitic rocks is a dark- to light-gray fragmental kaolinitic clay, which contains scattered pellets or aggregates of siderite, its lower part stained and mottled with red iron oxides. Fragments of the underlying laminated clay of Wills Point age are abundant at the base of this clay, and tan fragments of bauxitic clay and pisolitic bauxite are scattered locally near the top. The underclay has an average thickness of about 10 feet and grades into bauxitic clay above.

Nearly all the bauxite in the Nutt–Bailey and Nutt Extension deposits is pisolitic and distributed in the manner typical of type 2 deposits.

In the central part of the deposit, little matrix is present between the pisolites. The matrix present is formed chiefly of tan subspherical oolites, tightly packed between the much larger pisolites. This appears to be the highest grade of bauxite in the deposit, but in many places pore spaces are filled with crystalline siderite which lowers the grade considerably. This variety of ore thins out laterally and is not present along the edges of the ore body.

At the top of the bauxitic section in many drill holes there is as much as 2 feet of hard gray pisolitic bauxite high in silica content. Such a hardcap was not found in all the holes, but at least 1 or 2 feet of high-silica bauxite or bauxitic clay is always at the top of the deposit.

Between the bauxite and the overlying clastic sediments of the Wilcox group, 1 to 2 feet of kaolinitic clay overlies most of the deposit thickening along the fringes.

The overburden ranges from 158 to 310 feet in thickness. The Berger clastic and carbonaceous sediments above the bauxite-kaolin zone are 80 feet thick in some places. In others, particularly above more elevated parts of the nepheline syenite basement, the Saline formation rests directly on the bauxitic rocks. A basal hard black woody lignite bed 6 to 10 feet thick overlies most of the deposit. In one place the bed thins and is interlayered with gray silty clay, brown carbonaceous clay, and black clayey lignite. Nearby, lignitic clay is interbedded with the upper part of the bauxite-kaolin facies. A second lignite bed about the same thickness is 10 to 25 feet above the first and separated from it by gray to brown silty carbonaceous clay filled with lignite fragments and layers. The upper part of the Berger sediments is composed of gray to bluish-gray silty waxy clay, containing a few thin beds of fine-grained sand. Several beds of lignite and carbonaceous clay are also present.

The chocolate-brown clay member of the Saline formation ranges from 110 to 157 feet in thickness. The lower 50 to 60 feet is generally clayey and the upper part sandy. The basal contact of the formation, where seen in drill cores, truncates the horizontally laminated clay of Berger age at a slight angle. In one drill hole (USBM 3–238), a thin layer of bauxite and weathered feldspar fragments were recorded. The brown carbonaceous clay is interbedded with laminae, layers, and beds of loose sand and thin lignite layers. About 30 feet above the base is a 20-foot interval in which are layers of yellow, orange, or reddish-brown sandy clay. Hard siderite layers frequently cut in drilling have no definite stratigraphic position within this member

E. A. DIXON DEPOSIT

By Robert Schneider

Plate 25

The E. A. Dixon deposit (Malamphy and others, 1948, v. 7, p. 79–103, fig. 78) lies north of the Nutt–Bailey deposit from which it is separated by about 500 feet of low-grade or barren ground over a low buried southwestward-trending ridge of weathered nepheline syenite. Most of the deposit is in the S½SE¼ sec. 16, but it extends into the N½NE¼ sec. 21. It is on properties owned by D. B. Bates, E. A. Dixon, Mrs. G. P. Jackson, and Mike Sticka. Delimiting holes were drilled also on properties of Pauline Bates, M. P. Forster, Henry Forster, and E. E. Pitts. The ore was discovered in USBM drill hole 3–245, completed on June 31, 1943, in which was recorded 14.7 feet of bauxite of commercial grade at a depth of 245 feet. It was subsequently delimited by 70 drill holes.

The bauxite body within the 5-foot isopach is irregular in shape, elongate approximately N. 25° E., about 2,300 feet long and reaches a maximum of 700 feet in width. The ore is thickest in three places where small tributaries on the post-Midway erosion surface head westward off the nepheline syenite slope: The thickness was recorded as 36.8 feet in USBM drill hole 5–268; 34.2 feet in USBM drill hole 5–251A; and 27.9 feet in USBM drill hole 6–069A.

The alinement of the bauxite bodies, nearly parallel to the subsurface topographic features, is particularly striking in this area (pl. 25). The E. A. Dixon deposit lies along the steep east slope of a southwestward-trending valley, cut originally in the nepheline syenite surface. The valley has been partly filled by a rubble or debris of weathered nepheline syenite of probable Kincaid age. This is partly covered, particularly along the west side of the valley by dark-gray silty clay of the Wills Point formation. Where the debris forms part of the post-Midway surface, the upper part of it has been kaolinized to a fragmental clay, the fragments of which still retain the texture of the nepheline syenite detritus. This weathered debris wedges out along the

sides of the valley against residual kaolinized nepheline syenite. Its buried edge lies beneath the E. A. Dixon deposit (pl. 25), the southwest margin of which extends across the buried edge of the Wills Point formation.

Isopachs show that the three centers of maximum thickness of the ore each overlie abrupt changes in the slope of the main valley wall, just upslope from the edge of the debris. A cross section through the E. A. Dixon, Bates, and Kramer deposits is given in plate 25, section *B–B′*. The dip of the ore body along the line of the section is 5½° W. The greatest dip is in the central part of the body, 9° slightly north of west, nearly parallel to the line of the section.

The bauxite-kaolin zone, in the upper part of which the deposit occurs, reaches 50 feet in thickness locally, but averages about 24 feet. The underclay is composed of light-gray to gray, finely to coarsely fragmental kaolinitic clay which contains small siderite pellets and black ilmenite grains. Its thickness varies inversely with that of the bauxitic section above and averages 16 feet. Where it overlies kaolinized nepheline syenite it contains noticeably more and larger kaolin fragments than where it overlies the sediments of the Midway group. The lower part, which is generally stained and mottled brick red, reaches 15 feet in thickness and averages about 5 feet. The upper 2 to 3 feet contains small tan and orange bauxitic clay fragments similar to those near the base of the underclay.

The bauxitic sections reach 45 feet in thickness and average 13 feet. As much as 6 feet of sparingly pisolitic, fragmental bauxitic clay is at the base and as much as 3 feet of similar material is at the top. The bauxite in the deposit is mostly pisolitic, crudely layered or zoned in the manner typical of type 2 deposits.

Tiny black grains and blebs of ilmenite and anatase are scattered through the bauxite and small crystals of siderite and pyrite are found in some cavities.

The overclay is dark gray or brownish gray at the top and gray or light gray below. It contains relict pisolites, clay fragments, stringers of clayey lignite, and locally layers of woody lignite as much as 1½ feet thick. The overburden, including the bauxitic and kaolinitic clay above the ore, ranges from 164 to 289 feet in thickness and averages about 233 feet.

The Berger formation above the bauxite-kaolin zone ranges in thickness from 1 to 89 feet; thinnest in the northeasternmost upslope parts of the drilled area and thickest in the south-central part over the break in slope along the east margin of the buried subsurface valley (pl. 25). In most places a lignite bed is immediately above the bauxite-kaolin zone; in one drill hole, 21 feet thick. The lignite is interbedded locally with layers of gray kaolinitic clay. The upper part of the formation consists mainly of gray, bluish-gray, or green silty to sandy clay, in places carbonaceous, micaceous, or laminated. Sideritic siltstone layers, from less than 1 inch to 2 feet in thickness, are fairly common, in the greenish-gray clay beds. In places a thin lignite bed is at the top of the Berger.

The Saline formation has a minimum thickness of 131 feet, upslope on the basement ridge at the east-central margin of the deposit; it has a maximum thickness of 240 feet at the north end of the deposit over the break in slope mentioned above. The lower chocolate-brown clay member ranges in thickness from 17 to 125 feet. The upper part of the formation is variable. It is composed mostly of sand that grades laterally through clayey sand to sandy clay, and is interbedded with silty clay. Sands are tan, reddish-tan, or gray; clays are varicolored. Bluish-gray clay commonly contains layers of yellow clay and of lignite. Lignite generally is in thin layers, but beds as much as 10 feet thick occur. These sediments range in thickness from 45 to 180 feet. Comparison with sections in adjacent drill holes shows that the upper part of the chocolate-brown clay in places fingers laterally into the lower part of the sand and variegated clay facies.

HARRISON DEPOSIT

By Robert A. Harris

Plate 25

The main part of the Harrison deposit (Malamphy and others, 1948, v. 7, p. 43–52, fig. 75) is in the NE¼SE¼ sec. 16 but it extends into parts of the NW¼SW¼ and the SE¼NE¼ sec. 16. It is located on property owned by Pauline Bates, A. M. Carter, Henry Forster, Mrs. Clara Harrison, and J. S. Laird and can be reached from Highway 167 via the Ironton road, slightly more than a mile from their junction.

The bauxite was discovered in USBM drill hole 5–008, drilled September 2, 1942 and redrilled in May 1944 as USBM drill hole 5–276, in which was recorded 5.9 feet of ore at a depth of 181 feet. The body was delimited by drilling 30 holes.

The basement rock in this area is nepheline syenite, but because fresh samples were not secured it could not be determined whether the rock is the typical variety or pulaskite. The nearest outcrop, a quarter of a mile to the north, is pulaskite. The upper part of the nepheline syenite is weathered to a residual kaolinitic clay to depths as great as 72 feet, but generally averages 25 to 30 feet. The bauxite lies on a steep slope down to the change in grade at the base, along the northwest flank of the prominent buried valley that drained southwestward in early Eocene time.

Part of it rests on nepheline syenite detritus of probable Kincaid age that has partly filled the valley (pl. 25). A cross section through the Harrison and South Heckler deposits, together with columnar sections, appears in plate 25, section *A–A′*.

The ore body, a type 2 deposit, is elongate northeast with a prominent lobe projecting westward from its northern part, making it appear hatchet-shaped. The length within the 5-foot isopach is about 950 feet along a line oriented N. 30° E.; the greatest width reaches nearly 700 feet. Two major swells in the ore body are shown by isopach lines in plate 25. The thickest ore was recorded in the northern swell, 22.6 feet of pisolitic bauxite in USBM drill hole 6–108. The ore body is lenticular in cross section and thins out abruptly against the nepheline syenite ridge to the north and northwest. It is limited along the south edge by a stream channel of Berger age, filled with gray laminated silty clay. The dip of the main part of the ore body is 11½° SE., the steepest yet recorded for a type 2 deposit.

The rocks of the bauxite-kaolin zone average about 41 feet in thickness. Overlying the residual kaolinized nepheline syenite or the debris is a gray and white fragmental kaolinitic clay, with an average thickness of 14.6 feet. The upper part of this underclay is slightly bauxitic and beneath the ore body it grades upward into bauxitic clay.

Most of the bauxite in the ore body is pisolitic. The matrix ranges from grayish-tan to deep tan in color and most of it is mealy to earthy; locally it is oolitic. Siderite occurs in scattered grains, tiny veinlets, and botryoidal coatings in cavities. In some places it is very finely disseminated through the matrix.

The matrix in places contains scattered veinlets of hard secondary kaolinite, particularly in the upper part of the bauxite. The upper part of the bauxite is indurated in some places, but frequently where the silica content is moderate. Some of the high-silica parts at the top of the body are soft. Thus, a typical high-silica hardcap appears to be lacking. The bauxite is overlain in places by kaolinitic clay, in others by a lignite bed, which locally contains a basal conglomerate of rounded bauxitic pebbles.

The overburden ranges in thickness from 114 to 312 feet and averages about 212 feet.

The thickness of the Berger formation in the drilled area ranges from 15 to 101 feet, increasing southeastward, and averages 41 feet. A prominent lignite bed is generally on top of the bauxite-kaolin zone and attains a thickness of 21 feet in the northeastern part of the area. Toward the south the formation is cut out by channeling. Green and gray silty micaceous clay is common in the Berger formation and locally contains hard layers of sideritic siltstone. Dark-gray laminated clay fills a channel at the south end of the deposit, which is roughly alined with a similar channel over the Kramer deposit on the west side of the ridge.

The chocolate-brown to light-brown silty to sandy carbonaceous clay of the Saline formation ranges from 34 to 189 feet in thickness and averages 69 feet. It is interlayered with lignite seams and gray to brown clay or sand; in one place a thin bed of tan and pink sandy clay was noted. The upper part of the Saline formation ranges from 46 to 195 feet in thickness and consists of varicolored clay, including light tan, light gray, white, pink, and red tones, dark-gray sticky carbonaceous clay with lignite layers, and a little brown sand. The distribution of these beds is erratic.

HUBBARD DEPOSIT

Plate 25

The Hubbard deposit (Malamphy and others, 1948, v. 7, p. 53–67, fig. 76) is a small deposit several hundred feet southwest of the Harrison and about 500 feet northwest of the East Dixon deposit. It is in the SE¼NW¼SE¼ and the N½ SW¼SE¼ sec. 16, on properties of W. E. Hubbard and Mike Sticka. It was discovered in USBM drill hole 3–243, completed June 30, 1943, which recorded 3.9 feet of bauxite on the Sticka property at a depth of 268 feet. Subsequently, 31 additional holes were drilled to delimit this body.

The Hubbard deposit lies on the northwest slope of a prominent southwestward-trending valley on the post-Midway surface (pl. 25). It is in line with the Harrison and Bates deposits, all of which are on the opposite side of the subsurface valley from the East Dixon deposits. The bauxite lies along the buried edge of the Wills Point formation where it wedges out against a debris of nepheline syenite rocks, probably of Kincaid age. It is a type 2 deposit, formed within the bauxite-kaolin zone. As it has no obvious relation to any small valleys in the post-Midway surface but lies high on the slope, it apparently was formed chiefly by residual weathering of surface debris above the water table.

The ore body within the 5-foot isopach is northeasterly elongate; the long axis is about 1,100 feet long, and the body is about 300 feet wide at its widest point. The thickest ore, 13.9 feet, was recorded in USBM drill hole 20–088, near the northeast end of the body. A short lobe of thin ore at the southwest end extends northwestward in the shape of a hook. The bauxite and surrounding clay are lithologically similar in section to the nearby deposits. The ore body contains an

average of 12 percent silica, and 2 percent ferrous iron within the 5-foot isopach. Bauxite and kaolinitic clay as much as 3 feet thick overlie the bauxite and form the upper part of the bauxite-kaolin zone. The overburden of the Wilcox sediments including the clay ranges from 230 to 284 feet in thickness and averages about 260 feet.

BATES DEPOSIT

Plate 25

The Bates deposit (Malamphy and others, 1948, v. 7, p. 104–122, fig. 79) is in the SW¼SE¼ and the SE¼SW¼ sec. 16 and extends into the NW¼NE¼ and NE¼NW¼ sec. 21. It is on properties owned by Will Bailey, D. B. Bates, Mrs. M. E. Hope, and Mike Sticka and can be reached by gravel road from Highway 167. The bauxite was discovered in USBM drill hole 3–244, completed in July 1943. This was redrilled as USBM drill hole 6–102 in which was recorded 6.3 feet of bauxitic ore at a depth of 277.5 feet. The deposit was delimited by 63 drill holes.

Within the 5-foot isopach the Bates deposit is almost 2,000 feet long on a line oriented about N. 25° E. and it is about 450 feet wide at the widest part. Ore more than 8 feet thick lies in three separate patches associated with small lateral drainage channels on the post-Midway erosion surface. The deposit lies on the northwest side of the long southwestward-trending subsurface valley which also contains the E. A. Dixon, Harrison, and Hubbard deposits (pl. 25). A cross section and columnar sections through the Bates, Kramer, and E. A. Dixon deposits, shown in plate 25, section *B–B′*, dips about 5° to the southeast. Most of the ore overlies the surface of the Wills Point formation, but the north part follows the buried edge of the formation where it wedges out against the nepheline syenite debris of probable Kincaid age. The Wills Point reaches a thickness of 48 feet at the south end of the deposit and overlies gray clay and weathered syenite debris probably as much as 50 feet thick. The top of the Wills Point formation is light- or khaki-colored where weathered.

The bauxite in this type 2 deposit is mostly pisolitic but in places the lower part has a fragmental texture. Most of it has a low ferrous iron content except at the base of the ore where it is highly sideritic.

The bauxite is overlain by bauxitic and kaolinitic clay as much as 12 feet thick which forms the upper part of the bauxite-kaolin zone. The overburden, which includes this clay, ranges from 233 to 349 feet in thickness and averages about 279 feet. It is composed of Wilcox sediments similar to those overlying the nearby E. A. Dixon and Kramer deposits.

KRAMER AND KRAMER EXTENSION DEPOSITS

By Robert Schneider

Plate 25

These two deposits lie in a line southwest of the South Heckler deposit in the SW¼ sec. 16. The Kramer deposit (Malamphy and others, 1948, v. 7, p. 63–80, fig. 77) is on properties of W. E. Hubbard, A. H. Jennings, and A. M. Jennings, John and Ollie Kramer, and J. S. Laird. The smaller Kramer extension (Malamphy and others, 1948, v. 7, p. 123–131, fig. 80), southwest of and deeper than the Kramer deposit, is on properties owned by A. E. Connerly, L. E. La Pierre, Will Bayley, F. O. Clark, and Myrtis Moore. They are easily reached by a gravel road that joins Highway 167 on the east, about three-eighths of a mile south of the road entering Jennings Lake. The Kramer deposit was discovered when USBM drill hole 3–241 was completed on June 22, 1943 and recorded 11.2 feet of commercial bauxite. The two deposits were investigated by 83 drill holes.

The Kramer deposit is hook shaped in outline and lenticular in cross section. Its long axis within the 5-foot isopach is 1,700 feet long; it is about 400 feet wide near the south end and about 100 feet wide near the north end. At the southwest corner a lobe of ore extends westward about 400 feet. The deposit trends about N. 35° E., the central part dips about 5° due west. The Kramer extension lies about 600 feet southwest of the main body. It is subtriangular in shape, slightly more than 600 feet long and 400 feet wide at its widest part, elongate north-northwest, and it dips 4½° southwest.

The deposits lie on the west slope of a buried southwestward-trending ridge of weathered nepheline syenite which is partly overlapped by sediments of the Midway group (pl. 25). Both deposits are in the bauxite-kaolin zone which rests on the Midway sediments, but the northeast end of the Kramer deposit extends upslope beyond the buried edge of the Midway sediments and lies above weathered nepheline syenite. A cross section through the Kramer, Bates, and E. A. Dixon deposits appears on plate 25, section *B–B′*.

From a feather edge near the northeast end of the Kramer deposit the Wills Point formation thickens to about 50 feet at the south end of the same deposit, and is 87 feet thick in USBM drill hole 1–258, south of the Kramer extension. The Kincaid formation is composed of interbedded green and dark-gray clay and sandy limestone, 35 feet thick in the same drill hole, which overlies a weathered nepheline syenite debris as much as 50 feet thick.

Most of the bauxite is pisolitic, the pisolites making

up the major part of the rock. They range in size from ⅛ to 1¼ inches in places. Tan and orange fragments of bauxite and rarely of gray kaolinitic clay are found in the lower parts of both ore bodies.

Impurities in the rock include white to gray kaolinitic and brownish granular siderite. The silica content is lowest in the central part of the deposit and gradually higher toward the margins. Distribution of the siderite is erratic. The Kramer deposit contains an average of 8 percent silica where it is 8 feet or more thick; where it is between 5 and 8 feet thick it contains an average of 11 percent silica. The entire ore body within the 5-foot isopach averages 10 percent silica and 3 percent ferrous iron. The average silica and iron content for the Kramer extension deposit have not been determined. Bauxitic and kaolinitic clay as much as 12 feet thick above the Kramer deposit and 4 feet thick above the Kramer extension deposit overlies the bauxite and forms the upper part of bauxite-kaolin zone. The overburden of Wilcox sediments ranges from 198 to 295 feet and averages 250 feet above the Kramer deposit. It ranges from 316 to 378 and averages 340 feet above the Kramer extension deposit.

SOUTH HECKLER DEPOSIT

Plate 25

The South Heckler deposit (Malamphy and others, 1948, v. 7, p. 21–29, fig. 73) is in the SW¼NE¼ and the NW¼SE¼ sec. 16 on properties owned by C. E. Heckler and J. S. Laird. This deposit is a few hundred feet west of the Ironton road, at the corner about a mile south of its junction with Highway 167, where the road turns east toward Ironton. The land surface here is rolling and mostly wooded. The bauxite body was discovered in USBM drill hole 1–095. In a nearby drill hole (USBM 3–125) 6.7 feet of commercial-grade pisolitic bauxite was recorded at a depth of 150 feet. The deposit was investigated by 29 drill holes.

Within the 5-foot isopach the ore body is slightly more than 1,000 feet long and is nearly 350 feet wide across the northern part. It is elliptically keyhole shaped and elongate about N. 20° E. The ore is concentrated in two swells near the northeast and southwest extremities of the deposit. The deposit is on the opposite side of a narrow southwestward-trending subsurface ridge from the Harrison deposit (pl. 25). A cross section and columnar sections through this and the Harrison deposit appear in plate 25, section *A–A′*. The maximum dip just north of the line of the section is about 11° to the west-northwest. It lies along the east slope of the buried valley west of the ridge, northeast of and in line with the Kramer deposit. Its attitude is unusual in that the deep end is toward the head of the valley. The deposit is truncated at the north end by a channel of Berger age filled with a debris of kaolinitic nepheline syenite, gray silty clay, and carbonaceous clay, which in part follows the trend of an earlier lateral valley on the post-Midway surface.

The bauxite-kaolin zone which includes the deposit ranges in thickness from 6 to more than 37 feet. It rests directly on the weathered surface of the nepheline syenite, but a small outlier of the Wills Point formation overlying weathered nepheline syenite debris was recorded in drill holes at the south end of the deposit. It is thinnest along the upslope and downslope margins of the deposit and at the north end where it has been eroded, and it is thickest over small lateral subsurface valleys. The lower part of this zone is composed of the typical light gray kaolinitic sideritic fragmental underclay.

The bauxite is mostly pisolitic, tan or grayish-tan, well indurated in the upper part and soft and crumbly below. In a few places it overlies bauxitic clay with few or no pisolites; in USBM drill hole 3–125 the pisolitic bauxite and bauxitic clay overlie pisolitic kaolin. The thickest ore, 18.5 feet of pisolitic bauxite, was recorded in USBM drill hole 3–129B. The silica content has a moderately low average for the entire body; it is lowest in the central part and increases gradually toward the margins, as well as upward and downward. The ferrous iron content is average for a Pulaski County deposit, the siderite being distributed irregularly through the ore, but generally more concentrated in the middle and lower parts.

Bauxitic and kaolinitic clay as much as 6 feet thick overlies the bauxite in places and forms the upper part of the bauxite-kaolin zone. The overburden of Wilcox sediments, including the overclay, ranges from 108 to 150 feet thick above the ore and averages about 125 feet.

The thickness of the Berger formation ranges from about 9 to 57 feet. Irregularity in the thickness as recorded in the drill holes indicates that the Berger was channeled before deposition of the Saline formation. It is composed of massive lignite and lignitic clay interbedded with some gray silty clay or fine sand. The Saline formation ranges from 77 to 157 feet in thickness. Most of it is composed of the typical brown carbonaceous clay which locally is interbedded with yellow sand or sandy clay and cream, grayish-tan, gray, or reddish-brown silty clay. At the top, 9 to 66 feet, but generally less than 20 feet, of varicolored sand, is associated with clay, silt, or gravel.

JENNINGS DEPOSIT

Plate 25

Two small bauxite bodies occur in the S½NW¼ and the northern part of the NE¼SW¼ sec. 16, at the north edge of and northeast of Jennings Lake and west of the South Heckler deposit. These constitute the Jennings deposit (Malamphy and others, 1948, v. 7, p. 30–42, fig. 74) and are on properties of A. H. and A. M. Jennings, John and Mrs. Ollie Kramer, and the Daniel and Bettie Rauch Estate. The area was investigated by drilling 40 holes in several groups.

The bauxite occurrences are too small to be of commercial interest, but they are geologically noteworthy because they follow the pattern of distribution with relation to subsurface topography of the nearby type 2 deposits. The two ore bodies lie on either side of a southwestward-trending narrow buried ridge of weathered nepheline syenite. The ore body on the east slope of this ridge is shown in plate 25. It exceeds 5 feet in thickness only in USBM drill hole 18–203 in which was recorded 6.9 feet of pisolitic bauxite of ore grade at a depth of 223.5 feet. In USBM drill hole 18–282, 400 feet to the northeast, about 8 feet of high-silica tan pebbly pisolitic bauxite is separated by 3.7 feet of brown pebbly carbonaceous clay from several feet of pisolitic high-silica bauxite and bauxitic clay beneath. This small type 3 deposit above the carbonaceous clay also is indicated on plate 25; it was not delimited by drilling and may continue northward. The ore body on the west side of the buried ridge beneath the north end of Jennings Lake (pl. 25) lies in the bauxite-kaolin zone, above the weathered surface of the Wills Point formation near its upslope edge where the marine sediments wedge out against the nepheline syenite ridge. Bauxite of ore grade exceeds 5 feet in thickness in USBM drill holes 18–096A and 18–281, which are 400 feet apart along a line trending N. 26° E. The top of the bauxite in these two drill holes is 182 and 185 feet below the surface of the ground.

Bauxitic and kaolinitic clay as much as 14 feet thick overlies the bauxite bodies and makes up the lower part of the overburden. The upper part is composed of continental sediments of the Berger and Saline formations, similar to those overlying the South Heckler deposit.

BERGER AREA

The group of deposits described below lies on the SW¼ sec. 4, E½ sec. 8, W½ sec. 9, and NW¼ sec. 16, T. 1 S., R. 12 W. (fig. 58). They are all south of the settlement of Berger on the Chicago, Rock Island, and Pacific Railroad.

The deposits are on the west slope of the Pulaski nepheline syenite mass along the southern part of its outcrop area. The basement rocks are nepheline syenite, both the typical variety and the variety known as pulaskite. These are covered by marine sediments of the Midway group. Several of the larger deposits lie on a nepheline syenite slope just west of the contact between nepheline syenite and pulaskite. Many smaller deposits are scattered over the surface of the Midway sediments, and some are on the west slope of the major drainage system that in early Eocene time flowed southward.

The presence of bauxite in this area has been known for many years. Outcrops were described by early workers, including Powell (1842, p. 21) and D. D. Owen (1860, p. 70). The first mine in the Pulaski district at the northernmost of the four outcrops in this area was opened by Fred Berger in 1904 (pl. 1, no. 44). Further mining was done by the Republic Mining and Manufacturing Co. after 1906 at intermittent periods. Since 1931 mining has been continuous by the American Cyanamid and Chemical Corp. and by several other companies.

The work of the Federal drilling program in this area was mainly to supplement the prospecting already done by companies. The drilling of the Rauch Extension falls into this category. Also, several small new deposits were discovered in sec. 8, some distance west of the previously known deposits.

NORTH HECKLER DEPOSIT

Plate 25

The North Heckler deposit (Malamphy and others, 1948, v. 7, p. 11–20, fig. 72) is in the SE¼SW¼ sec. 9 and the NE¼NW¼ sec. 16, T. 1 S., R. 12 W. on property owned by C. E. Heckler. It is about 7 miles south of Little Rock and half a mile east of Highway 167 by gravel road. Drilling by the American Cyanamid and Chemical Corp. during the 1930's had led to the opening of the Heckler shaft mine (pl. 1, no. 35) by the company in the northernmost part of the property and at the south end of the West Rauch bauxite deposit. The much smaller North Heckler deposit was first cut in USBM drill hole 1–105, redrilled as USBM 1–173, in which several feet of siliceous pisolitic bauxitic rock was found at a depth of about 108 feet below the surface. A total of 37 holes was drilled to investigate this deposit.

The deposit consists of two small ore bodies connected by low-grade bauxite and high-alumina clay. They overlie a fairly steep slope on the buried nepheline syenite surface and dip westward. The thickest parts of the ore bodies are in small gullies that trend westward and northwestward on the post-Midway erosion surface (pl. 25).

The basement rock is nepheline syenite, the upper surface of which has been weathered to a residual kaolinitic clay. The clay mantle is thickest in the valleys where it reaches a maximum thickness of 75 feet. Weathered debris of the basement rock fills parts of the valleys above the residual kaolinized nepheline syenite. The rocks of the bauxite-kaolin zone range in thickness from 16 to 33 feet. Light-gray to bluish-gray sideritic fragmental clay, ranging from 4 to 33 feet in thickness, underlies the bauxitic rocks and locally fills the entire interval. Locally, it is overlain by gray pisolitic kaolin, which underlies the bauxite in part of the area and reaches a maximum thickness of 17 feet.

Most of the ore is pisolitic, gray to grayish-tan, fairly high in silica, and the upper part generally is well indurated. The bauxite has a maximum thickness of 21 feet in USBM drill hole 3–123. Some intervals in the upper part contain clay fragments and layers of carbonaceous clay which indicate reworking. The bauxite grades upward and downward into tannish-gray bauxitic clay. Above the bauxitic rock, is a thin light-gray kaolinitic clay, which becomes somewhat silty and plastic in the upper part. It was recorded in half the drill holes and reaches a maximum thickness of 2 feet.

The overburden consists of continental beds of the Wilcox group that range in thickness from 70 to 115 feet and average about 100 feet. In the lower part of the overburden are carbonaceous and clastic beds of the Berger formation, including 1 to 15 feet of lignite and lignitic clay overlain by as much as 23 feet of light-bluish gray, slightly carbonaceous silty clay, containing thin beds of hard, fine-grained sandstone. The silty clay is absent over the south part of the deposit. The lower member of the Saline formation consists of 57 to 86 feet of dark chocolate-brown silty clay, interbedded with gray and brownish-gray silty clay. These clay beds are micaceous and carbonaceous with local sandy and lignitic layers. The upper part of the overburden is composed of yellowish-brown silty sand and gray sandy clay with red stains, ranging from 4 to 19 feet in thickness. Thin interbedded gravel lenses containing pebbles of chert and quartzite occur in the eastern part of the area.

WEST RAUCH DEPOSIT

Plate 2

One of the largest bauxite bodies in the Pulaski mining district occupies part of the E½NW¼ and E½SW¼ sec. 9. It is on properties of the Alcoa Mining Co., C. E. Heckler, and the Rauch Estate (leased by the American Cyanamid and Chemical Corp.). The deposit crops out at the surface in several places along its east side. It was explored and developed by several mining companies. A small area near the middle of the deposit on the Daniel Rauch property (Malamphy and others, 1948, v. 6, p. 14–16, fig. 61) was drilled by the Federal Government in order to facilitate the development of ore suitable for use in petroleum refining.

The West Rauch deposit is northerly elongate and irregular in outline within the 5-foot isopach. The main ore body is continuous for about 3,500 feet. The northern part on the Alcoa property and the south-central part on the Rauch Estate property both are about 900 feet wide, but in between, in the part investigated by the joint Federal project, the ore narrows to about 300 feet wide. In the southern part of the Rauch Estate property the bauxite is divided into two lobes, the deeper of which, extending farther south, was mined in the Heckler shaft mine (pl. 1, no. 35). A small, separate subtriangular body on the Heckler property is in the southeast end of the deposit. Within the 5-foot isopach it is about 450 feet from north to south and 250 feet across. The general dip of the ore is westerly—3° on the average in the area of Federal drilling; and locally dips more than 10°. In the northern part of the deposit the ore ranges in thickness from about 8 to 13 feet. In the southern part it reaches 22 feet in many places and is thickest near the shaft of the Rauch mine where 32 feet of ore was recorded in a drill hole of the American Cyanamid and Chemical Corp.

The deposit is within the bauxite-kaolin zone, the lower part of which is a white to greenish-white fragmental clay which rests upon kaolinized nepheline syenite, a short distance upslope from the buried edge of the Wills Point formation. The west edge of the body nearly coincides with the change in grade between the Wills Point surface and the more steeply dipping nepheline syenite surface. The principal igneous rock outcrop several hundred feet east of the deposit is composed of pulaskite but, as gray nepheline syenite was noted in the drainage ditch at the side of the access road to the Rauch Estate pit mine, it is believed that the deposit rests largely on this rock rather than pulaskite.

Most of the ore is light tannish-gray hard or moderately hard pisolitic bauxite, but a small amount of softer fragmental or poorly pisolitic bauxite is in the lower part of the body. A large granitic-textured mass surrounded by pisolitic bauxite was noted in the Rauch Estate pit and is probably a remnant of an earlier type 1 deposit. An upper bed of bauxite rubble lay above the pisolitic bauxite in the central part of the deposit, locally separated from it by a bed of pisolitic clay, 2 to 3 feet thick. The rubble included both pisolitic and granitic-textured boulders. At the northeast end of the Federal-explored area (in USBM drill hole 2–061 and a nearby company drill hole) the upper part of the

bauxite was overlain and mixed with a large amount of quartzitic gravel, presumably in a stream channel.

The overburden ranges from several inches to about 135 feet in thickness. It is deepest along the west-central margin. Most of the northern part is shallow, not more than 50 feet deep. The small separate triangular body on the Heckler property ranges from 10 to 55 feet in depth and is shallowest at the southeast end. Gray and green silty clay or lignite of the Berger formation underlain by bauxitic clay covers the deeper parts of the deposit. Along the upslope margins the Berger is overlapped by the Saline formation. The Saline sediments consist of a small amount of brown carbonaceous clay and a large amount of white or light-gray locally micaceous sand. Apparently interbedded with this sand of Saline age, one or two layers of chert pebbles were noted, some of which contain fusulinids and other fossils of Paleozoic age.

Heckler shaft mine (pl. 1, no. 35).—The southern part of the deposit that extends onto the Heckler property was developed in 1939 by the American Cyanamid and Chemical Corp. After 18 holes had been drilled in the main deposit, a shaft was sunk. Mining operations continued until 1945. The overburden in this part of the deposit ranges in thickness from 58 to 120 feet, increasing to the west-northwest.

Rauch shaft mine (pl. 1, no. 36).—The thickest and deepest parts of the deposit were the first to be developed by the American Cyanamid and Chemical Corp. This mine, in the W½NE¼SW¼ sec. 9, was opened in October 1934. A 134-foot shaft was sunk where the overburden is 96 feet thick and the ore is 20 to 30 feet thick. The mine operated until 1943 when an extensive open-pit operation was begun in the area east of the underground workings. The overburden in the underground area ranged in thickness from about 35 to 135 feet increasing to the southwest.

Rauch Estate open-pit mine (pl. 1, no. 38).—The shallower ore, mostly in the E½NE¼SW¼ sec. 9 was mined by means of a group of open pits. The overburden in this part of the deposit ranges from several inches to 68 feet. Exploitation of this part of the deposit began late in 1942, and mining continued until 1945.

Rauch Extension open-pit mine (pl. 1, no. 39).—The north end of the deposit was owned by the Alcoa Mining Co. The ore had been known for a long time, and test pits had been dug about the time of World War I by the company. During World War II bauxite from this deposit was mined and used for producing activated bauxite used in the manufacture of high-octane gasoline. At this time about 70 holes were drilled by Republic Mining and Manufacturing Co. to delimit the ore body and in 1944 American Cyanamid and Chemical Corp. exploited an extensive open-pit mine.

The overburden on this property ranges from several inches to 97 feet.

PETER ROU DEPOSIT

Plate 2

The small Peter Rou deposit (Malamphy and others, 1948, v. 6, p. 17–25, fig. 62) was investigated and partly delimited in the S½NW¼SW¼ and adjacent parts of the SW¼SW¼ sec. 9, T. 1 S., R. 12 W., west of Highway 167. A total of 27 holes were drilled on the properties of D. H. Ford and G. D. Rauch, but the southeastern part of the deposit on the property of Peter Rou was not delimited. Bauxite was discovered in USBM drill hole 3–298, in which was recorded 4.4 feet of low-grade ore at a depth of 161 feet.

The deposit rests on the flat weathered surface of the Wills Point formation along the southeast crown of a low, buried southwestward-trending ridge. The Wills Point formation was penetrated in two drill holes on the Ford property; it was 79 feet thick in USBM drill hole 1–305, and 48 feet thick in USBM drill hole 3–298. The bauxite is separated from the Wills Point sediments below by a fragmental kaolinitic clay, as much as 18 feet thick, which grades upward through bauxitic clay into the ore.

The bauxite body is narrowly elongate; it extends within the 5-foot isopach at least 900 feet along a line oriented about N. 50° E., and its maximum width does not exceed 250 feet. It dips 1½° to the southwest. The greatest thickness of ore recorded was 10.3 feet in USBM drill hole 17–131, and this was the only drill hole in which the ore exceeds 8 feet in thickness. The body is a typical type 2 deposit, composed mostly of pisolitic bauxite. Fragmental bauxite occurs in places below the pisolitic, and in one drill hole was found above the pisolitic bauxite.

The overburden ranges from 144 to 164 feet in thickness above ore that is 5 feet or more thick. The clastic and carbonaceous sediments of the Berger formation in the drilled area range from 80 to 100 feet in thickness, increasing northward. The sand and chocolate-brown carbonaceous clay beds of the Saline formation range in total thickness from 54 to 80 feet, increasing southwestward.

WINN DEPOSIT

Plate 2

This deposit is in the SW¼NW¼ sec. 9, T. 1 S., R. 12 W. on the property of C. R. Winn just west of Highway 167. Early drilling by the Republic Mining and Manufacturing Co. found bauxite on this tract, but the deposit was not delimited at that time. The

Aluminite Mining Corp. drilled 29 holes on the property, east of Fourche Creek and southeast of the Big Inch pipeline, before opening a strip mine.

The ore body is a type 2 deposit developed in the bauxite-kaolin zone, which at this locality lies above the Wills Point formation. USBM drill hole 20–048, at the southwest corner of the Winn tract, recorded a thickness of 66 feet in the Wills Point and a thickness of 63 feet in the underlying Kincaid formation. The bauxite lies on the east side of a buried southwestward-trending drainage system, downslope from the West Rauch deposit (pl. 2).

The ore body is estimated from company drilling information to be nearly 800 feet long from north to south within the 5-foot cutoff, and about 400 feet wide. It was not, however, completely delimited by drilling at the south end. The ore body is elliptical in outline, northerly elongate, and lenticular in cross section. It dips about 2° to the southwest. Most of the ore mined was pisolitic, the upper part covered by a siliceous bauxite capping which was directly overlain by a thick lignite bed that contains two or three clay layers.

The overburden ranges from 63 to 87 feet in thickness, including the bauxitic clay capping and the lignite mentioned above. It is composed mostly of the sediments of the Berger formation, the thickest of which is a greenish-gray clayey sand containing angular erratic boulders of similar sand and stratified sandy clay. A typical section of the overburden is shown in figure 8.

Winn open-pit mine (pl. 1, no. 40).—An open pit, about 500 feet long by as much as 300 feet wide, was excavated in this deposit. The bauxite was 72 to 86 feet deep within the pit area. Along the south end of the workings several drifts less than 20 feet long were driven to mine additional ore.

Mining operations began in the fall of 1943 and continued from June to November 1944, when the mine was closed and the property returned to the owners.

DOLLAR DEPOSIT

Plate 2

The Sam J. Lewis lease on the W. C. Dollar property in the S½NW¼NW¼ sec. 9, T. 1 S., R. 12 W. was drilled by several operating and drilling companies before World War II but was not developed until the war emergency. The Bauxite Drilling and Testing Co. in 1943 drilled 18 holes to delimit the ore on the property for the Aluminite Mining Corp.

The ore body mined on this property was about 600 feet long alined easterly, and 125–225 feet wide. Drilling information indicates that the ore body dips about 5° to the west. The thickest ore recorded in the company drill holes was 16 feet, in the northeastern part of the mined area. Projection of the buried edge of the Wills Point formation on the map (pl. 2) indicates that the bauxite probably rests above the sediments of Paleocene age at their upslope edge.

Before stripping, the overburden ranged in thickness from 15 to 63 feet above the ore.

Dollar open-pit mine (pl. 1, no. 41).—The stripping was completed and the mine started operating in September 1943. About the time that the Aluminite Mining Corp. started working this property, it went into the hands of receivers who operated the open-pit mine. The mine was operated until November 15, 1944 when the Metals Reserve Company canceled its contracts with many wartime producers.

LEWIS DEPOSIT

Plate 2

In the N½NW¼NW¼ sec. 9, T. 1 S., R. 12 W., drilling near the present site of the plant and offices of the American Cyanamid and Chemical Corp. by the company disclosed a bauxite body that apparently is a south-southeastward continuation of the England deposit on the adjacent 40-acre tract to the north. According to available drilling records bauxite of minable thickness apparently is found in an ore body irregularly elliptical, with maximum dimensions about 600 by 400 feet, and as much as 14 feet thick. Information as to the grade of the bauxite is not available to the writers.

The deposit is reported to be 12 to 50 feet below the surface.

ENGLAND AND BERGER DEPOSITS

Plate 2

The northernmost bauxite deposits in the Berger area are in the W½SW¼ sec. 4, T. 1 S., R. 12 W., on the England property. Pisolitic bauxite crops out extensively in this tract, a short distance west of the Arch Street Pike (Highway 167). The road skirts the west side of the pulaskite outcrop area. The Chicago, Rock Island, and Pacific Railroad cuts through the northwest corner of the area; the Berger switch gave access to the old workings, and now serves the plant and offices of the American Cyanamid and Chemical Corp. and the Porocel Corp. at the south end of the property. Three or four separate ore bodies are on this tract, all of which have been mined. The Federal Government undertook no exploration of the area and all information regarding these ore bodies has come from company sources.

The deposits lie on the west flank of the nepheline syenite, east of a major southward-trending subsurface valley (pl. 2). The largest and southeasternmost body, the England deposit, was the site of an underground

mine operated by the Crouch Mining Co. (pl. 1, no. 42). Before mining, the ore body was more than 1,000 feet long within the 5-foot isopach, from the north end to the south line of the property, and in places it reached 600 feet in width. The thickest ore recorded in company drill holes was 18 feet, in the north-central part of the ore body. It probably is connected by thinner and lower grade bauxite to the Lewis deposit, which is within 200 feet of the south property line, to the south-southeast. The comparatively shallow westerly dip of the ore body (3½°), together with lithologic information from other company drill holes nearby on adjacent properties, indicates that it overlies the Wills Point surface.

The second largest and northernmost body, the Berger deposit, was the site of the original Fred Berger mine (pl. 1, no. 44), the first bauxite working in the Pulaski mining district. All the ore is shallow and much of it crops out at the surface. The maximum dimensions of the minable ore body were 800–900 feet long, and as much as 600 feet wide in places. The ore reached a maximum recorded thickness of 16 feet and dipped shallowly to the west-southwest. The deposit probably lies across the buried edge of the Wills Point formation which crops out northwestward from the mine, across the Fourche Creek bottom.

The remaining ore on the property was mostly in the southern part of the outcrop area, west of the highway and east of the underground mine. The deepest ore was covered by only a few feet of overburden.

The deposits are all composed principally of pisolitic bauxite and probably are confined to type 2, judging from samples collected from outcrops and dumps on the England property. They represent the northernmost extension of the bauxite-kaolin zone on the west side of the Pulaski nepheline syenite hill.

The overburden in this tract is composed mainly of sand, gravel, and clay, but some lignite was reported in the southwest corner of the property, above the bauxite in the England shaft mine.

England shaft mine (pl. 1, no. 42).—The England deposit in the W½SW¼SW¼ sec. 4, T. 1 S., R. 12 W., was worked by the Crouch Mining Co. Before mining, the company drilled about 25 holes on the England property to delimit the ore. The minable bauxite in this deposit was covered by 25 to 63 feet of overburden. A vertical shaft 63 feet deep was sunk, from which workings covering an area of 10 acres or more were developed. The company erected a calciner on the property. Mining began in November 1931 and continued periodically until 1940, when the mine was abandoned, the equipment removed, and the company transferred mining operations to the Young shaft mine in Saline County.

Berger open-pit mine (pl. 1, no. 44).—Fred Berger opened this mine in the outcrop of the north ore bed in 1904. After producing slightly more than 5,600 tons from 1904 to 1906 for the manufacture of refractory brick from calcined bauxite, Berger sold the property to the Republic Mining and Manufacturing Co. of Georgia. Mining is reported to have continued with interruption until about 1919. By the time the Berger pit was abandoned, it had attained the dimensions of about 400 by 600 feet. So far as is known, none of the ore in this working was covered by more than 10 feet of overburden. This same pit was referred to as the North England mine in a preliminary map of the bauxite region (Bryson, Gordon, and others, 1944).

England outcrop open-pit mine (pl. 1, no. 43).—During World War II the England property was leased by the American Cyanamid and Chemical Corp., and most of the shallow bauxite that remained was removed in 1943. The principal operation was in a small pit west of the highway and northeast of the underground mine. This ore was all within a few feet of the surface. The property was returned to the owners in July 1945.

ELSIE LEWIS DEPOSIT

Plate 2

A small deposit is known on the Elsie Lewis property, in the NE¼NE¼ sec. 8, T. 1 S., R. 12 W. The tract had previously been drilled by several of the operating companies, when in 1943 Jackson and Squire drilled 13 holes and discovered bauxite in the east-central part. Although not completely delimited, the ore within the 5-foot cutoff extends at least 450 feet north-northeastward. No development work has been done. As shown in the subsurface map (pl. 2) the bauxite rests upon the weathered surface of the Wills Point formation. The deposit lies from 84 to 100 feet below the surface.

TREADWAY DEPOSIT

By Horace W. McGee

Plate 26

The Treadway deposit (Malamphy and others, 1948, v. 6, p. 26–40, fig. 63) lies mostly in the SE¼NE¼ sec. 8, T. 1 S., R. 12 W., and extends into adjacent parts of the NE¼ and into the N½NE¼SE¼ sec. 8. It is on properties of Lewis Treadway and T. R. Vinson, about three-eighths of a mile west of Highway 167 by gravel road. Marginal holes were drilled also on properties of Elsie Lewis and Mrs. J. T. McGuire. The ore body was discovered in USBM drill hole 18–073, drilled January 14, 1944, in which 7 feet of pisolitic bauxite was recorded at a depth of 153 feet. A total of 52 holes were drilled to investigate the deposit.

Most of the ore is along a southward- to southeastward-trending valley on the post-Midway surface (pl.

26). Cross sections through this type 2 deposit are shown in plate 26. The ore lies on the weathered surface of the Wills Point formation, particularly on the west side of the valley. The Wills Point formation was recorded to be 88 feet thick in USBM drill hole 18–073 and 69 feet thick in USBM drill hole 20–049. The underlying Kincaid formation was 67 feet thick in drill hole 20–049. Lithologic descriptions and chemical analyses of the Midway sediments in these two drill holes have been given in the stratigraphic part of the text.

The principal ore body is about 1,500 feet long within the 5-foot isopach and trends N. 10° W. The maximum width is a little more than 400 feet. Ore thicker than 8 feet was found in two separate parts of the deposit in swells along the valley bottom. The thickest ore in the north swell was 24.7 feet, recorded in USBM drill hole 17–103; in the south swell it was 21.5 feet, recorded in USBM drill hole 17–078.

The bauxite is mostly pisolitic, tan in color, fairly well indurated above and crumbly and softer below. The bauxite grades downward through bauxitic clay to a gray kaolinitic clay, sideritic in many places and locally slightly silty. This clay is 10 to 12 feet thick under a large part of the ore body and rests upon the weathered surface of the Wills Point formation.

Bauxitic and kaolinitic clay as much as 8 feet thick forms the basal part of the overburden, which ranges in thickness from 105 to 161 feet, generally thickening southeastward. The upper part of the overburden is composed of carbonaceous and clastic sediments of the Berger and Saline formations, similar to those that cover the nearby Vinson-McGuire deposits.

VINSON-MC GUIRE DEPOSITS

Plate 26

Three small bauxite bodies connected by thin low grade ore constitute the Vinson-McGuire deposits (Malamphy and others, 1948, v. 6, p. 41–63, figs. 64 and 65), in parts of the SW¼NE¼ and the W½SE¼ sec. 8, T. 1 S., R. 12 W., on properties of T. R. Vinson and Mrs. J. T. McGuire. The locality is about five-eighths of a mile west of Highway 167 by gravel road. Bauxite was discovered by Eliot and Alley, private operators, who drilled 24 holes on the Vinson property early in 1944, at about the same time the Federal drilling program was investigating the Berger area. Subsequently the deposit was delimited by drilling 65 holes.

The three small ore bodies are related to a curved subsurface valley that in early Eocene time drained southwestward and then turned eastward. A cross section through the north end of this deposit and the south end of the Treadway are shown on plate 26, section *B–B′*. The northernmost of the three bodies, lying within the valley near its head, is nearly triangular in plan, about 600 feet long in an easterly direction, and 500 feet in a northerly direction (pl. 26). The thickest ore recorded, near the center of the body, was 10.0 feet, in USBM drill hole 18–150A. The small middle ore body lies on a southeast slope, across a narrow subsurface ridge south-southeast of the northernmost. It is about 550 feet long within the 5-foot isopach and has a maximum width of 250 feet. The thickest ore recorded in USBM drill hole 17–093 was 7.4 feet. The south ore body is nearly 850 feet long within the 5-foot isopach, along a line oriented north-northwest and the maximum width is about 400 feet. The thickest ore recorded in USBM drill hole 17–086 is 11.9 feet in an upper bed and 7.1 feet in a lower bed, the two beds are separated by 1 foot of lignite above 1 foot of bauxitic clay. The general distribution of the two separate beds is shown diagrammatically in plate 26.

The upper bed is composed principally of pebbly pisolitic bauxite (type 3 deposit). All the rest of the ore in this and the other two bodies is type 2. The pisolitic bauxite overlies a fragmental underclay ranging from 9 to 30 feet in thickness and averaging about 14 feet. The contacts are gradational between the ore and the surrounding rock. The upper part of the bauxite is high in silica and grades from bauxitic clay into kaolinitic clay. This siliceous cover on top of the ore ranges from 2 to 7 feet in thickness.

The overburden above the two northern bodies ranges from 96 to 165 feet in thickness. Above the type 3 ore body at the south end of the deposit, the overburden ranges from 151 to 170 feet in thickness. The Berger sediments above the bauxite-kaolin zone are composed mainly of greenish-gray silty clay with interbedded lignite. They range in thickness from 35 to 73 feet, thinning upslope with reference to the post-Midway surface. The Saline formation ranges in thickness from 50 to 118 feet, increasing to the south-southwest. The upper 9 to 30 feet is composed principally of brown to gray sand or sandy clay; the lower part is composed of chocolate-brown silty to sandy, carbonaceous clay locally with a lens of brownish-gray clay.

MC GUIRE DEPOSIT

Plate 2

The northwesternmost and one of the shallowest deposits in the Berger area is on the McGuire property in the NW¼NE¼ sec. 8, T. 1 S., R. 12 W., where it was worked by the Arkansas Bauxite Stripping Co. during World War II. Company drilling also has found what is probably the extension of this deposit on the adjacent Elsie Lewis property in the northwest

corner NE¼NE¼ sec. 8. Many holes were drilled by the company to delimit the deposit. The maximum recorded thickness of ore was 12 feet.

The deposit is one of those which rests upon the weathered surface of the Wills Point formation west of the nepheline syenite slope from which it is separated by a fairly large drainage valley. The ore body appears to be a type 2 deposit, but it is not known whether the source material was derived chiefly from the weathering products of nepheline syenite. The bauxite is mostly pisolitic. Parts of it are reported locally to have a high content of ferrous iron. Before stripping, the bauxite extended nearly to the surface and reportedly was covered by as much as 36 feet of overburden.

McGuire open-pit mine (pl. 1, no. 45).—The Arkansas Bauxite Stripping Co. opened this mine in 1943 and operated it for more than a year. The pit was 400 feet by 300 feet thick and trapezoidal in shape.

PRIMROSE CHURCH BASIN

The area around Primrose Church, including parts of secs. 3, 4, 9, and 10, T. 1 S., R. 12 W., is in a large natural basin within the Pulaski nepheline syenite mass (fig. 58). This has been nearly filled with continental sediments mostly of early Eocene age. The land surface if flat to gently rolling, partly wooded and partly cleared for farming. The area is crossed by the Sweet Home cutoff, a road that connects Highways 65 and 167. Good all-weather roads lead to or pass near the several bauxite deposits in this area.

The buried basin is elongate northeastward. Its post-Midway erosion surface (pl. 2) was drained by a narrow, irregularly shaped valley of gentle gradient, which begins at the west edge of sec. 10 and extends northwestward into the NE¼ sec. 9. A nearly right-angle bend is between this and the main part of the valley which trends about N. 60° E. It extends into sec. 3, then curves eastward to its outlet, a narrow steepsided opening almost normal to the main valley axis. The outlet is in the NE¼ sec. 10, and forms the boundary between the Woodyardville and Ironton areas. The basement rock in the basin, so far as is known, is composed of pulaskite. Two small buried patches of rock of Paleozoic age were found in drill holes on the north flank of the outlet to the basin.

The only important bauxite deposits in this area are located at the west edge, alongside a saddle in the main nepheline syenite ridge. Economically, these deposits are linked with those of the Berger area for they have been explored and mined along with those that lie west of the saddle. A small composite bauxite body was also discovered by the Federal drilling program on the Finnegan property at the east edge of the basin, near the Birnbach deposit.

The earliest exploration in this area apparently was done by the National Bauxite Co., which opened a mine in 1914, later operated by the Du Pont de Nemours Co. Further prospecting was done during the twenties by the Globe Bauxite Co. and the Republic Mining and Manufacturing Co., and during the thirties by the American Cyanamid and Chemical Corp. During World War II, mines were operated in this area by American Cyanamid and Chemical Corp. and by the Fourche Mountain Mining Co.; and since the war by the Reynolds Mining Corp. and by American Cyanamid and Chemical Corp.

The Federal project drilled wildcat holes here at three separate times, to supplement earlier company drilling for bauxite and to test the area for possibly extensive clay deposits.

Topographically, the Primrose Church basin offered an excellent trap for bauxite eroded off the nepheline syenite that rims it; but the entire area, with the exception of the previously mentioned deposits exploited by mining companies at the west end of the basin, is almost devoid of bauxite. Two isolated outcrops of bauxite and associated aluminous rocks of the bauxite-kaolin zone are upslope on the walls of the basin in the W½SE¼ sec. 4 and in the NE¼SE¼ sec. 9. A third bauxite outcrop in the N½SW¼ sec. 3, in back of the Primrose Church, appears to be a lens contained within the Wilcox continental sediments.

A large tonnage of kaolinitic clay, high in alumina content but containing some carbonaceous impurities, has been found in the basin. This clay has been found at depths ranging from about 7 to 120 feet and it is covered by overburden composed of lignitic and silty to sandy clay and bluish "pepper and salt" clayey sand of the Berger formation overlain by brown carbonaceous silty to sandy clay of the Saline formation.

RAUCH LAKE DEPOSIT

Plate 2

This deposit is mostly in the SW¼NE¼ sec. 9 and extends several hundred feet into the SE¼NE¼ sec. 9, T. 1 S., R. 12 W. It contains the oldest mine in this area, one of the earliest worked in the Pulaski mining district. The west end of the deposit crops out at the surface within several hundred feet of the nepheline syenite (pulaskite) outcrop in the center of sec. 9. The ore body was explored and delimited entirely by the operating companies but the eastern part of it is included within the area investigated by the Bureau of Mines and described as the Rauch clay area (Malamphy and others, 1948, v. 6, p. 3–13, fig. 60).

The ore body within the 5-foot cutoff is irregularly lobate, about 1,100 feet long from west to east; the greatest north-south dimension near the east end of the body is about 900 feet. It lies on the west side of the subsurface valley that drained the basin in early Eocene time and has a general northeasterly dip of 5°–6°. The ore body, so far as is known, is a type 2 deposit developed within the bauxite-kaolin zone. There does not, however, seem to be an appreciable thickness of underclay as indicated in drill hole USBM 8–036A. The bauxite is mostly pisolitic and light tan, but little is known about the lithologic details.

The overburden, as indicated by company drilling, reaches a maximum of 80 feet in thickness. It consists of the typical sediments of the Berger formation overlain by brown or variegated sand of the Saline formation.

Old Rauch open-pit mine (pl. 1, no. 33).—This property probably is one of those acquired by the National Bauxite Co. in 1907, which began mining operations in 1914 and continued through 1916. The mine is sometimes called the Old National pit. In 1917 E. I. du Pont de Nemours Co. acquired this property and operated it until 1921 at which time the mine was abandoned.

The stripped area of the Old Rauch mine is in the shape of a curve about 900 feet between the extremities and 250 to 300 feet across in places. The overburden that was removed before mining operations began was as much as 33 feet thick.

Rauch Leased open-pit mine (pl. 1, no. 34).—Between 1941 and 1943, about 140 holes were drilled around the edges of the Old Rauch pit by the American Cyanamid and Chemical Corp. to delimit the deposit. The ore extended for some distance east and south of the old workings to a depth of 80 feet. In 1943 the company stripped the south lobe of the deposit and began mining. Operations were suspended in 1946 and resumed the following year.

EAST RAUCH DEPOSIT

Plate 2

This deposit is in the NW¼NE¼ sec. 9 and extends a few hundred feet into the SW¼SE¼ sec. 4, T. 1 S., R. 12 W. It is on properties owned by the American Cyanamid and Chemical Corp., M. L. Buzbee, and Daniel Rauch. About 30 exploratory holes were drilled in the NW¼NE¼ sec. 9 by J. C. Childress in 1932. Further drilling by American Cyanamid and Chemical Corp. in the 20-acre tract at the south end preceded the opening of a strip mine in 1942. The rest of the deposit has been worked by the Fourche Mountain Mining Co. and the Reynolds Mining Corp. One of the holes drilled by the Bureau of Mines in its investigation of the Rauch Clay area (Malamphy and others, 1948, v. 6, p. 3–13, fig. 60) cut the north end of this deposit.

The ore body within the 5-foot isopach is about 1,500 feet long, 300 to 400 feet wide across the central part, and nearly 700 feet across the south end; it is elongate about N. 30° E. and dips fairly steeply to the east-southeast. The thickest ore in the north-central part, before mining, reached 26 feet and in the south-central part, about 25 feet.

The ore body, which lies within the bauxite-kaolin zone above weathered nepheline syenite, can be classified as a type 2 deposit. It is several hundred feet east of a low saddle in the main ridge of Granite Mountain, along a slope northwest of the principal subsurface drainage of the basin (pl. 2). A tributary ridge extends eastward and valleyward from beneath the central part of the ore body.

Most of the bauxite is pisolitic, tan, and soft to fairly well indurated. The lower part is fragmental in places. Along the upslope parts of the body are many boulders of granitic-textured bauxite, some of them as large as 6 feet in diameter. One rootlike mass of granitic-textured bauxite, about 12 feet high and 6 to 8 feet across, was exposed by the mining of the shallow ore in the Rauch-Owned pit (pl. 1, no. 32) at the southwest end of the deposit. The upper part of it was surrounded by pisolitic bauxite and the lower part by a fragmental-appearing kaolinitic clay grading in places laterally or downward into kaolinized nepheline syenite. This was interpreted as a small remnant of a type 1 bauxite deposit, similar to those noted in the West Rauch, Rummel, and Alford–Ross deposits.

The west and southwest margins of the deposit reach the surface in an outcrop of bauxite and bauxitic clay nearly 1,000 feet long. It was one of those cited by W. B. Powell (1842) more than a hundred years ago. A small isolated outcrop of high-silica bauxite and bauxitic clay is about 400 feet north-northwest of the north end of the body.

According to company drilling records the overburden reaches a maximum of 75 feet in thickness. It is composed of gray silty clay and lignite of the Berger formation overlain by chocolate-brown carbonaceous clay and variegated sand and clay of the Saline formation. The detritus in both of the sedimentary formations contains large quantities of weathered feldspar grains in place of the predominant quartz grains found outside of the basin. Dips on the lignite beds of the Berger formation immediately overlying the bauxite are steep, in places as much as 12°, due in part to steep initial dip and in part to subsequent compaction of the sediments fringing the bauxite.

Rauch-Owned open-pit mine (pl. 1, no. 32).—The south end of the deposit was mined by the American Cyanamid and Chemical Corp. in a 20-acre tract bought from Daniel Rauch. Six holes drilled by J. C. Childress in 1932 indicated that 5 acres in the northwest-central part of this tract were underlain by bauxite as much as 24½ feet thick. The company drilled 19 additional holes before stripping the bauxite. The pit was opened in 1942 and mining continued until 1944.

The upper surface of the bauxite in this mine dipped about 10° to the east. The ore was overlain by 7 to 67 feet of Wilcox sediments.

Rauch Property open-pit mine (pl. 1, no. 31).—The central part of the ore body in the NE¼NW¼NE¼ sec. 9 was worked by the Fourche Mountain Mining Co. The overburden was removed after about 75 exploratory holes had been drilled in the property by the Sweet Home Bauxite Co. in 1943. About three-fourths of the ore produced from August 1943 to January 1944 was classified as "low silica restricted" by the Metals Reserve Company and the rest as "high silica restricted." The mine has not been operated since 1944.

Buzbee open-pit mine (pl. 1).—The north end of the deposit on the M. L. Buzbee property in sec. 4 was explored and mined by the Reynolds Mining Corp. Late in 1942 the company drilled 30 holes to delimit the ore, most of the holes were spaced about 100 feet apart on a rectangular grid. The overburden was stripped and the ore mined during 1946, after which the pit was abandoned.

According to the drill-hole records the overburden at this end of the deposit ranged in thickness from 7 to about 65 feet.

FINNEGAN DEPOSIT

Plate 20

The Finnegan deposit (Malamphy and others, 1948, v. 5, p. 78–87, fig. 54) is in the SE¼SE¼ sec. 3 and extends into the northern part of the NE¼NE¼ sec. 10, T. 1 S., R. 12 W. It is on properties owned by J. D. and Lucy Finnegan, L. L. Hempstead, Garvin Johnson, and Mrs. W. E. Rowe. The ore body was found first in USBM drill hole 2–036, completed August 24, 1942, in which 4½ feet of pisolitic bauxite and bauxitic clay were logged but not cored. It was investigated by drilling 29 holes.

The relation of this deposit to the post-Midway erosion surface and to other small bodies south of it is shown in plate 20. Although it lies within the Primrose Church basin and is described with other deposits in this area, it is across a narrow southwestward-trending weathered nepheline syenite ridge from the Birnbach deposit of the Woodyardville area. Its structure and geologic history, moreover, appear to be closely related to that deposit. It also is in line with the general trend of the deposits of the Ironton area immediately to the south.

The bauxite-kaolin zone in which the Finnegan deposit has been developed lies immediately above weathered nepheline syenite. The south end is about 1,200 feet northeast of the buried edge of the Wills Point formation and overlaps a buried pendant of weathered shale of Paleozoic age in the nepheline syenite. The fragmental underclay including the bauxitic clay below the ore ranges from about 8 to 120 feet in thickness beneath the northern part of the deposit.

The ore body is narrow and sigmoidally curved. Within the 5-foot isopach it is 1,100 feet long, in a line oriented about N. 20° E. and has an average width of about 200 feet. It is a composite of two different types of bauxite bodies. The northern part is type 2, which reaches a maximum thickness of 14.3 feet in USBM drill hole 7–162B. The south half of this body is overlain by a type 3 deposit, a lens of hard, pebbly, pisolitic bauxite, separated from the type 2 below by 5 to 20 feet of kaolinitic clay, carbonaceous clay, and lignite. The carbonaceous beds are at the top and bottom of the intervening clay wedge.

The northern tip of the type 2 deposit is composed entirely of pisolitic bauxite. In USBM drill hole 7–162B the upper part is pisolitic but the lower half of the ore is composed of very fragmental bauxite, a photomicrograph of which is shown in plate 14*C*. In the holes to the south, the entire thickness of the type 2 deposit is composed of nonpisolitic fragmental bauxite. The bauxite in both types of deposits grades upward into more siliceous material overlain by bauxitic and kaolinitic clay, as much as 12 feet thick locally.

The overburden, including the bauxitic and kaolinitic clay above the ore, ranges from about 95 to 157 feet in thickness for the type 2 deposit, and from 131 to 154 feet for the type 3. The Berger sediments above the bauxite-kaolin zone consist of the typical gray silty clay interbedded with lignite. They are absent in a couple of drill holes above the subsurface ridge in the northeastern part of the drilled area. These beds reach a maximum thickness of 81 feet at the southwest edge of the drilled area. The Saline formation ranges in thickness from 19 to 104 feet; like the Berger, it is thinnest along the subsurface ridge and thickens southwestward across the valley. The chocolate-brown carbonaceous clay varies in thickness and in places is

underlain by a white silty clay or sandy silt, or by a dark gray carbonaceous clay. Locally the dark-brown carbonaceous clay is overlain by a plastic yellow and lavender clay. The upper weathered part of the formation consists of variegated sand, silt, and clay; the colors include red, gray, yellow, brown, and buff.

ECHO VALLEY

This area was formerly known as Fourche Cove. It is a natural embayment in the Pulaski nepheline syenite mass, that drains northeastward toward Fourche Bayou. The valley occupies most of the SE¼ sec. 22, the S½ sec. 23, all of secs. 26 and 27, the E½ sec. 33, and the N½ sec. 34, T. 1 N., R. 12 W. (fig. 58). The altitude of the ridges surrounding this valley on three sides range from about 395 to 535 feet; the lowest point, at the mouth of the cove, is about 245 feet.

The geologic map (pl. 1) shows the principal rocks exposed in this area. These consist of greenish-gray altered shale and quartzite of Paleozoic age, two masses of fourchite, and nepheline syenite dike rocks that have been discussed in "Intrusive igneous rocks." The valley bottom is filled with brown and gray sand and gravel that resembles that of the lentil along the northwest and upslope edge of the Saline formation in Pulaski and Saline Counties and it has been so mapped in Echo Valley (pl. 1). Two outcrops of pulaskite protrude through this gravel cover; along part of its east side is a long narrow outcrop of gray nepheline syenite.

Only one bauxite outcrop is exposed in the valley—on the line that divides the SE¼SW¼ sec. 23 and the NE¼NW¼ sec. 26. It is on the brow of a short tributary ridge near the north end of the valley and is surrounded by sand and gravel cover of the Saline formation, several hundred feet west of the main pulaskite outcrop. Abundant bauxite boulders are scattered across the surface of the ground in this area, at altitudes from 280 to 290 feet. Chemical analysis of this material has shown it to be of excellent grade, low both in iron and silica content. The bauxite appears nonpisolitic and when broken some of it is seen to contain scattered randomly oriented linear cavities, indicating a crude granitic texture. Its topographic position and its crude texture indicate that the bauxite is the remnant of a type 1 deposit.

Four holes (USBM 4–028 to 4–031, inclusive) were drilled in Echo Valley during August 1942 (Malamphy and others, 1948, v. 4, p. 3, fig. 42). All struck decomposed nepheline syenite rock after cutting through 6 to 26 feet of sediments, most of which probably are of Saline age. These include brown and gray unsorted silty sand and gravel with ironstone boulders, light-gray and red sticky clay, ocher-colored sandy clay, yellowish-brown clayey sand, silt, and sandy clay, and reworked kaolinized nepheline syenite.

The thinness of the cover and the apparent absence of sediments of the Berger formation, it is believed, preclude the possibility of undetected buried deposits of bauxite in this area.

AREAS INVESTIGATED BETWEEN THE TWO PRODUCING DISTRICTS

Part of the exploration by the government was directed toward an investigation of the nonproducing areas between the Pulaski and Saline mining districts. Three areas believed to be the most favorable for the accumulation of bauxite were explored. The first of these, the Mabelvale–Alexander area, comprises the land along the Midway–Wilcox contact, including aluminous deposits under relatively thin cover of sediments of the Wilcox group south of the contact, as well as in outliers north of the contact.

The other two areas surround small hills of nepheline syenite that protrude above the sediments of the Midway group, but are buried beneath sediments of the Wilcox group. One of them is called the Ledbetter high in the vicinity of Ledbetter Creek, at the border between Pulaski and Saline Counties and the other is called the Sardis high in the vicinity of Sardis, Saline County.

Although small deposits of low-grade bauxite have been found in all three areas, none is of sufficient size or grade to be of commercial interest except under stringent emergency conditions.

MABELVALE-ALEXANDER AREA

The Mabelvale–Alexander area extends from about a half mile west of Berger southwest to include Alexander, a strip of land about 8 miles long and as much as 3 miles wide, irregularly elongate southwestward. The town of Mabelvale near the center of the area is about 7 miles southwest of Little Rock.

About 50 holes were drilled, most of them in the N½ T. 1 S., R. 13 W., south of the Midway–Wilcox contact, several in secs. 7 and 8, T. 1 S., R. 12 W., and several others in outliers in secs. 31 and 32, T. 1 N., R. 12 W. These holes ranged from 13½ to 150 feet in depth (Malamphy and others, 1948, v. 4, p. 2–4, fig. 42; v. 5, p. 2–7, fig. 49; v. 10, p. 2–4, fig. 90).

Along the Midway–Wilcox contact in this area are many outcrops of bauxitic clay and bauxite (pls. 1 and 2). The post-Midway erosion surface slopes gently southeastward and was drained by several minor stream systems, now buried, with low hills and ridges between. Only one stream of major consequence crossed the area. Its buried valley lies in the same general position as the present-day valley of Otter Creek, about midway between Mabelvale and Alex-

ander. A second ancient stream, which bounds the area on the east, flowed southward in a valley immediately west of Berger. Between these streams the post-Midway topography has a relief of about 150 feet. One of the larger ridges, the northern limit of which is not known, extends southward from Mabelvale and curves eastward in sec. 14, T. 1 S., R. 13 W. Less prominent buried ridges lie at either side of it (pl. 2). The weathering profile on the surface of the Midway sediments is present in most places except in the bottoms of ancient stream drainage channels. This weathered zone has been stripped irregularly from the sides of the buried valley beneath Otter Creek.

The deposits of low-grade bauxite and bauxitic clay are located on the flanks of broad hills and ridges. Their topographic position in elevated areas of good drainage on the post-Midway erosion surface, separated from any possible sources of nepheline syenite detritus, indicates that the bauxitic rock probably was derived from the weathering of sediments of the Midway group in place. This conclusion is supported by the observed gradation downward of pisolitic bauxitic clay into weathered clay of Midway age and the unweathered clay beneath. The Mabelvale bauxite is believed to be analogous to the type 1 deposits residual on the nepheline syenite surface.

The clay beds of the Midway group are much less suitable both physically and chemically as a source of alumina than the nepheline syenite rocks. This feature is sufficient to eliminate the Mabelvale–Alexander area as an important source of bauxite.

LEDBETTER CREEK AREA

Underneath part of the area drained by Ledbetter Creek is a small buried hill of nepheline syenite rock that is called the Ledbetter high on plate 2. It is less than a mile west of the buried southern part of the Pulaski nepheline syenite hill, in an area of about 3 square miles in secs. 29, 30, and 31, T. 1 S., R. 12 W., Pulaski County, and in secs. 24, 25, and 36, T. 1 S., R. 13 W., Saline County (fig. 58). A main eastward-trending ridge extends for nearly 2½ miles; the altitude ranges from about 90 to 140 feet. The highest summit, in the SE¼SE¼ sec. 30, lies a little south of the main ridge and is the high point of a prominent tributary hill that extends for more than a mile south-southwest of the ridge. This summit, at an altitude of 168 feet, lies within 130 feet of the present ground surface.

Nearly 2 square miles of the nepheline syenite surface is not covered by sediments of the Midway group. The buried nepheline syenite outcrop on the post-Midway erosion surface (pl. 2) is irregularly distributed in a lobate area that is crudely hatchet shaped. In the western part of the Ledbetter high in Saline County, the north slope and much of the ridge top is covered by dark-gray silty clay of the Wills Point formation; the south slope and parts of the ridge crest are free from Midway sediments. In the eastern or Pulaski County part, the Midway sediments are absent on all of the summits and steeper slopes and show evidence of considerable erosion of the Midway before deposition of the Berger continental sediments. In a small embayment in the southwest corner of sec. 30, in the south-central part of the hill, a couple of drill holes entered limestone, clay, and debris of the Kincaid formation directly beneath the Berger sediments. Drill holes along the south side of the buried hill cut considerable coarse silty material in the Wills Point and conglomeratic beds in the Berger formations.

The Ledbetter high was discovered independently by several separate geophysical surveys: In seismic refraction surveys by Sherwin F. Kelly Geophysical Services, Inc. for the Republic Mining and Manufacturing Co.; by the National Geophysical Co. for the Reynolds Mining Corp.; and by magnetic and gravimetric surveys by the Heiland Research Corp., for the U. S. Bureau of Mines. The area was explored by more than 80 drill holes by the Republic Mining and Manufacturing Co. before 1944; Reynolds drilled at least a dozen additional holes on several properties.

Late in 1944 the Federal drilling program confined its efforts to testing, what were considered to be inadequately explored parts of the buried hill in Pulaski County. Fourteen holes were drilled, spaced about 1,000 feet apart in several rows. Locations and tabulated information from these drill holes have been published by Malamphy and others (1948, v. 8, p. 4, fig. 81). The 14 drill holes were sufficient to show that excessive erosion in the eastern part of the buried hill had stripped away any bauxite that might have formed on the nepheline syenite surface.

In the part that lies in Saline County, however, company exploration of this hill discovered in places as much as 18 feet of low-grade bauxite and kaolinitic clay of the bauxite-kaolin zone, overlying kaolinized nepheline syenite or clay of Wills Point age. Nearly all of the bauxite has a high iron content and much of it also has a high silica content. Part the bauxite is of ore grade by virtue of a silica content locally as low as 4 percent, but this is coupled with a high iron content. Bauxite showings were recorded in scattered drill holes in secs. 25, 26, and the NE¼ sec. 27, T. 1 S., R. 13 W., at depths ranging from about 160 to 260 feet below the surface. Very little bauxitic material is at present of commercial grade, but should ore requirements be materially lowered at some future time, further exploration of this area would be warranted.

SARDIS AREA

Near the settlement of Sardis is a small buried hill of nepheline syenite that is called the Sardis high on plate 2. It is a half mile east of the northeastern part of the buried Saline dome, from which it is separated by a major buried valley. The Sardis high lies mostly in secs. 15 and 16, T. 2 S., R. 14 W., and spurs extend northward into secs. 9 and 10 and west and south into secs. 14, 22, and 23 (fig. 60). Two principal summits are about 45 and 105 feet above sea level. The highest part of the hill, in the NW¼NW¼ sec. 15, is about 240 feet below the present ground surface.

The slopes of nepheline syenite are overlapped by the edge of the sediments of the Midway group. On the north and east sides of the Sardis high the dissected and gently sloping surface of these sediments forms the base of the slopes at altitudes that range from 50 feet below sea level on the northwest flank to 200 feet below sea level on the southeast flank of the hill. On the west and south sides of the Sardis high the trace of the contact between Midway sediments and igneous rock is irregular and in a few places it extends up the hillside. A minor summit in the SW¼ sec. 16 is apparently covered completely by sediments of Midway age at an altitude of 20 feet below sea level, whereas the bottom of the adjacent major valley to the west, more than 100 feet lower, between the Sardis high and the Saline dome, is stripped of sediments.

About 2 square miles of the nepheline syenite on the Sardis high are not covered by sediments of Midway age. In most places where the Midway formation is lacking, weathered to fresh nepheline syenite is overlain by fine to medium, gray to green clayey sand of the Berger formation, which in other areas seems to be associated with widespread erosion that has stripped away much or most of the deposits of the bauxite zone.

The buried Sardis nepheline syenite hill, like the buried Ledbetter hill, is the cause of a marked local magnetic anomaly shown on the map of Stearns (1930). The significance of the anomaly, however, was not discussed by Stearns and the hill was apparently not discovered until the geophysical surveys made during the expansion of the mining industry before World War II. The hill was discovered independently by refraction seismograph surveys made by Sherwin F. Kelly, Geophysical Services, Inc., for the Republic Mining and Manufacturing Co.; by the National Geophysical Co. for the Reynolds Mining Corp.; and by magnetic and gravimetric surveys made by the Heiland Research Corp. for the U. S. Bureau of Mines. The area was explored by more than 50 drill holes by Republic Mining and Manufacturing Co. before 1944. The joint Federal drilling program drilled 44 holes from December 1943 to April 1944, spaced about 1,000 feet apart on a triangular grid.

Locations and tabulated data of these drill holes have been published by Malamphy and others (1948, v. 11, p. 2–7, fig. 94; v. 12, p. 3, fig. 99). In nearly half of the holes, greenish-gray clayey sand and silt of the Berger formation were found unconformably overlying either decomposed to fresh nepheline syenite or somewhat weathered to fresh, black, silty clay of the Midway group. In these holes no recognizable bauxite-kaolin zone was present. Kaolinized nepheline syenite from a few feet to 24 feet in thickness was found in 13 holes. A true bauxite-kaolin zone was cored in 12 drill holes, of which 4 contained bauxitic clay and 2 contained bauxite. All 12 holes in which the bauxite-kaolin zone is present lie in southward-trending minor valleys or on south slopes that were protected from Eocene erosion by spurs or promontories of nepheline syenite to the north. Most of the bauxitic clay and kaolin overlies the lobes of the Wills Point formation that cover the slopes of nepheline syenite in the W½SW¼ sec. 15 and S½ sec. 16. This area is worth further exploration, for this part of the Sardis high was less exposed to erosion during the deposition of the Berger and Saline sediments than the other parts.

In one drill hole, USBM 13–147, nearly 10 feet of bauxite of high iron content was cored at depths from 464 to 474 feet. In this drill hole, which bottomed in limestone of the Kincaid formation, the Wills Point formation is 7 feet thick; the bauxite-kaolin zone, 26 feet; the carbonaceous and clastic sediments of the Berger formation, 129 feet; the Saline formation, most of which is composed of brown carbonaceous sandy clay, 207 feet; the Detonti sand, 83 feet; and an upper white clay overlain by surface sand and soil, 40 feet. No close drilling was done to delimit the bauxite in this hole.

It is not likely that any large bauxite deposits are associated with the buried Sardis high, although it is possible that one or more small deposits might be found that would be minable under emergency conditions.

SALINE MINING DISTRICT

Bauxite deposits associated with the Saline and the Bryant nepheline syenite masses comprise the Saline mining district. This was called the Bryant district by Hayes (1901) but the name was not generally accepted by miners or later writers. The U. S. Geological Survey Mineral Resources of the United States and the U. S. Bureau of Mines Minerals Yearbook refer to production from Saline County. The nepheline syenite rocks of the Saline dome (pl. 2) crop out extensively in T. 2 S., R. 14 W., near the town of Bauxite, but they do not form pronounced topographic highs as

in Pulaski County, nor is their area of outcrop nearly so great. The outcrops near Bauxite are separated by the valley of Hurricane Creek from several small outcrops of nepheline syenite east of the town of Bryant. These outcrops are the surface exposures of the buried nepheline syenite hill called the Bryant high on plate 2. The buried bauxite and kaolin rocks form extensive, flat-lying deposits on the northwest side of the Bryant high, and scattered, small deposits on the southeast side. The north and east sides are almost barren. Major deposits fill northeastward, northward- and westward-trending buried valleys of the Saline dome, and form extensive aprons about the flanks of the dome. The east side is relatively barren. The area covered by the deposits is shown in the subsurface map (pl. 2).

More than half of the bauxite in Saline County lies on the sloping sides of nepheline syenite hills along major buried valleys that in Eocene time drained the Saline dome. Much of this bauxite is residual upon the nepheline syenite, although a large part of it has moved down the valleys.

The rest of the bauxite is concentrated along the flanks of the Saline dome, and lies on sediments of Midway age that wedge out against the nepheline syenite. Some of these deposits lie entirely on the clay of Wills Point age, the upslope parts of others lie on nepheline syenite, and a few rest entirely on the nepheline syenite a short distance from the lip of the Midway sediments.

Many residual bodies crop out at the surface, along the line of outcrop of the nepheline syenite, but most of them are buried beneath Eocene continental sediments that include sand, clay, and lignite beds. The overburden thickens away from the igneous outcrops in all directions, but especially to the southeast due to the regional dip of the Coastal Plain sediments. The southernmost deposit is overlain by 475 to 585 feet of overburden. The Saline mining district is divided for convenience into 10 geographic areas, each named for the principal landmark or settlement within it. The limits of each area are determined by the surface and subsurface configuration of the topography of the nepheline syenite masses. Most deposits fall into groups clearly bounded by the limits of these areas, but some overlap and a few lying in one area are grouped with deposits of the adjacent area for convenience. The 10 areas, shown on the index map (fig. 60) are as follows:

1. Bryant area—the west and northwest flanks of the Bryant high, including deposits in part of secs. 2 and 3, T. 2 S., R. 14 W., and secs. 25, 34, 35, and 36, T. 1 N., R. 14 W.
2. Brooks area—the east and south flanks of the Bryant high, including deposits in sec. 31, T. 1 S., R. 13 W., and in sec. 1 and parts of secs. 2 and 12, T. 2 S., R. 14 W.
3. Davis area—a northward-trending buried valley on the Saline dome, including deposits in secs. 10, 15, and 22, T. 2 S., R. 14 W.
4. Hurricane Creek area—the northeast flank of the Saline dome, including deposits in secs. 11, 12, and 14, T. 2 S., R. 14 W., and part of secs. 7 and 18, T. 2 S., R. 13 W.
5. Mount Olive area—a northeastward-trending buried valley on the Saline dome, including deposits in secs. 13, 24, and part of 23, 25, and 26, T. 2 S., R. 14 W., and secs. 18, 19, and 20, T. 2 S., R. 13 W.
6. Brushy Creek area—an embayment on the southeast flank of the Saline dome including deposits in sec. 36, T. 2 S., R. 14 W., sec. 31, T. 2 S., R. 13 W., and sec. 1, T. 3 S., R. 14 W.
7. Neilson area—a southwestward-trending buried valley on the Saline dome, including deposits in sec. 27 and parts of secs. 22, 23, 26, and 28, T. 2 S., R. 14 W.
8. Detonti area—the southwest flank of the Saline dome, including deposits in secs. 28, 29, 32, 33, and 34, T. 2 S., R. 14 W., and secs. 3 and 4, T. 3 S., R. 14 W.
9. Bauxite–Woodland area—the west flank of the Saline dome, including deposits in secs. 9, 16, 17, 20, and 21, T. 2 S., R. 14 W.
10. Pine Haven area—deposits lying on the Wills Point formation, separated from the Saline dome by a buried valley peripheral to the dome. Includes deposits in secs. 4, 5, and the north half of part of 9, T. 2 S., R. 14 W.

BRYANT AREA

The deposits lie southeast and east of Bryant, a small town on the Missouri Pacific Railroad, and extend northwestward from the southeast corner of sec. 3, T, 2 S., R. 14 W., through secs. 34, 35, and 36, and into the SW¼SE¼ sec. 25, T. 1 S., R. 14 W. (fig. 60). All-weather gravel roads pass over or within a mile of all the deposits.

In the Bryant area the deposits are extensive blankets on the northwest and west slopes of the buried Bryant nepheline syenite mass called the Bryant high, and extend northwestward onto a broad flat subsurface valley partly filled with sediments of the Midway group (pl. 2) This valley trends N. 50° E., parallel to the crest of the nepheline syenite ridge. At the northeast end of the ridge, in the S½ sec. 20, T. 1 S., R. 13 W., the buried valley enters a large one that in early Eocene time drained the Paleozoic upland to the north and flowed southeastward across the north end and along the east side of the nepheline syenite hill.

Along the broad valley bottom on the post-Midway surface, beneath the bauxite deposits, are several depressions represented on the subsurface map (pl. 2) by closed contours. Most of the deposits are elongate in a northeasterly direction, but some are irregular in outline. The largest is slightly more than a mile long. Parts of the depressions are steep-sided gullies as much as 60 feet deep. Despite the large amount of drilling that was done in this area, much of it on 200-foot centers, no outlet to these buried basins was found.

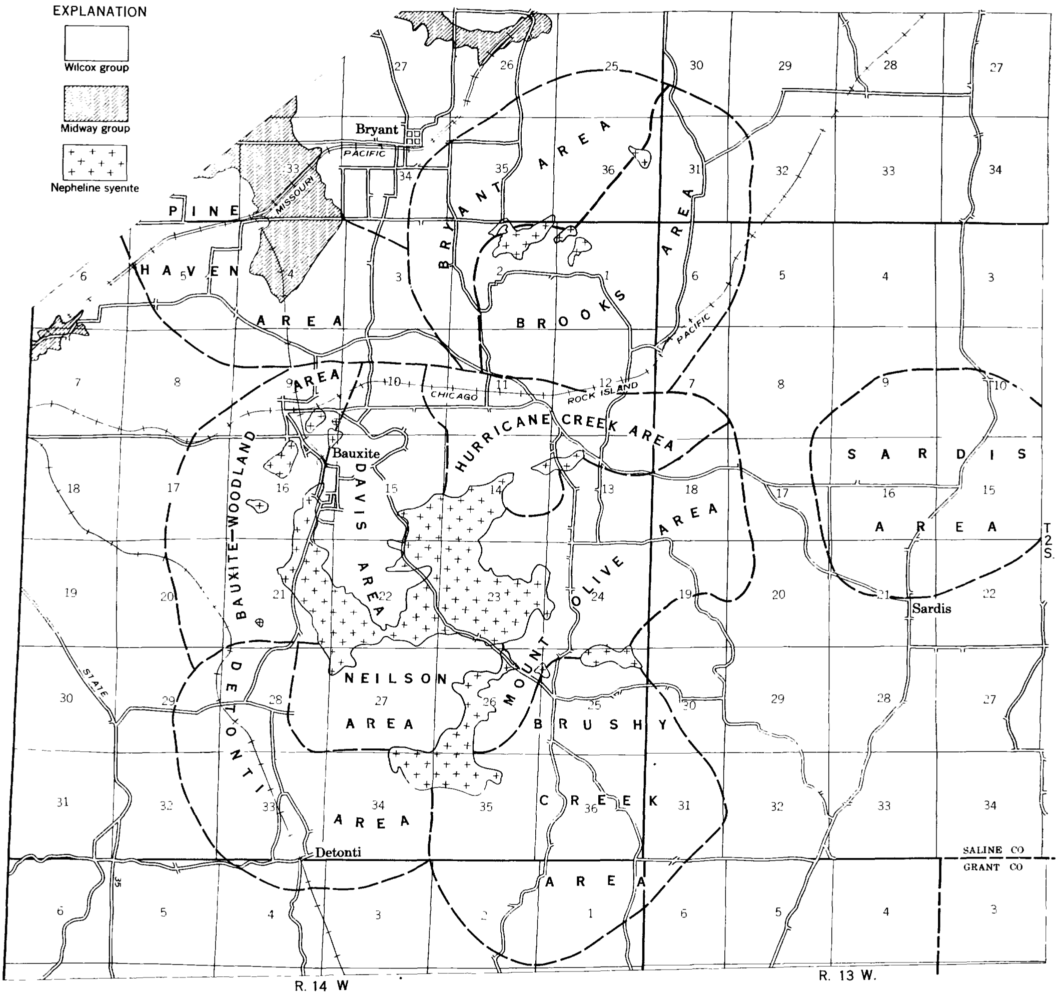

FIGURE 60.—Sketch map of the Saline mining district, showing the areas into which it has been subdivided for the purpose of describing the deposits.

The lowest part of the depression is less than 180 feet above sea level, whereas the lowest outlet northeastward into the main southward-flowing valley is more than 240 feet above sea level. It is possible that a narrow channel (between drill holes) might have connected the largest depression with either of two small northeastward drainage channels in the NE¼ sec. 25. That they probably were closed basins at the beginning of Berger time is indicated by the presence of lignite beneath the bauxite-kaolin zone in two of them, the only place in the bauxite region where such a relationship was found. This probably indicates that these basins contained shallow lakes or swampy areas at the same time bauxite was forming higher upslope on the nepheline syenite surface.

Two explanations of the origin of these basins are possible. The first is that they might be sinkhole areas formed by the downward movement of water, in this poorly drained region, through the Wills Point formation into the sandy limestone of the Kincaid formation below. This limestone is reported to have exceeded 100 feet in thickness in one drill hole. However, it is difficult to see how enough water could percolate through the fine clay of the Wills Point formation, which in

places is 50 feet thick. The second explanation is that they may have been caused by erosion along an ancient buried shear zone, perhaps a part of the same fault zone that originally controlled the intrusion of the nepheline syenite. This hypothesis is suggested in part by their elongation and in part by the fact that the basins are almost in line with the buried contact, as determined by drill holes, between the nepheline syenite and the rocks of Paleozoic age at the north edge of the igneous complex. The second explanation might also imply further movement along the fault in late Midway time. Erosion of the Wills Point sediments along this zone of weakness may have permitted a subterranean drainage to form in the Kincaid limestone. Thus it is possible that their configuration is the result both of erosion along a shear zone and of solution and collapse of sinkholes.

The thick bauxite deposits on weathered nepheline syenite southeast and east of the valley bottom are concentrated in reentrant basins and tributary valleys whereas those to the west and northwest, on the nearly flat surface of the Midway rocks, are typically thin and extensive, but are locally thick within the depressions.

The bauxite is covered by lignite and carbonaceous clay, silty to sandy clay, and sand of Wilcox age ranging in thickness from about 10 to more than 280 feet.

Before the Federal drilling program in the northwestern part of the area, company records of mining and drilling in the SW¼ and the NE¼ sec. 35, T. 1 S., R. 14 W., indicated that bauxite was present on clay of Midway age.

The first wildcat hole, USBM 2–196, drilled on May 25, 1943, in the northwest corner SE¼SE¼ sec. 35, T. 1 S., R. 14 W., recorded 22.4 feet of ore.

OSAGE DEPOSIT

By William B. Allen

Plate 2

The largest deposit associated with the Bryant nepheline syenite mass forms a fringe around its west end. It lies along the line between secs. 2 and 3, T. 2 S., R. 14 W., extends northward into the E½SE¼ sec. 34, thence eastward into the W½ sec. 35, T. 1 S., R. 14 W. Several large lobes of bauxite extend into adjacent areas. The deposit is more than 1¼ miles long in a north-south direction, and its maximum width is more than half a mile.

Exploration on the western part of the deposit was done by private companies. Additional information was gained from a series of holes in secs. 2 and 3, drilled by the Bureau of Mines to test the high-alumina clay deposits of the area (Malamphy and others, 1948, v. 16, p. 2–11, fig. 108). The Hardy ore bodies, comprising the eastern part of the deposit, were drilled on about 200-foot centers by the joint Federal project (Malamphy and others, 1948, v. 15, p. 29–92, fig. 107).

The deposit is a colluvial blanket (type 2) that mantles the weathered nepheline syenite slopes and also covers the lip of the Wills Point formation where it thins out against the nepheline syenite. Upslope parts of the deposit east and southeast of the Wills Point and nepheline syenite contact contain thick accumulations of bauxite, on the slopes of hills, that are residual (type 1 deposit). Northwest of the contact a large part of the deposit lies on the flat surface of the clay of Wills Point age. Here, the extensive flat blanket of bauxite is thin, somewhat irregular in quality, and clayey. The southern extension of the deposit, in which are situated the Quapaw and Hogue–Fletcher mines (pl. 1, nos. 51, 52, and 53), gently overlaps a buried ridge on the Midway surface and fills a southward-trending valley. The limits of the bauxite in this part of the deposit are poorly defined on the subsurface map (pl. 2), partly because of a lack of accurate information as to thickness and grade, and partly because the deposit passes laterally into a ferruginous rock that contains patches of bauxite. The ferruginous parts of the deposit are irregular in thickness and in lateral distribution.

The overburden ranges from less than 10 feet to more than 160 feet. It consists of lignite, carbonaceous clay, and sandy clay of the Berger formation overlain by dark-brown sandy carbonaceous clay and coarse sand of the Saline formation.

Hogue–Fletcher open-pit mine (pl. 1, no. 53).—This mine, owned and operated by Maner-Graham, is located in the NW¼SW¼ sec. 2 and extends eastward into the NE¼SE¼ sec. 3, T. 2 S., R. 14 W. Exploration of the area has been largely by private companies, although in July, November, and December 1943, a series of widely spaced holes was drilled by the U. S. Bureau of Mines, as part of a project to test the high-alumina clay near Bryant. Stripping operations by Maner-Graham began about January 1, 1943, and bauxite was mined from June to November of that year.

This is the southernmost mine on the large Osage deposit. The bauxite is a colluvial (type 2) accumulation in a large valley on the Midway surface, about 1,000 feet west of the buried edge of the Wills Point formation where it thins out against the nepheline syenite.

No examination of the ore was made while the mine was in operation. The pit is now filled with water and no bauxite is exposed, but it probably is similar in character to that of the Quapaw pit next described.

The pit is elongate and is L-shaped. Its total length is about 1,800 feet and its average width about 300 feet. The overburden ranges from about 50 to 70 feet, and is composed of lignite, lignitic clay, and sandy to silty carbonaceous clay of the Berger and Saline formations.

Quapaw open-pit mine (pl. 1, nos. 51 and 52).—The Quapaw is owned by the American Cyanamid and Chemical Corp. It is located about 2 miles south of the town of Bryant and lies in the SE¼NE¼ and the NE¼SE¼ sec. 3, T. 2 S., R. 14 W. The mine lies north of the Hogue–Fletcher mine previously described. It is about 2,000 feet long in a north-south direction and has a maximum width of about 750 feet.

Nearly all exposures of bauxite in the pit are now flooded, but one remaining contact at the south end was observed in the spring of 1945. Here the bauxite is light gray to almost white, fairly hard, pisolitic, and pebbly. The pisolites range in size from 5 to 20 millimeters in diameter, have dark-gray interiors and are generally softer than the matrix. The pebbles are tan, well-rounded granitic-textured bauxite, and range in size from 10 to 50 millimeters in diameter. The matrix contains a clay mineral that is hard and gray with a pearly luster. The ore is capped by a layer of tan to pinkish-tan crystalline siderite 2 to 3 feet thick. The overburden, 20 to 60 feet thick, is composed of lignite, lignitic clay, and carbonaceous clay of the Berger formation, overlain unconformably by dark brown sandy clay and sand of the Saline formation (fig. 5).

The date of stripping of the overburden is unknown but mining took place during 1942 and 1943. The ore that was mined is a part of the Osage deposit, and lies on the east flank of a ridge on the eroded and weathered surface of the Wills Point formation.

Rowland shaft mine (pl. 1, no. 47).—The mine operated by Taff, Fleming, Dryden and McWorkman, is located on the Rowland lease in NE¼SE¼ sec. 34, T. 1 S., R. 14 W.

Preliminary subsurface exploration of the property consisted of 25 test holes drilled on a rectangular grid pattern and spaced 300 feet apart.

The bauxite lies on a gently rolling to almost flat surface on clay of the Wills Point formation and is a part of the Osage deposit (pl. 2).

The ore body in the deposit is a lens-shaped, elliptical mass dipping gently toward the southeast corner of the lease, where the shaft is located. This point is about 1,000 feet northwest of the buried Midway and nepheline syenite contact.

The ore in the deposit averaged about 7 feet in thickness and lies about 117 feet below the surface.

One specimen of high-grade bauxite, obtained from a small dump on the property, is a light-gray to grayish-tan, firm, sparsely pisolitic rock. The matrix is essentially structureless and contains a few minute dark mineral grains. The pisolites are well rounded, slightly harder than the matrix, range in size from about 3 to 15 millimeters and make up about 15 percent of the bauxite. A chemical analysis of the specimen is shown below:

Analysis by field laboratory of the U. S. Bureau of Mines, Little Rock, Ark.

	Percent
Al_2O_3	59. 9
SiO_2	6. 1
Fe as Fe_2O_3	1. 5
TiO_2	2. 0
Ignition loss	30. 0
Insoluble	. 5
FeO	. 2

Bryant shaft mine (pl. 1, no. 48).—The mine is about 1 mile southeast of the town of Bryant and is in the SW¼SW¼ sec. 35, T. 1 S., R. 14 W. The Bryant mine is one of the old underground mines in Saline County. It was originally owned and operated by Consolidated Chemical Industries, Inc., and was known at that time as the Alexander 1 mine. The mine was operated in 1942 by the Dulin Bauxite Co., under whose ownership it was known as the Bryant mine, and in 1943 by the Osage Bauxite Co. of Bryant, who sank a new shaft and opened new workings.

The ore, which is found at an average depth of 120 feet, is concentrated in a shallow basin on the Midway surface. The deposit is a large irregular blanketlike part of the Osage deposit lying west of the southwest end of the Bryant nepheline syenite mass. Little is known about the ore except that it was pisolitic and similar in character to that found elsewhere in the vicinity. The ore averaged about 51 percent Al_2O_3, 10 percent SiO_2, and 6 percent FeO.

Elrod and West Elrod open-pit mine. (pl. 1, nos. 49 and 50).—This mine, located about 1½ miles southeast of Bryant, Ark., was formerly owned and operated by the Alcoa Mining Co. It was later owned by the Reynolds Metals Corp. It is divided into two parts referred to in this report as the Elrod pit and the West Elrod pit.

The West Elrod pit is in the NE¼NE¼ sec. 3, T. 2 S., R. 14 W. The overburden was stripped from the bauxite in the latter part of 1942 but the mine was not operated, and in late 1948, when last visited by the writers, it was being used as a basin for water pumped into it from the East pit.

The Elrod pit lies in the NW¼NW¼ sec. 2, T. 2 S., R. 14 W., and is separated from the West Elrod pit by a narrow unstripped ridge accommodating a road. The overburden was removed during the latter part of 1942 but mining operations did not begin until the latter part of the summer of 1944.

The mines are on the central or west-central part of the Osage deposit. A small nepheline syenite ridge, trending about N. 45° E., cuts across the southeast corner of the pit. The bauxite blankets this ridge and dips down the slope to the northwest onto the wedge of Midway sediments, the edge of which nearly parallels the long axis of the ridge.

The bauxite in the Elrod pit lies almost entirely on kaolinitic nepheline syenite. A small part of the bauxite in the extreme northwest corner of the pit overlies the Wills Point formation.

The surface upon which the bauxite rests forms the west flank of a large nepheline syenite hill, a small part of which crops out about 600 feet east of the mine. A large valley, trending almost due south on the eroded Midway surface, heads in the south-central part of the Elrod pit. This buried valley borders the Bryant nepheline syenite mass on its southwest end.

Most of the bauxite is pisolitic, but in the eastern part of the pit where the weathered nepheline syenite comes within 10 feet of the ground surface, an exposed face contains residual granitic-textured bauxite and weathered to fresh residual nepheline syenite boulders. Abundant small well-rounded boulders of fresh, weathered, and thoroughly bauxitized nepheline syenite are found scattered throughout the pisolitic ore, particularly in its lowermost part.

Ordinarily, the bauxite has a pale-tan to grayish-tan, firm to soft matrix, and hard well-rounded pisolites. Local areas in the ore have a high iron content and the largest of these is in the north-central part of the pit. This ore is reddish brown, hard, dense, heavy, and contains small black and red pisolites. Crystalline siderite commonly fills pores in the matrix and interstitial cavities between pisolites. This ore has been mined and blended with high-grade bauxite found elsewhere in the pit.

The overburden in the Elrod mine consists of gray kaolinitic clay, gray sandy clay, lignite beds and brown silty to sandy carbonaceous clay beds of Berger age overlain unconformably by sand and carbonaceous clay of the Saline formation. The thickness of the overburden ranges from about 10 feet in the eastern part to about 75 feet in the northwest corner.

The mine was operated by Alcoa Mining Co. through 1945, and more recently, by the Reynolds Mining Corp.

Martin shaft mine (*pl. 1, no. 46*).—This mine, operated by Schafer and Haire, is about three-quarters of a mile east of Bryant, Ark. in the SW¼NW¼ sec. 35, T. 1 S., R. 14 W. The operators drilled 42 test holes in the spring of 1943 to delimit the ore in the deposit. Development work on the mine began about December 1, 1943, after preliminary exploration was completed. Ore was produced through December 1944.

The ore lies at an average depth of 125 feet and is reached through a concrete-and-steel double compartment shaft with a manway.

The bauxite lies on a gently rolling to almost flat clay surface of the Wills Point formation and forms a large irregular blanketlike part of the Osage deposit, west of the Bryant nepheline syenite mass (pl. 2).

The ore has an average thickness of about 9 feet and is divided into three parts. The upper 2½ feet is soft and is described by the operators as being of "very high quality," a middle part 3 feet thick, hard, and of "very good quality," and a lowermost 3½ feet of a "clay type" ore which is lowest in grade. The average grade of the ore in this body was reported to be about 55.3 percent alumina, 7.0 percent silica, and 5.1 percent iron oxide. Evidently no hardcap was present anywhere in the mine.

Two specimens of pisolitic bauxite were obtained from a dump on the mine property. In the first, the matrix is light-grayish tan and is firm to brittle. The pisolites are well rounded, have soft to hard interiors and for the most part are harder than the matrix. They range in size from 4 to 20 millimeters across their greatest diameter and make up about 50 percent of the volume of the specimen. In the second specimen the matrix is tan, hard, and sideritic. The pisolites are well rounded and for the most part have soft light- to dark-gray interiors. They range in size from 4 to 15 millimeters in diameter and make up about 40 percent of the volume of the specimen. Chemical analyses of the two specimens are given below:

Analyses by field laboratory of the U. S. Bureau of Mines, Little Rock, Ark.

	Sample, in percent 1	2
Al_2O_3	59.2	51.8
SiO_2	4.6	3.0
Fe as Fe_2O_3	2.0	10.3
TiO_2	2.4	2.4
Ignition loss	31.2	32.0
Insoluble	.6	.5
FeO	.6	7.8

Neither the location nor the stratigraphic position of either specimen is known but the descriptions fit that of the middle zone of the ore as described by the operators.

Hardy ore bodies (*pls. 2 and 27*).—The bauxite described under this title forms the east end of the Osage deposit. Malamphy and others (1948, v. 15, p. 29–92, fig. 107) described it separately. For convenience in discussion, it will be divided into the North Hardy and the South Hardy ore bodies.

The North Hardy ore body is in the S½NW¼ sec. 35, T. 1 S., R. 14 W., and projects eastward into the SW¼NE¼ sec. 35. It underlies property owned by

Lela Hardy and R. M. Allison. The South Hardy ore body is in the south-central part of sec. 35, T. 1 S., R. 14 W., and underlies property owned by A. Wade, H. L. Thomas, D. A. Bray, Clyde and Retha Harris, the Louisiana Chemical Co., and Mrs. R. E. Delong. Neither ore body has been completely delimited by drilling. It is probable that the two bodies might connect if drilling were continued in the NE¼SW¼ sec. 35.

Early exploratory drilling in the Osage area by the Alcoa Mining Co. and the American Cyanamid and Chemical Corp. indicated that further prospecting was warranted, and the joint Federal project drilled 189 holes from January 18 to July 12, 1944 (Malamphy and others (1948, v. 15, p. 29–92, fig. 107).

The Hardy ore bodies lie on the northwest flank of a nepheline syenite ridge and extends blanketlike across the Wills Point formation. The buried contact of the Wills Point and the nepheline syenite on the post-Midway surface trends about N. 60° E. and is nearly parallel to the axis of the ridge. The relation of the deposit (type 2) to the post-Midway erosion surface is shown in the accompanying subsurface map (pl. 27).

The South Hardy ore body is irregular in outline, and is lens shaped in cross section. The thickest section of ore, about 30 feet (for example, USBM drill hole 9–399), lies in a shallow depression in the surface of the Midway sediments elongated parallel to the Midway and nepheline syenite contact. A minor part of the ore along the southeast edge of the body overlies nepheline syenite and its weathered derivatives.

The North Hardy ore body, like the south one, is lens shaped and irregular in outline. It overlies clay of the Wills Point formation. Here the post-Midway erosion surface is flat or gently rolling and again the thickest ore, about 17 feet, lies in a shallow depression in the post-Midway surface.

The bauxite in each ore body has essentially the same characteristics and can be divided into two parts. The upper part is hard, pisolitic, and sideritic. The lower part is soft, crumbly, and clayey, and may or may not be pisolitic. The pisolites, if present, are usually much larger than those occurring in the upper part of the ore. Pebbles of granitic-textured bauxite and of bauxitized Paleozoic rock are scattered throughout the lower section of the ore. The ore in both bodies averages about 42 percent available alumina. Ferrous iron, the main secondary impurity, is present in the south ore body in excess of 10 percent. No evidence of sorting or stratification of the bauxite was noted anywhere in the deposit.

The ore is covered by a hard gray to light-grayish-tan siliceous ferruginous rock from 2 to 3 feet thick, which should serve as a competent roof rock if the deposit were mined by underground workings.

Immediately overlying the hardcap and kaolinitic clay is a lignite bed which in turn is overlain by carbonaceous clay, sand, and lignitic clay of the Berger and Saline formations (fig. 61). The overburden ranges in thickness from 22 feet at the south end of the south ore body to about 160 feet at the north end of the north ore body.

FIGURE 61.—Section 35 mine, Saline County. Surface of pisolitic bauxite stripped in preparation for mining. View looking northeastward across large Reynolds open pit in sec. 35, T. 1 S., R. 14 W. Walls exposed in light-gray silty clay and lignite of Berger formation overlain by thin wedge of Saline formation containing sand and gravel at top.

Section 35 open-pit mine.—In 1948 the shallow southern part of the Hardy deposit was stripped by the Reynolds Mining Co. (fig. 61) but no mining was done by the end of 1948.

BRAY–THOMAS DEPOSIT

By William J. Powell

Plate 28

The Bray bauxite deposit is in the E½SE¼ sec. 35, T. 1 S., R. 14 W., and extends eastward into the W½SW¼ sec. 36, T. 1 S., R. 14 W. The ore underlies property owned by H. L. Thomas, D. A. Bray, and Clyde and Retha Harris. The land surface overlying the southern part of the deposit is gently rolling and clear of timber whereas the northern part is hilly and wooded. The altitude ranges from about 380 to 420 feet.

The discovery hole on the deposit was USBM 2–196, drilled May 25, 1943, in the NW¼SE¼SE¼ sec. 35, T. 1 S., R. 14 W., on the property of D. A. Bray. About 22.4 feet of bauxite was cored. The program to delimit the deposit began on October 15, 1943, and 88 holes were drilled, spaced about 200 feet apart (Malamphy and others, 1948, v. 15, p. 1–28, fig. 106).

The main mass of ore in the Bray deposit is a colluvial (type 2) accumulation on a broad nepheline syenite ridge extending northward from an outcrop in the N½ sec. 2, T. 2 S., R. 14 W. The greater part of the ore body rests on decomposed nepheline syenite, but a small lobe on the north margin lies on the Kincaid formation. The relation to the post-Midway erosion surface is shown in the subsurface map and the cross section and columnar sections (pl. 28).

The deposit is lens shaped and irregular. It trends in a northeast-southwest direction and is about 1,100 feet long by 530 feet wide. A siliceous hardcap, consisting of a hard gray to gray-tan, bauxitic or kaolinitic clay containing poorly formed pisolites and clay balls is present in much of the ore.

The highest grade ore, usually found in the middle of bauxite section, is fairly hard and porous, and contains abundant pisolites. It is overlain and underlain by softer, crumbly bauxite with fairly soft pisolites sparsely scattered through it.

The bauxite in the central and eastern parts of the ore body contains local concentrations of secondary iron. This ferruginous bauxite is hard, dense, and dark red to reddish-brown. Pisolites are brick red to black and are harder than the matrix. No evidence of sorting or reworking of pisolites was noted. The thickness of the bauxite ranges from less than 1 to 25.6 feet.

The overburden ranges from 12 to 153 feet in thickness and is composed of lignite, carbonaceous silty to sandy clay, and sand of the Berger and Saline formations.

THOMAS–WILLIAMS DEPOSIT

By Edwin A. Brown

Plate 29

This deposit is located in the NE¼ sec. 35 and the W½NW¼ sec. 36, T. 1 S., R. 14 W., on the properties of Clyde and Retha Harris, B. S. Williams, H. L. Thomas, R. M. Allison, Sarah B. Stover, and Addie B. Sillin. The land surface is gently rolling, wooded and cultivated over the western part, and gently to steeply sloping over the eastern part of the deposit. Surface altitude ranges from 400 to 500 feet.

Before our exploration of the general area, the Republic Mining and Manufacturing Co. drilled test holes, spaced about 600 feet, in part of the NE¼ sec. 35. Bauxite was found in several of the holes but mineral rights were not acquired by the company. During early wildcat drilling in this area by the Federal project, bauxite was first cored on this deposit in USBM drill hole 2–213A, drilled June 23, 1943, in the SW¼SE¼NE¼ sec. 35. Close drilling on a 200-foot hexagonal grid began October 19, 1943, and about 410 holes were drilled in and near the deposit (Malamphy and others, 1948, v. 14, p. 1–143, fig. 105).

The deposit (type 2) slopes gently to the southeast and forms an irregular lenticular blanket on a complex depression topography (p. 216) formed on the post-Midway land surface. The relation of the deposit to this surface is shown in the subsurface map and in the cross section and columnar sections (pl. 29). The deposit is about 3,800 feet long in an east-west direction, about 2,800 feet wide in a north-south direction. Bauxite of ore grade reaches a maximum thickness of 30 feet, averaging 11 to 12 feet, within a bauxite-kaolin zone ranging in thickness from 20 to 87 feet. Some of the depressions contain thick ore, but others, even within the limits of the ore body, contain little ore.

The bauxite is mealy, finely fragmental, and somewhat pisolitic or oolitic. Most of the pisolites are soft and poorly defined; in general they are most common and better formed in the upper part of the ore. Likewise the percentage of available alumina normally is highest in the upper part of the ore and decreases gradually downward. Within the ore body the available alumina ranges from 32 to 53.5 percent and averages about 38 percent, and the ferrous iron averages 5 to 6 percent. Bauxite of ore grade overlies 2 to 5 feet, and is overlain by 2 to 3 feet of finely fragmental clayey submarginal bauxite. No hardcap is present. The ore body is covered by overburden ranging in thickness from 115 feet at the northwest to 280 feet at the southeast.

HARRIS DEPOSIT (INCLUDES SOUTH HARRIS ORE BODY)

By Richard C. Shelton

Plate 30

This deposit extends from the NE¼SW¼ sec. 36 northward into the SW¼SE¼ sec. 25, T. 1 S., R. 14 W. The deposit containing the ore bodies underlies properties owned by Clyde and Retha Harris, Sarah Stover, J. W. Shipp, and B. A. Fletcher. The surface of the ground is hilly and wooded and ranges in altitude from 450 to 550 feet.

The large Harris ore body was discovered during the progress of the government wildcat program exploring the buried northwest flank of the Bryant high. In the discovery hole, USBM 2–215, in the SE¼NE¼NW¼ sec. 36 drilled June 25, 1943, 23.6 feet of ore was cored. Subsequently, the deposit was blocked out by drilling 306 holes spaced about 200 feet apart on a hexagonal grid (Malamphy and others, 1948, v. 13, p. 1–63, and 64–99, figs. 103, 104). A small ore body, part of the deposit with a high iron content, lies south of the main body. This was described by Malamphy and others as the "South Harris deposit" but is here considered along with the rest of the deposit.

The deposit lies on the northwest flank of the nepheline syenite ridge and extends westward downslope to the edge of the Kincaid formation (pl. 30). Its north end overlies what is probably the north edge of the nepheline syenite. This is marked by a trachytic border rock in contact with a black shale of probable Paleozoic age.

The trend of the long axis of the main ore body is about N. 30° E., nearly parallel to the buried nepheline syenite ridge to the east, and to the buried edge of the Midway sediments to the west. Its maximum length is about 4,200 feet and its average width about 900 feet.

Nearly all the bauxite is part of a colluvial accumulation (type 2 deposit). A small part upslope in the deposit and beneath colluvial ore is residual on the nepheline syenite (type 1 deposit) shown in holes USBM 9–047, 9–062, and 12–024A in which granitic bauxite was cored. The ore within an 8-foot isopach line lies in three distinct lobes. The thickest bauxite, especially in the northern part of the deposit, fills small valleys on the west slope of the nepheline syenite ridge. Ore is also concentrated along the break at the base of the slope.

The upper part of the ore is hard, the middle part is firm but mealy, and the lower part is soft and clayey. Most of it has a pisolitic texture, the pisolites are well defined and more abundant in the upper and middle parts. The pisolites are not sorted or stratified, and the matrix is homogeneous and structureless. Granitic-textured bauxite is present in the lower bauxite interval, in drill cores from the upslope parts of the deposit.

Locally within the deposit, the top 6 inches to 2 feet of bauxite, which has a high silica content and contains less than 32 percent available alumina, is indurated and forms a hardcap. Where the hardcap is not present the ore is overlain by 1 to 5 feet of bauxitic or kaolinitic clay.

The deposit and associated bauxitic and kaolinitic clay are overlain by 120 to 280 feet of soft clayey lignite, plastic carbonaceous clay and gray clayey sand of the Berger formation, and dark-brown carbonaceous silty clay and coarse red sand of the Saline formation. The top of the red sand of the Saline is an indurated ferruginous sandstone layer that caps most of Alexander Mountain.

BROOKS AREA

The deposits described below extend from the S½ sec. 31, T. 1 S., R. 13 W., to the N½ sec. 12, T. 2 S., R. 14 W. (fig. 60). They lie in a line nearly parallel to the axis of the ridge of the buried Bryant nepheline syenite mass along its east and southeast slope. All-weather gravel roads pass over each deposit.

The post-Midway erosion surface of the southeast flank of the nepheline syenite ridge is steep, whereas the same surface on the overlapping sediments of the Midway group dips gently to the south and east. The buried edge of the Midway sediments nearly parallels the axis of the nepheline syenite mass. The buried contact on the east side of the ridge is about 100 feet lower than that on the west side.

The south end of the Bryant high was drained in early Eocene time by one large valley trending almost due southward and located in the center of sec. 2, T. 2 S., R. 14 W. This valley emptied into a major southeast drainage channel.

The bauxite deposits, with one exception, are small and scattered. The small deposits of possible commercial value overlie nepheline syenite or its weathered derivatives. Over Midway sediments to the east, bauxite has been found only in isolated drill holes. Bauxitic and kaolinitic clay beds typical of the bauxite-kaolin zone are scattered over a large area east and south of the Bryant high, but the thickness of this clay ranges from 1–2 inches to about 60 feet in valleys on the nepheline syenite.

The only large deposit on the southeast side of the Bryant high is in secs. 1 and 12, T. 2 S., R. 14 W. Most of the bauxite overlies a gently rolling Wills Point surface but the northwest end of the deposit extends upslope and across the buried Midway and nepheline syenite contact.

The barren nature of the east slopes of the Bryant high is probably due to extensive erosion during Berger time. Sediments of the Wills Point have been stripped out of the main post-Midway valley along the east side of the nepheline syenite, exposing limestone of the Kincaid formation along most of the valley bottom. The limestone is overlain by coarse green sand of the Berger formation. Farther up the valley the limestone is absent, and green sand of the Berger formation overlies Paleozoic rocks or nepheline syenite in the valley bottom. The slopes of nepheline syenite above the valley bottom were scoured by the same erosion. Many of the drill holes in this area recorded kaolinized or even fresh nepheline syenite directly overlain by sand of the Berger formation. In minor valleys on the slopes, however, bauxite and kaolinitic clay is present in considerable thickness. The material is generally fragmental and interbedded with carbonaceous clay or thin lignite layers. A few small deposits of colluvial bauxite (type 2) are present. These generally are overlain by carbonaceous clay and lignite of the Berger formation and were apparently protected from the scour associated with the green sand of the Berger. The deposits probably are protected remnants of once extensive bodies of bauxite that were eroded away when the sand was deposited.

South of the Bryant high, the deposits in secs. 1 and 12, T. 2 S., R. 14 W., are covered by well-bedded lignite and carbonaceous clay of the Berger formation. The green sand is absent here, as is any evidence of extensive erosion after the accumulation of the bauxite.

The deposits of the Brooks area are covered by an overburden of carbonaceous clay, lignite, silty to sandy clay, and sand, all of Wilcox age. The thickness of this overburden reaches a maximum of 260 feet.

Exploration by the Federal drilling project in the Brooks area was a continuation of the exploratory drilling west and northwest of the Bryant high. Before this systematic program there had been some scattered company drilling in secs. 20, 29, and 31, T. 1 S., R. 13 W., and in sec. 1, T. 2 S., R. 14 W., which indicated the presence of buried nepheline syenite hills surrounded by gently dipping clay of the Midway. Drilling by the Geological Survey in 1934, under the supervision of M. N. Bramlette, showed bauxite overlying Midway sediments in sec. 1, T. 2 S., R. 14 W., and in sec. 6, T. 2 S., R. 13 W., not far from outcropping nepheline syenite to the north.

LASATER–MC MURRY DEPOSIT

By Elmer P. Kneedler

Plate 31

This deposit lies in the center of the NE¼ sec. 31, T. 1 S., R. 13 W. about 2½ miles south of the town of Alexander, on property owned by Mildred McMurry, Luke Ramsey, W. Northern, and B. V. Lasater. The topography is rolling, and is utilized in seasonal cultivation. The altitude ranges from 375 to 410 feet.

The discovery hole USBM 13–013 was drilled September 4, 1943, on the property of Mildred McMurry, and 14.7 feet of bauxite was cored. The ore body was subsequently delimited by drilling 41 test holes, most of which were about 200 feet apart (Malamphy and others, 1948, v. 10, p. 21–32, fig. 93).

The buried nepheline syenite surface on which the bauxite lies is cut by several tributary valleys that diverge from a saddle formed by a small knoll to the east. The deposit is a colluvial accumulation (type 2), elongate in a northeasterly-southwesterly direction, that blankets the sides and fills the bottom of parts of the tributary valleys, as shown in the subsurface map and section (pl. 31).

Three types of bauxite are in the deposit: (1) firm to hard pisolitic bauxite that is tan to grayish-tan, with hard well-rounded pisolites that average 5 or 6 millimeters in diameter and make up about 35 percent of the rock; (2) soft pisolitic bauxite that is tan with minor quantities of admixed reddish-tan and grayish white bauxite—the pisolites are hard to soft, and reach a diameter of 5 or 6 millimeters, and seldom make up more than 25 percent of the bauxite; (3) soft nonpisolitic rock that is tan, porous, mealy, and textureless, or in places is highly oolitic. In some parts of the deposit all three types of bauxite occur together and in others only one of the above types is found. Where they occur together the hard pisolitic bauxite is always uppermost with the soft pisolitic and the oolitic or textureless bauxite below it in that order. The lower part of the bauxite that fills small valleys in the underlying nepheline syenite is fragmental.

Secondary iron, especially siderite, is common in the deposit but is not present in prohibitive quantity.

The bauxite in the deposit is directly overlain by 2 to 12 feet of relatively soft kaolinitic clay. No hardcap is present over the ore. The overburden ranges from 127 to 200 feet and averages about 152 feet in thickness. It is made up of carbonaceous clay, sandy to silty clay, and sand of the Berger and Saline formations.

CHALKEY DEPOSIT

Plate 2

Several small bauxite deposits are located in the SW¼SE¼ and the S½SW¼ sec. 31, T. 1. S., R. 13 W. One of these was discovered during the Federal exploration program on the southeast side of Alexander Mountain. USBM drill hole 13–094, drilled in November 1943 and later redrilled as no. 13–106, first cored bauxite in this area. Shortly afterwards a private company drilled these properties with holes 200 to 500 feet apart.

Little is known of the character of the ore in these deposits as information from company records is limited. The deposits are patchy, valley-fill accumulations associated with minor drainage systems on the surface of the nepheline syenite. Because the deposits are small and fill valleys, the ore is probably fragmental and clayey.

The bauxite is covered by kaolinitic clay, lignite, and gray clay of the Berger formation, and brown clay and sand of the Saline formation, ranging from 190 to 220 feet in thickness.

WALDEN GROUP

By George E. Siple

Plate 32

The Walden deposit, located about 4 miles south of the town of Alexander, lies in the S½ sec. 1, T. 2S., R. 14 W. and extends southward into the N½ sec. 12, T. 2 S., R. 14 W.

It includes several ore bodies which are here discussed together. These bodies have been described separately by Malamphy and others (1948, v. 16, p. 1–106, figs. 108–114) under the names Fletcher deposit (no. 65), Mildred McMurry deposit (no. 66), Archer deposit

(no. 67), Walden deposit (no. 68), Walden extension deposit (no. 69), and Rock Island deposit (no. 70). All except the Rock Island deposit are shown on plate 32.

The topography of the area is rolling to hilly and the altitude ranges from about 321 to 453 feet. A good all-weather gravel road passes directly over the deposit containing the ore bodies, and a spur of the Rock Island Railroad passes within one-quarter mile of the main group of ore bodies. In 1948 the Reynolds Mining Corp. opened a vertical shaft mine, the Standard 80, in the largest ore body.

Exploratory drilling by mining companies and by the U. S. Geological Survey, supervised by M. N. Bramlette, indicated the presence of ore in the area. In April of 1944 drilling by the Federal project was started on the D. F. Walden property by blocking out around wildcat hole USBM 10–279 on 200-foot centers.

Drilling to delimit the deposit was done April to July 1944 and January to April 1945. A total of 281 holes was drilled before field operations were discontinued with the result that three of the ore bodies were not completely delimited.

The ore bodies are both valley-fill and valley-flank (type 2) accumulations which lie almost entirely on the eroded surface of the Midway sediments. A small part of the ore in the largest body extends up the slope to the northwest and onto the buried flank of a nepheline syenite mass which crops out about 1,000 feet farther in the same direction. The trace of the contact of the Midway group and the nepheline syenite on the post-Midway surface trends about N. 45° E. The relation of the ore bodies to one another and to the post-Midway erosion surface is shown in the subsurface map and in the accompanying cross section and columnar sections (pl. 32).

The ore lies in several distinct bodies. Only two of the ore bodies are connected by 5 feet or more of ore. The others are either completely isolated or are connected by bauxite less than 5 feet thick. The thickness of ore is more than 8 feet in 5 bodies. Each ore body is lens shaped, elongated in a northeasterly direction, and irregular.

The largest of these ore bodies lies downslope from, and its long axis is parallel to, the buried Midway and nepheline syenite contact. The rest of the ore bodies are south and east of it and overlie the clay surface of Midway age.

The bauxite in all the ore bodies has the same general physical character and consists of two main types: pisolitic and nonpisolitic. The pisolitic type predominates and overlies the nonpisolitic in vertical section. It is usually tan, gray or reddish brown and is soft throughout except in the middle third. Pisolites increase in abundance with depth until they make up about 60 to 65 percent of the rock near the middle part of the bauxite section. The pisolites range in size from 2 to 50 millimeters in diameter, the average is about 8 millimeters. Most of the large ones are compound. In the high-grade middle part of the ore body the pisolites are hard, concentrically banded, and have dark reddish-brown vitreous-appearing interiors. Above and below this high-grade ore the pisolites are softer. Many are filled with a soft muddy liquid and a few are hollow. Small crystals of siderite are disseminated throughout the matrix.

The nonpisolitic bauxite is soft, mealy to clayey, tan in color, semiplastic, and quite porous. Normally, it has a higher available alumina content than the pisolitic material.

Granitic-textured bauxite pebbles, well rounded to subrounded and light-tan to orange tan, are found below the nonpisolitic ore embedded in the upper part of the underlying bauxitic clay.

Laterally, the ore grades through low-grade bauxite and bauxitic clay to kaolinitic clay. No persistent hardcap or competent roof rock overlies the ore in any part of the area. However, local hard highly siliceous or ferruginous layers of low-grade bauxite are distributed throughout some parts of the individual ore bodies.

Overburden ranges in thickness from about 65 to 265 feet throughout the area and from 113 to 229 feet above ore in bodies having a thickness greater than 8 feet. In general, the overburden thickens from northwest to southeast and is composed of a basal lignite bed and dark-brown carbonaceous to lignitic clay interbedded with gray to green silty and sandy clay of the Berger formation, overlain by brown silty to sandy micaceous carbonaceous clay, and yellow, red, and white sandy clay to clayey sand of the Saline formation.

Standard 80 shaft mine.—This mine was opened by the Reynolds Mining Corp. in 1948 on the Walden ore body of this group of deposits.

BAUXITE OUTCROP, SOUTH SIDE OF ALEXANDER MOUNTAIN

A large outcrop of pisolitic bauxite is in the W½NW¼ sec. 1, and extends into the E½NE¼ sec. 2, T. 2 S., R. 14 W. Mineral rights on the property containing the outcrop are owned by the Alcoa Mining Co. which has prospected the area by trenching and drilling. The outcrop is elongate in a northerly direction, almost elliptical, and is about 1,500 feet long and 800 feet across at its widest point. The bulk of the bauxite deposit lies within the outcrop area on the south flank of the Bryant high, which crops out 100 feet north and east of the bauxite.

A large part of the bauxite in the outcrop has a hard, brittle pale-tan matrix with no apparent texture. The

pisolites are well rounded, concentrically color banded, and have dark reddish-brown vitreous interiors. They are closely packed and make up about 60 percent of the bauxite. They range from 2 to 6 millimeters in diameter.

A chemical analysis of a high-grade specimen obtained from a point near the center of the outcrop is given in the table below (sample 1).

Along the east margin of the outcrop, some of the bauxite has an extremely high ferric iron content. One specimen has a deep brownish-red, hard, brittle, slightly porous matrix with hard well-rounded pisolites ranging from 2 to 10 millimeters in diameter and making up about 65 percent of the bauxite. The pisolites are much harder than the matrix and those exposed on weathered surfaces have dark-gray metallic-appearing exteriors. The specimen was magnetic, and the pisolites seem to contain all or at least a major part of the magnetic constituents of the bauxite because individual pisolites are strongly magnetic. A chemical analysis of the specimen showed more than 50 percent total iron as Fe_2O_3 (sample 2).

The highly aluminous bauxite in the outcrop weathers to a grayish-tan, fairly porous rock. Its texture where pisolites have weathered out of the matrix resembles that of a vesicular extrusive igneous rock. An analysis of a weathered specimen of the high-alumina bauxite is given below (sample 3).

Analyses of bauxite samples from outcrop, south side of Alexander Mountain

[Analyses by field laboratory of U. S. Bureau of Mines, Little Rock, Ark.]

	Samples, in percent		
	1	2	3
Al_2O_3	60.6	27.2	55.2
SiO_2	4.3	5.9	8.6
Fe as Fe_2O_3	2.9	50.3	3.2
TiO_2	1.8	3.0	2.3
Ignition loss	28.4	13.2	.2
Insoluble	2.0	.4	.3
FeO	.2	.2	.4

1. Sample from center of outcrop.
2. Sample from east margin of outcrop.
3. Weathered "vesicular" bauxite.

The highly weathered product of the bauxite at the surface of the ground is a red sticky to gummy clay or "soil." The deposit has not been mined.

DAVIS AREA

Large deposits lie south and slightly east of the town of Bauxite and extend from the S½ sec. 22, T. 2 S., R. 14 W., northward into the S½ sec. 10 (fig. 60). This is called the Davis area, after the large Davis underground mining area in sec. 22, the largest mine system in the region. Good all-weather gravel roads, both county and private (company) roads, cross within a few hundred feet of every deposit. The Davis area is one of the subdivisions of the Saline nepheline syenite dome-shaped mass.

The post-Midway drainage consists of a long relatively steep sided major valley of gentle gradient that heads close to the top of nepheline syenite outcropping in the S½ sec. 22. The axis of the valley bottom begins in the NW¼NW¼SE¼ sec. 22 and trends about N. 40° W. to a point near the section line between secs. 22 and 15; from there it trends about N. 20° E. across sec. 15 and into sec. 10. In the northeastern part of sec. 10 this valley empties into a larger drainage system which trends eastward and slightly southward between the Saline dome and the Bryant hill. In general the west wall of the valley is more steep than the east. Many smaller tributary valleys enter in a direction about normal to its axis. These generally have a relatively high gradient.

The buried contact of the Midway sediments and the nepheline syenite is very close to the mouth of the drainage channel. The edge of the Wills Point formation trends westward across the S½SE¼ sec. 10, then due north along a line between the east and west halves of the same section.

The deposits in the Davis subsurface valley crop out spottily along the entire length of the contact between the nepheline syenite and Wilcox sediments, and all the ore bodies are underlain by nepheline syenite or its residual weathering products except for the ore of the Canal No. 1 mine in the SW¼SE¼ sec. 10, which overlies the buried Midway and nepheline syenite contact. The thickest bauxite and highest grade ore in this area is normally found on the flanks of small ridges, between adjacent valleys tributary to the main valley or its larger reentrants. This high-grade material thins out or is absent over the ridge tops. Bauxite on the floors of the main valley and large tributary valleys is normally poor grade. The total thickness of the bauxite and associated kaolinitic clay is not known, but exceeds 50 feet across most of the floor of the Davis valley.

Residual bauxite on the nepheline syenite slopes is granitic in texture, and grades upward into a rubbly or cobbly mass of granitic bauxite formed by breaking down of the residual material. Gradationally above it is pisolitic bauxite containing large, soft to hard, concentrically banded rude pisolites with admixed rounded blocks of birdseye ore and granitic bauxite. Overlying the pisolitic bauxite is a bed of varying thickness composed of pisolitic and granitic bauxite pebbles and cobbles, in a clayey matrix that is generally bauxitic but commonly is kaolinitic, and locally is composed of brown carbonaceous silt or sand. This bauxite is a basal conglomerate of the Saline formation.

Much of this material is high enough in grade to mine. Small well-rounded pebbles of what appear to be bauxitized Paleozoic shale were found in the upper part of a bed of low-grade rubbly bauxite in the extreme west end of the Section 15 mine. A chemical analysis of one of these pebbles indicated an available alumina content of about 61 percent. A small outcrop of rock of Paleozoic age, probably a roof pendant in the syenite, is about 600 feet southwest of this locality.

The deposits are extensive and continuous in this area. The overburden is relatively thin. The large amount of stripping and mining that took place from 1940 through 1943 caused most of the separate pits to coalesce into large mining areas. Fifteen of the 37 mines can be identified on plate 1 as follows:

Lantz (no. 55) NW¼NW¼ sec. 15
Section 10 (no. 54) SW¼SW¼ sec. 10
Canal No. 1 (no. 69) SW¼SE¼ sec. 10
African Camp (no. 67) SW¼NE¼ sec. 15
Norton (no. 68) SW¼NE¼ sec. 15
Alexander Hill (no. 64) SE¼SW¼ sec. 15
Section 15 (no. 65) S½SW¼ sec. 15
Maggie (no. 56) NE¼NE¼ sec. 21
Julia (no. 57) SW¼NW¼, NE¼SW¼, and NW¼SE¼ sec. 22
Davis (nos. 63, 63a) NW¼NW¼ sec. 22
Mary (no. 62) NE¼NW¼ sec. 22
Granite Branch (no. 61) SE¼NW¼ sec. 22
Johnson (nos. 58, 59) SW¼NE¼ sec. 22
Ella (no. 60) SE¼NE¼ sec. 22
Stringtown (no. 66) SW¼SE¼ sec. 15

These mines are all owned by the Alcoa Mining Co. except the Norton mine, property of the Norton Co., and all were begun as strip-pit mines except the Davis. The Maggie, Julia, Johnson, Mary, and Granite Branch are combination strip-pit and underground mines, the subsurface workings of which are part of a large system which merged with the Davis mine and was designated the Davis underground mine area by the Alcoa Mining Co. North of the underground area, pits in the southern part of sec. 15 and of the north-central part of sec. 22 have merged into one large stripped area. These are the Section 15, Alexander Hill, and Stringtown mines. They join the Maggie and Mary strip mines now covered by mine dumps. Most of the mines are drained through a canal 10 to 30 feet deep and 3 miles long.

The history of individual mines in this area is difficult to reconstruct satisfactorily. Reports before 1936 in the U. S. Bureau of Mines "Minerals Yearbook" and the U. S. Geological Survey "Mineral Resources of the United States," group all the Republic Mining and Manufacturing Co. (American) mines under the name "mines at Bauxite;" only rarely are individual mines named. Some of the earliest mines in the Saline district were located in the Davis area. Hayes (1901, pl. 61) showed the location of 6 pits in secs. 15 and 22 that were opened in 1900. They were on the outcrop edge of present large mining areas. The Maggie mine was listed as a producer in 1911, and the Lantz mine was stripped that same year according to the U. S. Geological Survey "Mineral Resources of the United States" (1912, p. 926). By 1923 the Maggie, Julia, Johnson, Ella, Granite Branch, and Mary had been operated, and that year the Davis tunnel, 4,000 feet long, was driven in sec. 22 to mine bauxite covered by 100 feet or more of overburden. From 1924 until about 1940 most of the ore from the Davis area was mined by underground methods. In 1936 production was reported from the Lantz mine, from the Davis mine called "area *A*," and from "area *B*" that included pits in secs. 14 and 15. Aerial photographs taken in July 1938 show that the Section 10 mine, a part of the Section 15 mine, and the Lantz mine were being worked, although most others appeared abandoned or unused. Large-scale stripping of the Section 10, Section 15, Alexander Hill, Stringtown, African Camp, Lantz, and Canal No. 1 mines was done in 1941 and 1942, and production from the area reached a peak in 1943. Since World War II only the Section 15, African Camp, and to a lesser extent the Section 10 mines have been active. The mine operators are reluctant to make a statement that a mine is abandoned, due to the fact that they have reopened supposedly abandoned pits when economic conditions permitted.

The area has been prospected entirely by company drilling. Most of it was first drilled on 220-foot centers on a rectangular pattern. More closely spaced drilling was undertaken before stripping and mining.

Overburden in the area consists of gray carbonaceous kaolinitic or silty clay of Saline, or possibly Berger age, found only over the deepest part of the major valley floor. Directly above is the brown silty to sandy carbonaceous clay and yellow to orange clayey sand of the Saline formation, overlain in turn by sandy clay of the Detonti formation which caps only the high hills in the southern part of the locality in the Davis underground mining area.

No production figures on ore mined in this area are available but it has probably produced a greater aggregate tonnage than any other throughout the bauxite district.

African Camp open-pit mine (*pl. 1, no. 67*).—The stripped surface of the bauxite of this mine in the SE¼NE¼ sec. 15, T. 2 S., R. 14 W., is one of the best examples in the region of a weathered post-Midway erosion surface in the nepheline syenite. The topography is shown in figure 35*A*; the character of the bauxite surface when stripped and its similarity to a broadly rounded syenite outcrop cleared of debris are

shown in figure 35*B*. Bauxite exposed on the surface is rubbly. In upslope parts of the pit angular to rounded blocks as much as several feet in diameter, of granitic-textured, birdseye, and vermicular ore are included in a concretionary pisolitic matrix. Mined faces show extensive exposures of granitic-textured bauxite, overlain by pisolitic ore containing rounded blocks. Near the center of the small valley shown in the photograph (fig. 35*A*), however, well-rounded cobbles of bauxite are in a matrix of gray kaolinitic to bauxitic clay. The African Camp mine is a residual (type 1) deposit.

Just north of the mine in a railroad cut is an exposure of massive granitic-textured bauxite cut into large angular blocks by horizontal and subvertical veins of ferruginous clay (fig. 42*A–C*) that bear a striking resemblance to joint systems in nepheline syenite. The veins are 3 inches to nearly 1 foot wide, are zoned parallel to the sides, and are evidently later than the bauxite although they apparently formed in preexisting joints formed in the original igneous rock.

West of the African Camp mine, on the south face of the adjoining Norton pit, white braiding kaolinite veins cut granitic-textured bauxite (fig. 40*C*). These are an inch or more thick, are well formed at the base of the bauxite face and die out near the top. They are considered evidence of subsequent kaolinization of the bauxite by silica or clay from below.

Bauxite in the African Camp mine ranges in thickness from 10 to 38 feet, and before stripping was covered by 11 to 53 feet of dark-brown laminated silty clay and loose tan sand, all of the Saline formation.

Section 15 open-pit mine (pl. 1, no. 65).—The extensive stripped area in the S½SW¼ sec. 15 and east part of the SE¼SE¼ sec. 16, T. 2 S., R. 14 W., covers the long east slope of a nepheline syenite hill, and much of the buried Davis valley at its foot. The north wall of the Section 15 mine is a continuous mined face more than 2,000 feet from the crest of the hill on the west, to the drainage canal near the center of the Davis buried valley. The bauxite face is 5 to 18 feet high and is overlain by a few feet to more than 50 feet of dark-brown carbonaceous laminated silty clay, and loose red sand of the Saline formation. Bauxite at the extreme west end of the face, in the SE¼SE¼ sec. 16 near the top of the hill, consists of well rounded pebbles of bauxite in a silty kaolinitic to bauxitic clay. Some of the pebbles have a shaly parting and closely resemble fissile shale of Paleozoic age. One well-rounded flat pebble, about 2½ by 1 by ¾ inches, with pink and gray laminae or banding, consists of nearly pure gibbsite. An analysis is given on page 100. The pebbles occur about 600 feet northeast of a small inlier of Paleozoic age in nepheline syenite. Granitic-textured bauxite is exposed along the north wall. It is massive in a few places, but in most places is broken by veining and concretionary action into blocks and fragments. The granitic-textured bauxite is overlain by concretionary bauxite consisting of rounded blocks and fragments in a pisolitic matrix. Near the foot of the hill, this rock grades to rubbly bauxite in a clayey matrix that contains much silt and sand. This is a basal conglomerate of the Saline formation. At one locality in the mine, 500 feet northwest of the southeast corner of sec. 16, a channel filled with bauxite boulders in a carbonaceous silty clay matrix of Saline age, overlies bauxitic and kaolinitic underclay; granitic textured and pisolitic bauxite were cut out by the erosion of the channel (fig. 54).

Relation of the granitic-textured zone to the overlying concretionary zone is shown in the central part of the mine, in a drainage ditch 200 feet northeast of the Davis portal. Apophyses and masses of pisolitic bauxite cut and in part underlie large masses of granitic-textured bauxite in place.

When the pit was examined early in 1945 a surface on the bauxite extended northeast of the Davis portal. It was lobate, broadly rounded and gently sloping. Downhill from the granitic-textured and concretionary bauxite just described, the ore thickened to more than 40 feet. A mine face 20 feet high, 500 feet northeast of the Davis portal, showed only pisolitic bauxite containing rounded granitic-textured blocks and fragments. At the west end of the face an exposure of bauxite resembled unconsolidated gravel. It consisted of "pebbles" 3 millimeters to 10 centimeters in diameter in a matrix of "sand" grains about 1 millimeter across. Pebbels were subrounded to well rounded, with polished but lumpy surfaces. Sand grains were well rounded, spheroidal, and were polished oolites rather than clastic grains. A crude sorting but no stratification was apparent in patches of finer or coarser consitutuents. The material was formed by concretionary processes, in the upper part of the thick bauxite. Such a formation is not uncommon, but occurrence of an uncemented matrix of loose oolites is unusual.

The deposit is largely residual (type 1), although much of the ore, particularly near the valley bottom, is an alluvial (type 4) accumulation at the base of the Saline formation.

Alexander Hill open-pit mine (pl. 1, no. 64).—This mine, in the SW¼SE¼ sec. 15, T. 2 S., R. 14 W., and the Section 15 mine are a part of the same mining area; they lie on long slopes of nepheline syenite on opposite sides of the early Eocene valley, here called the Davis valley. The floor of the mine is almost completely stripped of bauxite, and only "roots" or masses of granitic-textured bauxite are left in a gray to white kaolinitic clay that is massive in some places and

appears fragmental in others. The relations are best shown in a large clay pit in the mine, where kaolinitic clay was mined for experimental purposes after the overlying bauxite had been removed. The south face of the clay pit is 10 or 12 feet high, and many large "roots" of granitic-textured bauxite are cut by veins of the surrounding kaolinitic clay (fig. 40*A*). The clay veins range in thickness from less than 1 to more than 6 inches, and their structure and texture, massive or fragmental, pass with no change into the surrounding clay. The fragmental appearance of the clay is the result of chemical or mineralogic alterations that formed within it a mosaic of "fragments," although these in places are so rounded and scattered by the alteration that they appear to have a clastic origin. The identity of the material in the veins and in the surrounding kaolinitic clay is evidence for the resilicification or rekaolinization of the bauxite. Kaolinitic clay that preserves the texture of the underlying nepheline syenite is present in places along the wall, but always removed from bauxite by at least several feet of massive or fragmental clay, commonly by 10 feet or more.

Julia open-pit mine (pl. 1, no. 57).—This old mine extends for nearly a mile along the southwest edge of the Davis area and includes five spurs of nepheline syenite and interspersed tributary valleys, as shown on the subsurface map (pl. 2).

The bauxite surface before mining dipped steeply in a northeasterly direction. Most of the bauxite now showing in the mine is granitic in texture and residual boulders of nepheline syenite are abundant; some concretionary rock appears in the northeast wall of the pit, overlain by some dark-brown or variegated clay and sand of the Saline formation and about 50 feet of thin-bedded clay and sand of the Detonti formation. The indurated quartz sand at the top of the Saline is well exposed at the northwest end of the pit (fig. 11).

HURRICANE CREEK AREA

The bauxite deposits in this area extend from the SE¼SE¼ sec. 10, through secs. 12, 13, and 14, T. 2 S., R. 14 W., to the SW¼ sec. 7 and the NW¼ sec. 18, T. 2 S., R. 13 W. (fig. 60). The easternmost deposit is about 3½ miles east of the town of Bauxite. All can be reached by good all-weather roads. The land surface in this area is one of gentle relief and most of it is either under seasonal cultivation or has been stripped for mining purposes.

The post-Midway erosion surface, upon which the deposits lie, dips to the north and is somewhat steeper on nepheline syenite rocks than it is on sediments of Midway age (pl. 2). The break in slope at the buried edge of the Wills Point formation is much less pronounced in this area than in others nearby. The trace of the Midway and nepheline syenite contact trends in an east-west direction across the southern quarter of secs. 10, 11, and part of sec. 12, T. 2 S., R. 14 W., then turns southeastward across the northeast corner of sec. 13 and into sec. 18, T. 2 S., R. 13 W.

Many buried drainage channels, large and small, head in the nepheline syenite and trend generally northward at nearly right angles to the trace of the Midway and nepheline syenite contact. They connect with a major buried drainage system which heads in the SE¼NE¼ sec. 9, and the SE¼ sec. 3, T. 2 S., R. 14 W., and trends eastward in a direction nearly parallel to the contact.

The largest deposit in the area covers the nepheline syenite hills and fills the valleys of the N½ sec. 14, and extends onto the surface of the Wills Point formation in the southern part of sec. 11. This deposit contains the Section 14, Canal No. 2, Fletcher, Townsend, and Bizzell mines (pl. 1, nos. 71, 72, 70, 74, 75, and 76). Two other large deposits, the Hurricane–Covington and the Whitley, worked by the Reynolds Mining Corp. underground mines (pl. 1, nos. 78, 79, 80), lie to the east on the Midway sediments that flank the northeast side of the Saline dome.

In sec. 14 bauxite and associated kaolinitic clay are thick in the large valleys and thin over major ridge tops. In the Section 14 mine the deposit reaches a maximum of 64 feet in thickness but most of the material in the thickest sections is low grade. As a general rule high-grade ore is found on the flanks of small ridges or ridge spurs, whereas bauxite in all the large valleys and their reentrant tributaries, particularly near the floors, is low grade.

Much of the bauxite overlying nepheline syenite is residual and is lithologically similar to that found elsewhere on the higher slopes of the Saline County igneous rocks. A large part of the extensive blanket of bauxite in sec. 14 should be classed as a type 1 deposit. The lowermost part of the ore normally has marked granitic texture and it grades upward into a rubbly mass of granitic-textured bauxite blocks, overlain in turn by pisolitic bauxite containing smaller rounded "granitic" bauxite boulders. The pisolites are large and show rude concentric banding.

Pisolitic bauxite predominates in the deposits of colluvial and alluvial origin, found near and beyond the edge of the Midway sediments. Two distinct beds of pisolitic bauxite are worked in the Townsend and the Fletcher mines, in the SW¼SE¼ and SE¼SW¼ sec. 11. The beds, which are on the buried surface of the Wills Point formation, are locally separated from each other by carbonaceous kaolinitic clay and lignite, probably of Berger age. The upper bed is overlain

by chocolate-brown carbonaceous silty clay and is probably of early Saline age.

The Hurricane–Covington and Whitley deposits to the east lie on a Midway surface that slopes in places as much as 100 feet in a thousand. They are typical colluvial accumulations (type 2 deposits) of pisolitic bauxite overlain by kaolinitic clay and lignite of Berger age.

The deposits are covered by overburden that increases in thickness eastward, from a thin edge to a maximum of 280 feet. The eastern deposits are covered by lignite, lignitic clay, and gray silty to sandy clay of the Berger formation, overlain by brown carbonaceous silty clay and sand of the Saline formation. Westward the Berger formation thins and is overlapped by the Saline formation; and in sec. 14 the bauxite is directly overlain by sand and clay of the Saline formation.

The Hurricane Creek area has been prospected throughout by company drilling mostly during 1940–42. Many of the holes were drilled about 200 feet apart. Additional holes 100 or even 50 feet apart were drilled where more detailed information was needed. Every major bauxite deposit has been exploited either wholly or in part.

Section 14 open-pit mine (pl. 1, nos. 71 and 72).—This mine, owned and operated by the Alcoa Mining Co., is about 2 miles east of the town of Bauxite and occupies a large part of the N½ sec. 14, T. 2 S., R. 14 W. Mining began on an outcrop of bauxite at the southeast end of the present pit. By 1936 the mine had become a major producer. Large-scale strip mining was done in 1941.

The bauxite is restricted to that part of the post-Midway erosion surface on nepheline syenite. Ore is thickest on the flanks of drainage channels, which trend northward. The buried edge of the Midway sediments where they thin out against the nepheline syenite has a general east-west trend and closely parallels the line between secs. 11 and 14, which forms the north boundary of the mine.

The deposit possesses the physical characteristics of a residual weathered mantle, namely, granitic-textured bauxite in the lowermost part of the ore section grading upward to blocks of "granitic" bauxite in a pisolitic matrix (type 1 deposit). Ore at the surface and near the northern limits of the mine is generally rubbly in appearance and contains well-rounded pebbles and cobbles of "granitic" and pisolitic bauxite. This material is also found in the upper bauxite bed in the Townsend and Fletcher mines to the north, and is probably of Saline age (type 4 deposit).

High-grade bauxite, in places more than 20 feet thick, flanks the minor knolls and spurs. The valley bottoms, on the other hand, in the north-central part of the mine, are filled with a thick accumulation of low-grade bauxite. One company drill hole cored 64 feet of this material.

Overburden, as much as 88 feet in thickness and composed of black to dark brown lignitic and carbonaceous silty to sandy clay and white or tan sand of the Saline formation, covered the ore before stripping.

This mine has been and continues to be one of the largest producers of aluminum ore in the Saline district.

Mine 14 (pl. 1, no. 73).—Another open-pit mine, owned and operated by the Alcoa Mining Co., lies in the SE¼NE¼ sec. 14, T. 2 S., R. 14 W. It is less than 400 feet southeast of the Section 14 mine, and is separated from it only by a narrow saddle in the northeastward-trending nepheline syenite ridge. It was mined in conjunction with the Section 14 mine and is discussed as one of the mines of the Hurricane Creek area, although, as can be seen from the subsurface map (pl. 2), it lies on nepheline syenite at the head of a post-Midway valley that flows south and east into the basin occupied by the deposits of the Mount Olive area.

The deposit fills a saddle between nepheline syenite hills in the NW¼ sec. 13 and the center of sec. 14. Bauxite on the southwestern and northeastern parts of the ore body, lying on the flanks of these hills, is high grade and was reported to be 36 feet thick in one drill hole. Some of the ore in the southern part of the deposit, filling the southeastern tributary valley, is low grade.

The ore is largely residual on the flanks of the weathered nepheline syenite hills; the deposit is type 1. Granitic-textured bauxite is dominant throughout most of the mine area, overlain by pisolitic "birdseye" ore. Before the strip-mining was done the ore body was covered by 2 to 37 feet of sand and clay of the Saline formation.

Canal No. 2 open-pit mine (pl. 1, no. 70).—This strip-pit is about 1½ miles east of the town of Bauxite, in the SE¼SE¼ sec. 10, T. 2 S., R. 14 W. The mine is owned by the Alcoa Mining Co., and the property was explored by that company. Available records show that the ore was first drilled on a rectangular grid with holes spaced about 220 feet apart. The mine was in operation during 1943 and the first half of 1944.

The bauxite in this mine lies across the buried trace of the Midway and nepheline syenite contact which trends in an east-west direction through the S½ sec. 10. The bauxite is part of a much larger deposit which also is worked in the nearby Fletcher, Townsend, Bizzell, and Section 14 mines. The thickest and the highest grade ore lies on the flanks of a small buried ridge on the surface of the Wills Point formation. The

ridge extends northeastward from the main nepheline syenite mass, which crops out about 3,000 feet south of the mine.

The ore reaches a maximum of 26 feet in thickness and apparently is low grade. In June 1945, the pit was flooded and all working faces in the mine were covered with water. The pit is irregular in outline, elongate in a north-south direction, and is about 600 feet long and 300 feet across at its widest point.

Overburden ranging from 20 to 50 feet in thickness covered the ore. According to data available from company logs it was composed of "sand and clay," probably all of Saline age.

Fletcher open-pit mine (pl. 1, no. 74).—This mine, located in the SE¼SW¼ sec. 11, T. 2 S., R. 14 W., was prospected by the Arkansas Bauxite Corp. before it was acquired in 1941 by the American Cyanamid and Chemical Corp. From 1942 to 1944 it was mined by the latter company. In 1947 the property was reopened by the Reynolds Mining Corp. All exploration on the 40-acre tract was done by private companies.

As in the adjacent Townsend mine (pl. 1, no. 75), the bauxite is in two beds separated by a layer of bauxitic clay. The bauxite overlies the Wills Point formation, the surface of which dips gently northward. In the earlier pit working of American Cyanamid and Chemical Corp., only the upper bed was mined; later both beds and the bauxitic clay layer between them were worked by the Reynolds Mining Corp. A section of bauxite and bauxitic clay more than 50 feet thick was exposed in the pit face in October 1948.

The lower bauxite bed lies immediately on top of mottled red, gray, and khaki-colored weathered clay of the Wills Point formation. The bauxite is light gray, pisolitic, massive, and clayey. It contains, in the central and lower parts, lenses and channels from 6 inches to 2 feet deep and 5 to 10 feet wide, filled with stratified and crossbedded coarse sand and gravel, composed largely of tan bauxite grains and granules, and dark-brown to black hard, dense bauxite pebbles (fig. 52). Accumulations of dark mineral grains are found along the bottom of these channels. Carbonaceous clay balls and lignite fragments occur in the channels, and locally a thin bed of lignite covers the bottom.

The upper bauxite bed is a rubble of pebbles to large boulders of dark-reddish-brown pisolitic bauxite in a gray matrix of firm to clayey, cherty-looking pisolitic bauxite. The small blocks, particularly the pebbles, are composed of tan granitic-textured bauxite. The rubbly character of the bed is not conspicuous at a distance but is apparent on close examination.

The two bauxite beds are separated at the south end of the pit by several feet of gray kaolinitic to bauxitic clay that contains a brown carbonaceous clay layer nearly 2 feet thick. In places the carbonaceous layer is a dense, very clayey lignite. The carbonaceous clay thins and wedges out northward along the pit face, but the containing bauxitic-clay layer thickens and becomes more kaolinitic to the north. As interpreted from company drilling records this layer passes laterally into silty and sandy clay presumably of Berger age, north of the pit, in the area overlying the center of the large post-Midway valley between the Saline dome and the Bryant high.

The lower bauxite, believed to be of Berger age, represents an accumulation largely of colluvial material (type 2 deposit), but also contains small channels filled with bauxitic alluvium, deposited under conditions similar to those that resulted in the formation of type 3 deposits. The upper bed is a basal conglomerate of the Saline formation (type 4 deposit). Moreover the upper bed is directly overlain by brown carbonaceous clay and sand of the Saline formation 40 to 75 feet thick.

Townsend open-pit mine (pl. 1, no. 75).—This mine is located 2 miles east of the town of Bauxite, in the SW¼SE¼ sec. 11, T. 2 S., R. 14 W. It was opened and developed by the Arkansas Bauxite Corp. in 1939 and acquired by the American Cyanamid and Chemical Corp. on August 1, 1940. The mine operated from 1940 through 1944, became inactive in 1948 and the pit was flooded.

The bauxite lies on the post-Midway erosion surface that dips gently to the north. It overlies the Wills Point formation which thins on the nepheline syenite several hundred feet south of the mine.

The ore occurs in two layers separated by a wedge of bauxitic and kaolinitic clay that thickens to the north. According to drilling records, only the upper layer, as much as 14 feet in thickness, was mined. This is a rubble consisting of boulders of hard pisolitic bauxite in a soft, clayey and pisolitic matrix. The lower layer ranges from 2 to 20 feet in thickness.

Records of company drill holes north of the mine indicate that the bauxitic and kaolinitic clay separating the two bauxite layers pass laterally into gray carbonaceous clay, sandy clay, and sand, probably of the Berger formation. The upper bauxite layer is covered by carbonaceous clay and sand of the Saline formation ranging from 12 to 40 feet in thickness.

Bizzell open-pit mine (pl. 1, no. 76).—This pit, located in the SE¼SE¼ sec. 11, T. 2 S., R. 14 W., is shown on the map of Stearns (1930, pl. 1) as a mine of the Arkola Bauxite Co. No production is reported in U. S. Geological Survey "Mineral Resources" or U. S. Bureau of Mines "Minerals Yearbook" until 1937 when it was operated by the Arkansas Bauxite Corp.

It was abandoned early in 1938 and reopened from May to September of 1943 by the S. E. Evans Construction Co.

The ore in the deposit lies on the eroded and now buried surface of the Midway sediments and extends upslope southeastward onto the flank of the nepheline syenite. The edge of the Wills Point formation where it thins out against the nepheline syenite trends northeastward.

In June 1945 the mine was filled with water and all contacts between overburden and rocks of the bauxite-kaolin zone were obscured. No figures on the lateral extent or the thickness of the ore could be obtained. The pit was rectangular in shape, elongated in a north-south direction, and measured about 375 by 500 feet.

No information was obtainable on the character of the ore, but it probably is similar to that in the nearby Townsend mine on the same deposit.

The overburden is composed of silty to sandy carbonaceous clay and sandy clay of the Saline formation. It is estimated that the thickness ranges from 20 to 30 feet.

Ulmer open-pit mine (pl. 1, no. 77).—The Reynolds Mining Corp. opened and mined out this shallow pit in 1943. It lies in the SW¼SW¼ sec. 12, T. 2 S., R., 14 W., about 1,000 feet southwest of the Hurricane Creek mine. The pit is about 300 feet long and 150 feet wide. The pisolitic bauxite ranged from 6 to 10 feet in thickness, and was high both in silica and iron content. The ore body is a small patch of colluvial material (type 2 deposit) filling the head of a minor valley in the nepheline syenite, and before mining was overlain by about 17 feet of sand and clay of the Saline formation.

Hurricane Creek shaft mine (pl. 1, no. 78).—The Reynolds Mining Corp. has explored and mined the extensive Hurricane–Covington deposit that lies in the S½ sec. 12, T. 2 S., R. 14 W., and the Whitley deposit to the southeast, in the S½ sec. 7 and the N½ sec. 18, T. 2 S., R. 13 W.

The deposits are elongate in an east-west direction. They lie almost entirely on the eroded surface of the Wills Point clay, but the west upslope edge of the Hurricane–Covington deposit lies on nepheline syenite, which crops out about 1,000 feet farther south. Midway sediments cover the broadly rounded northeast flank of the Saline nepheline syenite mass and the post-Midway surface slopes as much as 100 feet in 1,000 under parts of the deposits. The floor of the buried valley between the Bryant high and the Saline dome forms a natural northern boundary to the deposits.

The two large ore bodies are separated by about 200 feet of low-grade material. The bauxite in each ore body reaches a maximum of 40 feet in thickness, is tan to grayish-tan, soft to firm, and abundantly pisolitic.

Both ore bodies, as determined from drilling records, are colluvial (type 2) in nature.

Mining has been done entirely by underground methods. The Hurricane–Covington deposit on the west has been mined by six shafts, the first of which was sunk in the fall of 1942. These are the Hurricane Nos. 1 and 3 and the Covington Nos. 4, 5, 6, and 7. Two shafts, the Whitley Nos. 8 and 9, were used to mine the Whitley deposit.

The overburden ranges in thickness from 80 to 230 feet above the Hurricane–Covington ore body and from 160 to 280 feet above the Whitley ore body. It consists of lignite and lignitic clay and gray silty to sandy clay of the Berger formation overlain by brown carbonaceous silty to sandy clay of the Saline formation.

MOUNT OLIVE AREA

Most of the deposits of this area (fig. 60) are associated with one large buried valley here called the "Mount Olive valley," which heads near Mount Olive in the NE¼NE¼ sec. 26, T. 2 S., R. 14 W.; it trends northeastward through sec. 24 into the SE¼ sec. 13, thence eastward and southeastward through the S½ sec. 18, T. 2 S., R. 13 W., along the north line of sec. 20; and empties into the main southward-trending buried valley between the Saline dome and the Sardis high (pl. 2). Both the Mount Olive valley and the main valley (corresponding to the present Hurricane Creek) east of and peripheral to the Saline dome are cut in nepheline syenite. Sediments of the Midway group originally covered the nepheline syenite between the Saline dome and the Sardis high, and overlapped the east flank of the Saline dome. Post-Midway erosion stripped these sediments from the basement rock so that throughout most of the area between secs. 8 and 33, T. 2 S., R. 13 W., on both valley bottom and hill slopes, weathered or fresh nepheline syenite is overlain directly by green sand of the Berger formation and few deposits remain.

Erosion has left a long tongue of sediments of the Wills Point formation, that extend southeastward through sec. 18 into sec. 17, and beyond its tip a small Wills Point outlier in the center of the S½ sec. 17 and the N½ sec. 20 The bauxite deposits lie on top of this tongue, as well as southwest of its upslope edge on the northeast flank of the Saline dome. The eroded northeast edge of the tongue is downslope toward the main valley; the south slope of the tongue forms a part of the north wall of the Mount Olive valley near its mouth.

The Hurricane Creek and the Little deposits in sec. 18, T. 2 S., R. 13 W. lie on the eroded surface of the

Wills Point formation. These are typical colluvial accumulations (type 2 deposits) of pisolitic bauxite. All other deposits in the Mount Olive area overlie weathered nepheline syenite. Most of those for which information is available contain residual, granitic-textured bauxite. The deposits in the upper part of the Mount Olive valley are mostly type 1. Residual bauxite is overlain by pisolitic ore that contains vitreous black pisolites in a red or gray matrix (birdseye ore), also many blocks of granitic-textured bauxite with well-formed dense crusts. In the lower part of the valley several types of deposits occur together. Residual granitic-textured bauxite on the nepheline syenite slopes is typical of type 1 deposits. Kaolinitic clay and lignite of Berger age wedges out against these, and is overlain by tan massive clayey bauxite containing lenses of bauxite sand and gravel (type 3 deposit). The upper part of this bed is pisolitic and rubbly, and the top 5 feet is a conglomerate of high-grade bauxite boulders in a carbonaceous clay matrix. The matrix is silty to sandy in places and locally contains dark-brown laminated clay typical of the Saline formation. The conglomerate is of early Saline age and is classified as a type 4 deposit. These relations are best shown in the Midwest pit and will be discussed in the description of that mine.

Overburden, consisting of continental sediments of the Wilcox group, is thin at the head of the Mount Olive valley near outcrops of bauxite. It thickens downslope to a maximum of 270 feet above the easternmost deposits near the mouth of the valley. The bauxite deposits in sec. 18, T. 2 S., R. 13 W., are covered by kaolinitic clay, carbonaceous clay, and lignite overlain by greenish silty clay and clayey sand, all of which belong in the Berger formation (see cross section, pl. 4). Over much of sec. 18 the Berger formation was eroded down to kaolinitic clay or to bauxite before deposition of the Saline sediments, and the thickness of the formation ranges from a thin edge to 112 feet. Some channels in green sand of the Berger formation, filled with brown sand of the Saline, are more than 40 feet deep. The Berger sediments extend up the valley into sec. 13, T. 2 S., R. 14 W. They wedge out into bauxite deposits in the NE¼ sec. 24, where kaolinitic clay and lignite are present between beds of bauxite in the Midwest pit, in the Childress shaft mine, and probably in adjacent property owned by the Alcoa Mining Co. where two layers of bauxite have been recorded in many company drill holes.

The overlying Saline formation consists of fine to coarse brown sand and dark-brown carbonaceous silty clay with fine sand laminae.

All exploratory drilling of deposits in the area was done by companies, except that in the S½ and NE¼ sec. 18, T. 2 S., R. 13 W., which was explored by the Federal drilling program.

DUPONT DEPOSIT

Plate 2

Three small ore bodies in the NE¼ sec. 26, T. 2 S., R. 14 W. make up this deposit. Southern lobes from two ore bodies extend into the N½ of the SE¼ of the section. The Republic Mining and Manufacturing Co. explored the deposits by drill holes spaced about 220 feet apart. None of the ore bodies has been mined. They lie south of the Mount Olive deposit, described in the next section, across a saddle in outcropping nepheline syenite (pl. 2) and have formed on hill slopes at the head of a buried valley that in early Eocene time drained secs. 25 and 26. The valley trends southeastward into sec. 36, T. 2 S., R. 14 W., and sec. 31, T. 2 S., R. 13 W., between deposits of the Brushy Creek area. The ore bodies at the head of the valley, however, are near Mount Olive and are considered as deposits of that area.

The bauxite lies on hill slopes of nepheline syenite and fills minor tributary drainage channels of the southeastward-trending valley at its head; its floor is covered with bauxite of high silica content, bauxitic clay, and kaolinitic clay.

Of the three distinct ore bodies in the deposit, the two larger ones are less than 200 feet apart and are separated by low-grade material that fills the valley floor. These two are probably largely residual deposits of type 1. The third ore body is downslope and east from the others, is narrow, and is most likely a colluvial (type 2) accumulation. The bauxite in the two larger ore bodies ranges from less than 6 to more than 34 feet in thickness and is covered by 14 to 80 feet of overburden, consisting of dark-brown carbonaceous clay and sand of the Saline formation. Bauxite in the small ore body has a maximum thickness of 22 feet and is covered by about 110 feet of overburden.

In the northeast corner SE¼SW¼ sec. 26 another small deposit was drilled by the Republic Mining and Manufacturing Co. The deposit is crescent shaped and lies on nepheline syenite at the head of a buried valley tributary to the main drainage system in secs. 5 and 36. The bauxite is reported in driller's logs to be 10 to 14 feet thick, and it is covered by 25 to 60 feet of overburden.

MOUNT OLIVE DEPOSIT

Plate 2

This deposit lies mostly in the SE¼SE¼ sec. 23, NE¼NE¼ sec. 26, the NW¼NW¼ sec. 25, and the N½SW¼ and S½NW¼ sec. 24, T. 2 S., R. 14 W. The lobe of bauxite in the northwest corner of sec. 25 was

explored and mined by the Superior Bauxite Co. and later by the American Cyanamid and Chemical Corp. The Republic Mining and Manufacturing Co. explored the part of the deposit in secs. 23 and 26 with holes about 220 feet apart, but it has not been mined. The rest of the deposit in sec. 24 was explored and mined by the Southern Bauxite Co., the American Cyanamid and Chemical Corp., and the Hurricane Creek Mining Co.

The ore body lies at the head of the buried Mount Olive valley, a post-Midway erosion surface on the nepheline syenite (pl. 2). Bauxite has formed on the steep slopes of the headwalls of the valley and along its northwest side, and has accumulated in minor tributary drainage channels; the deposit is hooked around the head of the valley and the valley floor is covered with low-grade material.

None of the cores from the drilling was seen by the writers, and the bauxite in mines on the deposit was largely flooded and covered by slumped overburden, but that in the Cleveland pit (pl. 1, no. 93) is well exposed. The ore consists of some granitic-textured bauxite overlain by rubbly pisolitic material containing blocks of granitic bauxite and of pisolitic bauxite in a pisolitic matrix (type 1 deposit). According to company records, it ranges in thickness from less than 5 to 40 feet throughout the entire deposit, and is overlain by dark-brown carbonaceous silty clay and brown to red sand of the Saline formation, reaching a maximum of 80 feet in thickness.

Cargill (Superior) open-pit mine (pl. 1, no. 98).—In 1924 the Superior Bauxite Co. opened this mine in the NW¼NW¼NW¼ sec. 25, T. 2 S., R. 14 W., near Mount Olive Church. In 1930, it was bought by the Kalbfleisch Corp. (later the American Cyanamid and Chemical Corp.) and worked until July 1931. It was reopened in 1934 (Branner, G. C., 1935, p. 123–124) and operated for several years, and it was mined again in 1941 and 1943.

The pit is small and lies at the bottom of a narrow but steep surface valley. Before mining the bauxite was covered with 4 to 20 feet of overburden, and ranged in thickness from about 7 to 40 feet.

Cargill (south shaft) mine (pl. 1, no. 97).—The American Cyanamid and Chemical Corp. sank a 75-foot vertical shaft 800 feet east of the Cargill (Superior) pit to complete the mining of ore in this part of the Mount Olive deposit. Mining began in September 1934, and continued until about 1940.

Cargill (Southern) open-pit mine (pl. 1, no. 94).—A pit in the SW¼SW¼ sec. 24, T. 2 S., R. 14 W., was opened by the Southern Bauxite Co. in 1922 and mined for several years thereafter. It was acquired by the American Cyanamid and Chemical Corp. in the early thirties, was mined for several years, was abandoned from 1938 to 1942. It was reopened in 1942, enlarged, and again mined for a short time.

Bauxite in the Cargill (Southern) mine averaged about 12 feet in thickness and was covered by 6 to nearly 40 feet of sandy clay of the Saline formation.

Cargill (north shaft) mine (pl. 1, no. 95).—A shaft, in the SW¼SW¼ sec. 24, T. 2 S., R. 14 W., was sunk by the American Cyanamid and Chemical Corp. in 1934. No information has been obtained on the depth of the overburden, or the thickness of the ore. The period of production of the mine is not known, but it appears on the map of Bramlette (1936, pl. 9), was active in 1938, and was probably abandoned by 1942. The deposit mined is small, separate from the Mount Olive deposit, and lies on nepheline syenite near the head of the buried Mount Olive valley.

Cleveland (Southern) open-pit mine (pl. 1, no. 96).—The Southern Bauxite Co. mined this small pit in the SE¼SW¼ sec. 24, T. 2 S., R. 14 W., in the early twenties. It was acquired by the American Cyanamid and Chemical Corp. along with other Southern Bauxite Co. properties in 1930, but apparently was not reopened until 1940 when another area was stripped alongside the old pit. The mine was abandoned in 1941. According to driller's logs, as much as 14 feet of bauxite was overlain by sand and clay that ranged from a few feet to 25 feet in thickness.

Cleveland open-pit mine (pl. 1, no. 93).—Although not mentioned in mining reports before 1940, this pit had been opened and abandoned before July 1938, as it appears as a flooded mine in aerial photographs taken at that time. It lies next to a bauxite outcrop in the NW¼SW¼ sec. 24, a short distance northeast of the Cargill (Southern) pit, and is believed to have been mined first in the early twenties by the Southern Bauxite Co. It was reopened by the American Cyanamid and Chemical Corp. in 1940, and worked periodically until 1944, when it was sublet to the Hurricane Creek Mining Co. The pit was then considerably enlarged and strip-mined to a depth of nearly 80 feet. The newly stripped area extended into the Ozark 24 property in the southwest corner NE¼SW¼ sec. 24.

Bauxite exposed over most of the pit walls is pisolitic and rubbly appearing. Blocks of granitic bauxite several feet in diameter are present. Cobble-sized blocks 6 inches to a foot in diameter are abundant, formed of well-developed "sponge" ore, or porous bauxite with well-preserved gibbsitized feldspar laths, grading into a surrounding crust of crystalline gibbsite about a centimeter thick. Analyses of the spongy center and dense crust of a bauxite block from this mine are given in the table on page 110, sample 3). Blocks of birdseye ore are abundant. These contain large black vitreous pisolites in a dense iron-red, or less commonly porcellaneous

gray matrix. Large blocks of vermicular bauxite are not common, but they occur in masses several feet across, and small blocks of this material are common. The matrix of all these blocks is red to gray, generally hard and pisolitic. The overall aspect of the material exposed here is of bauxite from the upper pisolitic or concretionary zone common to high-level residual (type 1) deposits in Saline County. In thickness the bauxite in the mine ranged from less than 5 to more than 20 feet. The ore body is apparently a small outlier to the main Mount Olive deposit.

Ozark 24 open-pit mine (pl. 1, nos. 89, 90, 92).—In 1939 the American Cyanamid and Chemical Corp. opened this property in the NE¼SW¼ and SE¼NW¼ sec. 24, T. 2 S., R. 14 W. The mine was worked from a series of open pits. As one pit was worked out, a new one was stripped by dragline, and overburden stripped from the new pit was backfilled into the old one. Eleven separate pits, most of them long and narrow, are shown on a company map of the property, dated October 1942. Production continued until 1944.

The bauxite ranged from about 5 to 22 feet in thickness, and was covered by 15 to 65 feet of overburden that consisted of dark-brown carbonaceous silty clay and sand of the Saline formation.

West Ozark open-pit mine (pl. 1, no. 88).—This pit is in the NW¼SW¼ sec. 24 on property formerly owned by the Southern Bauxite Co. a short distance north of the Cleveland mine. Apparently no mining had been done before July 1938, as no excavation is visible on aerial photographs taken at that time. The mine lies across the county road from the Ozark 24 pits and was worked during the same period as these pits by the American Cyanamid and Chemical Corp.

East Ozark open-pit mine (pl. 1, no. 91).—This mine was opened by the American Cyanamid and Chemical Corp. in 1943. It lies in the northwestern corner NW¼SE¼ sec. 24, next to the Ozark 24 pits. The mine worked a small lobe of bauxite that projected south from the McDonald deposit that is described in a later section of this report.

Cleveland–Evans open-pit mine (pl. 1, no. 87).—The Hurricane Creek Mining Co. sublet this property from the American Cyanamid and Chemical Corp. and mined it in 1943. It is in the SE¼NW¼ sec. 24, immediately north of and includes parts of two former pits of the Ozark 24 mine. The pit was stripped to a depth of 30 to 62 feet. The bauxite before mining ranged from 6 to 22 feet in thickness.

MC DONALD DEPOSIT

Plate 2

This large deposit fills most of the NE¼ sec. 24 and the W½SE¼ sec. 13, T. 2 S., R. 14 W. An elongate body in the SE¼SE¼ sec. 13, separated from the main deposit by high-silica bauxite and bauxitic clay, is considered to be a part of the McDonald.

The ore lies on both sides of and across the buried Mount Olive valley and extends for nearly three-fourths of a mile along slopes of nepheline syenite (see pl. 2).

Most of the bauxite ranges in thickness from less than 8 to about 30 feet, but 48 feet of bauxite was reported by G. C. Branner (1935, p. 123), in the McDonald mine. High-silica bauxite filling the valley bottom in the northeastern part of sec. 24 is as much as 56 feet thick. The deposit is overlain by bauxitic and kaolinitic clay, thin over the upper parts of slopes and thick over the valley. The clay is overlain by dark-brown carbonaceous silty laminated clay and sand of the Saline formation that ranges in thickness from 23 feet near the center of sec. 24 to 230 feet in the center of the SE¼ sec. 13.

Parts of the deposit in sec. 13 and in the S½ of the NE¼ of sec. 24 were explored by the Republic Mining and Manufacturing Co., with holes drilled from 200 to 600 feet apart. The central part of the deposit in the N½NE¼ sec. 24 has been worked in the following mines: McDonald, Gates, Midwest, Childress, and Gray (east and west pits) (pl. 1, nos. 84, 85, 82, 81, 86, and 83). The north tip of the deposit, in the southwest corner SW¼NE¼ sec. 13, has been worked by the Northern mine (pl. 1). The extreme southwest corner of the deposit was mined as a part of the Ozark 24 and the East Ozark mines (pl. 1, nos. 89, 90, 91), described above.

No descriptions are available to the writers of the bauxite found in the drilling; only that exposed in the Childress and Midwest mines was seen. It is probable that the deposit is largely residual on the nepheline syenite slopes, as is the adjacent Mount Olive deposit, seen in the Ozark and Cleveland pits. A little granitic-textured bauxite was mined at the east end of the Midwest mine. This was overlain near the center of the pit by a wedge of bauxitic and kaolinitic clay 5 to 10 feet thick that locally contained several feet of lignite. A similar clay and lignite layer reportedly is present in the Childress mine a quarter of a mile to the west, and also is recorded in several logs of holes drilled to the south by the Republic Mining and Manufacturing Co., in the S½NE¼ sec. 24. These beds apparently are part of a tongue of Berger sediments that thickens toward the mouth of the buried Mount Olive valley. Overlying this layer in the Midwest mine is a bed of tan clayey bauxite containing small lenticular channels filled with bauxite sand and gravel, well stratified and locally crossbedded. Gradationally above is a rubble of boulders and large blocks of pisolitic and granitic-textured bauxite of indistinct outline in a similar gray

or tan hard matrix. The uppermost 5 to 10 feet of bauxite in the pit consists of hard, rounded boulders in a bauxitic to kaolinitic clay matrix. This was partly mined, but across much of the pit the matrix was silty, and locally consisted of dark-brown sandy clay typical of the overlying Saline sediments.

These relations indicate a complicated history for the deposit. It is probably a residual deposit (type 1) that is overlain in the valley floor by alluvial bauxite probably of Berger age (type 3) and by a conglomeratic bauxite at the base of the Saline formation (type 4).

McDonald shaft mine (pl. 1, no. 84).—In 1933 the Crawford Bauxite Co. completed a 90-foot shaft on this property in the SW¼NE¼NE¼ sec. 24. It was called the Patricia No. 1 mine in the U. S. Geological Survey "Mineral Resources" for 1933, and was mined until 1935. It was acquired by the Arkansas Bauxite Corp. and mined from 1938 to the spring of 1940 as the McDonald mine.

Bauxite was reported to be as much as 48 feet thick, covered by 70 to 80 feet of sand and clay.

Gates shaft mine (pl. 1, no. 85).—This mine in the SE¼NW¼NE¼ sec. 24 was operated from 1939 to 1941 by Consolidated Chemical Industries, Inc., as the Alexander No. 2 mine. It was then acquired along with the McDonald lease by American Cyanamid and Chemical Corp., and renamed Gates mine. It was operated until the fall of 1943.

Midwest open-pit mine (pl. 1, no. 82).—Located on the Gray property in the NE¼NE¼ sec. 24, this mine was stripped in 1943 and mined during 1944 by the Midwest Mines Co. Before mining the property had been explored intensively by the American Cyanamid and Chemical Corp. and by Jackson and Squire.

The pit is about 800 by 300 feet, and more than 80 feet deep to the top of the ore. Bauxite occurs in two principal beds, separated by 5 to 15 feet of bauxitic clay, kaolinitic clay, and lignite. In the center of the pit the lower bed was 13 feet thick, the upper 18 feet, separated by 15 feet of bauxitic to kaolinitic clay. Each bauxite bed was irregular, not so much in thickness as a lithologic unit, as in chemical grade. Material from different parts of the mine, nearly identical in appearance, might range from bauxitic clay to high-grade ore. The intermediate clay layer pinched out to the southeast where upper and lower beds merged as shown in figure 62. In the southeast corner of the pit the lower bauxite (*a*) is granitic-textured. The wedge of kaolinitic to bauxitic clay (*b*) overlying the lower unit is gray, compact, and somewhat fragmental. It is overlain by a few feet of tan clayey bauxitic clay (*c*) containing small lenses, one-half inch to a foot thick, of bauxite sand or gravel. The thin lenses are of fine-grained detritus, the thick ones are pebbly. In the overlying main bed of ore (*d*), the bauxite is light-tannish-gray and compact. Pisolites are scattered through the matrix; rounded fragments or blocks 6 inches to 4 feet across are visible but are ill defined. They consist largely of pebbly and pisolitic bauxite in a drab greenish-gray cherty-looking matrix. Rounded blocks of both granitic-textured and vermicular bauxite are present. The uppermost bed is conglomeratic and consists of rounded boulders of granitic-textured and pisolitic bauxite in a gray matrix. At the southeast end of the pit this bed (*e*) merges with the one below, and the gray matrix is bauxitic; here the entire interval was mined as ore. Westward the bed thickens and shows a distinct contact with the underlying bauxite (*f*). The bauxite boulders are more sparse, the matrix clay is kaolinitic with much admixed silt, and many

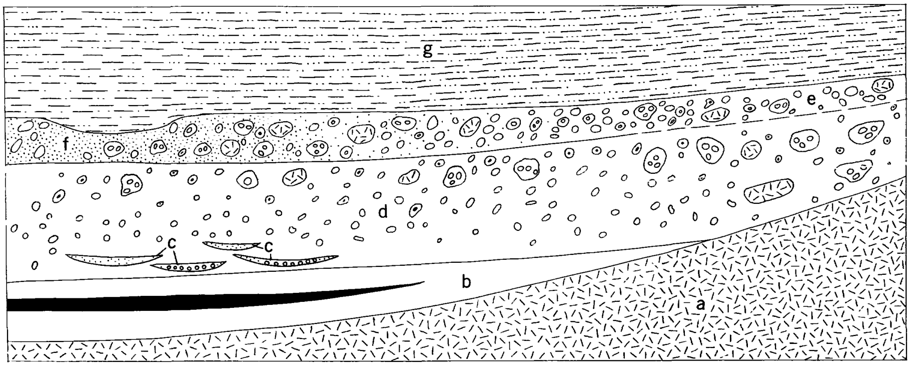

FIGURE 62.—Diagrammatic section in the Midwest mine. Granitic-textured bauxite and bauxitic clay (*a*). Bauxitic to kaolinitic clay (*b*) containing bedded lignite (Berger formation). Lenses of bauxite detritus in clayey bauxite matrix (*c*). Pisolitic bauxite containing masses of pisolitic and granitic-textured bauxite (*d*). Bauxite boulders in bauxite matrix (*e*) grading westward to bauxite boulders (*f*) in silty to sandy clay matrix (Saline formation). Carbonaceous silty clay and sand (*g*) (Saline formation).

of the spaces between boulders are filled with carbonaceous silty to sandy clay typical of the Saline formation. This bed is a basal conglomerate of the Saline formation. The top of it dips westward, and on the west wall of the pit is cut by a long channel, 6 feet deep, filled with sand and clay of the Saline formation. The overburden consists of about 20 feet of dark-brown rubbery silty clay with thin partings of fine-brown micaceous sand, overlain by 50 feet of fine tan to brown quartz sand with abundant fine dark-brown clay partings. The top 10 feet of the overburden is soft red quartz sand with white plastic clay layers 0.5 to 2 centimeters thick.

Childress shaft mine (pl. 1, no. 81).—The Hull-Macke Mining Co., later the Macke Mining Co., developed and mined this property in the N½NW¼NE¼ sec. 24, from 1943 to January 1945. The ore was reached by a shaft 129 feet deep. Bauxite, ranging from a few feet to 31 feet in thickness, is covered by 60 to 100 feet of sand and clay of the Saline formation.

Two layers of bauxite are reported in logs of several of the exploratory drill holes, but so far as is known, only the upper bed was mined. The ore was reported to average 52 percent Al_2O_3, 11.3 percent SiO_2, and 3.3 percent FeO. The lower bauxite bed is reportedly 14 feet thick. It is overlain by 9 to 27 feet of clay and lignite, probably the west edge of a tongue of the same sediments seen in the Midwest pit at about the same altitude. The layer, of probable Berger age, is overlain by the upper mined bed of bauxite. When the mine was visited in the spring of 1944, the lower drifts were in tan clayey ore containing lenses filled with bauxite gravel. One drift exposed medium-grained well-stratified bauxite sand with distinct crossbedding along one face. This was cut by a channel or lens 3 feet thick filled with unsorted bauxite gravel, containing pebbles as much as 7 centimeters across. In drifts cut into the upper part of the bauxite bed, the ore was a rubble of pebbles and boulders or blocks of bauxite in a matrix of firm, structureless, tan clayey bauxite. The matrix was mealy, nonplastic to moderately plastic, and ranged from high-grade ore to bauxitic clay containing about 45 percent alumina and more than 20 percent silica. The boulders in the ore were mostly brownish-red hard pisolitic bauxite with abundant vitreous pisolites. Gray cherty-looking boulders containing pisolites and fragments were likewise abundant. Common, but less prominent because they were poorly defined, were large angular blocks several feet in diameter of pisolitic bauxite in a tan matrix. These blocks were somewhat harder than the surrounding clayey bauxite but much softer than the rounded boulders.

The channeling and stratification in bauxite directly overlying lignite and clay suggest that it was deposited by alluvial agencies in late Berger time (type 3 deposit). Above this, the ore is apparently colluvial, possibly deposited as a mudflow; the uppermost part containing rounded boulders is apparently alluvial and may be a conglomerate at the base of the Saline formation (type 4 deposit) although no unconformity was apparent.

Gray (east pit) mine (pl. 1, no. 86).—The mine lies in the S½NW¼NE¼ sec. 24 next to the Gates and Childress underground mines. It was stripped with a dragline and mined late in 1944 by Jackson and Squire. Bauxite in the pit ranged from 18 to 23 feet in thickness and was covered by 65 to 75 feet of dark-brown silty clay and brown sand of the Saline formation.

Gray (west pit) mine (pl. 1. no. 83).—This open pit in the SE¼NE¼NE¼ sec. 24 was stripped by means of a dragline and mined late in 1944 by Jackson and Squire. The bauxite, according to drilling records, was 10 to 20 feet thick and was covered by about 65 feet of overburden. The overlying sediments exposed in the pit walls are dark-brown laminated silty clay and brown sand of the Saline formation.

Northern open-pit mine.—This strip-pit in the southwest corner SW¼NE¼ sec. 13 was mined in 1948 by the Reynolds Mining Corp. No information is available to the writers on the thickness of the bauxite, or the depth of overburden.

LITTLE DEPOSIT

Plate 2

This deposit in the NE¼ sec. 18, T. 2 S., R. 13 W., consists of two ore bodies connected with low-grade bauxite and bauxitic clay. It was investigated by drilling 24 holes spaced about 200 feet apart (Malamphy and others, 1948, v. 11, p. 8–16, fig. 95). The deposit was not completely delimited by offset holes to the southwest. The bauxite lies on the eroded surface of the Wills Point formation, flanking the northeast side of the Saline nepheline syenite mass. The post-Midway erosion surface dips northeast and contains several northeastward-flowing drainage systems. The deposit lies across one of these and is divided into two small ore bodies by the valley bottom. Both ore bodies contain pockets of high-grade bauxite 18 to 21 feet thick. The ore is pisolitic in the upper part, and sparsely so in the lower part. Small but thick pockets of high-grade ore are surrounded by bauxite that is thin, fragmental, and low grade. Total iron as Fe_2O_3 averages about 10 percent throughout.

The deposit overlies red and gray sideritic kaolinitic clay and is overlain by a few feet of kaolinitic clay of the bauxite-kaolin facies. Overburden ranges from 216 to 256 feet in thickness and is composed of 60 to 90 feet of gray clayey sand of Berger age interbedded with some silty clay and lignite, and overlain by

dark-brown clayey sand and silty clay of the Saline formation.

The uppermost 12 to 19 feet of the overburden consists of sand, gummy sandy clay, and gravel of the Hurricane Creek flood plain.

HURRICANE CREEK DEPOSIT

By William B. Allen

Plates 4 and 33

The largest ore body drilled by the Federal project in the Mount Olive area is located in the S½NE¼ and the N½SE¼ sec. 18, T. 2 S., R. 13 W., south of the Bauxite–Sardis road and north of Hurricane Creek. The land surface is in the creek bottom land at an average altitude of about 300 feet. The Hurricane Creek deposit was investigated by drilling 194 holes spaced about 200 feet apart. (Malamphy and others, 1948, v. 11, p. 17–86, fig. 96).

The deposit lies near the south end of the tongue of Midway sediments that extends southeastward through sec. 18 into sec. 17 (pl. 2). The post-Midway erosion surface on the Wills Point formation slopes about 4° to the southeast under most of the deposit. The slope forms the north side of the valley that drained the Mount Olive area in early Eocene time. The relation of the deposit to the post-Midway erosion surface is shown in the subsurface map (pl. 33) and in the columnar sections (pl. 4).

The bauxite forms a large lenticular blanket as much as 18 feet in thickness, that averages about 12 feet within an 8-foot cutoff. Several long lobes of ore extend westward and southward. Some of these are joined to the main body by bauxite less than 8 feet in thickness.

The ore contains well-developed pisolites in a tan structureless matrix that is firm at the top, grading to mealy, friable bauxite in the bottom part. Silica and ferrous iron are comparatively low.

Upslope and in the center of the deposit the grade drops sharply above and below the bauxite. Overlying and underlying high-silica bauxite is thin. Downslope the flat-lying bauxite near the valley bottom passes more gradually into bauxitic clay above and below, and the bauxitic unit contains abundant fragments of both pisolitic and granitic-textured bauxite.

A high-silica bauxitic hardcap a foot or more in thickness covers a large part of the ore body. The bauxite is underlain by 5 to 20 feet of bauxitic clay, kaolinitic clay, and red-mottled sideritic clay that overlies weathered clay of the Wills Point formation. The bauxite is overlain by 2 to 20 feet of bauxitic and kaolinitic clay. Lignite and gray silty clay a few feet thick overlie the kaolin, and these are covered by greenish-gray sandy clay and clayey sand, all of Berger age. These sediments are completely eroded over the north part of the deposit, and also along the west and south edges, where dark-brown sand and clay of Saline age lie on clay of the bauxite-kaolin facies. The total thickness of overburden ranges from 196 feet at the north to 247 feet at the east side of the deposit. The uppermost 12 to 19 feet consists of recent sand, gummy sandy clay, and gravel of the Hurricane Creek flood plain.

BAILEY DEPOSIT

Plates 4 and 33

This deposit includes four ore bodies, each more than 8 feet thick but separated from each other by thicknesses of less than 5 feet of bauxite and bauxitic clay. They are called the Bailey deposit (no. 57) by Malamphy and others (1948, v. 11, p. 103–139, fig. 98), who published the locations, short logs, and analyses of cores of the 88 holes drilled to investigate this deposit. Part of the largest ore body, in the N½ frac. SW¼ sec. 18, T. 2 S., R. 13 W., was drilled by the Federal project. A larger part drilled by mining companies lies in the NE¼SE¼ sec. 13, T. 2 S., R. 14 W. This ore body covers the steeply sloping south end of a nepheline syenite ridge in the NE¼ sec. 13 and extends downslope to the north edge of the buried Mount Olive valley bottom. The relationship to the underlying post-Midway surface is shown in the subsurface map (pl. 33) and in the columnar sections (pl. 4).

The bauxite is orange, granitic-textured, and somewhat mealy at the base, tan and pisolitic in the middle, and in the upper part pebbly and fragmental in a gray high-silica matrix. Flat-lying bauxite at the foot of the slope is conglomeratic. The ore ranges in thickness from a few feet to 22 feet in the part of the body drilled by the cooperative project and reaches a maximum thickness of 28 feet in the company-drilled area. The ore body is in part a residual (type 1) deposit and in part a colluvial accumulation (type 2).

Across the buried valley on north-sloping nepheline syenite are three small ore bodies that make up the rest of the Bailey deposit. The first, in the northern part of the S½ frac. SW¼ sec. 18 is thin, low grade, and consists mainly of 5 to 10 feet of fragmental bauxite accumulated at the foot of the hill. The second, in the northwest corner SW¼SE¼ sec. 18, contains 8 to 12 feet of ore, high-grade and pisolitic in the lower part, low grade and fragmental above. The material covers the side slopes of a small buried tributary valley (pl. 33). The third, about 300 feet east of the second, is a small pocket of high-grade pisolitic bauxite about 10 feet thick cored in only one drill hole.

Fragmental bauxitic and kaolinitic clay 10 to 30 feet thick overlies the bauxite of each body in the deposit. This is covered by 120 to 219 feet of overburden. It consists of lignite, and gray silty clay of the Berger formation, absent over the upslope and as much as 30 feet thick over the downslope parts of the deposit; tan sand and dark-brown carbonaceous silty clay of the Saline formation; and 12 to 19 feet of recent sand, gummy sandy clay, and gravel of the Hurricane Creek flood plain.

TINDALL DEPOSIT

Plate 33

Two ore bodies in the SE¼SE¼ sec. 18, T. 2 S., R. 13 W., are included in this deposit that was investigated by drilling 45 holes spaced about 200 feet apart (Malamphy and others, 1948, v. 11, p. 87–102, fig. 97).

The smaller of the two ore bodies, in the west center of the 40-acre tract, lies near the foot of a steep slope on the nepheline syenite (pl. 33). The post-Midway erosion surface dips eastward, and the bauxite has accumulated above a thick wedge of fragmental kaolinitic and bauxitic clay. Some of the ore is mealy, pisolitic, and high-grade but most of it is fragmental and low grade. The matrix of the fragments is clayey bauxite, or gray bauxitic and kaolinitic clay.

The larger of the two ore bodies, in the southern part of the 40-acre tract, lies on the eroded post-Midway surface of the nepheline syenite near the foot of the slope, filling minor valleys cut in the basement rock. It lies on fragmental bauxitic and kaolinitic clay over kaolinized nepheline syenite and is a colluvial ore body (type 2 deposit). The ore body extends south into the NE¼NE¼ sec. 19. This part of it was drilled by the Republic Mining and Manufacturing Co. in 1944. The bauxite cored by the cooperative drilling program is tan, pisolitic and firm to mealy near the center of the body, whereas that near the margins is fragmental and less pisolitic. It ranges from a few feet to 17 feet in thickness, and that in sec. 19 cored by Republic Mining and Manufacturing Co. reaches a maximum of 22 feet. It is covered by a few feet to 20 feet of fragmental bauxitic and kaolinitic clay.

The Tindall deposit is covered by 182 to 272 feet of overburden. Lignite, carbonaceous clay, and gray silty clay of the Berger formation is absent over the west ore body, but present over the southern one, and it reaches a maximum thickness of about 50 feet at the east edge of the deposit. The rest of the overburden consists of laminated dark-brown carbonaceous silty to sandy clay and brown to tan sand of the Saline formation, overlain by about 15 feet of recent sand, clay, and gravel of the Hurricane Creek flood plain.

CHAMBERS DEPOSIT

Plate 2

The ore body lies in the NE¼NE¼ sec. 19 and the NW¼NW¼ sec. 20, T. 2 S., R. 13 W. The land surface is the flat, wooded flood plain of Hurricane Creek.

The ore body is closely related to the two adjacent bodies in the Tindall deposit and lies on the northwest side of a post-Midway drainage basin that trends northeastward through sec. 19, near its mouth where it empties into the recurved valley draining the Mount Olive area (pl. 2). The deposit rests on fragmental kaolinitic clay overlying kaolinized nepheline syenite. Bauxite reaches a maximum thickness of 18 feet and is brown and pisolitic in the center of the body and fragmental near the margins. Bauxitic and kaolinitic clay from a few feet to 35 feet thick blankets the deposit, and this is covered by overburden consisting of lignite, carbonaceous clay, and gray to green silty to sandy clay of the Berger formation overlain by nearly 200 feet of dark-brown carbonaceous silty clay and sand of the Saline formation. About 15 feet of recent alluvium of the Hurricane Creek flood plain covers the surface.

MC RAVEN DEPOSIT

Plate 2

This small body of bauxite is in the NW¼SW¼ sec. 20, T. 2 S., R. 13 W. The property was drilled by the Reynolds Mining Corp., with holes spaced 200–600 feet apart. Two adjacent holes cored about 8 feet of ore, and a third hole nearby cored about 4 feet. As the drilling was scattered and few holes disclosed bauxite, the deposit may be very thin, irregular, and low grade. The subsurface map (pl. 2) shows the possible outline of the ore body and its relation to the subsurface topography. It lies on nepheline syenite, on the north wall of an easterly drainage basin.

The ore was reported to be brown, hard to mealy, and pisolitic containing large pisolites in the upper part of the bauxite, and light brown, hard to clayey, in the lower part. It is covered by 207 to 233 feet of lignite and gray silty clay of the Berger formation and dark-brown carbonaceous silty clay and sand of the Saline formation.

BRUSHY CREEK AREA

Several large deposits are in the upper drainage basin of Brushy Creek, in sec. 1, T. 3 S., R. 14 W., and secs. 25 and 36, T. 2 S., R. 14 W. and sec. 31, T. 2 S., R. 13 W. (fig. 60). The area is about 25 miles southwest of Little Rock in Saline County, and about 4 miles southeast of the town of Bauxite by good county road. It is rolling country with a maximum relief of about

150 feet, the lowest point on the creek being about 305 feet above sea level.

The deposits have accumulated in a buried embayment in the Saline dome (pl. 2). The embayment is flanked on the north and east by a major buried ridge of nepheline syenite that is exposed in the northeastern part of sec. 25, T. 2 S., R. 14 W., and trends eastward and southeastward through secs. 30, 29, and 32, T. 2 S., R. 13 W. On the west it is bounded by another ridge that crops out in the northwestern part of sec. 35, T. 2 S., R. 14 W., and trends southeastward into sec. 36. The floor of the embayment is covered by silty clay of the Wills Point formation.

The trace of the buried contact of the Wills Point on the nepheline syenite indicates considerable post-Midway erosion before accumulation of the bauxite. The contact is low across valleys and high over ridges. The east edge of the tongue of Midway sediments in sec. 31, T. 2 S., R. 13 W., rises 280 feet in about three-quarters of a mile in crossing the nepheline syenite ridge in the northwestern part of the section.

Several buried valleys drained the major ridges in early Eocene time. The largest of these, here called the Brushy Creek valley, heads in sec. 26 and trends southeastward onto the surface of the Wills Point formation. The ore bodies of the Dupont deposit in sec. 26, near Mount Olive and discussed under the Mount Olive area, lie along the headwalls of this valley. The deposits discussed in this section are the East Bauxite, MacNeil, and Grubbs–Hawkins; also the Long-Bell deposit in sec. 1, T. 3 S., R. 14 W., just southwest of the embayment. These are all on or near the edge of the Wills Point formation, and all are overlain by Berger sediments. They are typical type 2 bauxite deposits in the colluvial bauxite-kaolin facies of the Berger formation.

Bauxite in these deposits is dominantly pisolitic, with abundant well-developed pisolites in a matrix that is firm or hard in the upper part of the ore, and mealy or soft and clayey in the lower. Pisolites are sparse or absent near the base of the bauxite. Upslope most deposits have a hardcap of high-silica bauxite; downslope, they are fragmental and more kaolinitic. Near the valley bottom the bauxite of ore grade is thin, but the bauxitic section is thicker. The buried Brushy Creek valley, between the East Bauxite and the Grubbs–Hawkins deposits, is filled with 60 feet or more of fragmental kaolinitic clay that contains pisolites and pebbles of bauxite. The bauxite-kaolin zone thins southeast of the deposits to 10 or 20 feet and consists of kaolinitic clay containing bauxite fragments.

The deposits are covered by lignite, carbonaceous clay and gray silty clay to clayey sand of the Berger formation, which is more than 100 feet thick over the downslope part of some of the deposits. Upslope it thins and pinches out against the nepheline syenite. The north tip of the East Bauxite deposit is not covered by later Berger sediments. Above the Berger and overlapping it is the Saline formation, a thick unit of sand and dark-brown carbonaceous silty clay. Upslope from the edge of the Berger sediments, the Saline generally rests on fresh or decomposed nepheline syenite. The bauxite and kaolin are both absent except for small fragmental remnants at the bottoms of drainage valleys. The small Hudspeth-Fletcher deposit in the SE¼NE¼ sec. 25 is of this type, as is the East Cargill deposit in the SW¼SW¼ sec. 25 (not shown on the subsurface map as it contained no ore-grade bauxite). Both deposits contained minor amounts of dark-brown silty clay or sand in crevices between bauxite boulders, and they are thought to be alluvial accumulations at the base of the Saline formation. Apparently all bauxite in this area not protected by Berger sediments on the nepheline syenite slopes was eroded at the end of the Berger deposition. Only the high residual patches that comprise the Dupont deposit were left. During the accumulation of the Saline sediments, material eroded from the hills was locally preserved in parts of the valley bottoms and covered by the sands of the Saline.

Thus little bauxite remains on the steep south slopes of the Saline dome in secs. 25, 34, 35, and 36, T. 2 S., R. 14 W. The only large deposits are near or over Midway sediments and protectively covered by Berger sediments. The east slope of the Saline dome, as explained in the previous section, was subject to extensive erosion during the deposition of the Berger as well as the Saline sediments, and therefore little bauxite is found in secs. 19, 20, 29, 30, and 32, T. 2 S., R. 13 W.

MC NEIL DEPOSIT

By Arthur L. Jenke

Plate 34

This deposit is in the W½NE¼ sec. 31, T. 2 S., R. 13 W. on property of D. A. McNeil (mineral rights, Missouri Pacific Railroad). It lies about 500 feet northeast of the East Bauxite deposit from which it is separated by a buried subsurface ridge.

The deposit and part of the low-grade bauxitic rock between it and the East Bauxite deposit were investigated by 75 drill holes. (Malamphy and others, 1948, v. 12, p. 8–35, fig. 100).

The relationship of this deposit to the post-Midway erosion surface and to the East Bauxite body are shown in plate 34. The bauxite occupies the west side of a narrow valley on the post-Midway surface, the axis of which trends about N. 15° W. The ore lies in a lens-

shaped body, elongate in a northerly direction. It is about 1,400 feet long by 600 feet wide and covers an area of about 11 acres. The ore body dips to the south about 26 feet in 1,000. It pinches out abruptly on the north, east, and west sides and gradually southward. The ore reaches a maximum thickness of 28.5 feet in USBM drill hole 15–147 near the center of the deposit.

The deposit lies over the buried trace of the Wills Point and nepheline syenite contact, which nearly parallels the valley axis. The clay beneath the bauxite is like the underclay in the East Bauxite deposit—a red and gray mottled kaolinitic clay alternating locally with pale blue-green sideritic rock—2 to 16 feet thick.

Most of the ore is pisolitic bauxite, similar to that in the East Bauxite deposit. The ferrous iron content is high and lowers the grade of the ore.

No hardcap or roof rock was found over the ore in the McNeil body. The bauxite grades upward into bauxitic clay overlain by kaolinitic clay, which reach a maximum thickness of 44 feet over the ore.

In the area between the East Bauxite and McNeil deposits the lower part of the bauxite has been replaced by secondary iron minerals—mainly siderite, and to a much lesser extent, hematite and goethite. Much of the rock is olive-drab to brown with a greenish cast, porous, very hard, heavy, and brittle. It is composed largely of crystalline siderite and in some places of sideritic oolites cemented with siderite or limonite (goethite). In places the upper part of this rock is filled with small white rounded kaolinitic fragments. The upper part of this bed generally is siliceous. In USBM drill hole 15–125, 150 feet west of the McNeil ore body, bauxite containing magnetic pisolites was cored at a depth that ranged from 351 to 354 feet. The pisolites are hard, dark gray to black, vitreous, and set in a nonmagnetic matrix of dense red sideritic bauxite.

The thickness of the overburden, including the bauxitic and kaolinitic clay mentioned above, ranges from 366 to 403 feet, and is lithologically similar to that overlying the East Bauxite deposit.

EAST BAUXITE DEPOSIT

By Arthur L. Jenke

Plate 34

This large deposit, composed mainly of pisolitic bauxite, occupies most of the S½NW¼ sec. 31 and extends southeastward into the SW¼NE¼ sec. 31, T. 2 S., R. 13 W., and also northwestward into the E½NE¼ sec. 36, T. 2 S., R. 14 W. It is on land owned by B. H. Baxley, Cargill Securities Co., N. M. Carl and C. B. Carl, International Paper Co. (Missouri Pacific Railroad, mineral rights), and D. A. McNeil. Part of this area was leased in 1949 by the Dulin Bauxite Co. At the end of that year a steel-lined circular shaft was partly completed.

The deposit was discovered by the Federal drilling program in USBM drill hole 14–004C, drilled on August 31, 1943, and in which 10.3 feet of bauxite was cored. It was the fourth hole in an exploratory drilling program designed to test a subsurface area about which little was previously known. Later, between October 11, 1943 and December 21, 1944, 285 holes were drilled to delimit all but the southeastern tip of the deposit, most of which were spaced at intervals of about 200 feet on a triangular grid (Malamphy and others, 1948, v. 12, p. 36–149, fig. 101).

The East Bauxite deposit is a lens-shaped mass lying on the northeast flank of a broad, gently sloping subsurface valley, the axis of which trends about N. 30° W. Its outline and relationship to the post-Midway erosion surface and the nearby McNeil deposit are shown in plate 34. Cross sections and columnar sections are also given in this plate. The principal ore body within the deposit is almost elliptical in outline with its major axis in a direction nearly parallel to the trend of the valley. An elongate northward extension is at the northwest end of the main ore mass; and smaller lobes are along the north and south margins. The elliptical part is about 2,600 feet long and 1,500 feet wide, and the entire ore body covers an area of about 64 acres. It dips to the southeast about 40 feet in 1,000.

The ore is thickest in the western part of the ore body where it reaches a maximum of 43 feet. The grade of the ore drops abruptly to the west and south; in other directions the deposit thins gradually. The thickest ore lies in small valleys and valley re-entrants but the bauxite is limited to the flanks of major drainage features. Like others in the vicinity, this is a type 2 deposit formed in the colluvial apron at the margin of the Berger formation.

The basement rock is gray nepheline syenite, which has been overlapped by a wedge of dark-gray clay of the Wills Point formation. The main part of the deposit rests upon the Wills Point but the northwest lobe extends across the edge of the wedge and rests upon weathered nepheline syenite which has been altered to a white to blue-gray kaolinitic clay locally with granitic texture. Scattered through this clay are altered biotite flakes and siderite pellets; iron stains and pyrite nodules and grains also occur particularly in the upper part.

These clay beds are overlain by a transported fragmental clay as much as 15 feet thick. In most places the clay is mottled, pale red and gray, sideritic, and kaolinitic, locally it is pale blue or green and without ferric oxide staining. Where slightly bauxitic it has a pale tan to pink cast. The clay contains scattered

pisolites and in places vertically elongated bifurcated tubules that resemble root marks or worm burrows. The clay fragments in this rock are small, rounded, and sparse.

The vertical transition from underclay to bauxite of ore grade occurs within 1 to 4 feet. The normal succession upward starts with pale tan, soft pisolitic bauxitic clay at the base and grades through high-iron and high-silica bauxite into the hard, dense, red to reddish-tan pisolitic ore. There is a further gradation upward into softer tan pisolitic bauxite high in available alumina. The soft ore is overlain by high-silica bauxite grading into light-gray bauxitic clay at the top of the deposit.

The lower part of the bauxite has pisolites with soft almost liquid centers, particularly along the sides of the ore bodies. Some pisolites in this lower part of the ore section are filled with white kaolinite, with a veined or lattice structure possibly resulting from shrinkage. Samples from near the bottom of the ore in USBM drill holes 14–058, 14–061, and 16–050 had ignition losses 6 to 15 percent lower than normal for gibbsitic bauxite, probably indicating the presence of the monohydrate boehmite.

Pisolites are most abundant in the middle of the ore section and decrease in quantity vertically in both directions. The pisolites in this ore are hard, moderately round to spherical concretionary structures, commonly with concentric color banding. They have dark-gray to nearly black or reddish-brown resinous-looking interiors and red to brown hard thin outer rinds or shells. They range in size from about ⅛ to 1 inch across the largest diameter. Compound pisolites are common in good grade ore. The bauxite lacks evidence of any stratification.

Ore that is porous and composed chiefly of pisolites with little or no matrix is the highest grade. Such ore breaks apart under slight pressure. The matrix of the high-grade ore is rich tan in color, soft, mealy, and crumbles easily. Much of the highest grade ore lies near the top of the ore body. At depth the bauxite is hard, dense, red, and high in iron.

The iron content of the East Bauxite deposit is of major commercial importance. The iron is mainly present in the ferrous carbonate, siderite, and to a lesser extent in the ferric oxide minerals, hematite and goethite. The siderite is concentrated in the lower half of the ore but varies greatly at equivalent depths in adjacent drill holes. It is crystalline and fills interstices between pisolites and pore spaces in the matrix of the bauxite. In places, in the lower part of the deposit, small cavities or vugs are coated with well-developed siderite crystals. Pyrite is not common and where present is in thin crystal coatings on crystalline siderite in cavities. The ferruginous ore can be beneficiated and much of the siderite removed by crushing and roasting followed by magnetic separation.

Rock that could be used as a competent roof in mining is almost entirely absent and was cored in only three drill holes. In these drill holes the rock is a hard light gray pisolitic, highly siliceous bauxitic. The absence of an extensive hardcap necessarily means that some of the ore will have to be left to support the overlying clay during mining.

The pisolitic bauxitic clay at the top of the deposit grades upward into lower grade bauxitic clay that in most places is white, nonsilty, and nonplastic. Pisolites are scarce but fragments composed of kaolin, brown carbonaceous clay, and lignite are common. Clayey lignite and black to brown carbonaceous clay layers are interbedded with this upper bauxitic clay. They usually are fine-grained, silty, and seldom fragmental. Brown carbonaceous clay beds were found directly overlying the ore in a large area. Basinward they probably unite with lignite beds in the Berger formation, but drilling was not sufficiently widespread to permit correlation of the carbonaceous units. Siderite, where present, usually is in small sand-sized grains concentrated locally in layers about 6 inches to 1 foot thick. The upper bauxitic clay section reaches a maximum of 42 feet in thickness over the minable part of the deposit, but is absent locally where it has been removed by post-bauxite channeling. The thickness generally increases downdip to the southeast.

The bauxitic clay is overlain by few inches to 15 feet of gray to almost white firm brittle kaolinitic clay, locally containing small white to cream-tan, brown, or black (lignitic) fragments, some of which are surrounded by "halos" or reaction rims. Carbonaceous and lignitic clay beds are interlayered with this overclay also.

The bauxitic and kaolinitic clay beds are overlain by carbonaceous and clastic sediments of the Wilcox group that range in thickness from 249 to 542 feet. These sediments thicken southward, the maximum thickness being recorded in a drill hole about 1,500 feet south of the southeast edge of the ore body. The lower part of this section, which thickens from a feather edge to 116 feet southward, is composed of beds of the Berger formation. These include medium and dark-gray (locally light blue or green) silty to sandy clay, lignite, clayey lignite, and brown carbonaceous clay. They vary in thickness and grade one into the other, laterally and vertically. Lignite and carbonaceous clay predominate in the lower part; layers of medium-grained loose quartz sand and hard shells of fine-grained siderite are fairly common in the upper part. The Berger formation is overlain by 200 to 335 feet of dark-

brown silty, micaceous, carbonaceous clay of the Saline formation which, in some places, grade into brown quartz sand. Throughout most of the area the carbonaceous clay is capped by a hard dark reddish-brown ferruginous sandstone, which ranges in thickness from a few inches to about 2 feet. Thin ferruginous sandstone layers and lignite lenses are scattered through the clay. Tan bauxitic-looking clay beds are found in a few places in the Saline formation and also in the underlying Berger. The uppermost bed of the Saline formation overlying the southern part of the deposit is a white sandy clay. This is overlain by a bed of massive woody lignite believed to be the one that marks the base of the Detonti sand in this area. The Detonti sand is composed of pale-yellow to orange sandy clay at the base, grading upward to medium or dark-gray sticky clay. Above the clay is a fine- to medium-grained loose sand capped by surface soil.

Above the ore the overburden, including the bauxitic and kaolinitic clay beds at the base, ranges from 351 to 487 feet in thickness.

GRUBBS–HAWKINS DEPOSIT

Plate 2

About a quarter of a mile southwest of the East Bauxite body is another large deposit which lies in the N½SE¼ and SW¼NE¼ sec. 36, T. 2 S., R. 14 W. It consists of two ore bodies separated by a narrow area of thin bauxite of high-silica content. The Hawkins ore body is on property formerly owned by Alva Hawkins and Hudspeth–Fletcher; and the Grubbs ore body north of it is on property formerly owned by Betty Grubbs, Marie Ledbetter, and Tinsley. The properties are now owned by the Alcoa Mining Co.

The Hawkins ore body was discovered early in the wildcat drilling program of the Federal project, designed to explore the southeastern part of the Saline dome. Sixteen feet of bauxite was cored in USBM drill hole 15–005, on September 23, 1943 (Malamphy and others, 1948, V. 17, p. 17, fig. 18). The Republic Mining and Manufacturing Co. drilled out the body in the spring and summer of 1944, and during the course of the drilling the Grubbs ore body was discovered and delimited. Of 95 holes drilled on the properties, 65 were in or near the ore bodies. These drill holes were spaced 200 to 300 feet apart on a rectangular grid.

The Grubbs–Hawkins deposit is part of a large blanket deposit of bauxite and kaolin that fills the mouth and sides of the subsurface valley beneath Brushy Creek. The ore bodies flank ridge spurs on the buried nepheline syenite (pl. 2) and fill minor valleys in these spurs. The Grubbs ore body lies entirely on nepheline syenite and extends downslope to the buried edge of the Wills Point formation, whereas the Hawkins ore body extends beyond the lip of the Wills Point. The deposit is a colluvial accumulation (type 2).

The Hawkins body is about 1,700 by 1,100 feet, nearly crescent shaped and lenticular in cross section. The Grubbs ore body measures about 1,400 by 1,000 feet and is irregular in outline. The ore lying within the 8-foot isopachs in each body is separated by a relatively small ridge of nepheline syenite covered by a thin hardcap of high-silica bauxite.

The bauxite is of three main kinds—(1) a lowermost reddish-tan mealy or clayey bauxite, somewhat fragmental, sparsely pisolitic, and relatively high in iron (10 to 16 percent), overlain by (2) high-grade light-tan crumbly pisolitic bauxite containing closely packed, well formed, hard, and uniform pisolites, grading upward into (3) hard tan to gray pisolitic bauxite, containing large pebbles and angular fragments of bauxite. Most of the Hawkins ore body is capped by 5 to 10 feet of hard bauxite of the third kind, of which the top 6 inches to 2 feet contains more than 20 percent silica. Very little hardcap is present in the Grubbs ore body.

The ore exceeds 30 feet in thickness in both bodies and averages about 14 feet. Underlying the bauxite along the axis of the Hawkins ore body is a channel of bauxite conglomerate—cobbles and pebbles of dark-red pisolitic bauxite in a greenish-gray sideritic clay matrix.

Laterally the ore grades gradually into bauxitic and kaolinitic clay; vertically the transition zone occupies 6 inches to 1 foot at the top, and 1 to 3 feet at the bottom of the bauxite.

The overburden consists of gray silty clay, brown carbonaceous clay and lignite of the Berger formation, overlain by brown sand and clay of the Saline formation, and tan sand of the Detonti sand. Overburden ranges from 325 to 405 feet on the Grubbs ore body, and from 375 to 450 feet on the Hawkins ore body.

LONG–BELL DEPOSIT

By Constantine N. Bozion

Plate 2

A large deposit explored only by wildcat drill holes lies mostly in the S½NW¼ sec. 1, T. 3 S., R. 14 W., about 5½ miles southeast of Bauxite.

The area was first prospected by the Republic Mining and Manufacturing Co. in the spring of 1943, when 15 holes were drilled in sec. 1, the majority of which are in the northwest quarter. Bauxite was reported in only one hole. The Federal project drilled 12 holes in the section early in 1944 as part of a wildcat program to explore the south flank of the Saline nepheline syenite mass. These were spaced about 1,000 feet apart on a triangular pattern. Seven drill holes cored 5 to 16 feet of bauxite. (Malamphy and others, 1948,

v. 17, p. 3–16, fig. 117). The 4 southernmost holes all cored 5 feet or more of bauxite, but they were not offset to the south because of the depth and difficulty of drilling.

The Long–Bell deposit lies on clay of the Wills Point formation about 500 feet south of the buried edge of the Wills Point formation, on an eroded surface that dips about 100 feet in 1,000 to the south (pl. 2). The outlines of the body shown on the map include 5 wildcat holes that cored more than 8 feet of bauxite of 32 or more percent available alumina. The outline is an approximation to show the possible extent of the deposit. As the drilling was widely spaced, nothing is known of the uniformity of the bauxite in thickness or in grade throughout the deposit, or whether more than one ore body is present.

The bauxite is light tannish gray to buff, and pisolitic. The pisolites are brown to black, hard near the top and soft near the bottom of the bauxite. They occupy from one-quarter to one-third of the volume of the rock and are in a matrix that is dense, hard, and high in silica in the top 1 to 3 feet, but softer and more porous below. Iron in the form of crystalline siderite fills the pore spaces and the total iron as Fe_2O_3 ranges from 8 to 15 percent in ore.

The ore overlies 13 to 25 feet of fragmental sideritic bauxitic and kaolinitic clay and is overlain by 3 to 5 feet of gray kaolinitic clay. The deposit is covered by 475 to 585 feet of overburden, consisting of lignite, carbonaceous silty clay, and gray silty to sandy clay of the Berger formation; dark-brown silty carbonaceous clay and brown sand of the Saline formation and gray silty clay and tan to gray Detonti sand.

DETONTI AREA

Many deposits, most of which are covered by a thick overburden of Wilcox sediments, lie southwest of the nepheline syenite outcrops, near Detonti, Saline County (fig. 60). Detonti is about 4 miles south of Bauxite, on the single-track freight line operated by the Missouri Pacific Railroad between Bauxite and Sheridan. All-weather gravel roads link the area with Bauxite, Sheridan, and Sardis.

The country, which is flat to gently rolling, has a maximum relief of about 100 feet, from 300 to 400 feet above sea level. Little Lost Creek, the principal continuously flowing stream, meanders southward along the east edge, whereas intermittent streams drain most of the area.

The buried bauxite deposits lie along the southwest edge of the Saline dome. A few of the small bodies in secs. 28 and 34, T. 2 S., R. 14 W., rest partly or entirely on slopes of nepheline syenite, but the others, including all the large ones, lie wholly on the eroded surface of the Wills Point formation. The buried edge of this formation on the nepheline syenite hillsides trends southeastward in a broad arc from the northwest corner of sec. 28 to the southeast corner of sec. 34, a distance of nearly 3 miles in which it drops about 200 feet because of the regional southeasterly dip. As can be seen in the subsurface map (pl. 2), the topography of the post-Midway erosion surface in this area is marked by southward-trending buried valleys and ridges. The ridges are broad and rolling and have a maximum relief of about 50 feet, to which is added the apparent relief due to the regional dip of the erosion surface. The large deposits lie on slopes that are downhill extensions of the flanks of the Saline dome, but the ore bodies of the Crouch deposit lie on the ridges and in valleys cut in the Wills Point formation more than 4,000 feet from the nepheline syenite. The large deposits and most of the smaller ones are within colluvial accumulations and are type 2 deposits, including upslope parts that rest on nepheline syenite. A few of the small ones filling valleys may have an alluvial origin. A small part of the bauxite in secs. 28 and 33 overlying colluvial deposits is interstratified with lignite and gray sandy clay according to logs of holes drilled in the NE¼SW¼ sec. 28, by the Alcoa Mining Co. This is evidently bauxite of alluvial deposition within the Berger formation (type 3). Whether or not any of it is minable is not known.

An extensive bed of conglomeratic bauxite lies on top of the lignite and gray clay of the Berger formation, and is overlain by dark-brown silty clay and brown sand of the Saline formation. This bed, which has been reported in many drill holes of the Federal project, is in the SW¼ sec. 34, T. 2 S., R. 14 W. It consists of tan silty and sandy bauxitic clay 2 to 10 feet thick and is similar in the E½ sec. 33 but locally thickens to 20 feet. The bed of conglomeratic bauxite occupies most of the W½ sec. 28, and has been reported in many drill hole logs of the Alcoa Mining Co. In this section it ranges from a few feet to more than 30 feet in thickness, and is separated from underlying colluvial deposits by an interval of lignite and gray silty clay of the Berger formation that ranges in thickness from less than 20 to more than 50 feet. Cores from this bed in many drill holes were analyzed, and some of the bauxite was found to be of ore grade. One Alcoa hole in the NW¼SW¼ sec. 28 was reported to contain 26 feet of bauxite from this bed. In the NE¼SE¼ of the section, the layer is reported to be about 18 feet thick. It is separated by about 40 feet of lignite and gray sandy clay of the Berger formation from the bauxite worked in the Young mine of the Crouch Mining Co. (pl. 1, no. 116). The conglomeratic bauxite was reported by L. M.

Richards, superintendent of the mine (personal communication, October 1948), to consist of cobbles of highgrade pisolitic bauxite in a gray clay matrix. He thought that it would be possible to mine the material and wash the silty kaolinitic matrix from the bauxite cobbles, leaving an ore of abrasive grade.

Bauxite in the colluvial (type 2) deposits of the area is reported to range from a few feet to 34 feet in thickness and is overlain by lignite and gray silty to sandy clay of the Berger formation, and dark-brown carbonaceous silty clay and brown sand of the Saline formation.

At the south end of the area, near Detonti, black woody lignite and gray sandy clay of the Detonti sand overlies the Saline formation. The Detonti sand reaches a thickness of about 50 feet above the Detonti deposit, and the basal lignite of the formation ranges from 4 to 10 feet in thickness. The total thickness of overburden in the area ranges from about 150 feet at the north end to 500 feet in the southwest above part of the Detonti deposit.

Wildcat holes drilled by companies and by the Federal project cored several feet of bauxite; a few were of high grade in secs. 29 and 32, T. 2 S., R. 14 W., west of the deposits shown on the subsurface map (pl. 2). Apparently an extensive blanket of the bauxite-kaolin zone covers the gently-rolling buried hills and valleys of the post-Midway erosion surface. Most of the bauxite, however, is high in iron. Pockets of ore low in iron and silica and more than 7 feet thick are not common, and it is not known from available data whether any bodies exist that are large enough and of sufficiently high grade to mine.

Some ferruginous bauxite cored in secs. 29 and 32 is brownish-red or brick red, with small black pisolites. Material of this description from an Alcoa drill hole in the NW¼NW¼ sec. 29 had the following analysis:

Analysis of ferruginous bauxite from drill hole C-613, at depth 175–180.5 feet

[Analysis by the Alcoa Mining Co., Bauxite, Ark.]

	Percent
Al_2O_3	33. 1
SiO_2	5. 8
Fe as Fe_2O_3	33. 2
TiO_2	2. 2
Ignition loss	25. 7
FeO	20. 0

The ferruginous bauxite was found to be magnetic by Louis Ball of the Alcoa Mining Co. Pieces of the core were strongly attracted to a magnet and could be rolled across a table top. Pisolites were in general much more strongly magnetic than the matrix. The bauxite was similar in appearance and in chemical analysis to that cored in the NE¼ sec. 9, in drill hole FHA-11-8 (pl. 38).

WEST CARGILL DEPOSITS

By Forrest A. Hewitt

Plate 35

Bauxite ore in the West Cargill area lies in two ore bodies, the principal parts of which are in the SW¼ sec. 34, T. 2 S., R. 14 W. The marginal parts extend into the SE¼ sec. 33, T. 2 S., R. 14 W., the NW¼ sec. 3, T. 3 S., R. 14 W., and the NE¼NE¼ sec. 4. The two ore bodies are on properties owned by the Cargill Securities Co., the International Paper Co., Samuel Carson, James Carson, F. E. Huey and R. C. Young.

The bauxite was discovered during exploration on 1,000-foot centers by the Federal drilling program in USBM drill hole 19–072 on March 31, 1944. This was redrilled as USBM drill hole 19–075 in which was recorded a thickness of 11.2 feet of commercial-grade ore. An additional 175 test holes were drilled subsequently from May 1944 to April 1945 and all but the south end of the east ore body was delimited (Malamphy and others, 1948, v. 18, p. 3–66, fig. 121).

The two ore bodies and their relationship to the post-Midway erosion surface are shown on the subsurface map, plate 35. Cross sections through each ore body and selected columnar sections also appear on this plate. The ore bodies are about a quarter of a mile apart, separated by a low buried ridge of Midway age that trends southwestward. Both are irregular in outline. The west ore body is about 2,400 feet long and 600 feet wide, trends S. 42° W. and dips 3½° S. The east ore body is 1,800 feet long, as far as delimited, and 1,000 feet wide; it trends about S. 17° W. and its long axis is inclined 3½° S.

Each of the ore bodies lies along the slopes of a subsurface valley and partly fills the bottom of it. Both lie mostly over the Wills Point formation but extend upslope beyond its edge and lap onto weathered nepheline syenite. The upper part of the nepheline syenite has been altered to residual kaolinitic clay in most places. The clay contains scattered siderite pellets and pyrite cubes and aggregates. In several drill holes at the north end of the east ore body, the upper part of the nepheline syenite, above the kaolinitic part, was bauxitic.

The deposits can be classified as type 2, and apparently have formed mostly by the accumulation of bauxitic colluvium in stream valleys. They were enriched by a subsequent bauxitization, particularly along higher slopes. Most of the ore is pisolitic, but in places the basal part is fragmental.

The kaolinitic underclay is thick above subsurface ridges and thin in valleys. It is composed of gray and red mottled clay containing subrounded tan to white fragments, 1 to 4 millimeters across. In places basal

beds of clay debris show the texture of nepheline syenite. Clay fragments are more abundant where the underclay is directly above nepheline syenite and they gradually decrease downslope above the Wills Point formation.

The lower part of the ore is soft and mealy, reddish tan with a greenish cast. It contains much siderite, commonly in rounded, very dark aggregates. This grades upward into rich tan mealy pisolitic bauxite, which generally is the highest grade ore in the deposits. Above this is a hard pisolitic bauxite made up of dark-brown to black spherical and concentrically banded pisolites. Many of these in the top of the deposit have kaolinitic interiors. The bauxite is overlain by light-tannish-gray bauxitic clay, containing pisolites with soft semiliquid interiors. The pisolites range in size from 2 to 11 millimeters.

Hard siliceous cap rock was found in only one drill hole, hence bauxite of ore quality will probably have to be left as a roof during mining. Two beds of bauxite, separated by a highly bauxitic clay, were found at the south end of both bodies. The thickness of this bauxitic clay wedge varies considerably and reaches 5 feet in places. The two bauxite beds are not thick enough to be mined singly.

The overclay is light gray, massive, fragmental, and kaolinitic. It is not present everywhere, having been removed in places by channeling. The thickness reaches a maximum of 15 feet and averages about 4 feet.

The Wilcox sediments above the east ore body have an aggregate thickness that ranges from 277 to 394 feet and increases southward. Above the west ore body the thickness ranges from 319 to 419 feet. The sediments of the Berger formation above the overclay reach a thickness of 58 feet in places. These sediments consist mainly of gray and greenish-gray silty to sandy clay, but include as much as 20 feet of lignite and lignitic clay locally near the base. The chocolate-brown carbonaceous clay and brown sand of the Saline formation range from about 240 to 300 feet in thickness. Layers of tan clay that appear bauxitic and hard sideritic siltstone are common throughout this formation and lignite lenses were cut in the lower part. The Detonti sand is absent in the northern part of the West Cargill area and reaches a thickness of 30 feet in the southern part. The base overlying the Saline formation is a light-gray sandy clay, usually mottled and stained red and yellow near the surface of the ground. Hard siliceous layers occur in the sandy parts of the formation. Locally terrace or stream gravel interbedded with sand and clay form the surface deposit.

DETONTI DEPOSIT

By William J. Powell

Plate 36

A small irregular accumulation of bauxite on properties owned by the International Paper Co., J. H. Carson, and D. Y. Young is in the S½SE¼SW¼ sec. 33, T. 2 S., R. 14 W. and the N½NE¼NW¼ sec. 4, T. 3 S., R. 14 W. in Saline County.

The deposit is 4½ miles south of the town of Bauxite, about 7 miles by the all-weather county road that passes within 100 feet of it. The discovery hole, USBM 21–068, was drilled on May 8, 1944. Subsequently, 53 drill holes were sunk, most of which were spaced about 200 feet apart, and all but the northwest end of the ore was delimited. (Malamphy and others, 1948, v. 18, p. 97–119, fig. 123.) The relatively small area covered by ore more than 8 feet thick makes it unlikely that this deposit will soon be mined under existing economic conditions.

The relation of this deposit to the post-Midway erosion surface is shown in plate 36. The bauxite has accumulated on the west slope of a southward-trending subsurface valley (type 2 deposit). Bauxitization is indicated in plates by increased thickness over small ridges. All the bauxite lies above sediments of the Wills Point formation. The dark-bluish-gray clay of this formation has a weathered zone at the top consisting of banded khaki-colored clay, red and gray clay, and light gray to white clay.

Between the weathered Wills Point sediments and the bauxitic rocks is an underclay, 0.5 to 18.0 feet thick, averaging 7.4 feet. This underclay is a green to gray or tannish-gray fragmental sideritic kaolinitic clay with local kaolin fragments and dark mineral grains at the base. Red and gray mottled clay was found beneath the north and central parts of the deposit. Bauxitic clay beneath the ore ranges from 0.5 to 13.6 feet in thickness and averages 5 feet.

A large part of the bauxite and surrounding bauxitic clay is fragmental in texture, many of the fragments are composed of kaolinitic or bauxitic clay. In places the bauxite is pisolitic and adjacent to it the overlying bauxitic clay is pisolitic also. Pisolites in the more siliceous rock at the top of the deposit commonly have pasty or almost liquid interiors.

Bauxite of a grade better than 32 percent available alumina reaches a maximum thickness of 11 feet in USBM drill hole 15–207 in the northwest part of the deposit. Bauxite of a grade higher than 24 percent available alumina reaches a maximum thickness of 22.7 feet. High-silica bauxite is abundant in the

deposit. The silica content averages about 13 percent within the 5-foot isopach. It appears to be concentrated in the south-central part of the deposit and is highest in the fragmental type of bauxite. Pellets of siderite are widely distributed through these rocks, and are most concentrated in the pisolitic bauxite. The FeO content averages about 4.5 percent in the ore.

The bauxitic clay above the ore ranges from 1 to 26.3 feet in thickness and averages 14.4 feet. It is overlain by gray fragmental kaolinitic clay which in places contains scattered elongated lignite fragments. The thickness of the overclay reaches a maximum of 16 feet.

The overburden, including the bauxitic and kaolinitic clay mentioned in the preceding paragraph, ranges in thickness from 417 to 513 feet and averages about 462 feet. It is made up of beds of the Berger and Saline formations and the Detonti sand.

SUTTON DEPOSIT

By Horace W. McGee

Plate 37

This deposit lies mostly in the W½NE¼ sec. 33, T. 2 S., R. 14 W., about 4 miles south of the town of Bauxite. An all-weather gravel road and a branch of the Missouri Pacific Railroad pass the locality.

As far as is known the NE¼ of the section had not been drilled by mining companies. The ore body was discovered during a wildcat program of the Federal project to explore the southwest flank of the Saline nepheline syenite hill. In April 1944, 12.6 feet of bauxite was cored in USBM drill hole 13–162C. Later the deposit was explored by drilling 64 holes spaced about 200 feet apart. It was not completely delimited either at the north or south end when drilling was stopped at the close of the project (Malamphy and others, 1948, v. 18, p. 67–96, fig. 122).

The deposit is a colluvial accumulation of pisolitic bauxite within the bauxite-kaolin facies of the Berger formation (type 2). It overlies the eroded and weathered surface of the Wills Point formation near the buried edge of the Wills Point on nepheline syenite, as can be seen in the subsurface map of the deposit and the accompanying cross sections (pl. 37). The post-Midway erosion surface dips to the southwest about 100 feet in 1,000, and is cut by minor southwestward-trending drainage channels that are filled with kaolinitic clay and bauxitic clay that underlies the bauxite.

Nearly all the bauxite is pisolitic, grayish tan, and fairly firm. The top of the bauxite bed is hard and brittle; the lower part is softer, porous, friable, and near the bottom is clayey. Pisolites are mostly 3 to 6 millimeters in diameter, and are round. They are fairly uniform, soft to firm, and gray to brown. Hard black banded pisolites are present in the upper part of the bauxite bed, but they are not dominant. Pisolites make up 30 to 50 percent of the volume of the ore, are closely packed, but do not touch one another. They are best formed and most abundant in the upper half of the bed. Small pebbles of bauxite, and kaolinitic clay are scattered throughout the deposit, especially near the base, but without stratification or layering.

Practically all the bauxite contains siderite which is more abundant in the lower than in the upper part of the ore. Total iron analyzed as Fe_2O_3 ranges from about 5 to 20 percent, and probably averages more than 10 percent for the ore body.

The bauxite, a few feet to 33 feet thick, is underlain by a thin layer of high-silica bauxite and fragmental bauxitic clay, grading downward into kaolinitic clay that ranges from a few feet to 15 feet in thickness. It is overlain by 5 to 45 feet of high-silica bauxite and bauxitic clay, and by 5 to 15 feet of kaolinitic clay containing one or two thin carbonaceous beds. In the southwest, downslope part of the ore body, two beds of bauxite are separated by a wedge of kaolinitic and bauxitic clay, as can be seen in cross section *B-B′* (pl. 37). The clay separating the bauxite beds is similar in appearance to the bauxite above and below, but is more fragmental. It is possible that the upper bed is a type 3 deposit, but it is not stratified and shows no other evidence of alluvial deposition, and drilling information downslope is insufficient to reveal whether the bauxitic clay layer merges with lignite and silty clay of the Berger formation.

The bauxite-kaolin facies is overlain by beds of Berger and Saline age. The Berger formation ranges in thickness from 10 to 80 feet, and consists of thin lignite beds that locally attain a thickness of 20 feet; carbonaceous clay and gray silty to sandy clay. It is overlain unconformably by 147 to 334 feet of dark chocolate-brown silty clay and brown sand of the Saline formation. The base of this unit is a light-gray to tan, silty to sandy bauxitic clay or bauxite gravel that is about 2 feet thick over most of the deposit, but reaches a maximum thickness of 20 feet.

The total thickness of the overburden, down to the top of the ore, ranges from 278 to 406 feet.

CROUCH DEPOSIT

Plate 2

Four ore bodies are included in this deposit, in the SE¼SE¼ sec. 29, the E½NE¼ sec. 32, and the NW¼NW¼ sec. 33, T. 2 S., R. 14 W. They lie along the east side and at the head of a southward-trending buried valley cut in the surface of the Wills Point formation, as can

be seen on the subsurface map (pl. 2), as much as a mile from the edge of the Wills Point on nepheline syenite. The deposit is an extensive blanket of bauxite and associated kaolin in which occur the four lenticular ore bodies that consist of bauxite more than 8 feet thick. The bauxite reaches a maximum thickness in the northwest ore body, in the SE¼SE¼ sec. 29, where it is more than 25 feet thick in USBM drill hole 19–023B (Malamphy and others, 1948, v. 17, p. 29–30, fig. 118). These holes were drilled as part of a wildcat program of the Federal project to test the Detonti area. Closer drilling with holes spaced from 200 to 400 feet apart was done by the Republic Mining and Manufacturing Co.

The bauxite in the ore bodies is pisolitic, hard at the top, softer and more clayey near the base. Locally it is low in silica, but in all the ore bodies it is moderately high in iron. The lower half of the bauxite is sideritic, and the total iron reported as Fe_2O_3 generally ranges from 10 to 20 percent. The base of the bauxite in several company drill cores was a mottled red and tan firm sideritic clay similar to that in USBM drill hole 19–023B (Malamphy and others, 1948, v. 17, p. 39), which contained 46.1 percent of alumina, 5.3 percent of silica, and 18.6 percent of iron.

The deposit is covered by 3 to 6 feet of high-silica bauxite, bauxitic clay, and kaolinitic clay, and this is overlain by 300 to 350 feet of lignite, gray silty clay and gray sand of the Berger formation, and dark-brown carbonaceous silty clay and brown sand of Saline age.

YOUNG DEPOSIT

Plate 2

A group of ore bodies form a large deposit in the W½ and NW¼SE¼ sec. 28, T. 2 S., R. 14 W., at the north end of the Detonti area. One of these bodies has been worked in the Young mine of the Crouch Co. (pl. 1, no. 116) in the NE¼SW¼ of the section. All the ore bodies are connected by high-silica bauxite, bauxitic clay, and kaolinitic clay that forms a large blanket over much of sec. 28. This deposit probably is joined to the west end of the Neilson deposit, in the east part of sec. 28, by bauxitic and kaolinitic clay and possibly by less than 5 feet of bauxite. The relation of the deposit to the post-Midway erosional surface on which it rests may be seen in the subsurface map (pl. 2). The extensive blanket of bauxite and clay lies on the southwest flank of the Saline nepheline syenite mass, and extends onto the eroded top of the Wills Point formation that slopes to the southwest. It is principally a type 2 deposit. The small ore bodies of the deposit lie well out on the Wills Point surface, or over the buried contact of the Wills Point and nepheline syenite; one is upslope on nepheline syenite. The largest and thickest ore body in the N½SW¼ and S½NW¼ sec. 28, overlies clay of the Wills Point formation a short distance downhill from its edge on the nepheline syenite. The southwest, downslope edge of this ore body is apparently limited by a low hill on the post-Midway surface in the SW¼SW¼ of the section. The ore either thins or decreases in grade near the base of the slope.

The bauxite in the deposit is for the most part creamy tan, hard near the top but crumbly below, and pisolitic. The pisolites are well formed, hard, closely packed and have subvitreous, dark reddish-brown to gray interiors. This type of ore grades down into rusty-tan nonpisolitic, crumbly sideritic bauxite. The bauxite overlies bauxitic to kaolinitic clay 10 to 30 feet thick above the weathered Wills Point sediments. It is overlain by high-silica bauxite, and by bauxitic to kaolinitic clay that is thin above most of the deposit. Much carbonaceous material is found at the top of the deposit, and a 10-foot lignite log was recovered from the upper part of the bauxite in the Young mine (fig. 63).

FIGURE 63.—Part of a 10-foot lignite log found near the top of pisolitic bauxite in the Young mine, Saline County. Soft lignite core has crumbled away. Harder outer part, reinforced with crystalline siderite and surrounded by tan pisolitic bauxite is shown.

The bauxitic clay is overlain by well-indurated lignite and gray silty to sandy clay of the Berger formation ranging from 15 to 50 feet in thickness. A conglomeratic bauxite layer a few feet to 30 feet thick lies unconformably on top of the Berger. This is the basal bed of Saline age described in the previous section, covered by 150 to 230 feet of thinly bedded dark-brown carbonaceous silty clay and fine to coarse tan sand of the Saline formation. The total thickness of the beds overlying the deposit ranges from about 150 to 300 feet.

The bed of conglomeratic bauxite (type 4) at the base of the Saline formation was cored in many company drill holes. It covers a significant part of sec. 28, and may be a source of ore, therefore a typical drilling log is reproduced here. The interval 0–175 feet is revised from the driller's log of the overburden.

Alcoa Mining Co. drill hole K-107 NW¼SE¼ sec. 28, T. 2 S., R. 14 W.

Description	*Feet*
Saline formation:	
Clay, sandy, red, yellow, pink	0 – 35
Clay, sandy, brown	35 – 75
Clay, sandy, brown; some sideritic indurations	75 – 95
Clay, sandy, brown	95 –115
Clay, sandy, brown; lignite fragments and thinly interbedded lignite layers	115 –175
Clay, gray to brown, silty and plastic to nonsilty, nonplastic, kaolinitic	175 –187
Cored interval, from 187 to 285 feet, logged by W. E. Benson	
Bauxite, conglomeratic. Fragments and pisolites, red-brown to orange, and pisolitic boulders of bauxite in a matrix of bauxitic clay, tannish-gray, hard	187 –196
Bauxitic clay, pisolitic, fragmental. Pisolites yellow and tan; matrix light tannish-gray	196 –198
Berger formation:	
Clay, light gray to bluish-gray, plastic to nonplastic; slightly silty to nonsilty; small sideritic pellets in lower part	198 –215.5
Lignite, lignitic clay, and clay, carbonaceous, gray, interbedded. Beds less than 0.5 feet thick	215.5–222
Clay, gray, kaolinitic; not silty, slightly plastic. Sparsely fragmental with small fragments and pisolites of bauxite	222 –229.5
Clay, medium- to light-gray, fragmental, kaolinitic. Thin beds of lignite and lignitic clay at 229.5–230.5; 244–245; 251–252	229.5–252
Clay, gray, fragmental, kaolinitic, to clay, gray, fragmental, bauxitic	252 –258
Bauxitic clay, pisolitic, light gray, grading to bauxite. Pisolites are gray	258 –261
Bauxite, pisolitic; gray and tan pisolites in an orange-brown matrix, sideritic	261 –267
Bauxite, fragmental, tan and orange	267 –273
Clay, gray, nonsilty, bauxitic to kaolinitic, some red mottling	273 –277
Clay, kaolinitic, sideritic, fragmental, bluish-gray. Large white kaolinitic clay fragments	277 –285
End hole at 285 feet.	

Chemical analyses of the core are not available, but the interval 190–193 feet, in the conglomeratic bauxite, was reported to contain more than 40 percent available alumina, while in the lower bauxite unit, 5 feet averaged more than 40 percent and 9 feet averaged more than 32 percent available alumina.

The sediments of the Berger formation are relatively free of silt and lignitic beds in this hole, located near the nepheline syenite slopes in the center of the NW¼SE¼ of the section. In holes drilled to the west of this, the lignite was more thickly bedded, and the gray clay was sandy, containing much quartz as well as feldspar. The Berger becomes progressively sandier to the west, away from the Saline dome. The basal conglomeratic bauxite of the Saline formation also becomes sandy away from the Saline dome.

Section 28 shaft mine (*pl. 1, no. 117*).—Production from this mine of the Alcoa Mining Co. in the NW¼SW¼ sec. 28 was reported for 1943 and 1944 in "Minerals Yearbook" under the name "Young mine." No quantity of ore was produced after the main drifts were driven. The mine has a 300-foot rotary-drilled shaft above which is an enclosed headframe with a movable belt conveyer to a semicircular stockpile around the shaft. The method of drilling and lining the shaft has been described by MacPherson (1945, p. 11) and a photograph of the headframe was reproduced by Malamphy and others (1948, v. 1, fig. 2*B*). Bauxite in the mining area ranges from about 8 to 23 feet in thickness, and it is covered by 265 to 300 feet of overburden. In 1948 the mine was not in operation, but it was kept open and dry.

Young shaft mine (*pl. 1, no. 116*).—This mine of the Crouch Mining Co. in the NE¼SW¼ sec. 28 is the deepest in the region. Its shaft was the first to be drilled with a rotary drill. A special reaming bit more than 7 feet in diameter was used after a 16-inch pilot hole had been drilled. The methods used in drilling and lining the shaft are discussed by MacPherson (1945, p. 11).

The mine was developed and a calcining plant built during 1941. It was worked mostly for abrasive ore and was still producing when visited by the writers in October 1948.

The bauxite in the mined area ranges from about 8 to 18 feet in thickness, and is covered by about 260 to 300 feet of overburden.

NEILSON AREA

NEILSON DEPOSIT

Plate 2

This mining area, second to the Davis area in size and productivity, lies mostly in sec. 27 and the W½ sec. 26, and extends into the E½ of sec. 28, T. 2 S., R. 14 W. (fig. 60). It is named for the extensive Neilson underground mine area of the Alcoa Mining Co.

All the mines in the area exploit a single deposit of bauxite in a major embayment bounded by outcropping nepheline syenite, in secs. 22 and 23 on the north, sec. 26 on the east, and sec. 34 on the south (pl. 1).

The embayment forms the principal buried post-Midway drainage system of the southwest quadrant of the Saline nepheline syenite dome, as can be seen on the subsurface map (pl. 2). The main valley, that heads near the center of the north line of sec. 26 and trends southwestward into sec. 28, is here called the Neilson valley. Many tributary valleys from the northwest and southeast separate spurs of nepheline syenite that abut the main valley.

Bauxite covers much of the embayment. It is of highest grade on the sides and ends of the spurs, thins or is cut out in the line of outcrop near their crests; and drops markedly in grade in the tributary valleys. The main valley is filled with an accumulation of bauxite and bauxitic clay mostly of low grade but containing areas of high-grade ore. The thickness of the ore ranges from a few feet to 60 feet in the Globe mine (pl. 1, no. 103). The deposit is covered by overburden, thin near outcrops, and reaches a maximum of 204 feet in thickness in the NE¼ sec. 27. It consists of laminated dark-brown carbonaceous silty clay and brown sand of the Saline formation, including some bedded clayey lignite overlying the bauxite, and thin-bedded clay and Detonti sand.

Bauxite on the higher slopes of the area consists principally of granitic-textured ore overlain by pisolitic or rubbly concretionary bauxite. The whole deposit is largely residual (type 1), with a thick downslope accumulation of conglomeratic bauxite (type 4) in the valley floor. Whether any appreciable deposits of alluvial (type 4) ore have been mined here is not known.

There are 13 mines in the area, as follows:

West Maud (pl. 1, no. 109)	NE¼NW¼ sec. 27
West Maud Extension (pl. 1, no. 110)	SW¼NW¼ sec. 27
Middle Maud (pl. 1, no. 108)	NW¼NE¼ sec. 27
East Maud (pl. 1, no. 107)	NE¼NE¼ sec. 27
Neilson (pl. 1, no. 100)	SW¼SW¼ sec. 23
East Neilson (pl. 1, no. 99)	SE¼SW¼ sec. 23
Section 26 (pl. 1, nos. 101, 102)	SW¼NW¼ sec. 26
Globe (pl. 1, no. 103)	NW¼SW¼ sec. 26
Bertha (pl. 1, nos. 104, 105)	NW¼SW¼ sec. 26
Bertha Extension (pl. 1, no. 106)	N½SE¼ sec. 27
Southern Acid and Sulphur Co. shaft (pl. 1, no. 111)	NW¼SW¼ sec. 27
Ozark 28 (north and south shafts) (pl. 1, nos. 112, 113)	NE¼SE¼ sec. 28
Globe 28 (east and west shafts) (pl. 1, nos. 114, 115)	SE¼NE¼ sec. 28

The Globe, Globe 28, and Ozark 28 mines were mined by the American Cyanamid and Chemical Corp.; the rest, except for the Southern Acid and Sulphur Co. mine, are owned by the Alcoa Mining Co. All the Alcoa Mining Co. mines started as open pits. Inclines driven from the East Maud, Neilson, and Section 26 mines merged to form the Neilson underground mining area. The Bertha mine also was extended underground, but was not connected with the Neilson.

The slopes of the bauxite-covered hills are steep—as much as 20° in the Maud and Section 26 mines, and locally as much as 42°.

The history of individual mines of the area is for the most part hard to trace, as production has generally been reported by companies rather than by individual mines, in U. S. Geological Survey "Mineral Resources" and the U. S. Bureau of Mines, "Minerals Yearbook."

Hayes (1901, pl. 61) located the site of a pit on the north line of sec. 27, on the bauxite outcrop in the present East Maud mine, but no description of the mine is available.

The open pits of the East Maud, Middle Maud, and the Globe mines, the earliest in the Neilson area, were in operation before 1910.

The Maud group and Section 26 mines were in operation in the twenties and are shown on the map of Stearns (1930, pl. 1). By 1938, as can be seen from aerial photographs taken at that time, all the mines listed above were open except for Bertha Extension. In 1941–42 the West Maud Extension was enlarged, and the Bertha Extension was stripped. Production was reported from all the Alcoa Mining Co. mines until 1945. After the war, underground mining was done through the Section 26 incline until the fall of 1948, when the mine was abandoned because of a long-continued fire in lignite overlying the bauxite. Most of the Bertha Extension and much of the West Maud Extension have not been mined.

Maud group open-pit mines (pl. 1, nos. 107, 108, 109, 110).—The East, Middle, and West Maud mines are each a nearly crescent-shaped cut around the end of a nepheline syenite spur. Mining operations began at bauxite outcrops and were continued down slopes as great as 20° until the overburden exceeded 50 to 75 feet, after which inclines were driven to connect with the Neilson underground workings. Much residual bauxite is present in outcrops at the top of the mines. Some of this preserves an excellent granitic texture, but is high in silica because cavities are filled with a brittle, cherty-appearing clay mineral, probably kaolinite. Residual boulders of nepheline syenite are common in these mines.

Section 26 mine (open-pit and incline) (pl. 1, nos. 101, 102).—As can be seen in plate 2, the ancient weathered surface of the nepheline syenite slopes steeply at this mine. The inclined shaft slopes 20° for 300 feet, and locally the bauxite surface slopes as much as 42° near the line between the SW¼NW¼ and the NW¼-

SW¼ sec. 26, which forms the boundary between this and the Globe mine. An Alcoa Mining Co. drill hole at the top of this steep slope cut through 58 feet of bauxite that averaged about 50 percent available alumina, and the hole ended in ore. Residual boulders are common in this mine. One of the best-exposed is shown in the photograph on plate 10*D*, and another boulder close to it was studied by Goldman (1949) and is discussed in the section on residual (type 1) deposits on pages 116, 117 of this report. Other large boulders underground were 12 to 14 feet in diameter. The incline to the underground workings has exposed more clearly than in any other mine the division of a residual deposit (type 1) into a zone of leaching and a zone of concretion. Granitic-textured bauxite is exposed along the walls of the 20° slope, overlain by pisolitic and rubbly concretionary ore.

Globe open-pit mine (*pl. 1, no. 103*).—This mine in the NW¼SW¼ sec. 26, T. 2 S., R. 14 W., one of the oldest mines in the Neilson area, was opened probably before 1910 and was mined for some time by the Globe Bauxite Co. Production was reported through 1927. It was acquired in 1927 by the Superior Bauxite Co., was mined in 1930–31 by the Kalbfleisch Corp., and later was worked from time to time until the middle of 1944 by the American Cyanamid and Chemical Corp. Bramlette (1936) called this the Old Calumet pit. Cash (1929, fig. 113) published a photograph of the pit face showing a 60-foot wall of granitic-textured bauxite, the thickest known occurrence of residual ore.

Southern Acid and Sulphur Co. shaft mine (*pl. 1, no. 111*).—This shaft, located in the NW¼SW¼ sec. 27, T. 2 S., R. 14 W., is shown on the map of Stearns (1930, pl. 1), but no record is available of any production from the mine.

Ozark 28 (*north and south shafts*) (*pl. 1, nos. 112, 113*).—This mine in the NE¼SE¼ sec. 28 was opened in 1937, by the American Cyanamid and Chemical Corp. It was abandoned late in 1943. Waste bauxite scattered near the shafts is largely pisolitic (birdseye) ore, with large black pisolites in a hard red matrix, or less commonly in a gray cherty-appearing matrix. Vermicular bauxite fragments can also be recognized. The ore mined was apparently from the concretionary zone of a residual (type 1) deposit.

Globe 28 (*east and west shafts*) (*pl. 1, nos. 114, 115*).—These two shafts in the SE¼NE¼ sec. 28 were opened about 1941 by the American Cyanamid and Chemical Corp., and production continued until the middle of 1944. The bauxite is of the same type as that in the Ozark 28, discussed above.

Bertha Extension open-pit mine (*pl. 1, no. 106*).—This is one of the largest and deepest pits in the region in the NW¼SE¼ sec. 27, T. 2 S., R. 14 W. The overburden ranged from 35 to 120 feet before stripping. The ore was deposited on a broad knoll, or gently sloping spur of the nepheline syenite, as can be seen from the subsurface map (pl. 2). The ore ranges in thickness from 6 to 34 feet. Production from this mine was reported in "Minerals Yearbook" in 1943 and 1944, but little if any of the bauxite had been mined up to October 1948, when the pit was visited by the writers.

BAUXITE-WOODLAND AREA

A group of deposits and mines extends from the town of Bauxite to the community of Woodland, a wartime government-housing project in sec. 21, T. 2 S., R. 14 W. The deposits occupy the SE¼ sec. 9, most of, secs. 16 and 21, and the eastern part of secs. 17 and 20 (fig. 60).

Residual (type 1) deposits flank ridges and cover low saddles of nepheline syenite; colluvial (type 2) deposits lie on the eroded surface of the Wills Point formation along the west side of the Saline dome (pl. 2).

Outcropping bauxite and nepheline syenite on the east side of secs. 16 and 21 separate the deposits of this area from those of the Davis area to the east. To the north and west the occurrence of bauxite in the Bauxite–Woodland area is limited by an early Eocene valley on the surface of the Wills Point formation, peripheral to the nepheline syenite dome and about half a mile from the buried edge of the Wills Point formation. Deposits lie along the east side of the valley in secs. 9, 17, and 20; the bottom and west side of the valley are relatively barren.

Deposits on nepheline syenite (type 1) are covered by overburden of the Saline formation, thin near outcrops, but reaching a maximum thickness of more than 125 feet over a part of the Section 16 mine. Colluvial (type 2) deposits are covered by overburden ranging from 30 feet in sec. 9 to 130 feet in sec. 20. The Holly Creek deposit in sec. 20 is covered by gray clay and lignite of the Berger formation, 30 to 40 feet thick at the south end of the deposit but thinning upslope and to the north. In sec. 17, a thin edge of the Berger formation covers much of the Poodle deposit, and is represented in the Poodle mine, in the NW¼NW¼ sec. 16, by a thin lignite bed overlying gray kaolinitic clay in the lowest part of the mine. The Berger is not present in the Stuckey or Ramsey mines to the northeast.

Bauxite in the residual deposits on nepheline syenite reaches a maximum thickness of about 30 feet in the Pruden mine. In the colluvial deposits it ranges in thickness from a few feet to a maximum of 48 feet in sec. 20, recorded in a drill hole of the Alcoa Mining Co.

A list of the 13 mines of the area and their locations follows:

Mine	*Location*
Spring Hill (pl. 1, no. 119)	NW¼NW¼ sec. 21
Smith (pl. 1, no. 118)	NW¼NE¼ and NE¼NW¼ sec. 21
Section 16 (pl. 1, no. 120)	SE¼SW¼ sec. 16
Lone 7th (pl. 1, no. 121)	NW¼SE¼ sec. 16
Pruden (pl. 1, no. 122)	Center sec. 16
Pruden Extension (pl. 1, no. 123)	SW¼NW¼ sec. 16
Poodle (pl. 1, no. 126)	NW¼NW¼ sec. 16
Section 17 (pl. 1, no. 124)	SE¼NE¼ sec. 17
Standard (pl. 1, no. 125)	NE¼NE¼ sec. 17
Annie	NW¼NE¼ sec. 16
Tank	NE¼NE¼ sec. 16
Stuckey (pl. 1, no. 127)	NW¼SE¼ sec. 9
Ramsey (pl. 1, no. 128)	S½S½SE¼NE¼ sec. 9

The Ramsey was opened by the Arkansas Bauxite Stripping Co., the Stuckey by the Reynolds Mining Corp., and the Standard by the Arkansas Bauxite Corp. All others are owned by the Alcoa Mining Co.

Much of the earliest mining of the region was done in this area. Hayes (1901, pl. 61) published the location of three pits, probably operated by the Illinois Chemical Co., on outcrops of the present Pruden mine, and one pit of the Pittsburgh Reduction Co. near the old Tank mine.

Production from the Tank mine is reported in U. S. Geological Survey "Mineral Resources" in 1911, and the irregular floor of a mined out part of this pit was photographed by Mead (1915, pl. 3). The sites of this and the nearby Annie mine are now covered by mills and buildings of the Alcoa Mining Co. The large area now called the Pruden mine has been worked almost continuously since 1898.

During 1934 the Smith, Pruden, and a part of the Tank mine were operated by the Republic Mining and Manufacturing Co., and the shaft of the Standard mine was completed by the Arkansas Bauxite Corp., formed to mine bauxite for quick-hardening cement. These mines are listed as active on Bramlette's map (1936, pl. 9). Aerial photographs taken in 1938 show that the Smith, Spring Hill, Pruden, and several smaller mines in the town of Bauxite were working or had been abandoned. From 1941 to 1943 large surfaces of bauxite were cleared in the Section 16, Pruden and Pruden Extension, Poodle and Lone 7th mines, and the Section 17 mine was partly stripped. The Stuckey and the Ramsey mines were opened in this period. Since the war only the Section 16 mine and infrequently the Pruden have been worked.

HOLLY CREEK DEPOSIT

Plate 2

This large body of ore in the SE¼ sec. 17 and the E½E½ sec. 20 was explored by the Alcoa Mining Co. who drilled a large number of holes spaced about 200 feet apart in a rectangular pattern.

The bauxite overlies the Wills Point formation near its buried edge on nepheline syenite and extends along the eastern slope of a valley peripheral to the Saline dome. Locally the deposit overlaps nepheline syenite.

The bauxite ranges in thickness from a few feet to more than 48 feet that averaged more than 53 percent available alumina, as recorded from one drill hole that bottomed in good ore.

The bauxite overlies and is overlain by bauxitic and kaolinitic clay, but nothing is known of the regularity of these beds. Overburden consists of lignite and gray silty clay of the Berger formation and dark-brown silty to sandy clay and sand of the Saline formation, and ranges from 30 to 130 feet in thickness.

SECTION 16 DEPOSIT

Plate 2

Section 16 open-pit mine (pl. 1, no. 120).—This mine is a long opencut that extends from the SE¼SW¼ sec. 16 into the N½N½NW¼ sec. 21 and exposes a steeply sloping surface for more than half a mile along a nepheline syenite hillside. The top of this slope was covered by a few feet of Wilcox sediments before stripping, but the foot of the stripped slope abuts a wall of sand and clay more than 125 feet high. A stripped but unmined slope of bauxite at the east end of the mine is shown in figure 35*B*. A large residual boulder of kaolinized nepheline syenite is exposed on the surface of the bauxite.

The ore is granitic-textured bauxite, well exposed along the top of the slope and in mine cuts, overlain by concretionary pisolitic bauxite in which persist large subangular to rounded blocks of granitic-textured, birdseye pisolitic, and vermicular bauxite. The mine is a good example of a residual (type 1) deposit. The thickness of the ore ranges from a few feet to about 30 feet. This is the only mine in the Bauxite-Woodland area that was active at the end of 1948.

PRUDEN DEPOSIT

Plate 2

Pruden open-pit mine (pl. 1, nos. 122, 123; figs. 37, 38).—This mine, together with the Pruden Extension, forms one of the larger stripped areas of the district. It lies mostly in the NE¼SW¼ and SE¼NW¼ sec. 16, and the Pruden Extension continues in the SW¼NW¼ to the west line of sec. 16. Mining began before 1900, probably by the Illinois Chemical Co., in three small pits located on outcrops of the present mined area.

The bauxite surrounds a small hill of nepheline syenite west of the center of the section. East of this hill the ore covers a saddle and to the north it fills a valley

in the nepheline syenite. The bauxite ranges from a few feet to 30 feet in thickness, and before strip mining began it was covered by overburden generally less than 15 but in places 25 to 40 feet thick.

In the S½SE¼NW¼ sec. 16, at the north end of the mine, a lobe of bauxite covers the south end of a spur of nepheline syenite. In 1944–45 a road cut through the middle of the lobe exposed a vertical section of the deposit from the outcropping nepheline syenite at the top of the hill, to the toe of the slope. The relations of the several types of bauxite in a residual deposit, both in vertical section and on the steep cleaned surface were so well shown that this part of the Pruden pit (called the "Schoolhouse mine") has been selected as representative of residual (type 1) deposits. Suites of specimens were collected by Goldman, and the deposit was mapped by Tracey and Jenke. After much of the bauxite was mined, the exposure was again studied.

A generalized map, and cross sections are reproduced (figs. 37 and 38) and the types of rock are discussed in more detail in the section on deposits of type 1.

The bauxite is granitic textured in the zone of leaching, overlain by pisolitic (birdseye bauxite) and vermicular ore in the zone of concretion. The surface is rubbly in appearance; upslope because of concretionary action, but near the base of the slope because of downhill movement with some admixture of silty clay. The zone of leaching is best developed on the steep end of the spur where more than 20 feet of "granitic" bauxite is exposed at the very crest of the 20° slope (fig. 18). Large residual boulders of nepheline syenite, fresh or kaolinized are concentrated at this place. Clay veins and "horses" cut through the bauxite, and isolate some large blocks of residual bauxite.

At the west end of the exposure is a bed of conglomeratic bauxite (type 4) about 4 feet thick, overlying carbonaceous, silty kaolinitic clay of Saline that wedges out against the bauxite surface.

At the south end of the Pruden mine an unusual bauxite outcrop stands as a 20-foot ledge alongside a small stream. The lower part of the bauxite is granitic textured, the upper part is pisolitic and concretionary. At the base of the outcrop and across the stream a gentle slope of nepheline syenite is exposed. The relation of bauxite directly above well-exposed nepheline syenite is rarely seen in outcrop.

The Pruden pit has been mined sporadically since the war. Only small parts of the Pruden Extension have been mined as much of the ore is high in silica and iron.

POODLE DEPOSIT

Plate 2

This large deposit, on which are located the Poodle, Section 17 open pit, and the Standard shaft mines, is in the E½NE¼ sec. 17 and the NW¼NW¼ sec. 16, T. 2 S.' R. 14 W. It lies on the post-Midway erosion surface of the Wills Point formation, and extends downhill from the Midway and nepheline syenite contact nearly to the bottom of the buried valley peripheral to the Saline dome. A small part of the deposit overlaps the nepheline syenite, and merges upslope with bauxite in the Pruden Extension mine (pl. 2).

The deposit is a typical colluvial (type 2) accumulation. Bauxite in the deposit ranges in thickness from 8 to 28 feet, but 54 feet of high-silica bauxite and bauxitic clay was reported from one drill hole. Overburden ranges from 40 to 80 feet in thickness, and consists of minor lignite and gray clay of the Berger formation overlain by dark-brown carbonaceous silty laminated clay and tan sand of the Saline formation. The Berger formation was identified in logs of company drill holes. It covers the southwestern part of the deposit and thins out upslope. At the north edge of the deposit the Berger apparently is represented by a thin lignite bed that rests on kaolinitic clay just above the bauxite in the north face of the Poodle mine. Sediments of Saline age above the Berger formation are 40 to 75 feet thick.

Section 17 open-pit mine (pl. 1, no. 124).—This pit in the SE¼NE¼ sec. 17 was partly stripped early in the war, but the bauxite was not uncovered.

Standard shaft mine (pl. 1, no. 125).—The collar of this shaft, in the NE¼NE¼ sec. 17, is now buried beneath overburden from nearby pit mines. The mine was owned by the Arkansas Bauxite Corp. and operated by the West Bauxite Mining Co. It was opened in 1934 to produce bauxite for quick-hardening cement. The depth of the shaft is not known, but the ore is covered by about 50 feet of overburden.

STUCKEY DEPOSIT

Plate 2

Stuckey open-pit mine (pl. 1, no. 127).—This mine, operated by the Reynolds Mining Co., was stripped by dragline and mined by progressive stripping of new ore and backfilling of waste into the mined-out areas. Two pits were in operation for most of 1943 and 1944.

The deposit (type 2) lies mostly over clay of the Wills Point formation. The bauxite is grayish tan to brown, pisolitic, rubbly in appearance, and most of it high in iron. Pockets of bauxite within the deposit are completely replaced by siderite. Cavities in the ore, some several inches in diameter, are lined with botryoidal siderite some of which are coated with barite crystals.

Within the mined area the bauxite ranges in thickness from 10 to 30 feet. It is covered by 30 to 70 feet of sand and clay of the Saline formation. The lower part, exposed over most of the pit walls, is a laminated dark-brown carbonaceous silty clay, covered by about

10 feet of fine white quartz sand with some thin partings of brown clay. Pyritized leaves, twigs or roots, and seed pods were found in this bed.

RAMSEY DEPOSIT

Ramsey open-pit mine (pl. 1, no. 128).—This small pit, opened and operated by the Arkansas Bauxite Stripping Co., is located in the S½S½NE¼ sec. 9, T. 2 S., R. 14 W. Exploratory drilling before 1942 was done by the American Cyanamid and Chemical Corp. and the Dulin Bauxite Co. Later a few test holes were drilled by the Arkansas Bauxite Stripping Co. Production from this pit is reported for the company during January and February of 1944, together with the McGuire and Willie Thomas pits in Pulaski County. The tonnage mined in this pit was probably small and operations were discontinued because of excessive iron content.

According to the information available, the thickness of the deposit ranges from about 8 to 16 feet. Low-silica bauxite is generally high in iron and high-silica bauxite is low in iron. This is illustrated by the analyses from drill hole 21 of the Arkansas Bauxite Stripping Co. The hole is outside the pit limits, but recorded the thickest section of bauxite of any logs available.

Analyses of bauxite from drill hole 21, Arkansas Bauxite Stripping Co.

Depth (feet)	Al_2O_3	SiO_2	Fe as Fe_2O_3	Ignition loss
40–42	49. 40	20. 10	2. 20	26. 60
42–46	51. 07	10. 08	7. 20	29. 65
46–50	23. 21	8. 14	37. 80	29. 75
50–54	53. 16	4. 02	10. 70	30. 02
54–58	43. 67	2. 64	20. 60	31. 49

The abundance of iron, mostly in the form of siderite, is interesting because of the topographic position of the bauxite. The deposit, although it partly overlaps nepheline syenite on the north side of the Saline dome, lies on clay of the Wills Point formation, on a saddle between the Bryant and the Saline masses. Other deposits and occurrences of bauxite along this saddle, both in outcrop and in drilled localities, are all high in iron.

The Ramsey deposit is covered by 15 to 50 feet of tan sand and dark-brown silty clay of the Saline formation.

PINE HAVEN AREA

Deposits of bauxite and high-alumina clay are found northwest of Pine Haven, a wartime Federal housing project. They are mostly in the S½SE¼ sec. 5, SW¼SW¼ sec. 4, and NE¼NW¼ sec. 9, T. 2 S., R. 14 W., Saline County (fig. 60).

The bauxite lies on the eroded clay surface of the Wills Point formation, and is associated with a major Eocene buried valley that trends southwestward and south around the northwest periphery of the Saline nepheline syenite dome (pl. 2). The Pine Haven clay deposit, which includes the Pine Haven bauxite deposit, lies on the northwest slopes of the buried valley. A smaller deposit that includes three small ore bodies lies on the southeast side of the valley on a low ridge on the Midway surface.

The deposits are covered by red to brown sand and clay of the Saline formation. Part of the Pine Haven deposit crops out, but the small body in sec. 9 is covered by 40 to 65 feet of overburden.

The gray clay and lignite of the Berger formation is absent above the deposits although it is thin over the buried valley bottom between deposits. The high-alumina clay is probably of the bauxite-kaolin zone of the Berger formation, but a large part of the bauxite probably is reworked in the basal Saline sediments. The deposits are probably largely type 4.

The only mine in the area was the Fletcher-Hudspeth-Harris open pit (pl. 1, no. 129), NW¼NE¼ sec. 9, T. 2 S., R. 14 W., operated by S. E. Evans Construction Co., also by Leydig and Fleming. It was abandoned because of excessive siderite in the bauxite.

PINE HAVEN DEPOSIT

By Edwin A. Brown

Plate 38

This deposit lies in the SW¼SW¼ sec. 4 and the S½SE¼ sec. 5, T. 2 S., R. 14 W. The bauxite which was trenched and drilled by the Republic Mining and Manufacturing Co. in their early explorations, crops out in the northwestern part of the deposit. In 1943 the Bureau of Mines drilled 29 holes spaced about 1,000 feet apart on a triangular grid in secs. 4, 5, 8, and 9 in a search for large deposits of high-alumina clay. Four of these holes were within the bauxite deposit, and in March 1945, 12 more holes were drilled by the joint Federal project to delimit the ore body, but the program was not completed (Malamphy and others, 1948, v. 16, p. 107–120, figs. 108, 115, and 116).

The deposit lies on a southeasterly slope on the north side of a large valley cut in the surface of the Wills Point formation (pl. 2). Nepheline syenite crops out 1 mile southeast and 2½ miles northeast, and rocks of Paleozoic age crop out 2 miles to the north. The deposit is separated from the nearest outcrops of nepheline syenite on the post-midway surface by broad valleys that do not now contain evidence of former presence of bauxite. Nepheline syenite, therefore, does not seem to be a likely source for the bauxite of the

deposit. The rocks of Paleozoic age exposed upslope, although a possible source, are a considerable distance away. No good evidence was found to indicate the source of the bauxite.

The bauxite-kaolin zone ranges from 5 to 45 feet in thickness in the area of the deposit, and it consists of a lower kaolinitic part and an upper bauxitic part. The lower kaolinitic part is red-stained, cream to gray clay 2 to 15 feet thick. In drill hole USBM 12–504 a thin carbonaceous clay bed was cored near the top of the kaolinitic underclay. The upper bauxitic part ranges from a few feet to 35 feet and averages 25 feet in thickness.

The lower third of the bauxitic interval is formed of fragmental kaolinitic clay, bauxitic clay, and low grade bauxite containing scattered fragments of orange to tan and brown pisolitic bauxite. This may represent a type 2 deposit, although little of the material is of ore grade. The upper two thirds of the bauxitic interval contains the ore, which is tan, gray, or cream colored mealy bauxite, and rubbly pisolitic bauxite. The thickness of minable bauxite ranges from a few feet to about 15 feet (pl. 38). The northeastern extension of the deposit contains, in the upper rubbly part of the bauxite, abundant small gray to black soft pisolites covered by black, hard rinds. The rubbly bauxite is similar in appearance to much of that in type 4 deposits in Saline County, and may represent such a deposit at the base of the Saline formation.

Graphs of the available alumina and the alumina-silica ratio of the analyzed intervals from the drill holes show a consistent trend throughout the deposit. From bottom to top of the bauxite-kaolin zone, the curves rise to a low peak in the lower bauxitic interval (type 2 deposit), decline, then rise to a higher peak in the upper bauxite (type 4 deposit).

Erosion of part of the bauxite-kaolin zone and the bauxite in Saline time and later is indicated by the absence of a kaolinitic overclay, and by the outcropping of bauxite in a part of the deposit.

The deposit is covered by as much as 32 feet of yellow, tan, and brown sandy clay and dark chocolate brown silty clay of the Saline formation. Gravel beds were logged in some of the drill holes. Gray carbonaceous silty clay and lignite of the Berger formation were not present, although they are found less than one-half mile to the southeast.

OTHER ECONOMIC DEPOSITS

HIGH-IRON BAUXITE

Some bauxite bodies have an iron content high enough to make the commercial extraction of alumina unprofitable by present processes. Iron impurities are of two principal types: (1) those in which the iron occurs mainly as the carbonate, siderite, and (2) those in which iron oxide minerals predominate. As already pointed out, the distribution of siderite is spotty, although it occurs in all the buried bauxite deposits.

Bauxite that contains a large amount of ferric iron oxide is concentrated in two principal areas. The most important one is between the Alexander Mountain and Saline nepheline syenite hills in Saline County, in a large area underlain by clay of the Wills Point formation, surrounding and west of the Hurricane Creek alumina plant. High-iron bauxite in this area is found in outcrops and to a depth of about 150 feet.

Another area of high-iron bauxite is immediately west of the Saline dome, extending for a couple of miles above the surface of the Wills Point formation. All the high-iron bauxite deposits in this area are buried, most of them under more than 200 feet of overburden.

These deposits might conceivably become of commercial interest under conditions of bauxite shortage and if a process were available by which both alumina and iron might be recovered.

CLAY

HIGH-ALUMINA CLAY

Extensive deposits of high-alumina clay are found in association with the bauxite deposits that fringe the buried nepheline syenite hills in Pulaski and Saline Counties. The bauxite bodies grade both laterally and vertically through bauxitic clay into the surrounding high-alumina clay. This high-alumina clay and bauxite constitutes a facies of the Berger formation along its upslope edge and commonly is referred to as the bauxite-kaolin zone. The bauxite-kaolin zone attains a maximum thickness of 80 feet, but in most places does not exceed 60 feet.

A typical kaolinitic clay of this zone contains more than 35 percent of alumina, less than 45 percent of silica, and less than 5 percent iron oxide. Analyses of many clay samples surrounding bauxite bodies in Arkansas have been given by Malamphy and others (1948). The principal impurities in the clay are siderite locally oxidized to limonite, ilmenite, carbonaceous matter, and local biotite. The spotty distribution and local concentration of impurities in this clay has been the principal deterrent to its use thus far.

The distribution of the high-alumina clay deposits fringing the Pulaski nepheline syenite hill are shown in plate 39. Data are not sufficient to prepare a similar map for Saline County. Tracey (1944, p. 246, 249) has given what he called a conservative estimate that the Arkansas bauxite region contains at least 100 million tons of high-alumina clay that is covered by no more than 50 feet of overburden.

CERAMIC CLAY

Raw clay has been mined from a few small pits in the vicinity of Benton for more than 50 years for use in the manufacture of white ware and other pottery. Several analyses of this clay from old pits in this area have been given by J. C. Branner (1898, p. 62). This clay has all come from gray clay lenses in the gravel and sand facies of the Saline formation. In the past few years most of the pits have been abandoned and many are obliterated. During the forties most of the clay being mined in central Arkansas has come from beds of Wilcox age in the vicinity of Malvern and only one pit in the bauxite region, the Hicks or Old Leach pit, has been mined at infrequent intervals by the Niloak Pottery Co.

FULLER'S EARTH AND BENTONITE

The first fuller's earth produced in the United States came, according to Branner (1912, p. 520), from a bed of Tertiary clay near Alexander, Ark. Presumably this clay was from one of the gray marly clay beds now included in the Kincaid formation. It was used by the Southern Cotton Oil Co. of Little Rock, but only for a short time, as it proved unsatisfactory (Lang and others, 1940, p. 4).

Bentonite has been mined sporadically from deposits in the undifferentiated Claiborne and Jackson groups in Saline County. According to the Arkansas Geological Survey (1942, p. 15, 39–41) 3,484 short tons were produced from 1933 to 1938 at the Palmer deposit in the SE¼SE¼ sec. 13, T. 2 S., R. 13 W., and the Long-Bell deposit in the NE¼NE¼ sec. 23, T. 2 S., R. 13 W.

GRAVEL

A large amount of gravel has been mined from the gravel and sand facies of the upslope edge of the Saline formation. According to severance tax records filed with the Arkansas Geological Survey the production during the 18-year period from 1923 to 1940 in Saline County was 2,501,216 cubic yards, of which by far the greatest part was from the Saline formation. The principal producing localities have been the Haskell–Dickinson, Kertin, and the Ball–Benton gravel pits near Benton.

LIGNITE

Although lignite beds are fairly common in the Wilcox group, particularly in the Berger formation, all are lenticular and many contain a large amount of clay. The spotty distribution of these deposits makes a general estimate of reserves impossible without detailed drilling.

Lignite at the base of the Detonti sand was found in several bauxite drill holes in the southern part of sec. 33, T. 2 S., R. 14 W. and the northern part of sec. 4, T. 3 S., R. 14 W., the location of which has been shown in a map published by the U. S. Bureau of Mines. The lignite here lies beneath an overburden of one to 51 feet of sand. This is possibly an extension of the deposit mined on a small scale and for a short time at a locality in the SE¼SW¼SE¼ sec. 8, T. 3 S., R. 14W. The lignite which broke easily into large blocks was sold to a cleaning and dyeing establishment in Benton (Ark. Geol. Survey, 1942, p. 91).

LIMESTONE

Hopkins (1893, p. 142) reported that the Tertiary limestone now included in the Kincaid formation was formerly burned for lime at Little Rock near the old penitentiary and also about a third of a mile north of the county hospital, and on Fourche Creek near Olsen switch, SE¼ sec. 8, T. 1 S., R. 13 W., Pulaski County. The limestone is not of good quality and deposits are few, but their relative isolation from other larger and more suitable deposits gives them some local value.

Several of these deposits and their nearby subsurface extensions have been investigated by the Arkansas Geological Survey (Corbin and Heyl, 1941) as a possible source of agricultural lime.

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