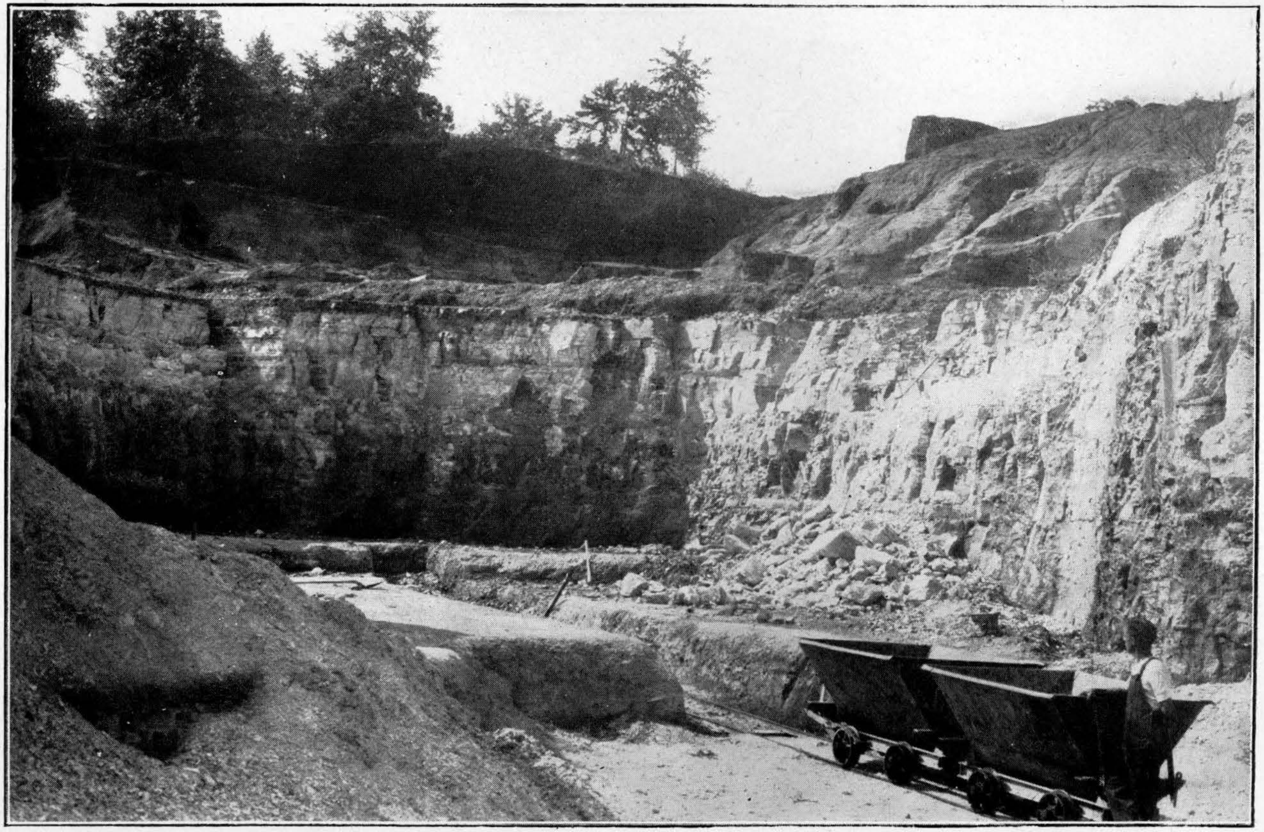

FULLERS EARTH MINE OF THE GENERAL REDUCTION COMPANY, PIKES PEAK, TWIGGS COUNTY.
Photo by S. W. McCallie

GEOLOGICAL SURVEY OF GEORGIA

S. W. McCALLIE, State Geologist

BULLETIN No. 31

A REPORT

ON THE

BAUXITE AND FULLERS EARTH

OF THE

COASTAL PLAIN

OF

GEORGIA

BY

H. K. SHEARER,

Assistant State Geologist

Atlanta, Ga.

THE INDEX PRINTING COMPANY

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LETTER OF TRANSMITTAL

GEOLOGICAL SURVEY OF GEORGIA,
ATLANTA, JUNE 14, 1917.

To His Excellency, NAT. E. HARRIS, *Governor and President of the Advisory Board of the Geological Survey of Georgia.*

SIR: I have the honor to transmit herewith the report of Mr. H. K. Shearer, Assistant State Geologist, on the Bauxite and Fullers Earth of the Coastal Plain of Georgia, to be published as Bulletin No. 31, of this Survey.

Very respectfully,
S. W. MCCALLIE,
State Geologist.

PREFACE AND ACKNOWLEDGEMENTS

The accompanying report on the Bauxite and Fullers Earth Deposits of the Coastal Plain of Georgia is the result of field work during the summers of 1914, 1915 and 1916, and includes such tests of fullers earth as could be made with the laboratory facilities available. The tests were made by the writer in the laboratory of the Geological Survey, following methods commercially employed in testing fullers earth. While there is a large field for research work on the properties of fullers earth, it was found to be impracticable to do much along that line with the time and materials available.

The writer wishes to express his thanks to Mr. K. R. Slocum of the General Reduction Company, Mr. W. L. MacGowan of the Floridin Company, Mr. J. T. Mitchell of the Lester Clay Company, and Mr. Thos. C. Law and Mr. Wm. Kelley of the Picard-Law Laboratories, for advice and assistance in the work on the fullers earth; also to the managers and superintendents of all the bauxite mines visited for their courtesies and interest in the work.

All of the analyses, unless otherwise stated, were made by Dr. Edgar Everhart, Chemist for the Geological Survey of Georgia. Mr. J. P. D. Hull, Assistant State Geologist of Georgia, has rendered assistance in making tests of fullers earth and in preparation of illustrations.

HAROLD K. SHEARER.

June, 1917.

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TOPOGRAPHIC AND GEOLOGIC FEATURES OF THE COASTAL PLAIN

As an introduction to the description of the bauxite and fullers earth deposits it is necessary to describe briefly the physiography and general geology of the Coastal Plain. These subjects are more fully discussed in the recent report on "The geology of the Coastal Plain of Georgia," by Otto Veatch and L. W. Stephenson[1]; but the field work in preparation of the present report has shown the necessity of making important changes in the correlation of the strata, notably in the areal distribution of the Jackson and Claiborne strata.

PHYSIOGRAPHY

The Coastal Plain includes the portion of the State lying south and southeast of the Piedmont Plain. The division between the two is the Fall Line, passing through Columbus, Macon, Milledgeville and Augusta. The area underlain by Cretaceous and later sediments is about 35,000 square miles, but as a physiographic unit the Coastal Plain includes also several thousand square miles of the crystalline area formerly overlapped by these sediments.

Topography.—The region is a low plain with an average tilt to southward or southeastward of three to four feet per mile. The eleva-

[1] Geol. Survey of Ga. Bull. 26, 1911.

tion varies from sea level to a maximum of 700 feet along the Fall Line.

The surface is sufficiently diversified to justify the recognition of several physiographic areas, of which the most distinctive is the Fall Line Hills area, a belt 40 to 50 miles wide extending entirely across the State just south of the Fall Line. This belt is characterized by flat-topped hills having a uniform elevation, intersected by deep valleys with steep slopes, which are cut by deep V-shaped gullies. The larger rivers have cut their valleys down more than 400 feet below the level of the upland plains.

The Fall Line Hills belt coincides roughly with the outcrop of the Cretaceous and Eocene beds, in which occur the bauxite deposits and the more extensive beds of fullers earth treated in this report. Throughout the area good sections of the geologic formations are exposed in creek beds and gullies, so that the working out of the geology is comparatively easy.

A large area south of the Fall Line Hills is included in the Dougherty Plain and Altamaha Upland. These areas are flat to gently rolling, but the Southern Limesink region, comprising the southern tier of counties in the western half of the State, exhibits more broken topography, although the relief is much less than in the Fall Line Hills. In the Limesink region are found most of the fullers earth deposits of the Alum Bluff formation.

Drainage.—The Coastal Plain is made up of seven drainage basins: (1) Savannah; (2) Ogeechee; (3) Altamaha; (4) Satilla and St. Marys; (5) Suwanee; (6) Ochlockonee; and (7) Apalachicola, drained by Chattahoochee and Flint rivers. The first four drain into the Atlantic, and the other three into the Gulf of Mexico. The rivers rising in the Piedmont are Savannah, Ogeechee, Oconee, Ocmulgee, Flint, and Chattahoochee, all of which have cut deep valleys through the Fall Line Hills belt, and are in many places bordered by high bluffs. These rivers are characterized by their muddy water; while the smaller rivers rising in the Coastal Plain are clear, but usually discolored by organic matter in solution or suspension.

The rivers flow south or southeast, corresponding to the initial slope of the new land surface on which they started their courses; but occasionally deflected by slight irregularities in the original surface or by geologic factors. In the areas underlain by the soft limestones of the Jackson, Vicksburg and Chattahoochee formations, limesinks and caverns are common and a considerable portion of the drainage flows through underground channels.

Elevations.—As no topographic maps have been made within the area of the Coastal Plain, excepting portions of the Columbus, Talbotton and Milledgeville quadrangles, a list of elevations of places mentioned in the report is given below. Most of the elevations are taken from a list previously published;[1] the others are based on aneroid barometer readings, carried from near-by points of known altitude, and checked several times in most cases. The limit of error for such elevations is believed to be about 10 feet.

List of Elevations

Locality	Authority	Elevation Feet
Abbeville (low water, railroad bridge)	U. S. A. Eng.	169.33
Adams Park	U. S. G. S.	259
Adel	G. S. & F.	246
Albany	C. of Ga.	184
Americus	C. of Ga.	360
Andersonville	C. of Ga.	394
Augusta (Union Station)	City Engineer	143
Augusta (river gage)	Weather bureau	100
Bainbridge	A. C. L.	110
Bainbridge (river level)	Aneroid	80
Bath	Aneroid	400
Baxley	U. S. G. S.	206
Belair	Ga. R. R.	295
Berzelia	Ga. R.R.	488
Bonaire	G. S. & F.	354
Boston	A. C. L.	194

[1] Geology of the Coastal Plain of Georgia; Geol. Survey of Ga. Bull. 26, pp. 51-57, 1911.
Ground waters of the Coastal Plain of Georgia; U. S. Geol. Survey Water-supply paper 341, pp. 44-51, 1915.

Locality	Authority	Elevation Feet
Bullards	U. S. G. S.	259
Byromville	A. B. & A.	365?
Byron	C. of Ga.	515
Cairo	A. C. L.	237
Chalker	Aneroid	330
Climax	A. C. L.	277
Cochran	U. S. G. S.	342
Coley	Sou. Ry.	303
Columbus (Union Station)	C. of Ga.	260
Columbus (river level)	U. S. G. S.	200
Cordele	G. S. & F.	336
Cuthbert	C. of Ga.	446
Danville (M. D. & S. station)	Aneroid	460
Davisboro	C. of Ga.	302
Dawson	C. of Ga.	352
Dixie	A. C. L.	130
Dover	C. of Ga.	104
Dry Branch	M. D. & S.	368?
Dublin	M. D. & S.	231?
Dublin (low water level)	U. S. A. Eng.	160.6
Dudley	M. D. & S.	325?
Elko	G. S. & F.	443
Ellaville	J. W. Spencer	591
Faceville	A. C. L.	296
Fitzgerald	A. B. & A.	388?
Fitzpatrick	M. D. & S.	541?
Fort Gaines	C. of Ga.	163
Fort Gaines (zero on river gage)	Aneroid	95
Fort Valley	C. of Ga.	522
Gallemore	M. D. & S.	394?
Gibson (Augusta Southern station)	Aneroid	385
Gordon	C. of Ga.	348
Greens Cut	C. of Ga.	284
Griswold	C. of Ga.	447
Grovania	G. S.& F.	444
Grovetown	Ga. R.R.	495
Harlem	Ga. R. R.	548
Hawkinsville	Weather Bureau	235
Hawkinsville (low water level)	U. S.A. Eng.	200.2
Hephzibah	Weather Bureau	402
Irwinton (Court House)	Aneroid	460
Jeffersonville	M. D. &. S.	526

Locality	Authority	Elevation Feet
Kathleen	G. S. & F.	330
Knoxville	J. E. Thomas	640
Lewiston	C. of Ga.	385
Lilly	A. B. & A.	364?
Louisville	Weather Bureau	259
Louisville (Court House)	Aneroid	315
Lumber City	U. S. G. S.	146
Lumber City (low water level)	U. S. A. Eng.	84.7
McBean	C. of Ga.	134?
McBean	Aneroid	180
McIntyre	C. of Ga.	261
Macon (near old Sou. Ry. station)	U. S. G. S.	311
Macon (low water level)	U. S. A. Eng.	279.02
Macon Junction	C. of Ga.	350
Marshallville	C. of Ga.	500
Metcalf	A. C. L.	170
Midville	C. of Ga.	186
Milledgeville	Ga. R.R.	276
Milledgeville (low water level)	U. S. A. Eng.	241.29
Millen	C. of Ga.	156
Montezuma	C. of Ga.	300
Montrose	M. D. & S.	391
Oconee	C. of Ga.	223
Ogeechee	C. of Ga.	111
Oglethorpe	C. of Ga.	299
Ousley	A. C. L.	148
Perry (Court House)	Aneroid	380
Pikes Peak (station)	M. D. & S.	534
Quitman	A. C. L.	173
Richland	S. A. L.	600
Roberta	Rough estimate	620
Roberts	Ga. R.R.	557
Rockyford	C. of Ga.	130
Sandersville (Augusta Southern station)	Aneroid	455
Shell Bluff (low water level)	U. S.A. Eng.	87
Shell Bluff (highest point)	U. S.A. Eng.	237
Shellman	C. of Ga.	379?
Smithville	C. of Ga.	332
Sunhill	C. of Ga.	362
Swift Creek	M. D. & S.	324?
Tennille	C. of Ga.	469
Thomasville	A. C. L.	250

Locality	Authority	Elevation Feet
Thomson	Ga. R.R.	503
Tifton	A. C. L.	370
Tivola	G. S. & F.	300
Toomsboro	C. of Ga.	227
Valdosta	A. C. L.	215
Vienna	G. S. & F.	350
Wadley	C. of Ga.	234
Warrenton	Ga. R.R.	500
Warthen	Aneroid	485
Waynesboro	C. of Ga.	286
Westlake	U. S. G. S.	235
Whigham	A. C.L.	265
Wrens	Aneroid	410

The abbreviations used are:

A. B. & A.	—Atlanta, Birmingham & Atlantic Railroad.
A. C. L.	—Atlantic Coast Line Railroad.
C. of Ga.	—Central of Georgia Railway.
Ga. R. R.	—Georgia Railroad.
G. S. & F.	—Georgia Southern & Florida Railway.
M. D. & S.	—Macon, Dublin & Savannah Railroad.
S. A. L.	—Seaboard Air Line.
U. S. A. Eng.	—United States Army Engineers.
U. S. G. S.	—United States Geological Survey.

STRUCTURE

The geologic structure of the Coastal Plain formations is simple, as the beds are almost undisturbed except for a gentle tilting which has given them a general southward and coastward dip. There is evidence of slight folding, producing broad anticlines and synclines which have had some effect on the drainage, but can not be detected by ordinary observation. The crystalline basement at the Fall Line has a slope of 50 to 75 feet per mile, the Lower Cretaceous beds probably dip as much as 40 feet per mile, while the younger formations have progressively lower angles of dip up to the Alum Bluff formation, which lies practically horizontal. Within the Coastal Plain all economic deposits of clay or bauxite have the form of nearly horizontal beds or lenses.

GEOLOGY

The Coastal Plain of Georgia, considered as a geologic unit, is underlain entirely by strata of Cretaceous and later age. The beds consist of a variety of sands, clays, marls, and limestones, dominantly of marine origin, resting unconformably on the eroded surface of the ancient crystalline rocks which make up the Piedmont and Appalachian provinces. The Coastal Plain beds are to a large extent unconsolidated, and have been but little altered from their original condition. They have not been subjected to any great orogenic movements, the only disturbance being an uplift accompanied by very slight tilting and warping.

The thickness of the sedimentary beds of the Coastal Plain has been estimated at 4,000 to 5,000 feet. On account of the variability of the strata and lack of good exposures over a large part of the area it is impossible at present to make a closer estimate.

The subdivisions of the beds are shown in the accompanying table.

Table of Geologic Formations of the Coastal Plain

System	Series	Group	Formation	Member	Thickness
Quaternary	Recent				
	Pleistocene	Columbia	Satilla formation		10-50
			Okefenokee formation		5-40
Tertiary	Pliocene		Charlton formation		Undeterm
	Miocene		Duplin marl		10-15
			Marks Head marl		45
		Appalachicola	Alum Bluff formation		150
	Oligocene		Chattahoochee formation		150
			Vicksburg formation		50?
	Eocene	Jackson	Barnwell formation	Sand and marl Twiggs clay	150?
			Ocala limestone		100?
		Claiborne	McBean formation Undifferentiated Cl.		100?
			Wilcox formation		150
			Midway formation		400
Cretaceous	Upper		Ripley formation	Providence sand member Cusseta sand member Marine beds	950
			Eutaw formation	Tombigbee sand member Lower beds	560
	Lower		Not subdivided		350-600
Pre-Cambrian					

PRE-CAMBRIAN ROCKS

The crystalline area of Georgia, including the Piedmont Plain and the Blue Ridge, is composed of igneous and metamorphic rocks, including granites, gneisses, schists, basic eruptives, and highly metamorphosed shale, sandstone, and limestone. These constitute the oldest rocks of the State, and are in the main of pre-Cambrian age. They have been deeply buried and subjected to intense differential pressure, which caused complex folding and faulting, with the development of schistosity.

From the rocks of this area has been derived practically all of the material which makes up the sediments of the Coastal Plain. The bulk of the sediments represents the products of the erosion of 2,000 feet or more of rock from the crystalline area of the State. The unconformity at the top of the crystalline rocks represents an enormous interval of time. The Piedmont and Coastal Plain areas remained above sea level during the entire Paleozoic era and the greater part of the Mesozoic; and when the Coastal Plain portion finally became submerged, in early Cretaceous time, the land had been reduced to an almost featureless plain.

LOWER CRETACEOUS

The Lower Cretaceous beds consist chiefly of coarse, cross-bedded, arkosic sand with subordinate lenses of light-colored to pure white clay approaching kaolin in composition. Interbedded with the white clays are smaller lenses of bauxite. The series contains no marine fossils and is of shallow water, and presumably of fresh water origin. The origin of the kaolin and the bauxite with detailed descriptions of the beds will be taken up under the discussion of the bauxite deposits. It is evident that the coarse sands and more or less pure kaolins were derived from the thoroughly weathered material which must have covered the surface of the crystalline rocks when the forces of erosion became active after a long period of quiescence. The absence of limestone and other calcareous sediments is notable, and is significant of deposition of completely weathered material in shallow water.

UPPER CRETACEOUS

EUTAW FORMATION

The Eutaw formation, of Upper Cretaceous age, consists of calcareous sand, sandy limestone and more or less sandy clay of marine origin, and crossbedded sands and clays of shallow marine or estuarine origin. The basal beds are arkosic, micaceous sand and dark gray to black clay containing lignite. There is considerable variation in the character of the materials, both vertically and horizontally, but fossil marine shells occur throughout the formation and are locally sufficiently abundant to form shell marls. The Tombigbee sand member, which comprises the upper 120 feet of the formation near Chattahoochee River, consists of massive marine beds of calcareous sand and clay. The total thickness of the formation is estimated to be 560 feet along the Chattahoochee, but it thins rapidly toward the east, and is overlapped by the Ripley formation in Taylor County. It is separated from the Lower Cretaceous by an unconformity, but is conformable with the overlying beds of the Ripley formation.

RIPLEY FORMATION

The Ripley formation consists of gray, calcareous, micaceous sand; dark gray to black sandy clay and shell marl, with at intervals nodular layers of gray, calcareous sand or impure sandy limestone of marine origin; fine to coarse crossbedded sand with subordinate lenses of light colored clay or dark, lignitic clay of shallow water origin. Marine beds only are exposed along the Chattahoochee, but eastward two shallow water members occupy positions at the top and bottom of the formation, the Cusseta sand member below and the Providence sand member above. The marine beds pinch out between the two sand members and disappear in Macon County. The sand members are non-calcareous beds, consisting predominantly of coarse, irregularly bedded sands with subordinant lenses and layers of light-colored clay. Lithologically these members resemble the Lower Cretaceous beds, and the Providence member in Houston County contains workable deposits of kaolin. Although both the other kaolin-bearing formations, the Lower Cretaceous and the Midway, contain bauxite, none has ever been discovered in the Upper Cretaceous beds.

The thickness of the Ripley formation along the Chattahoochee is estimated to be 950 feet, with an average dip of 32 feet per mile. This formation, like the Eutaw, thins to eastward, and disappears beneath the Eocene beds in Twiggs County.

At the close of the Ripley deposition the surface was uplifted and remained above sea level for a long period. That the post-Cretaceous unconformity is an important one is shown by the fact that few, if any, species of plants or animals survived from the Cretaceous into Eocene time.

MIDWAY FORMATION

The Midway formation consists of ferruginous sand and local beds of white clay, together with fossiliferous limestone, marl, clay, and calcareous quartzite. The basal beds consist of sand and clay which resemble lithologically the underlying Cretaceous material. Higher in the section limestones become prominent, and are exposed at Fort Gaines and along Flint River near Oglethorpe. Overlying the limestone along Flint River is a series of shallow water deposits of coarse sand with lenses of white clay and associated bauxite, almost identical with the Lower Cretaceous beds in appearance and composition. These beds are destitute of fossils, and are referred to the Midway formation on account of their geographic position, although there is a slight possibility that they may belong to the Wilcox.

The estimated thickness of the Midway formation is 400 feet. Like the Upper Cretaceous beds, it is overlapped by later formations to the northeast, and disappears in Houston County.

WILCOX FORMATION

The Wilcox formation consists of dark-colored, lignitic and glauconitic clay in the nature of fullers earth and vari-colored unconsolidated sand and clay. On Chattahoochee River the formation consists largely of glauconitic shell marl, characterized by *Ostrea thirsae* (Gabb), but farther eastward determinable fossils are very rare.

In the Coastal Plain Report the following statement is made:[1] "In Schley and Macon counties and in the vicinity of Andersonville, the strata which might be referred to this formation on the basis of geographic position are mainly red and vari-colored sands with massive beds of white clay, very pure and in the nature of sedimentary kaolin, bearing little resemblance to the strata on Chattahoochee

[1] Geol. Survey of Ga. Bull. 26, p. 228, 1911.

River.'' When that report was written the unconformity at Copperas Bluff on Flint River had not been recognized, and the Sweetwater bauxite mine, which shows an unconformity between the kaolin and the red sands, had not been opened. In this report all of the bauxite and kaolin are considered as belonging to the Midway formation, while the red sands and the pyritic beds of Copperas Bluff are correlated with the Wilcox. As there is no paleontologic evidence to support this correlation, it must be considered subject to revision.

The maximum thickness of the Wilcox formation is estimated at 150 feet, and the width of the belt of outcrop between Chattahoochee and Flint rivers does not exceed five or six miles. No exposures attributable to the formation are found east of Flint River, as the Jackson formations overlap onto the Cretaceous a short distance from the river. The Wilcox beds are separated from the Midway by a distinct unconformity, but the relation with the Claiborne strata is obscure. Apparently deposition was practically continuous from the Wilcox up into the Claiborne, although evidence of a slight unconformity is found at several localities.

CLAIBORNE AGE

Field work by J. E. Brantly, formerly Assistant State Geologist of Georgia, Dr. C. Wythe Cooke, of the United States Geological Survey, and the writer, has shown that the Claiborne is of much smaller areal extent than formerly mapped, and that the ''Congaree clay member of the McBean formation'' and a large part of the ''Barnwell sand'' should be referred to the Jackson.[1]

The Claiborne in Georgia consists of two formations, which are, however, not areally continuous, as the strata of Claiborne age are overlapped by the Jackson throughout the central part of the State.

[1] The stratigraphy of the Eocene beds of the Coastal Plain of Georgia is discussed in a manuscript report by C. W. Cooke and H. K. Shearer, now awaiting publication by the U. S. Geological Survey as a Professional Paper of the series of "Shorter contributions to general geology." The evidence for changes in correlation and nomenclature of the formations making up the Claiborne and Jackson is discussed in that paper.

McBEAN FORMATION

The McBean formation consists of sandy shell marl and argillaceous, glauconitic, calcareous and lignitic sands. It outcrops only in the Savannah and tributary valleys, in Richmond and Burke counties, the best exposures being at Shell Bluff, Savannah River, and along McBean Creek.

A thickness of 80 feet of McBean beds is exposed at Shell Bluff, and the entire thickness is something more than 100 feet. The McBean formation overlies beds of Lower Cretaceous age with marked unconformity, but deposition was almost continuous upward into the Jackson, and only locally is there any indication of an unconformity.

UNDIFFERENTIATED CLAIBORNE

Beds of Claiborne age also outcrop in western Georgia, with the best exposures in the Fort Gaines Bluff on Chattahoochee River and in the Danville Ferry Bluff on Flint River, 16½ miles east of Americus. Fossiliferous beds are exposed at both these localities, and the horizon has been determined as equivalent to the beds below the *Ostrea georgiana* horizon at Shell Bluff; in the area between the two rivers the formation is thin and fossils are rare.

Along Chattahoochee River Langdon[1] recognized a lower buhrstone and an upper calcareous member of the Claiborne. The division, however, can not be carried farther eastward, so the beds are classed as undifferentiated Claiborne, although at least the lower portion is probably equivalent to, and areally continuous with the Tallahatta buhrstone of Alabama.

Between Flint and Chattahoochee rivers the Claiborne rests upon the Wilcox formation, and at Fort Gaines and Cuthbert there is evidence of an erosion unconformity, probably of minor importance, separating the two formations. It is overlain by red argillaceous sand belonging to the Jackson or Vicksburg formations, but as the upper and northern portions of the Claiborne also weather to red sand, it is difficult to locate the contacts. The thickness of the Clai-

[1] Geology of the Coastal Plain of Alabama; Geol. Survey of Ala., p. 744, 1894.

borne on Chattahoochee River was measured by Langdon as 212 feet. At Fort Gaines the total thickness of beds which may be considered as Claiborne is 200 or 205 feet, but at Cuthbert it is reduced to 50 feet or less. The average thickness of beds outcropping between Cuthbert and Americus probably does not exceed 100 feet.

Near Fort Gaines certain strata of the Claiborne have some resemblance to fullers earth, but the clay is not likely to be of any economic value.

JACKSON AGE

The Jackson in central Georgia reaches its greatest development east of Mississippi, and is by far the thickest and most important Eocene formation of the State. At the close of the Claiborne period a marked depression of the land occurred in central and eastern Georgia, and the entire area covered by earlier Eocene and Cretaceous beds sank below sea level. Strata of Jackson age were deposited, covering all of the earlier Coastal Plain formations and overlapping onto the crystalline rocks of the Piedmont area.

The "Congaree clay member of the McBean formation" and the greater part of the "Barnwell sand" of the Coastal Plain report[1] have been found to be of Jackson age, as they overlie the typical Jackson bryozoan limestone throughout central Georgia. The subdivisions of the Jackson group described in the paper previously mentioned[2] are as follows:

Jackson
- 2. Barnwell formation.
  - Twiggs clay member of Barnwell.
- 1. Ocala limestone.

OCALA LIMESTONE

The Ocala limestone is a thick stratum of highly fossiliferous limestone and marl, characterized especially by *Pecten perplanus* Morton, *Periarchus pileus-sinensis* (Rav.), and numerous Bryozoa, known as the "Rich Hill fauna", from a typical exposure at Rich

[1] Geol. Survey of Ga. Bull. 26, 1911.
[2] See footnote p. 12.

Hill, Crawford County. Along the course of Flint River below Dooly County, and throughout southwestern Georgia, the Ocala limestone makes up the whole of the Jackson; but to northward and eastward, as the Jackson shore line is approached, the limestone grades into clay and the clay into sand not only vertically, but also along the strike. The typical Ocala limestone is not found northeast of Wilkinson County, although the Jackson strata farther northeast carry local lenses of limestone with a somewhat different fauna.

TWIGGS CLAY MEMBER

The Twiggs clay member of the Barnwell formation, formerly described as the "Congaree clay member of the McBean formation"[1], is named from Twiggs County, Georgia, where it is best exposed and seems to be thickest. The member consists of extensive, but not entirely continuous, beds and lenses of clay, varying from porous and siliceous to calcareous, glauconitic, pyritiferous, carbonaceous, or lignitic. Almost all of the clay has some of the characteristics of fullers earth, and a large part of it is light and porous and free from calcium carbonate, pyrite, and carbonaceous matter, and therefore likely to be of commercial value as a bleaching earth.

The clay member occurs at the base of the Barnwell formation and near the northern margin of the area of deposition. It lies conformably above the Ocala limestone, which passes from pure limestone into marl, calcareous clay, and fullers earth by insensible gradations, and is overlain by red sand of the Barnwell formation. Local unconformities between the clay member and the red sand have been noted at several points near the northern margin of the formation. The Twiggs clay member, including some interbedded sand, attains a thickness of at least 100 feet in Twiggs County, but the average thickness is much less.

BARNWELL FORMATION

The Barnwell formation lies principally above the Twiggs clay member, and the entire formation, where the clay member is absent,

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[1] Geol. Survey of Ga. Bull. 26, pp. 267-284, 1911.

consists dominantly of argillaceous and glauconitic sand which becomes red or mottled on weathering. There are local beds of limestone, occuring principally in Washington County, and beds made up of *Ostrea georgiana* shells in a matrix of marl or calcareous clay become increasingly prominent from Wilkinson County eastward to Savannah River. Local beds of plastic clay and fossiliferous chert layers, which were originally limestone or calcareous sandstone, are also abundant.

The thickness of the Barnwell formation has not been accurately measured, but it is considerably in excess of 100 feet. As the coast line during Jackson time moved farther inland than at any time since the Lower Cretaceous, and as the Jackson deposits near the shore consisted entirely of argillaceous sand which, in the absence of the limestone and fullers earth strata, must be correlated with the Barnwell formation, it overlies unconformably all of the earlier sedimentary deposits of the Coastal Plain, and locally overlaps onto the crystalline area. The relation of the Barnwell to the overlying formations is not well determined, principally on account of the similarity of its materials to some of the overlying beds. In eastern Georgia it is overlain unconformably by sands and clays of the Alum Bluff formation. West of Oconee River it is overlain by red, argillaceous sand containing fossiliferous chert which indicates Vicksburg (Oligocene) age, but the boundary between the formations has not been accurately located. In southwestern Georgia and southern Alabama the Barnwell formation is absent, and the Ocala limestone is conformably overlain by very similar limestone of Vicksburg age.

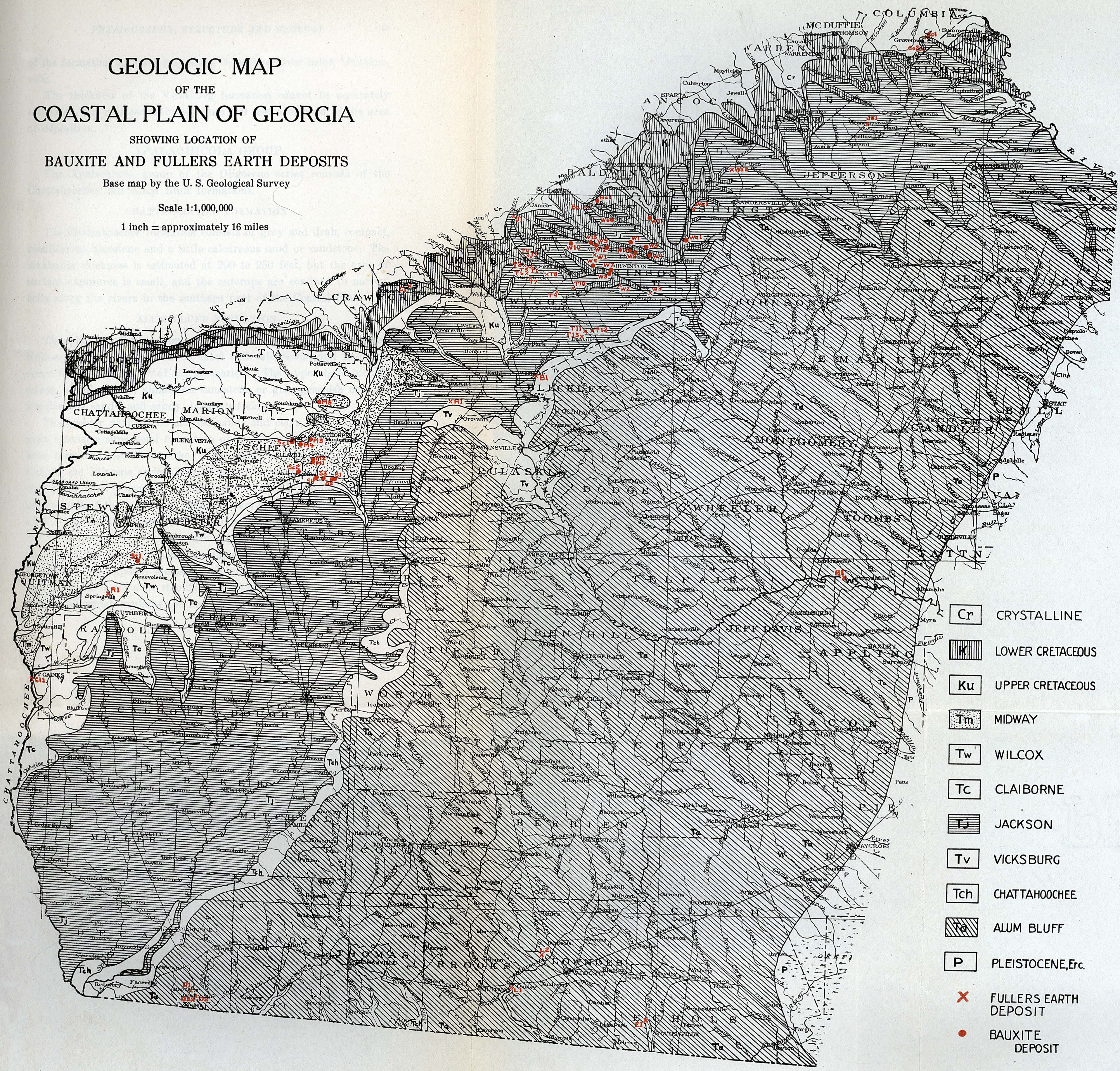
VICKSBURG FORMATION

The Vicksburg, the earliest Oligocene formation in Georgia, is thin, and consists principally of bright red argillaceous sand, which is largely residual and shows no trace of stratification. Fossiliferous chert fragments and ledges are abundant, derived from the complete silicification of thin beds of impure limestone. Unaltered limestone

GEOLOGIC MAP
OF THE
COASTAL PLAIN OF GEORGIA
SHOWING LOCATION OF
BAUXITE AND FULLERS EARTH DEPOSITS
Base map by the U. S. Geological Survey

Scale 1:1,000,000

1 inch = approximately 16 miles



of the formation is found only along Ocmulgee River below Hawkinsville.

The thickness of the Vicksburg formation cannot be accurately estimated, but it is certainly less than 100 feet over most of the area of deposition.

APALACHICOLA GROUP

The Apalachicola group of the Oligocene series consists of the Chattahoochee and Alum Bluff formations.

CHATTAHOOCHEE FORMATION

The Chattahoochee formation consists of gray and drab, compact, fossiliferous limestone and a little calcareous sand or sandstone. The maximum thickness is estimated at 200 to 250 feet, but the area of surface exposures is small, and the outcrops are confined to narrow belts along the rivers in the southern part of the Coastal Plain.

ALUM BLUFF FORMATION

The Alum Bluff formation presents a number of lithologic phases. Fullers earth and local beds of marl and calcareous sand and clay occur in the lower part of the formation. The upper beds include coarse, angular sand, aluminous sandstone or grit, greenish or gray argillaceous sands, and sandy, laminated clays.

The greater part of the mottled sands and clays, which form the most extensive superficial formation of the Coastal Plain, and which were formerly described as the "Altamaha" or "Lafayette" formation of the Pliocene series, is believed to be weathered material of the Alum Bluff formation. This weathered and residual material covers most of the portion of the State east of Flint River and south of Vienna, Dublin, Hawkinsville, Sandersville and Waynesboro, but the outcrops of the fullers earth and calcareous beds follow the courses of the larger streams throughout the southern part of the State, and are exposed almost continuously along the Florida line. The thickness is not more than 200 or 300 feet, but the beds lie almost horizontal, which explains the large area of outcrop.

MIOCENE SERIES

The Miocene series consists of two thin marl formations, the Marks Head and the Duplin, which are exposed only along the lower courses of the rivers flowing into the Atlantic.

PLIOCENE SERIES

The lower part of the Pliocene series is the Charlton formation, which is calcareous. Widely distributed sand, clay, and gravel, devoid of fossils and calcareous beds, have been referred to as the "Altamaha (Lafayette?) formation" of the Pliocene, but over a large area they can not be distinguished from the weathered material of the Alum Bluff formation. The original "Altamaha grit" of Dall belongs to the Alum Bluff formation.

PLEISTOCENE AND RECENT SERIES

The quarternary strata are divided into the Okefenokee and Satilla formations of Pleistocene age and recent surficial sand deposits. The Pleistocene beds consist of flood plain and coastal terrace deposits, swamp deposits, and beach sand and mud.

PART 1. BAUXITE DEPOSITS

DEFINITION

The statement has been made many times that there are three hydrated oxides of aluminum: diaspore ($Al_2O_3H_2O$), bauxite Al_2O_3.-$2H_2O$), and gibbsite or hydrargillie ($Al_2O_3.3H_2O$). Of these, diaspore and gibbsite are definite minerals, found in crystalline form; but the dihydrate has never been identified and its existence is doubtful. For practical purposes, bauxite may be defined as an ore rather than a mineral, being a hydrate of alumina, or a mixture of several hydrates, of sufficient purity to serve as a commercial source of aluminum or its salts.

OCCURRENCE AND DISTRIBUTION

GENERAL DISTRIBUTION

Although aluminum is the most abundant metal in the crust of the earth, its tendency to enter into combination, especially with silica, is so great that the free metal is never found in nature, and rather unusual geologic conditions are necessary for the separation and accumulation of the oxide or hydroxide. As no method for extracting aluminum from the silicate minerals has proven profitable, and since the limited deposits of corundum, the anhydrous oxide, are more valuable for abrasives than as a source of aluminum, bauxite at the present time provides all the aluminum of commerce.

Bauxite is found in a limited number of localities, widely distributed over the earth, but the known deposits are all comparatively small. In view of the rapidly increasing demand for aluminum and its compounds these deposits are likely to become exhausted in the near future, so all new discoveries, however small, are worthy of careful investigation.

The known bauxite localities are: in France, in the departments of Bouches du Rhone, Var, Herault, Ariege, and Puy-du-Dôme, especially near the villages of Baux, Thoronet, and Villeveyrac; in Germany, principally near Vogelsburg; in Austria near Wochein and Freistritz and in the province of Istria; in Ireland in the Glenariff Valley, county Antrim; in India, rather widely distributed in the form of laterites; in Italy; in British and Dutch Guiana; and in the United States in Arkansas, New Mexico, north Georgia, Alabama and Tennessee, and the Coastal Plain of Georgia.

FOREIGN LOCALITIES[1]

France.—The deposits of southern France, of which those near the village of Baux were first discovered and are best known, are found at or near the base of the Upper Cretaceous beds, which lie unconformably above the Urgonian limestone of the Lower Cretaceous. The bauxite forms a bed 30 feet or more in thickness just above the unconformity. Above the principal bed are thinner bauxite strata interbedded with marl and concretionary limestone. Locally the bauxite nodules have a calcareous matrix. The stratification of the bauxite and associated beds is sharp and distinct, and the series as a whole has all the characteristics of a lacustrine or estaurine deposit. The origin of the alumina is ascribed to sulphate solutions brought to the surface by hot springs or geysers. The aluminum hydroxide was precipitated by the reaction between aluminum sulphate and calcium carbonate and deposited along with the other sediments. The strong tendency of the newly precipitated hydrate to assume nodular form and to pull other material into that form is shown in one bed which contains limestone concretions "as large as apples", with cores of bauxite. Since deposition the formations have undergone rather intense folding, which was naturally accompanied by high pressure and probably high temperature. This has brought about partial dehydration of the mineral, so that it now approximates diaspore in composition.

Deposits of another type are found at various places in the department of Puy-du-Dôme. The bauxite is principally of the red variety, and forms a mass 15 to 75 feet thick, resting upon an eroded surface of gneiss. It is overlain by clay and basalt of Miocene age, limestone being entirely absent. The deposits have probably the same origin as those of Germany and Arkansas.

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[1] The following brief descriptions of foreign deposits are abstracted from Hayes, C. W., Bauxite: U. S. Geol. Survey Sixteenth Ann. Rept. pt. 3, pp. 547-597, 1895; and from the chapters on bauxite in the U. S. Geol. Survey Mineral Resources.

Germany.—The German deposits occur principally in the vicinity of Vogelsburg. The bauxite is associated with iron ore, both occurring as small masses in a gray or reddish-brown, slightly rearranged residual clay. Both clay and bauxite are products of weathering of the basalt, as the ore retains the texture and some of the minerals of the basalt. The ore is dominantly the trihydrate. The German deposits are of small commercial importance, and no production is reported in recent years.

Austria.—The bauxite of Wochein, in the province of Styria, Austria, is dense and earthly, without nodular structure. On account of its unusual character it is given the distinctive name of wocheinite. The aluminum content is high, over 70 per cent in some analyses, but the iron oxide is also high and the low content of water is insufficient to form even the monohydrate.

Bauxite deposits are said to be of frequent occurrence in the form of small pockets in a red sandstone in the province of Istria, near the port of Torre. The ore is of good quality and uniform composition. There are calculated to be 1,000 workable pockets containing an average of 300 tons each.

Hungary.—Extensive deposits, estimated at 5,000,000 to 18,000,000 tons, occur as irregular lenses and superficial accumulations in a Jurassic limestone of the Bihar Mountains in Hungary. The occurrence seems to be similar to the Baux deposits of France.

Ireland.—The deposits of Ireland are found in Glenariff Valley, county Antrim, in the extreme northeastern part of the island. The ore forms a continuous bed associated with pisolitic iron ore, with flows of dolerite and beds of tuff both above and below. Hayes[1] states that both iron ore and bauxite appear to be lacustral deposits, derived from the volcanic rocks largely by alteration in place and secondary replacement. They are, therefore, in many respects similar to the German and Arkansas deposits. The dominant aluminum mineral is the trihydrate, and the ores contain high percentages of one or more of the impurities silica, titanium dioxide, or ferric oxide.

[1] Hayes, C. W., Bauxite: U. S. Geol. Survey Sixteenth Ann. Rept., pt. 3, p. 549, 1895.

India.—The laterites of India are superficial deposits due to complete weathering, during which practically all of the silica has been leached from the rock. In samples from the Bailier tahsil, Balaghat district, the alumina ranged from 52 to nearly 59 per cent, with silica from 0.58 to 2.65 per cent. The proportion of titanium oxide is always high, and the iron oxide is usually so, although in one sample it was only 2.70 per cent. Small quantities of ore have been mined and shipped to Europe, but the recent production has been used only in the manufacture of cement.

Italy.—In Italy, one bauxite mine has been in operation since 1907, with an annual production of about 6,000 tons. The ore forms a surface deposit (1,000,000 square meters of a thickness of 3 meters) on the slope of Monte Turchio. The bauxite is highly ferruginous, sometimes containing over 25 per cent of Fe_2O_3, and was formerly classified as an iron ore.[1]

Guiana.—During the last two or three years there has been considerable activity in exploring for bauxite in British and Dutch Guiana. An American syndicate has purchased or secured the mineral rights on about 20,000 acres of land.[2] The deposits are known to be large, but no description of the geology has been published. The known deposits are located on or near Demerara and Surinam rivers, along the line separating the recent sedimentary beds of the Coastal Plain from the mountainous crystalline area.

AMERICAN LOCALITIES

North Georgia-Alabama-Tennessee.[3]—Bauxite was first discovered in the United States near Rome, Ga., and the first mining was done on the Holland property, in Floyd County in April, 1888. The principal deposits of the region are found in the valley of the Coosa River, between Adairsville, Ga. and Jacksonville, Ala., but several important deposits have also been found in Tennessee near Chattanooga.

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[1] Molinari, Dr. Ettore, General and industrial inorganic chemistry, Translation of 3d. ed., p. 571, 1912.

[2] Phalen, W. C., U. S. Geol. Survey Mineral Resources 1915, p. 162, 1916.

[3] Hayes, C. W., Bauxite: U. S. Geol. Survey, Sixteenth Ann. Rept., pt. 3, pp. 547-597, 1895.

Watson, Thomas L., A preliminary report on the bauxite deposits of Georgia: Geol. Survey of Ga. Bull. 11, 1904.

The deposits differ from all other American, and from most of those of foreign countries, as they are not bedded, and are not the product of weathering of any associated rock. The bauxite occurs in compact, irregularly shaped masses or pockets, always in residual material from the Knox dolomite or in immediately overlying formations. The deposits are not associated with any particular horizon within the dolomite; on the other hand their stratigraphic range is at least 4,000 feet. The pockets are, however, localized in groups about certain centers and along fault lines, and nearly all outcrop between 850 and 950 feet above sea level, although the relief of the district varies between 650 and 1,200 feet. The ore is closely associated with, and usually surrounded by, masses of white or mottled kaolin, but neither the ore nor the kaolin contain any calcareous matter from the dolomite, nor any fragments of the chert which are so abundant in the surrounding residual clays.

These facts indicate that the deposits were formed near the surface during a period when the land was nearly base-levelled. This condition existed during Eocene time. The best explanation of the genesis of the deposits is that proposed by Hayes, who supposes that the alumina was derived from the thick beds of the Conasauga shale underlying the Knox dolomite. The aluminum was dissolved from the shale as sulphate, pyrite being abundant enough to provide a source of sulphuric acid. Later the solutions found outlets to the surface, especially along fault lines or in areas of fracturing of the rocks, and issued as large springs, probably thermal, and may in some cases have formed geysers. In passing through the dolomite formation the aluminum was precipitated in the form of hydrous oxide, which was carried up and deposited in the vents and spring basins. The soft and freshly precipitated alumina was kept in motion by the ascending current of water, which accounts for the pebble and boulder structure of a large part of the ore. There are all gradations between bauxite and kaolin, so the latter must have had a similar origin; but for some reason the silica was present in quantity and condition to combine with the alumina before and during deposition.

The production of this area has fallen rapidly in recent years, and it appears that the high grade ore in easily accessible localities is nearly exhausted.

There are also small bauxite deposits of similar type but of no present commercial value in Virginia and Pennsylvania.

Arkansas.[1]—The Arkansas bauxite deposits were discovered by Dr. J. C. Branner in 1891, and their production has increased so rapidly that since 1910 they have produced over 80 per cent of the bauxite mined in this country. In 1915 their output was more than 90 per cent of the total. The ore is residual from the weathering of a nepheline syenite, which outcrops in two areas in Saline and Pulaski counties. The bauxite occurs as irregular beds overlain by Tertiary sediments. The beds in places occasionally reach a thickness of over 30 feet, although the average thickness is only 11 or 12 feet. The deposits have a vertical range of 200 feet in the Bauxite district, a fact which can not be reconciled with the formerly accepted hypothesis that the deposits were chemical sediments precipitated in a shallow sea. There are three types of ore: the pisolitic, found at the top of the deposits, and resembling the Georgia ores; the granitic, a high grade ore found below and preserving the original syenite structure; and the amorphous, resembling kaolin in physical appearance. The ore grades downward through kaolinized syenite into fresh syenite. All grades of ore are highly porous. Iron carbonate is abundant in portions of the deposits, but it has evidently been introduced subsequent to the formation of the ore.

Mead reaches the following conclusions in regard to the origin:

"1. The bauxite and associated clays are the products of the surface weathering of the syenite by normal processes of rock decomposition, and are in no sense chemical sediments.

Bauxite deposits occurring on the syenite surface have developed in situ from the syenite.

The deposits developed in situ from the syenite show evidence of the downward secondary concentration of alumina.

[1] Hayes, C. W., The Arkansas bauxite deposits: U. S. Geol. Survey Twenty-first Ann. Rept., pt. 3, pp. 435-472, 1900.
Mead, W. J., Occurrence and origin of the bauxite deposits of Arkansas: Economic Geology, vol. 10, pp. 28-54, 1915.

Bauxite lenses occurring interstratified with the Tertiary sediments consist of material which has been removed from its place of origin by Tertiary streams.

2. The texture of the kaolinized syenite has been essential to the alteration of the kaolin to bauxite.

3. The oolitic or pisolitic texture of the bauxite has developed in place from the granitic or amorphous types of bauxite."

The tonnage of the deposits was estimated by Hayes at 6,600,000 tons in outcrops and 43,700,000 tons under cover. Mead says that these estimates are very greatly in excess of the amount shown up by detailed exploratory work, but the deposits constitute by far the greatest known reserves of bauxite in the United States.

New Mexico.[1]—The deposits occur in the vicinity of Silver City. On account of difficulty of transportation they are considered commercially unavailable at present. They are most closely related to the Vogelsburg type of deposits, as they are derived from the alteration of a basic volcanic rock in place. The area is about half a mile square, of nearly horizontal beds of volcanic porphyry and basalt breccia. Aluminous solutions of solfataric origin, produced by the decomposition of pyrite, are drawn to the surface by capillary action. As the climate is arid, the sulphate of aluminum (alunogen) is deposited at the surface, while the internal residual mass is bauxite. The structure of the bauxite is amorphous, perhaps because the limited amount of water present was insufficient to permit the rearrangement of the alumina in nodules.

BAUXITE DEPOSITS OF THE COASTAL PLAIN OF GEORGIA

HISTORY

The discovery of bauxite in Wilkinson County was made by Otto Veatch, Assistant State Geologist of Georgia, in the course of field work carried on in connection with the preparation of a report on the clay deposits of the State. A brief description of the deposits was published as an appendix to that report, in 1909. The first shipment

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[1] Blake, William P., Alunogen and bauxite of New Mexico. Trans. Am. Inst. Min. Eng., vol. 24, pp. 571-573, 1894.

from the field was made by the National Bauxite Company in the summer of 1910. This company worked out the small deposits on the Adkins and Cannon properties during 1910, 1911 and 1912, and in June 1915, started work on another small deposit on the Cason property.

The Republic Mining & Manufacturing Company in 1912 began shipping ore from the Parker-Honeycutt-Daniel deposit, probably the largest single ore-body in the district. It is reported that several carloads were shipped from this deposit before the company took charge. It is known as the McIntyre mine. Although the mine has not been operated continuously, some ore has been shipped each year since the opening. The rate of production has been from one to two cars per day during the periods of operation.

The Sumter County deposits were discovered by L. M. Richard in 1912, and operations were begun at the Sweetwater mine by the Republic Mining & Manufacturing Company in May, 1914. This was the only mine operating in the district until early in 1916, when Mr. B. F. Easterlin started to work the deposit on his property, and the Kalbfleisch Corporation opened a mine on the Lane and McMichael properties, north of Andersonville.

LOWER CRETACEOUS BAUXITE DEPOSITS

GEOLOGY OF THE LOWER CRETACEOUS

Conditions of deposition in eastern United States.[1]—During most of the Paleozoic era, the area east of the Appalachians, as far as the present coast and beyond, was land, and when the Appalachians came into existence, at the close of the Paleozoic, some parts of the old continent of Appalachia were bowed or depressed so as to become sites of deposition, and here the Triassic beds of the Atlantic province were laid down. The sedimentation was attended and followed by igneous intrusions, and probably by faulting and warping. At the close of the Triassic period, as nearly as is now known, the surface was again deformed, and a period of erosion which lasted through the Jurassic was inaugurated. By the beginning of the Lower Cretaceous period,

[1] Abstracted from Chamberlin and Salisbury, Geology, vol. 3, 2d. ed., 1907, and Geol. Survey of Ga. Bull. 26.

both the Appalachian Mountains and the area of the present Piedmont Plateau had been degraded well toward base-level. Little warping of the surface therefore appears to have been necessary to convert portions of the coastal lands into sites of sedimentation.

The part of the Lower Cretaceous series exposed along the Atlantic coast is known as the Potomac group. A corresponding series is exposed in a continuous belt of outcrops, extending from eastern Alabama across Georgia and South Carolina into North Carolina. These two series are not traceable into one another on the surface, and the only fossils found in the southern series are a few poorly preserved leaves, but physical evidence indicates that they represent approximately the same period of deposition.[1] Beds representing the upper part of the Lower Cretaceous series were never deposited in the Southeastern States, or were removed by erosion before the Upper Cretaceous beds were laid down.

The Potomac group and the Lower Cretaceous strata of the South Atlantic and Gulf States belong to the terrestrial rather than the marine type of deposits. The whole eastern mountain and plateau region seems to have suffered peneplanation during the Jurassic period, attended inevitably by the deep decay of the underlying crystalline and other rocks, and the consequent accumulation of a heavy mantle of residuary earth and insoluble rock. The warping which inaugurated the Lower Cretaceous period seems to have involved a rise of the axis of the Appalachian tract, and a consequent rejuvenation of the drainage from it, while the coastward tract was left relatively flat, or perhaps bowed downward, making it a zone of lodgment for the sediments brought down from the north and west. The quickened drainage of the axial tract, acting on material prepared for easy removal, loaded itself with a burden it could not carry across the low coastal tract, and deposition resulted. Marshes, lakes, and lagoons were probably features of the area, and the perfect separation of the sand from the clay at many places points to the existence of local conditions which allowed of the differentiation of sediments to an un-

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[1] Stephenson, L. W., Cretaceous deposits of the eastern Gulf Region: U. S. Geol. Survey Prof. Paper 81, pp. 10, 11, 1914.

usual degree. The presence of feldspar in the sand, and of pieces of schist in the gravel beds, shows that erosion sometimes exceeded chemical decay. This betokens high land to the north and west from whence the sediments were derived, and is one of the reasons for the belief that the region west of the site of deposition was tilted upward at this time.

Areal distribution in Georgia.[1]—The Lower Cretaceous strata present in Georgia are believed to represent a part of the Potomac group of the Middle Atlantic States. This terrane appears as outcrops in Georgia in an extremely irregular belt 2 to 30 miles in width, extending entirely across the State from Chattahoochee River in the vicinity of Columbus, northeastward to Savannah River in the vicinity of Augusta. The irregularities of the belt are due partly to the unevenness of the surface of the basement rocks upon which the formation rests, partly to overlaps of younger formations, and partly to the deep erosion valleys that the streams have developed along the Fall Line region. The last named condition causes the underlying basement rocks to appear much farther southward in the bottoms of the valleys than would otherwise be the case, and likewise causes the Lower Cretaceous beds themselves to appear still farther down these valleys beneath the underlying younger formations. The area in which the beds appear includes parts of the following counties: Muscogee, Chattahoochee, Talbot, Marion, Taylor, Macon, Crawford, Bibb, Twiggs, Jones, Wilkinson, Baldwin, Washington, Hancock, Warren, Glascock, Jefferson, McDuffie, Columbia, and Richmond.

Stratigraphic position.—The Lower Cretaceous beds in Georgia rest upon a basement of ancient crystalline rocks, all of which are believed to be of pre-Cambrian age. The surface of the crystalline rocks is very uneven in detail, but in general slopes to the south and southeast. Calculations from well borings at several places have shown that the amount of this general slope in the region of the Fall Line varies from 25 to over 50 feet per mile. In Jefferson County, it maintains a slope of between 35 and 40 feet to the mile for a distance of nearly 40 miles from the Piedmont border.

[1] Abstracted from Geol. Survey of Ga. Bull. 26, pp. 73-77, 1911.

Between Chattahoochee and Ocmulgee rivers the formation is overlain unconformably by Upper Cretaceous strata belonging to the Eutaw and Ripley formations, and to a very limited extent, where both of these formations are absent, by Eocene strata. Between Ocmulgee and Savannah rivers it is overlain unconformably by the Claiborne and Jackson stages of the Eocene.

Lithologic characters.—The Lower Cretaceous materials consist dominantly of arkosic sand, with, however, a considerable percentage of clay in the form of interbedded lenses. The sands are usually coarse to very coarse in texture, and generally cross-bedded. They are composed largely of angular to subangular quartz grains, with an important percentage of mica flakes and disseminated grains and particles of kaolin. In addition, there are subordinate amounts of undecomposed feldspar and various other minerals derived from the crystalline rocks of the adjacent Piedmont region. Locally the sand beds have been indurated, forming friable sandstones. The clay lenses vary in lithologic character, shape, and extent. In thickness they range from an inch or less to a maximum of 30 or 40 feet, and in horizontal extent from a few square yards to many acres. In general, the clays are light drab or gray in color, and are more or less sandy. Locally, however, there are commercially important clay lenses of remarkable whiteness and purity, approaching kaolin in composition. Lamination is rare, the beds being as a rule massive and breaking with a hackly or conchoidal fracture.

For the most part the formation displays great irregularity of bedding, but in places a distinct banding of the clay and sand layers is apparent, individual beds being traceable for considerable distances.

Locally, coarse gravel lenses and layers occur in the formation, this being especially true of the basal portions. Unconformities of little or no time significance occur locally within the formation. As a result of the shifting of the channels which produced these unconformities clay beds within the formation have been torn to pieces and redeposited, as evidenced by the large number of rolled clay balls and boulders which in many places occur scattered through the sands.

The better grades of commercially important clays, so far as known, occur in the region between Ocmulgee and Savannah rivers. Beds of very fine quality are especially abundant in Twiggs and Wilkinson counties where mining operations have been carried on more extensively than elsewhere.

Strike, dip, and thickness.—The strike of the Lower Cretaceous beds in Georgia is in general northeast and southwest, with the dip a little south of southeast. On account of irregularity of bedding and of the limited extent of the exposures, the exact amount of the dip can not readily be determined. It is greater, however, than the gradients of the larger streams and probably averages 25 or 30 feet to the mile. Data are available for a fairly accurate determination of the thickness of the formation in the Chattahoochee Valley below Columbus. The point on Chattahoochee River adjacent to Columbus, where the surface of the basement rocks passes beneath water level, has an elevation of about 195 feet above sea level. Data furnished by well borings near the mouth of Bull Creek show that this surface dips southward at an average rate of between 50 and 60 feet per mile. The top of the Lower Cretaceous terrane passes below water level at Broken Arrow bend 7 miles south of Columbus, in an air line, and about 180 feet above sea level. If the dip of the surface of the basement rocks is 50 feet to the mile, 7 miles south of Columbus it would be 350 feet lower, or 155 feet below sea level. The thickness of the formation at Broken Arrow Bend would therefore be 155 plus 180, or 335 feet. If the dip of the basement rock surface is 60 feet, the thickness is 405 feet. The average of these amounts, 370 feet, is believed to be a close approximation to the total thickness at this point.

Calculations based on well data have shown that the probable general dip of the unconformity separating the Lower Cretaceous and the overlying Eutaw beds in this region varies from 48 to 50 feet per mile. If the upper and lower planes of unconformity maintain their apparent angles of dip they diverge and the Lower Cretaceous formation thickens southward, but it is not likely that the crystalline surface maintains so great a degree of slope for any great distance from the Fall Line.

A well at Reynolds, Taylor County, is said to have penetrated 600 feet of strata before encountering the underlying crystalline rock. As the well starts in Lower Cretaceous strata, the whole thickness should be referred to this formation.

Three and a half miles southwest of Louisville, Jefferson County, a well 1,143 feet deep is believed to have penetrated about 790 feet of Cretaceous strata between the overlying Eocene beds and the basement rock. None but Lower Cretaceous strata outcrop from beneath the Eocene beds along the Fall Line to the northwest of Louisville, but it is not at all certain that all of the Cretaceous beds penetrated in the Louisville well should be referred to that division. In fact it seems highly probable that buried Upper Cretaceous strata exist between the Eocene and Lower Cretaceous beds. The thickness of the Lower Cretaceous at this point is therefore believed to be considerably less than 790 feet.

From well data and other considerations, it may be shown that in general along the line where the formation passes beneath the Upper Cretaceous or Eocene formations, as the case may be, its thickness ranges from 350 to 600 feet.

Physiographic expression.—The belt in which this Lower Cretaceous terrane outcrops constitutes part of a dissected plain which is characterized by a broken, hilly topography, the area presenting in fact the roughest surface of any portion of the Coastal Plain of Georgia. The elevation of the upland surface ranges from 400 to 600 feet above sea level. The major streams crossing the area have elevations at the fall line ranging from 100 to 250 feet. The surface relief therefore reaches a maximum of at least 400 feet. This hilly topography is the result of active stream erosion caused by the relatively high elevation of the area and favored by the unconsolidated, sandy character of the materials of which the formation is predominantly composed.

The surface soil throughout the greater part of the area is composed of loose gray or yellowish sands, the product of the weathering and leaching of the underlying sand beds of the formation. These surface sands have been shifted more or less by winds and torrents so that in places they have been entirely removed, and elsewhere have been heaped up to abnormal thicknesses. The area forms a part of the so-called "sand hill" region of the northern part of the Georgia Coastal Plain.

Paleontologic characters.—A few faint, indeterminable leaf impressions have been observed in white, sandy clay in a cut of the Georgia Railroad at Carr's Station, Hancock County. With this exception no fossil remains have been discovered in the beds of this formation in Georgia.

Location of bauxite deposits.—Although the outcrop of the Lower Cretaceous beds extends in an unbroken belt across the State from the Chattahoochee to the Savannah, bauxite has been found only in a limited district near the central part. The greater number, and also the richer of the deposits are in Wilkinson County, but the area of bauxitic clays with some smaller deposits is known to extend into Twiggs, Washington, and Baldwin counties.

DESCRIPTIONS OF INDIVIDUAL DEPOSITS

WILKINSON COUNTY

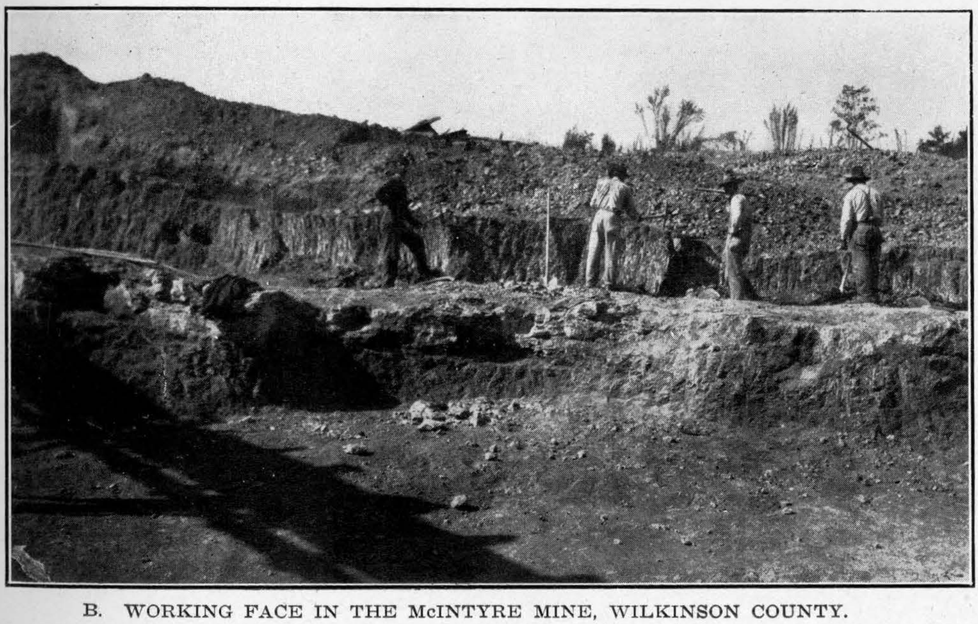
The Lower Cretaceous strata are exposed in the valley of the Oconee River in the eastern part of Wilkinson County, and in the valleys of Commissioners and Big Sandy creeks almost to the southern boundary. Deposits of bauxite are known in all parts of the county, and are likely to be found throughout the area of outcrop of the formation. All known deposits are at or near the contact of the Cretaceous with the unconformably overlying Eocene beds.

PARKER-HONEYCUTT-DANIEL GROUP OF PROPERTIES (MCINTYRE MINE)

(Map locality W-1)

Location.—Bauxite occurs on the property of Mrs. W. R. Parker, J. R. Honeycutt, W. E. Honeycutt, and James Daniel, located 3

A. BAUXITE DRIER, REPUBLIC MINING & MANUFACTURING CO., McINTYRE MINE, WILKINSON COUNTY.



B. WORKING FACE IN THE McINTYRE MINE, WILKINSON COUNTY.

miles northeast of McIntyre and 1½ miles north of the 159 milepost on the Central of Georgia Railway. The mining rights on all of the properties are held by the Republic Mining and Manufacturing Company. H. M. Skelton, of Irwinton, is the superintendent of the mine which is commonly known as the McIntyre mine.

The ore is found along both sides of a small branch of Commissioners Creek; the best bauxite, and the only part which has been worked, being on the Parker and Daniel tracts, west of the branch. The topography, location of the bauxite outcrops, and workings up to November, 1916, are shown in the accompanying sketch and section (fig. 1).

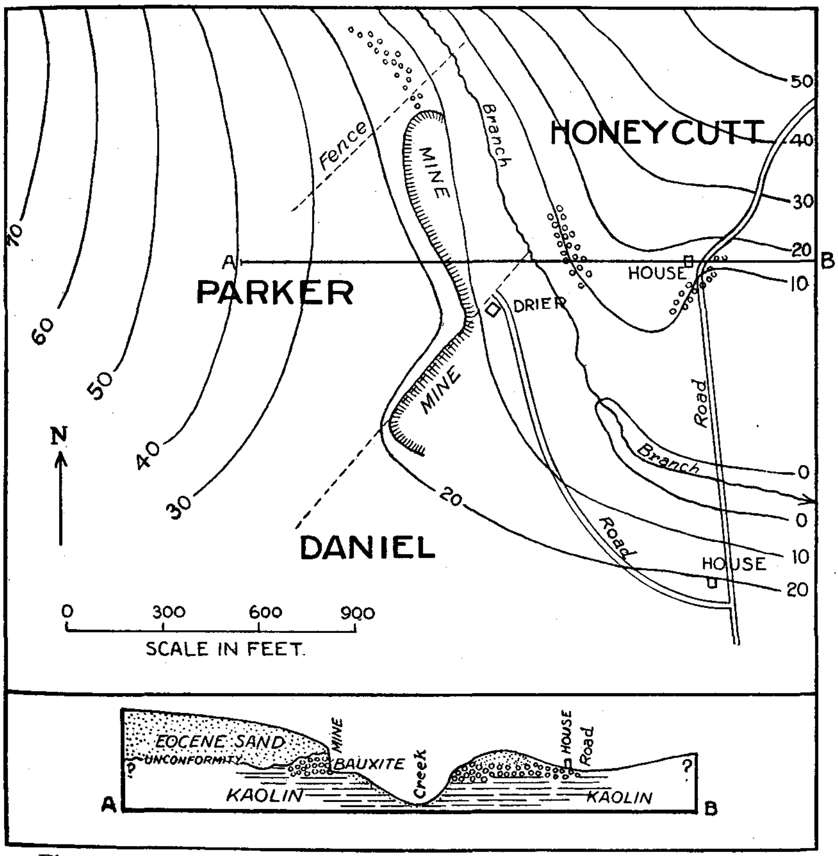


Fig. 1.—Topographic sketch map and section of the McIntyre bauxite mine of the Republic Mining & Manufacturing Co., Wilkinson County.

Geologic relations.—The bauxite has the form of a lens at the top of the Cretaceous beds. It grades down into white or stained and mottled plastic kaolin, and is overlain unconformably by Eocene sands and clays. Although the character of the ore varies greatly, it is evident that all exposures belong to the same lens, which has been partly eroded by the branch.

The character of the underlying beds is plainly shown in the well at the drier. The well is 17 feet deep, starting several feet below the base of the bauxite bed, and when examined contained only 5 feet of water. At the surface is yellowish clay with occasional large soft nodules, which grades down into smooth, plastic kaolin. Several feet above the water line the kaolin is splotched and mottled with red, while the material from the bottom is tough, plastic, maroon colored clay.

The upper surface of the bauxite is a distinct unconformity, approximately plane and level, but very irregular in detail. Along the face northwest of the drier there are circular cavities like pot holes filled with Eocene clay, some of which penetrate the entire thickness of the ore bed (see Pl. III, B). The material overlying the bauxite in the mine consist of 3 to 4 feet of tough sandy blue clay, peculiarly stained and mottled with red and yellow, and several feet of loose gray sand forming soil and subsoil. There is no marked bed of basal conglomerate, but the blue clay contains occasional boulders of bauxite up to one foot in diameter, and rounded quartz pebbles up to 2 inches. In the slope of the hill to the west, which rises about 50 feet, small gullies and washes show typical red and yellow argillaceous sands of the Eocene.

The deposits.—The exposures west of the branch are the working face of the mine and exploration pits to the north. The length of the face northwest of the drier is 200 yards, and exploration work has shown up ore continuing around the slope 20 yards to the fence line and about 100 yards in the cultivated field beyond. The base of the workable bauxite is about 15 feet above the level of the branch. The thickness of ore is said to have been as much as 9 feet in the worked-

A. WORKING FACE IN THE McINTYRE BAUXITE MINE OF THE REPUBLIC MINING & MANUFACTURING CO., SHOWING BEDDED BAUXITE WITH AN UNCONFORMITY ABOVE.

B. McINTYRE MINE. UPPER SURFACE OF THE BAUXITE STRIPPED PREPARATORY TO MINING, SHOWING "POT HOLES" AND IRREGULARITIES.

Photo by S. W. McCallie

out portion on the Daniel property, but the greatest thickness exposed at the time of examination was little over 6 feet. The ore along the face northwest of the drier, which was being worked in November, 1916, had a maximum thickness of 6 feet, with average hardly 5 feet, and was thinning rapidly toward the west.

Where the working face swings around at the south end of the pit the ore not only thins but changes in character, becoming softer, with larger and more scattered nodules. It is evidently grading into kaolin along the strike as well as in depth.

On the Honeycutt property, which lies east of the branch, no mining or exploration work has been done since Veatch's examination. Red, highly ferruginous bauxite, in a bed at least 4 feet thick, outcrops in the slope east of the branch, about 150 yards from the mine and at the same level. Lower on the slope is an outcrop of dark red, plastic clay. Another small outcrop of red bauxite occurs in the public road near the Honeycutt house. The bauxite outcrops are 500 feet apart, on opposite sides of a small knoll, which rises only 5 feet above the exposures. If the bed is continuous in the intervening distance the area underlain is about 4 acres, with overburden nowhere exceeding 5 feet.

The ore.—The upper 3 feet (more or less) of the bauxite bed in the mine is hard, white, finely pisolitic ore. This charges in depth into softer, iorn-stained ore of similar texture, which in turn grades into soft kaolin with scattered nodules. The nodules in the best portion of the ore average less than one-fourth inch in diameter, but there are scattered complex pebbles with a maximum diameter of 6 inches. The complex pebbles consist of a number of small, soft pisolites in a gray or brown, dense, flinty matrix, but most of the bauxite has a white, porous and chalky, instead of a flint-like matrix, and is therefore softer than the high-grade ore from other occurrences in the vicinity. As a rule the pisolites have a thin hard shell with softer or powdery center, and are the same color or a little darker than the matrix.

At the angle of the face nearest the drier the ore is only 3 feet thick, and is ferruginous and dark yellow in color. Along the face to the southwest, several hundred feet from the drier, the bauxite becomes horizontally banded, with thin white and thick red layers, apparently due to variations in iron content during deposition (see Pl. III, A). The bauxite of the red bands has light colored pisolites in a red matrix. On the contrary, the low grade red bauxite of the Honeycutt property, a part of the same lens, is made up of dark red, pebble-like nodules in a white, sandy matrix.

The ore in the face northwest of the drier is also, in part, distinctly stratified, with layers of bluish plastic clay up to 2 inches in thickness, while some beds are more ferruginous than others. Perpendicular "veins" a few inches thick and occasional larger irregular masses of soft, white, kaolinic material, with the same pisolitic texture as the bauxite, but of very different composition, cut across the bedding.

When exposed to the weather, the bauxite becomes lighter in color, harder, and apparently higher in alumina. The lightening of color and enrichment are probably due to removal of clay and iron oxide while the hardening is caused by repeated solution and recrystallization of very minute quantities of silica and alumina.

Veatch collected surface samples from these properties before mining was started, the analyses of which gave the following results:

Analyses of surface samples[1]

Constituents	1.	2.	3.	4.
Silica (SiO_2)	9.41	10.20	8.48	38.14
Alumina (Al_2O_3)	57.80	53.11	50.94	30.26
Ferric oxide (Fe_2O_3)	.96	7.66	9.50	17.54
Ignition	29.21	26.55	27.80	12.12
Titanium dioxide (TiO_2)	2.77	2.30	2.02	1.57
	100.15	99.82	98.74	99.63
Moisture	.35	.35	1.94	.55

1. Surface sample from Parker property.
2. Surface sample from Honeycutt property.
3. Surface sample from Honeycutt property.
4. Red clay underlying bauxite, Honeycutt property.

[1] Veatch, Otto, Geol. Survey of Ga. Bull. 18, pp. 440-442, 1909.

To show the gradation of bauxite into kaolin with depth, a series of samples was taken by the writer from the best part of the face, 100 feet southwest of the drier. The first sample was from the Eocene sandy clay overburden 6 inches above the unconformity, the second was bauxite 6 inches below the unconformity, and the remainder were taken at one foot intervals, giving a total section of 10½ feet below the contact. Average samples were taken, but the large ferruginous concretions scattered through the lower part of the bed were avoided. A thickness of 5½ feet of the section below the unconformity may be called bauxite, as that is the portion mined and shipped. A pit was dug 5½ feet below the floor of the mine for the purpose of getting these samples. The lower part of the bauxite in the face, and the clay to a depth of 7 feet below the unconformity, are stained yellow, and the clay carries large, soft nodules to a depth of 8 feet. From 8 to 10 feet the white kaolin is mealy, while below 10 feet it is soft and plastic. Through the material from 5 to 10 feet are scattered large, irregular, hard, ferruginous concretions, with maximum dimensions up to one foot. The concretions seem to have been affected by weather, as they lack the soft centers of pyrite, sulphur, and soluble salts found at other localities.

An auger boring 8 feet deep in the bottom of the pit penetrated some red-stained clay, and was in gray-blue plastic kaolin at the bottom.

Analyses of ore from Republic Mine, showing gradation into kaolin

Constituents	S-63	S-64	S-65	S-66	S-67	S-68
SiO_2	50.57	23.72	10.63	14.12	18.84	22.40
Al_2O_3	30.45	50.15	57.91	54.15	52.03	51.56
Fe_2O_3	3.22	1.13	.96	1.61	2.25	2.89
FeO	.00	.00	.00	.00	.00	.00
MgO	.03	.04	.03	.02	.00	.03
CaO	.08	.00	.02	.00	.00	.00
Na_2O	.21	.02	.04	.01	.02	.01
K_2O	.51	.05	.03	.02	.02	.02
Ignition	13.28	23.10	28.70	27.50	25.26	21.34

TiO_2	1.81	2.18	1.44	2.27	1.74	2.01
P_2O_5	.00	.00	.00	.00	.00	.00
S	.00	.09	.09	.12	.05	.01
MnO	.11	.00	.00	.00	.00	.00
ZrO_2	....	.003	.007	....	....	....
BaO	.00	.00	.00	.00	.00	.00
	100.27	100.483	99.857	99.82	100.21	100.27
Moisture	.69	.73	.38	.63	.53	.45

Constituents	S-69	S-70	S-71	S-72	S-73	S-74
SiO_2	23.73	28.89	27.38	31.79	36.35	42.40
Al_2O_3	50.75	47.16	46.81	44.21	44.06	39.08
Fe_2O_3	2.73	1.77	2.41	1.12	1.13	.96
FeO	.00	.00	.00	.00	.00	.00
MgO	.00	.00	.00	.00	.00	.02
CaO	.00	.00	.00	.00	.00	.00
Na_2O	.00	.03	.05	.32	.08	.12
K_2O	.00	.06	.04	.18	.10	.24
Ignition	21.33	20.09	20.43	20.10	16.83	14.74
TiO_2	2.31	2.17	1.99	1.81	1.99	2.35
P_2O_5	.00	.00	.00	.00	.00	.00
S	.00	.00	.02	.03	.00	.02
MnO	.00	.00	.00	.00	.00	.00
ZrO_2	....	....	....	....	....	....
BaO	.00	.00	.00	.00	.00	.00
	100.85	100.17	99.13	99.56	100.54	99.93
Moisture	.37	.42	.48	.48	.50	.38

The dried ore as shipped is said to average 55 per cent alumina, and weighs 3,300 pounds per cubic yard.

Development.—The ore on the Daniel property has been entirely worked out, having graded into kaolin to the west. The area originally underlain by bauxite on that property seems to have been about 8,000 square yards. The unworked area remaining on the Parker property is probably somewhat larger.

The maximum overburden being moved (November, 1916) was 11 feet, 25 feet back of the working face northwest of the drier. The overburden will not increase much more, as this is about the limit of the extent of the ore bed to westward. Stripping and mining have been carried on entirely by hand labor. As the overburden in the area likely to be underlain by bauxite does not exceed 10 or 15 feet, with average less than 10 feet, it has not been considered profitable to use steam shovels.

The ore is dried in a rotary kiln, and hauled in wagons 1½ miles to the railroad siding at Wriley station.

Production and uses.—The mine was opened in 1912, and during 1913 produced about a carload per day. Work was stopped for several periods when the demand for bauxite was not great, but in 1916 the mine was being actively worked and was producing about two cars per day.

The greater part of the ore shipped has been low in iron, and has been used principally in the manufacture of alum. All of the ore known on the Honeycutt property, and a part of that remaining on the Parker property contains considerably more than two per cent of ferric oxide, and will probably therefore be used for aluminum manufacture.

GENERAL BAUXITE CORPORATION PROPERTY

(Map locality W-2)

The bauxite property formerly owned by Dr. N. T. Carswell was purchased in 1916 by the General Bauxite Corporation, 52 Broadway, New York, of which Mr. A. Rust-Oppenheim is president. It is situated just south of the Central of Georgia Railway, 3 miles west of Toomsboro. This property is one of the first on which bauxite was discovered, in fact, Dr. Carswell claims to have known of the occurrence before Veatch announced the discoverey near McIntyre.

A considerable amount of prospecting has been done in the valley of a small branch which flows northeast into Commissioners Creek.

The location of the pits described is shown on the accompanying sketch map (fig. 2).

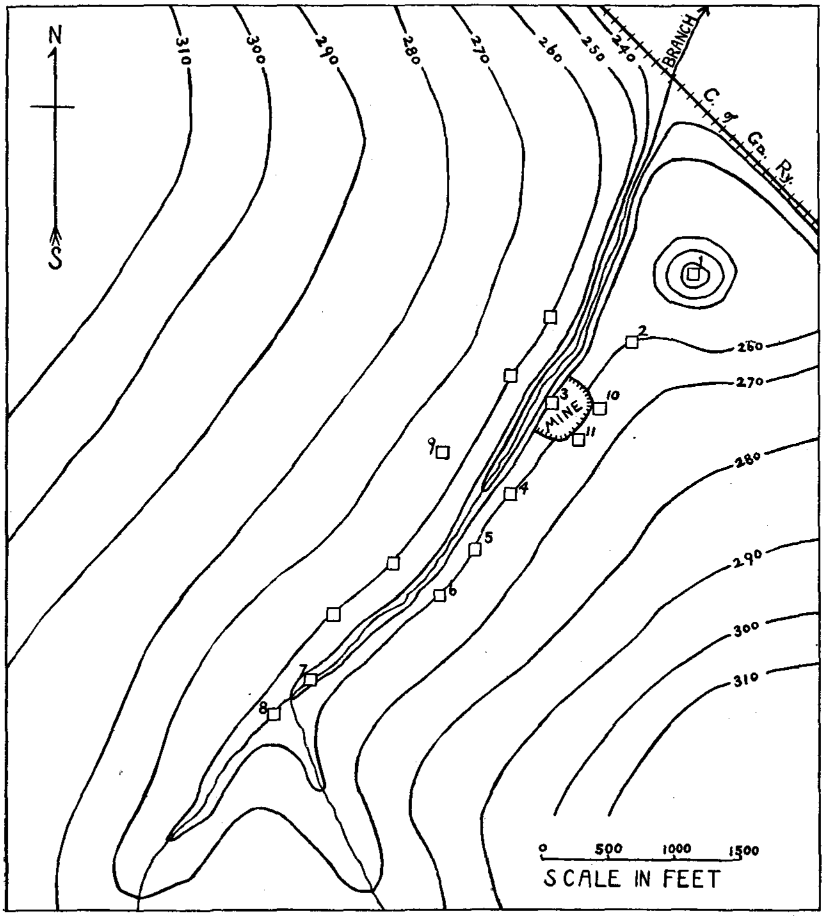


Fig. 2.—Sketch map of bauxite explorations on the property of the General Bauxite Corporation, Wilkinson County. The numbers refer to pits described in the text.

Geologic relations.—The bauxite is found in the Lower Cretaceous kaolin beds at or near the unconformable contact with the overlying Eocene sands and clays. The unconformity was observed at the junction of the two small branches, altitude 250 feet, near pits Nos. 7 and 8. A basal conglomerate consisting of fragments of bauxite and indurated clay in a matrix of mottled clayey sand overlies the Cretaceous indurated bauxitic clay. The upper surface of the Cretaceous is irregular, as kaolin is found up to an altitude of 280 feet at pit No. 1. The Eocene beds overlying the bauxite and kaolin belong to the Barnwell formation of the Jackson group. No continuous section of the Eocene beds is exposed, but there is apparently about 40 feet of red sandy clay or argillaceous sand immediately above the Cretaceous. Calcareous, pale yellow clay of the character of fullers earth, is exposed in gullies near the tops of the hills to the east and west of the valley, at an altitude of about 300 feet, and one mile southwest of the bauxite locality is a bed of bryozoan limestone, typical of the Jackson group, at approximately the same horizon as the fullers earth.

The Lower Cretaceous strata consist of white, plastic kaolin; indurated and bauxitic white kaolin; red kaolin, both plastic and indurated; white kaolinic sand; and bauxite, all of which is rather siliceous. The character of the material shows great local variation, and none of the beds are continuous for any great distance along the strike.

The ore.—All possible gradations between kaolin and high grade bauxite may be found on the property. The following table includes all analyses of kaolin and bauxite made by Dr. Edgar Everhart for the Geological Survey of Georgia. The samples marked "S" were collected by the writer, others were collected by Otto Veatch and H. C. Parker. These analyses are arranged in order of alumina content, to show the gradation between kaolin and bauxite.

Analyses of samples from the property of the General Bauxite Corporation

Constituents	1	2(S-88)	3	4(S-87B)	5	6
SiO_2	40.12	45.24	44.63	39.73	43.96	35.14
Al_2O_3	34.56	36.04	38.75	39.47	39.69	41.09
Fe_2O_3	11.80	1.61	1.73	1.09	.73	1.29
MgO	.00	....	tr.	....	.10	....
CaO.	.00	....	tr.	....	.00	....
Na_2O	tr.	....	tr.	....	.05	....
K_2O	tr.	....	.28	....	.10	....
Ignition	12.49	13.91	13.59	15.97	14.23	20.66
TiO_2	1.49	1.71	1.50	1.82	1.62	2.01
S	....	....	tr.	....	tr.	....
MnO	....	....	tr.	....	....	....
	100.46	98.51	100.48	98.08	100.48	100.19
Moisture	.58	.66	.90	.78	.89	.42

Constituents	7	8	9(S-89)	10(S-182)	11(S-231)	12
SiO_2	27.88	30.98	28.36	12.35	9.79	1.18
Al_2O_3	42.91	46.37	48.29	56.70	57.00	61.52
Fe_2O_3	1.61	1.29	1.92	1.61	1.61	1.70
MgO	....	....	....	....	....	....
CaO	....	....	....	....	....	....
Na_2O	....	....	....	....	....	....
K_2O	....	....	....	....	....	....
Ignition	25.46	19.58	20.05	27.55	30.30	32.70
TiO_2	1.81	1.81	.90	1.63	.90	2.76
S	....	....	....	....	....	....
MnO	....	....	....	....	....	....
	99.67	100.03	99.52	99.84	99.60	99.86
Moisture	.70	.52	.25	.39	.54	....

1. Red kaolin. Veatch, Otto, Geol. Survey of Ga. Bull. 18, p. 166, 1909.
2. S-88. Claystone exposed at junction of branches, just below the Ecocene contact.
3. Plastic white kaolin. Veatch, Otto, Geol. Survey of Ga. Bull. 18, p. 164, 1909.

4. S-87B. Average sample of soft, nodular clay from 8 feet of beds in pit No. 5.
5. Indurated nodular clay or ''chimney rock.'' Veatch, Otto, Geol. Survey of Ga. Bull. 18, p. 165, 1909.
6. Average sample from top to bottom of pit No. 11. Collected by H. C. Parker.
7. Average sample from bottom and walls of pit No. 10. Collected by H. C. Parker.
8. Bauxitic clay from bottom of pit No. 11. Collected by H. C. Parker.
9. S-89. Bauxitic clay, average sample from 8 feet of beds exposed in pit No. 9.
10. S-182. Bauxitic clay, average sample of 6-foot bed of bauxite in pit No. 11, on site of the mine.
11. S-231. Average sample of 5-foot beds of bauxite in a cut on the slope above pit No. 3, on the site of the mine.
12. Hard nodules of high-grade bauxite. Veatch, Otto, Geol. Survey of Ga. Bull. 18, p. 444, 1909.

Pits Nos. 1, 2, and 3 cut only indurated white clay, with scattered clayey nodules. The material is only slightly bauxitic, and has no value at present except as a fire clay.

Pit No. 4 shows 6 feet of indurated, nodular, maroon-colored clay. The material is the same as that in the preceding pits, except that it contains a higher percentage of ferric oxide.

Pit No. 5 cuts 5 feet of indurated white clay, underlain by 8 feet of softer, light-colored clay with soft pisolites. According to Dr. Carswell, the pit penetrated 27 feet of the latter material, which appears to be bauxitic, but the analysis (S-87B) shows it to run very little higher in alumina than an ordinary kaolin. Pit No. 6 is said to have cut 14 feet of clay similar to that in the bottom of pit No. 5.

Pits Nos. 7 and 8 are in the branch, and were filled with water when examined. As may be seen from the material excavated, they cut some clay with nodules one inch in diameter of hard, high-grade bauxite. It was from this locality that the sample (analysis No. 12) was taken. The rock in the branch immediately beneath the unconformity, which is well exposed, is a very hard white claystone with irregular flinty concretions (analysis S-88).

Along the slope northwest of the branch are several pits. None of these show good bauxite, but they cut more or less indurated kaolin, massive or nodular, and one reaches plastic kaolin. Pit No. 9, directly opposite pit No. 4, is the best looking prospect, showing 8 feet of mealy, very unplastic clay containing a few hard pisolites. Analysis of an average sample (S-89) shows it to be a low grade bauxite, but the percentage of alumina is higher than the appearance of the material would lead one to believe.

The pits above described are the earlier explorations. During the summer of 1915 two more pits, Nos. 10 and 11, were dug in the slope above Nos. 2 and 3. These pits disclosed a lens of bauxite of considerable extent and of much better quality than any previously discovered on the property. Pit No. 10 just reached the bauxite, while No. 11 penetrated the bed, showing the following section:

Section in pit No. 11

	Feet
3. Sandy soil containing fragments of bauxite........	1
2. White bauxite, of medium hardness, containing hard pisolites up to one inch in diameter.............	6
1. Somewhat plastic white kaolin.....................	1

Samples 6, 7, and 8 in the preceding table of analyses were taken from these pits by H. C. Parker, and sample 10 (S-182) is an average of the 6-foot bed of bauxite in pit No. 11. Sample 11 (S-231) is from the same bed, exposed in a cut in the slope a few feet below pit No. 11.

Mining operations were started on this property by the General Bauxite Corporation in 1916. The mine was opened on the slope between pits Nos. 3 and 11. When visited, in November, 1916, the opening was small and only six carloads of ore had been shipped. The working face was 50 feet long, and the maximum thickness of the ore was 5 feet at the south end of the workings, but the bed is known to become thicker farther south in the hill. The ore occurs in small and irregular lenses, cut by masses of "chimney rock." The relations of ore to indurated clay are shown in the accompanying sketch (fig. 3), which shows the working face in November, 1916.

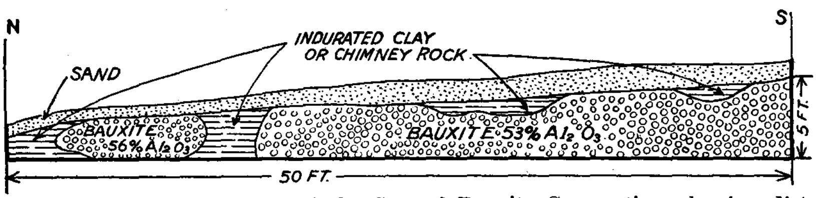


Fig. 3.—Section in mine of the General Bauxite Corporation, showing distribution of bauxite and chimney rock.

All of the ore shipped is of good quality for alum manufacture, contining less than two per cent of ferric oxide, but the silica content is too high for use in the manufacture of aluminum. The alumina content of shipments is kept above 52 per cent, while the best carload analysis received was 58 per cent.

No high-grade, low-silica bauxite has been found except the hard pisolites from the pits at the junction of the branches. The material containing these nodules was not visible at the time of the writer's visits, and it can not be stated whether or not the nodules are in sufficient abundance to make a washable ore.

Besides the lens of 52 to 58 per cent alumina bauxite now being worked, there is a large quantity of clayey bauxite which would carry over 50 per cent of alumina after drying. The low grade bauxite mixed with plastic kaolin would undoubtedly produce a fire brick of superior quality.

Conditions affecting mining.—The deposit is very favorably located in regard to transportation, as the principal prospects are within half a mile of the Central of Georgia Railway. The bauxite lens is so far above water level that drainage will cause no trouble. The principal mining problem will be the handling of the overburden, which will become heavy if the deposit is extensive.

Development, methods, and tonnage.—A tramway about three quarters of a mile long has been built from the mine to Nadine Station on the Central of Georgia Railway. Mining is done by manual labor. The ore body is well drained, and the ore as mined contains only 3 or 4 per cent of moisture, so it is shipped without preliminary drying.

About 500 tons had been shipped up to March, 1917. Dr. T. Poole Maynard, of Maynard and Simmons, who have conducted the recent exploration work, states that the reserve of bauxite in sight is 25,000 tons, with a possibility of discovering more.

CANNON PROPERTY

(Map locality W-3)

A deposit on the property formerly belonging to Mrs. Cannon, 1½ miles north of Toomsboro, was worked by the National Bauxite Company, but has been abandoned for some years.

The pit is at the top of a small knoll, and has a working face about 250 feet long and 5 feet high. The best ore, which was of very high grade, seems to have occurred as one or more small lenses in indurated white clay in the northern part of the mine. The overburden amounts to only 1 or 2 feet of soil, so the unconformity separating the Cretaceous from the Eocene is not observable. A drainage ditch running off to the southwest shows the material underlying the ore to be mealy, nodular clay, grading down into more or less stained, plastic kaolin without nodules.

The high grade ore, now exhausted, was hard, with olive-gray flinty matrix, making up a larger part of the mass than the pisolites. The latter are one-fourth to one inch in diameter, with thick hard shells and softer white centers.

In the southeast end of the pit 10 feet lower than the north workings, some washable ore still remains. The bed is several feet thick, but its extent could not be determined. The ore consists of hard pisolites, mostly an inch or more in diameter, in a mealy, slightly indurated, clayey matrix which could be removed by washing, without difficulty. Samples of the matrix and nodules were taken separately, and analyses gave the following results:

Analyses of bauxite from the Cannon mine

	S-91	S-92
Silica (SiO_2)	28.98	2.78
Alumina (Al_2O_3)	47.07	61.16
Ferric oxide (Fe_2O_3)	1.12	1.28
Ferrous oxide (FeO)	.16	.16
Magnesia (MgO)	.03	tr
Lime (CaO)	.00	.00
Sodium oxide (Na_2O)	.04	.06
Potash (K_2O)	tr	.08
Ignition	20.87	32.63
Titanium dioxide (TiO_2)	1.62	1.62
	99.89	99.77
Moisture	.32	.25

S-91 Matrix.
S-92 Pisolites.

CASON PROPERTY

(Map locality W-4)

This deposit is located three-tenths of a mile east of Toomsboro station, about 60 yards north of the railroad and 40 yards south of Commissioners Creek, just on the edge of the creek swamp. Work was started June 1, 1915, by the National Bauxite Company.

The area known to be underlain by bauxite measures 35 by 75 yards, and the thickness of workable ore is 7 feet. The overburden consists of 1 to 3 feet of superficial loose sand. As is usual, the bauxite grades downward into white kaolin. The ore shipped during 1915 is said to have contained nearly 60 per cent alumina when air dried, with average iron oxide content of less than two per cent. An average sample of about a carload of ore in the drying shed in March, 1916, has the following composition:

Analysis of bauxite from the Cason mine

	S-232
Silica (SiO_2)	4.30
Alumina (Al_2O_3)	61.06
Ferric oxide (Fe_2O_3)	1.61
Ignition	30.89
Titanium dioxide (TiO_2)	1.63
	99.49
Moisture	.44

The ore is coarsely pisolitic, with hard nodules in a matrix varying from hard to soft. On account of the lack of impervious overburden the ore is considerably iron stained, but the stains are only on the surface of the nodules, so the iron content is not nearly so high as it appears. A part of the ore is stained black by carbonaceous matter washed down through the sandy soil, but this stain does not materially affect the quality.

As the quantity of ore is known to be small, it has not been considered advisable to install a drier. The ore is shipped after drying in sheds or in the sun for several days.

About 6 inches of the ore at the top of the bed is mixed with sand, and must therefore be screened, for which a trommel is used. The base of the bauxite bed is below the level of Commissioners Creek, so it is necessary to pump out the surface water which flows into the pit.

Up to the latter part of November, 1916, an area 180 feet long and 100 feet wide has been worked out, and 125 carloads (about 4,000 tons) had been shipped. The estimated amount remaining at that time was only about 1,000 tons.

There is no probability of finding bauxite farther south than this property, because the upper surface of the Cretaceous beds dips below the grade of the larger streams.

HOLLEMAN PROPERTY

(Map locality W-5)

No recent work has been done on this property, so the following description is taken from Veatch's[1] report:

"Scattered boulders of bauxite have been found on the Holleman property, 3 miles west of McIntyre. A white clay, semi-indurated, which has been quarried out for building purposes, occurs here, and the bauxite fragments lie in the slope beneath this clay bed. It seems probable that they are erosion remnants of a bed which existed above the clay bed. The ore here shows 60 per cent of alumina.

"On the same property on the south side of the Central of Georgia Railway track, fragments of a highly ferruginous, pebbly bauxite were observed in the soil. Search in the ridge, above the fragments, failed to reveal any bauxite bed."

J. U. PARKER PROPERTY

(Map locality W-6)

This property is situated 5 miles north of McIntyre, on lot 172, 4th district, Wilkinson County. This bauxite occurrence is in a valley one mile north of the Parker residence.

In a small gully in the hillside is an outcrop of slightly indurated

[1] Veatch, Otto, Geol. Survey of Ga. Bull. 18, p. 443, 1909.

nodular clay overlying soft, white kaolin. A few feet farther down the slope fragments of high grade bauxite are found in the soil. Sandy soil with bauxite boulders is found for a distance of half a mile down the valley, and covers an area of many acres. By aneroid readings, the nodular clay outcrop is at an altitude of 370 feet and the bauxite area from 310 to 350 feet. A number of test pits in the bottom show that the soil contains bauxite to a depth of only about 18 inches, below which is yellow-stained kaolin.

The boulders vary in size from one foot down, and are of very high grade ore, as shown by the following analysis:

Analysis of J. U. Parker bauxite[1]

Silica (SiO_2)	2.12
Alumina (Al_2O_3)	60.55
Ferric oxide (Fe_2O_3)	1.89
Ignition	32.97
Titanium dioxide (TiO_2)	1.96
	99.49

The bauxite is light drab in color, hard and flinty, with scattered pisolites, few of which are over half an inch in diameter. In a thin section the matrix is also seen to be made up almost entirely of small nodules.

No bauxite in place has ever been found, although two carloads of float ore were shipped some years ago. It seems probable, judging from the topography, that the original bauxite lens was at about the horizon of the present bauxitic clay outcrop, overlying the kaolin bed; but it has been entirely eroded, leaving only detrital material scattered through the soil of the bottom.

UNDERWOOD PROPERTY
(Map locality W-7)

The property of Andrew Underwood (colored) is situated 1½ miles southeast of Irwinton.

Fragments of bauxite are found in the soil on a small knoll,

[1] Veatch, Otto, Geol. Survey of Ga. Bull. 18, p. 442, 1909.

which has been thoroughly explored by 23 pits from 3 to 10 feet deep. The area prospected is about two acres. The hill rises only 15 feet above the public road, which passes to the south. The pits near the base of the hill cut soft, plastic kaolin; while those at the summit show massive or nodular indurated clays or low grade bauxite.

Hard bauxite, in the form of boulders and pebbles, is found only in a limited area, about 100 feet square, on the middle and lower slope of the southeast side of the knoll. The exploration work indicates that the original lens of hard ore was very small, and it has all been eroded except for the fragmental material. The float ore is light brown, very hard and of flinty texture, with small, hard, scattered pisolites. It is of exceptionally high grade, as shown by the following analysis:

Analysis of hard bauxite from the Underwood property

Silica (SiO_2)	4.72
Alumina (Al_2O_3)	62.46
Ferric oxide (Fe_2O_3)	.81
Ignition	31.03
Titanium dioxide (TiO_2)	.23
	99.25

One of the test pits near the top of the hill shows the following section:

Section in test pit on the Underwood property

	Feet
4. Black sandy soil containing bauxite pebbles	1.5
3. Reddish bauxite, moderately hard, with irregularly distributed pisolites about one inch in diameter	2
2. Clayey bauxite, similar to the overlying bed in texture, but softer and lighter in color	2
1. White kaolin with scattered soft nodules, showing only slight evidence of bauxitization	1.5

Bed No. 3 is bauxite of good quality for alum manufacture, as shown by the following analysis, but the amount in sight is very small.

[1] Veatch, Otto, Geol. Survey of Ga. Bull 18, p. 445, 1909.

Analysis of bauxite from 2-foot bed, Underwood property

	S-42
Silica (SiO_2)	12.51
Alumina (Al_2O_3)	56.11
Ferric oxide (Fe_2O_3)	1.93
Ignition	27.81
Titanium dioxide (TiO_2)	1.72
	100.08
Moisture	.28

Where the public road crosses a small branch, one-eighth of a mile east of the bauxite deposit, the unconformity between the Cretaceous and Eocene beds is exposed. The basal beds of the Eocene contain pebbles of kaolin, but no bauxite.

FOUNTAIN PROPERTY

(Map locality W-8)

The Fountain property is situated about half a mile south of the Underwood property, or 2 miles southwest of Irwinton.

The bauxite prospects are in a spur running west from a flat-topped hill. A pit at the end of the spur, just above a plantation road, shows a thickness of 5 feet of bauxite, overlain by 2 feet of red argillaceous sand containing pebbles and boulders of bauxite. An average sample was taken from the 5-foot bauxite bed in this pit. The bauxite is stained yellow by limonite, but analysis shows that the iron content is not excessive, and it is probable that where the overburden is a little heavier the percentage of ferric oxide will be less.

Analysis of bauxite from 5-foot bed, Fountain property

	S-288
Silica (SiO_2)	14.32
Alumina (Al_2O_3)	55.67
Ferric oxide (Fe_2O_3)	2.10
Ignition	25.39
Titanium dioxide (TiO_2)	2.36
	99.84
Moisture	.55

The property has not been thoroughly explored, but the indications are that an area of about one acre is underlain by a bed of bauxite of this quality and at least 5 feet in thickness. Dr. Heinrich Ries made an examination of the property, and he estimated 15,000 tons of "high-grade bauxite." However, all of the ore in sight is siliceous, containing nearly 15 per cent silica, so it can not be considered suitable for the production of metallic aluminum.

Another spur of the hill, to the north of the bauxite deposit, shows only indurated kaolin, or "chimney rock." The deposit is at the same elevation as that on the Underwood property, and is of very similar character.

DUPREE PROPERTY

(Map locality W-9)

The property of J. T. Dupree consists of lots 44, 45, and 46, 4th district, 4½ miles in a straight line northwest of Irwinton, and 2 miles south of Claymont station on the Central of Georgia Railway.

Although all bauxite known on the property is of low grade, it is of special interest from a geologic viewpoint because the relations of kaolin, bauxite, and fullers earth are exposed in a single section.

About 70 feet below the level of the Dupree residence is the top of the Cretaceous beds. The upper portion of the Cretaceous is made up of kaolin, varying from pure, white, plastic clay to various stained, nodular, and more or less indurated varieties. The indurated clay beds or lenses outcrop at numerous localities throughout the area of the property. The material is usually a little harder than chalk, and contains fine to coarse clayey pisolites, no harder than the matrix. Some fragments of good bauxite have been found in the soil over or near these indurated clay beds, but the small amount of prospecting done has failed to disclose any deposits of importance.

The best exposures are along the course of a small branch in the southern part of the property, where the following section is shown:

Section along branch, Dupree property

Eocene
Jackson group
Barnwell formation

	Feet
8. Yellow clayey sand, in head of the gully.........	10
7. Yellow-gray, sticky, plastic clay....................	
6. Occasional outcrops of fullers earth, mostly of good quality, but contains some sandy layers. Possible thickness	45
5. Red-and-blue mottled sandy clay with a thin basal conglomerate containing small pieces of kaolin and bauxite and small, well-rounded quartz pebbles.	
(Unconformity)	

Lower Cretaceous

4. White, massive, slightly indurated kaolin on one side of the branch; on the other side, soft, finely nodular, light colored, sandy bauxite.
3. Soft red bauxite, consisting of red pisolites or pebbles in a white, sandy matrix. The bed has a maximum thickness of at least 10 feet, and grades upward into light colored, slightly indurated clay with scattered soft nodules.
2. White kaolin, plastic and free from grit. Between 2 and 3 feet exposed, but the thickness is probably considerably greater.
1. Light colored kaolinic sand, with interbedded layers of white clay breccia.

The relations of the beds are shown in figure 4.

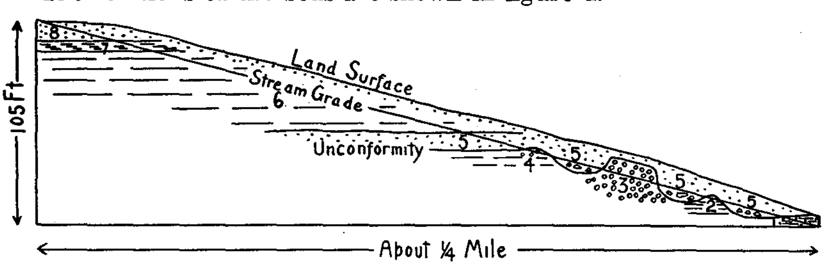


Fig. 4.—Section along branch, Dupree property, Wilkinson County, showing relation of bauxite, kaolin, and fullers earth. Numbers in the section refer to beds described in the text.

The bauxite of bed No. 3 is of an unusual type. It is both ferruginous and siliceous, as shown by the following analysis of an average sample from a pit beside the branch:

Analysis of red bauxite from Dupree property

	S-49
Silica (SiO_2)	22.10
Alumina (Al_2O_3)	45.96
Ferric oxide (Fe_2O_3)	7.77
Ignition	22.05
Titanium dioxide (TiO_2)	1.37
	99.25
Moisture	1.14

The "pisolites" are dark red. Many are perfectly round and about the size of buckshot, others are irregular in shape and an inch or more in diameter. The outside of these nodules or pebbles shows traces of botryoidal structure, but the interior structure is not concretionary. They appear to be water worn pebbles around which a thin shell of limonitic material has been deposited. The interior of the pebbles is usually made of angular grains of soft white material, easily cut with a knife, and of bauxitic or halloysitic nature, surrounded by red bauxite which has the appearance of limonite, the whole being cut by later veinlets of a white, translucent mineral. The matrix is almost white, and is made up largely of grains of quartz sand, with a little white mica, cemented by bauxitic material. Although quartz is so abundant in the matrix, sand grains within the pebbles are rare, which suggests that the two materials were transported and deposited together by the action of water. The distance of transportation, however, may have been very small.

A pit in the bank of the stream shows 5 feet of this material. Another pit, about 4 feet deep is at the top of the bank, 10 feet above the level of the stream. This pit shows that the red bauxite grades upward into a white, slightly indurated clay with large scattered nodules.

The base of the bauxite bed can not be seen, as the unconformity cuts down below the level of the branch. The next exposure of the Cretaceous, 7 feet lower, is very pure, white, plastic kaolin.

JONES PROPERTY

The property of W. A. Jones, of Gordon, adjoins the Dupree property on the southeast.

A deposit of hard red bauxite occupies the top of a small knoll, and probably underlies an area of 10 acres. The thickness of the bed apparently does not exceed 2 or 3 feet. The one test pit which penetrates the bed shows only 8 inches of hard red bauxite, underlain by 3 feet of light colored bauxitic clay. At lower points on the property are exposures of plastic, non-bauxitic kaolin.

The red bauxite is similar to that on the Dupree property, previously described, but it is much harder. Fragments found on the surface are harder than the bauxite in the pit. The hardening is probably due to weathering effects at or near the surface, at depth the material may become soft. A great deal of the superficial rock has been used locally for chimneys and foundations.

Analyses of red bauxite from the Jones property

Constituents	1	2	S-52
Silica (SiO_2)	12.50	20.25	25.35
Alumina (Al_2O_3)	49.60	40.43	38.20
Ferric oxide (Fe_2O_3)	15.40	17.06	16.71
Ignition	19.83	19.77	17.73
Titanium dioxide (TiO_2)	2.35	1.49	1.83
	99.68	99.00	99.82
Moisture		1.25	1.40

1. Hard lump bauxite, analyzed for Pennsylvania Salt Manufacturing Company, at Natrona, Pennsylvania.
2. Veatch, Otto, Geol. Survey of Ga. Bull. 18, p. 446, 1909.
S-52. Sample from 8-inch bed of hard red bauxite in test pit.

McNEAL PROPERTY

The bauxite deposit on the property of J. R. McNeal is situated west of that on the Jones property, across a small valley.

The occurrence is similar to that just described. An area of a number of acres is strewn with fragments of hard red bauxite, some of which must have been derived from a bed at least 3 feet thick. Analyses show a composition very similar to the Dupree and Jones deposits..

Anaylsis of red bauxite from the McNeal property[1]

Silica (SiO_2)	17.97	16.02
Alumina (Al_2O_3)	43.12	43.98
Ferric oxide (Fe_2O_3)	18.73	15.43
Ignition	17.30	20.89
Titanium dioxide (TiO_2)	2.72	1.89
	99.84	98.21
Moisture	2.65	2.79

Occasional fragments of hard, flinty, high grade bauxite are found, but none has been discovered in place. A pit 16 feet in depth, below the level of the main bauxite bed, was filled with water when visited, but the dump shows that the material penetrated was mostly porous, chalky, mealy or indurated clay, with at least one bed of red bauxite.

BUTLER PROPERTY

A small tract of land north of the McNeal deposit is owned by Judge Butler, of Irwinton. Several shallow pits have been sunk, showing only yellowish, slightly bauxitic clay, with occasional soft, light colored nodules.

SHEPPARD PROPERTY

The property of J. M. and J. J. Sheppard adjoins the Jones and Dupree places on the southeast.

The deposit differs from the others of the vicinity, as the bauxite is light colored. An area of a number of acres in the valley bottom is strewn with fragments of indurated clay and bauxite, some of the latter being of the high-grade pisolitic variety with flinty matrix.

There is one pit from which a carload of ore was shipped by

[1] Veatch, Otto, Geol. Survey of Ga. Bull. 18, p. 446, 1909.

Hatfield Brothers, of Irwinton. An average sample of the bed exposed in the pit, 4 feet in thickness, gave the following analysis:

Analysis of bauxite from the Sheppard property

	S-87A
Silica (SiO_2)	25.06
Alumina (Al_2O_3)	49.33
Ferric oxide (Fe_2O_3)	2.09
Ignition	21.30
Titanium dioxide (TiO_2)	2.00
	99.78
Moisture	.29

This bauxite is not nodular, but consists of irregular or shell-like, white, flinty concretions in a soft, granular, gray matrix. There is a little iron stain along fractures. The pit is at the foot of a gentle slope, so the overburden will not increase rapidly.

There is another pit, 150 feet east of the preceding, which shows 5 feet of very similar material. There are small lenses, usually about one foot thick and a few feet in extent, of high-grade bauxite, but the indications are that it would be difficult to mine ore containing over 50 per cent of alumina.

The Sheppard, Jones and Dupree properties have been prospected by Maynard and Simmons, engineers, of Atlanta.

COLUMBIA KAOLIN AND ALUMINUM COMPANY

(Map locality W-10)

The property formerly owned by Mrs. Z. T. Miller has been purchased by the Columbia Kaolin and Aluminum Company, Walter Swindell, of Washington, D. C., being president. The location is 3 miles south of Gordon, and a tramway from Gordon was under construction during the summer of 1916. The intention is to mine both bauxite and kaolin.

A large area, at least half a mile in length, is strewn with fragments of indurated kaolin, and numerous small outcrops occur. Several shallow pits cut more or less indurated clay with scattered nodules.

Half a mile south of the public road is a hill 50 feet high, the south and west sides of which are strewn with fragments of hard, high grade, flinty bauxite, resembling that of the Adkins and J. U. Parker properties. A trench 120 feet long, with a maximum depth of 20 feet has been dug in the southwest slope of the hill. The relations of the beds exposed in the cut is shown in the accompanying sketch (fig 5).

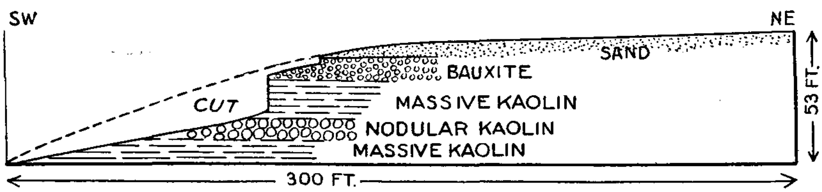


Fig. 5.—Section on property of the Columbia Kaolin & Aluminum Co., Wilkinson County, showing relation of bauxite to kaolin.

The knoll seems to be due to the influence of the lens of resistant bauxite. The following is the analysis of an average sample from the 8-foot bed of bauxite exposed in the trench.

Analysis of bauxite from the Columbia Kaolin and Aluminum Company property

	S-98
Silica (SiO_2)	10.92
Alumina (Al_2O_3)	57.29
Ferric oxide (Fe_2O_3)	1.13
Ignition	28.69
Titanium dioxide (TiO_2)	1.99
	100.02
Moisture	.68

This analysis shows an ore of good quality for the manufacture of alum. The quantity is not large, as the bed, 8 feet thick, underlies a possible area of only an acre or two.

The overburden consists chiefly of argillaceous red sand, and will not exceed a thickness of 10 feet at any point.

Indurated and nodular clay is found on the property of J. W.

Batchelor, Jr., and at other places in the vicinity of the Columbia Kaolin and Aluminum Company's property.

R. L. STUBBS PROPERTY

(Map locality W-11)

Bauxite occurs on the property of R. L. Stubbs, near Oconee River, about 9 miles north of Toomsboro. The occurrence has been examined by H. C. Parker, who states that bauxite boulders are found on the surface, but no bedded deposit has been discovered. The ore is finely pisolitic and of good quality, as shown by the following analysis of a sample taken from loose boulders:

Analysis of bauxite from R. L. Stubbs property

	S-249
Silica (SiO_2)	13.52
Alumina (Al_2O_3)	57.19
Ferric oxide (Fe_2O_3)	.48
Ignition	27.00
Titanium dioxide (TiO_2)	2.07
	100.26
Moisture	.09

BALDWIN COUNTY

ETHRIDGE PROPERTY

(Map locality Ba-1)

On the property of J. I. Ethridge, 2 miles northeast of Stevens Pottery, is an occurrence of bauxite. An area of several acres on the north slope of a hill is strewn with float ore. A shallow pit at an altitude of 410 feet (aneroid reading), cuts only Tertiary sand. A second pit, 10 feet lower, cuts a foot of bauxite, with hard nodules predominating over the softer matrix, and grading down into iron stained kaolin. A third pit, 10 feet below the second, cuts a foot of clayey bauxite with hard nodules, also grading down into stained kaolin.

The ore found on the surface is hard, white, and apparently of good quality. The structure is coarsely pisolitic, with simple nodules over half an inch in diameter. The quantity in sight is too small to be of commercial value, but the quality is good, and it is not impossible that a workable bed might be found by more careful prospecting.

TWIGGS COUNTY

The Lower Cretaceous strata are exposed in all valleys in the northern part of Twiggs County, but up to the present no bauxite likely to be of commercial value seems to have been discovered. At Myrick Mill on Big Sandy Creek, in the northesatern part of the county, is a bed of indurated, nodular clay which has superficial appearance very much like bauxite, but low alumina content. A part of the kaolin in the mine of the Georgia Kaolin Company is very slightly bauxitic.

Southwest from Twiggs County to Chattahoochee River the kaolin beds become less extensive, and no trace of bauxite is known.

WASHINGTON COUNTY

The area of bauxitization of the Cretaceous kaolin extends from Wilkinson County across the Oconee River into Washington County near Oconee station.

On the property of Dr. L. A. Grable and on the Elkins estate (Map locality Wa-1), 1 to 2 miles southwest of Sheppards Bridge over Buffalo Creek, are a number of exposures of more or less bauxitic, nodular and indurated clays. A few test pits have been dug, but no bauxite of workable grade has been found. Nevertheless, the area between Buffalo Creek and the Oconee River is worthy of careful examination.

Northeast from this point to Augusta there are abundant exposures of Cretaceous kaolin, but traces of bauxitization were noted at only one point. In the lower portion of the kaolin bed at the plant of the Albion Kaolin Company, near Hephzibah, Richmond County, are a few scattered, hard nodules of bauxitic material.

MIDWAY BAUXITE DEPOSITS

GEOLOGY OF THE MIDWAY AND WILCOX FORMATIONS[1]

Areal distribution.—The Midway occurs in a narrow belt, extending from Fort Gaines on Chattahoochee River to Montezuma on Flint River, and thence a short distance into Houston County. The average width of the belt is 8 to 10 miles. It is the surface formation over portions of Clay, Quitman, Stewart, Randolph, Marion, Schley, Webster, and Macon counties. The Wilcox formation extends from the vicinity of Fort Gaines to Flint River in the northeastern part of Sumter County. The width of the belt of outcrop is on the average perhaps not more than 5 or 6 miles.

Stratigraphic relations.—The Midway formation rests unconformably upon the Upper Cretaceous. No conclusive physical evidence of an unconformity representing a considerable time interval between the Cretaceous and Midway has yet been discovered in Georgia, but there is paleontologic evidence that this interval is as great as in adjoining States. Irregular contacts that appear to represent erosion unconformities between the two divisions were noted, especially in the gullies north and west of Lumpkin, Stewart County. The strata of the basal Midway and the Upper Cretaceous seem to be lithologically similar and on account of the inadequate exposures considerable difficulty is experienced in determining the exact location and nature of the contact.

The Wilcox formation includes the strata lying between the Midway and the Claiborne. At Fort Gaines the Wilcox and the Midway are separated by a remarkable erosion unconformity, represented by holes in the white limestone of the Midway formation filled by black sandy clay of the overlying formation. Paleontologic and lithologic differences and the erosion unconformity furnish a sufficient basis for the separation of the formations at Fort Gaines. East of this locality, however, the paucity of the fossils, the fact that no unconformity could be discovered, and the unsatisfactory character of the

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[1] Abstracted from Geol. Survey of Ga. Bull. 26, pp. 216-235, 1911.

evidence furnished by the lithologic composition of the strata, has rendered the discrimination of the two formations very difficult; therefore, the boundary line as mapped is necessarily tentative.

Lithologic characters.—The Midway is mainly a marine formation and consists of sands, clays, marls, and limestones. Much of the sand, however, has a fresh-water aspect. The lower part of the formation consists principally of sands and clays and the upper part consists of marls, clays, and limestones, but there is such variety in the character of the sediments that sharp lines of division based upon lithology can not be drawn. Thin layers of flint interbedded with sands and clays were noted in the lower part. The sands are vari-colored, generally friable, and in several places contain lenticular, massive layers of white clay. In the lower part of the formation limonite is rather widely distributed in the sands in the form of thin crusts and as hollow concretions having black, polished, and botryoidal interiors. The limestones are fossiliferous, usually very hard and generally highly arenaceous. Friable marl, made up of glauconite, quartz sand, clay, and shells occurs, and also laminated, black clay, and fullers earth. The limestones are conspicuous at several localities and are more abundantly fossiliferous than other parts of the formation. Individual beds of limestone in natural exposures are thin, from 2 or 3 to 25 feet in thickness, and are interbedded with clays, marls, and sands. Sands and clays make up by far the greater part of the beds. The lithologic character and the character of the fossils indicate a very shallow water deposition for the whole formation.

The Wilcox formation on Chattahoochee River is made up of sandy, glauconitic shell marl, dark colored, laminated, often lignitic, sandy clay, in places consolidated into mudstone, and usually dark or gray glauconitic and lignitic sand. The laminated clay exposed in the bluff at Fort Gaines can be traced northeastward, having in Randolph County north and west of Cuthbert the nature of fullers earth, which is locally glauconitic. Farther eastward in Schley and Macon counties and in the vicinity of Andersonville, the strata which might be referred to this formation on the basis of geographic position are mainly red and vari-colored sands with massive beds of white clay, very pure and in the nature of sedimentary kaolin, bearing little resemblance to the strata on Chattahoochee River.

As a result of later investigations, these kaolin-bearing beds are believed to belong to the Midway formation, while the carbonaceous and pyritiferous beds of Copperas Bluff represent the Wilcox.

Thickness.—The thickness of the Midway on Chattahoochee River was estimated by Langdon[1] at 218 feet. The width of the outcrop on Chattahoochee River is about 8 miles and it is believed that Langdon's estimate is nearly correct, but it is probably excessive rather than too small. The thickness of the whole Midway northeastward is probably greater, and while it can not be accurately estimated, is about 300 to 400 feet. The width of the outcrop on Flint River is about 15 miles and it is not believed that an estimate of 400 feet is excessive. As recorded dips of the strata are variable, individual beds not continuous, and only a few well data available, no accurate estimate is possible.

It seems very probable that Langdon's estimate of 402 feet for the thickness of the Wilcox is excessive, in view of the small thickness of the formation at Fort Gaines, and from the fact that Vaughan has determined *Exogyra costata* from the Blakely well at a depth of 500 to 510 feet. The thickness of strata between the Claiborne and the Midway formations at Fort Gaines does not exceed 75 feet. It is difficult to form an accurate estimate of the thickness of the Wilcox formation as is true also of the Midway formation, for east of Chattahoochee River neither the base nor the top of the formation has been accurately established. There is a natural exposure of the formation revealing an estimated thickness of 100 feet of strata at Peterson Hill, 4½ miles northwest of Cuthbert. The maximum thickness at any place over the area of outcrop probably does not exceed 150 or 200 feet. There is no positive proof of strata of Wilcox age on Flint River. They may be entirely overlapped by the

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[1] Langdon, D. W., Geology of the Coastal Plain of Alabama: Geo. Survey of Ala., p. 369, 1894.

Claiborne, but assuming that the strata lying between the Midway formation at Dripping Bluff and the Claiborne or Jackson formations is Wilcox, the thickness is perhaps 100 feet. Considering the kaolin-bearing beds to be Midway, the thickness remaining for the Wilcox formation is even less than this estimate.

Both the Midway and Wilcox formations have a gentle dip to southeast, amounting to only a few feet per mile. On account of the slight inclination and the inconstancy of individual beds, it is not possible to make direct measurements of the strike and dip.

Physiographic expression.—The topography of the area underlain by these formations is rather broken and hilly, somewhat similar to the Cretaceous area to the northward, and in contrast with the level topography of the areas to the southward underlain by Upper Eocene and Oligocene strata. A few limesinks occur in the vicinity of Fort Gaines and north of Cuthbert.

Paleontologic characters.—Both formations are poorly fossililerous. Thirteen invertebrate forms and one vertebrate (a turtle) have been reported from the Midway. Thirteen invertebrates make up the entire known fauna of the Wilcox. These fossils are found only in the limestone and chert beds, and are therefore of little value in correlating the kaolin and bauxite deposits.

Location and age of the bauxite deposits.—The bauxite deposits of the Lower Eocene are associated with a horizon of plastic to indurated and nodular, white, sedimentary kaolin and white kaolinic and micaceous sand which extends from Flint River in northern Sumter County through Macon County and the eastern part of Schley County. The kaolin beds of this horizon cap the hills near Ideal, Macon County, and dip beneath the level of Flint River a little below Copperas Bluff, Sumter County. During the time of formation of these beds the depositional conditions were practically identical with those which existed during the Lower Cretaceous period.

The exact age of the kaolin and bauxite deposits can not be stated with certainty. Along Chattahoochee River two Lower Eocene formations, the Midway and the Wilcox, are exposed, separated from each other and from the underlying and overlying formations by recognizable unconformities. The beds contain sufficient fossils for definite identification. Along Flint River the calcareous and fossiliferous Midway beds have been identified in bluffs near Montezuma, but the presence of the Wilcox formation has not been positively determined by fossils.

White, sedimentary kaolin of sufficient purity for use as fire clay, if not pottery and paper clay, are recognized in both Midway and Wilcox formations. It is probable, although not absolutely certain, that all of the bauxite-bearing beds west of Flint River belong to only one of these formations. These beds overlie the fossiliferous Midway beds, but are not known to be separated from the latter by an unconformity. Like the Lower Cretaceous beds, the kaolin and associated sands are free from fossils. The bauxite and kaolin are overlain with marked unconformity by crossbedded red and white sand in the Sweetwater mine, and by the pyritiferous, sandy clay which forms the "copperas bed" in Copperas Bluff. The former of these exposures of the unconformity was not opened up, and the latter seems not to have been recognized by the authors of the Coastal Plain report. In this report these formations are classified respectively as Midway and Wilcox, although it is admitted as a possibility that the kaolin and bauxite may belong to the Wilcox and the overlying sands to the Claiborne formation.

The bauxite deposits are in the form of rather small lenses in the kaolin, and are confined to the valleys of Sweetwater, Camper, and Buck creeks. The ridges between the creeks are capped by sand formations, so the likely places for prospecting are the middle and lower slopes of the valleys of the creeks and larger branches. East of Flint River no bauxite has been found, and the probability of its discovery is slight, because the Wilcox formation and the upper part of the Midway have been removed by erosion, or are overlapped by latter deposits. Both formations disappear in Houston County. To westward the area in which bauxite may occur is not limited, but none has yet been discovered beyond the eastern part of Schley County, excepting at one locality in Stewart County.

In general, all occurrences of white kaolin are likely to contain deposits of bauxite, especially if the kaolin is indurated or has nodular structure. Bauxite is invariably associated with kaolin.

DESCRIPTIONS OF INDIVIDUAL DEPOSITS

SUMTER COUNTY

SWEETWATER MINE

(Map locality S-1)

Location.—The mine is situated near the center of lot 187, 1½ miles west of Flint River, on the south slope of the valley of Sweetwater Creek, which here forms the boundary between Sumter and Macon counties. It is 5½ miles by road from Andersonville, the nearest railroad station, but only 3½ miles from Republic Spur, on the Central of Georgia Railway, where the ore is loaded.

The deposit was discovered and explored in 1912 by L. M. Richard, and mining operations were started in May, 1914. The mine is operated by the Republic Mining and Manufacturing Company, G. H. Harris being the superintendent.

Geologic relations.—The bauxite has the form of a true bedded deposit, conformable with both underlying and overlying strata. The section exposed in the working face in November, 1914, is shown in the accompanying sketch (fig. 6).

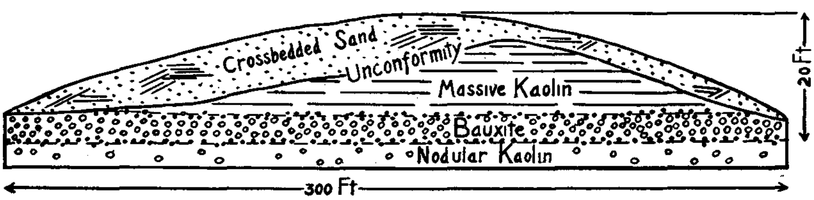
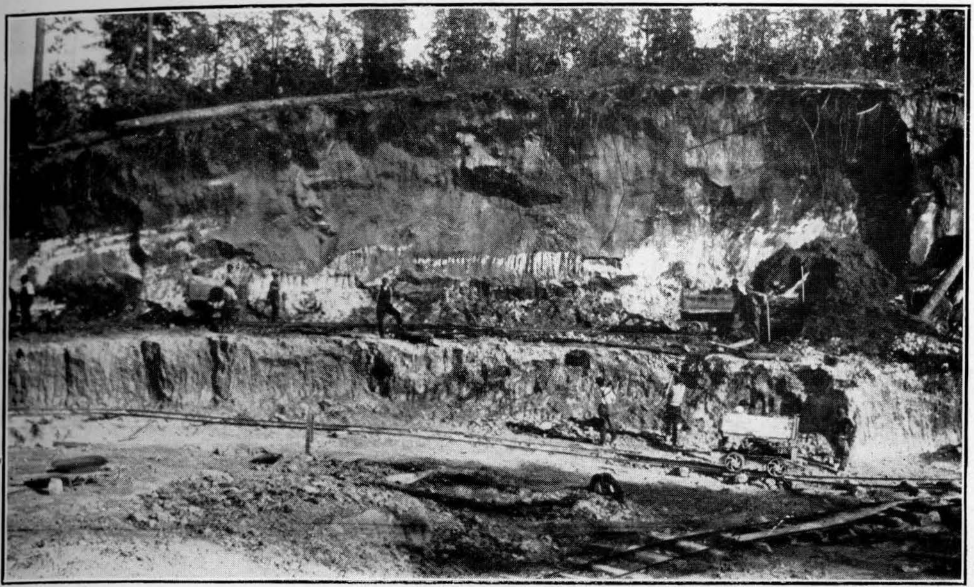


Fig. 6.—Working face in Sweetwater mine, Sumter County, showing relation of bauxite to kaolin.

Section in Sweetwater bauxite mine

	Feet
Recent	
7. Sandy soil	1 to 2
Wilcox formation	



A. WORKING FACE IN SWEETWATER BAUXITE MINE OF THE REPUBLIC MINING & MANUFACTURING CO., SUMTER COUNTY. NOVEMBER, 1914.

B. WORKING FACE IN SWEETWATER BAUXITE MINE OF THE REPUBLIC MINING & MANUFACTURING CO., SUMTER COUNTY. NOVEMBER, 1914.

6. Red and yellow, clayey sand and very pure, white sand, interbedded and crossbedded....	2 to 30
(Unconformity)	
Midway formation	
5. White, plastic kaolin. The maximum overburden at the time of examination was 30 feet, and the greatest thickness of kaolin was 20 feet, reaching almost to the surface at one point. For 2 or 3 feet below the unconformity the kaolin was stained and mottled with red and purple, but the lower part of the bed was pure and exceptionally free from grit......	0 to 20
4. Gradational phase, consisting of soft clay with small, soft nodules; contains also a few ferruginous concretions filled with soft granular material consisting of sulphur, marcasite, and various sulphates........................	1
3. Bauxite	5 to 6
2. More or less stained bauxitic kaolin, grading downward into non-bauxitic clay............	?
1. Covered interval to level of the creek..........	20+

The elevation of the bauxite bed is 300 feet above sea level by aneroid measurement, which is approximately 100 feet below the railroad grade at Andersonville.

In July, 1916, an area of 6 or 8 acres had been worked out giving a working face about 200 yards along. The section exposed remained about the same as that described, but the maximum overburden had increased to 45 feet, while the greatest thickness of the kaolin overlying the bauxite had decreased. The kaolin in sight was stained and not of as good quality as the thicker portion already stripped off and thrown away.

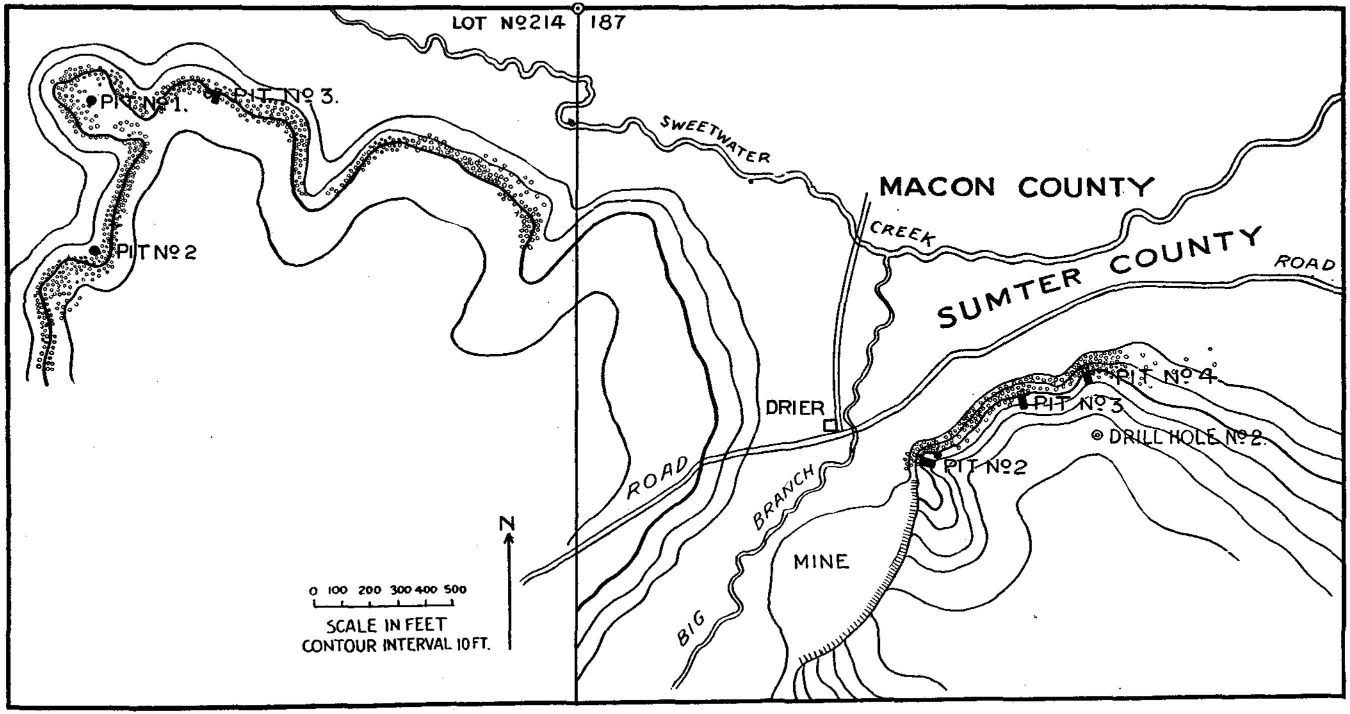


Fig. 7.—Sweetwater mine and Thigpen lot, Sumter County, showing distribution of bauxite deposits. *Map by L. M. Richard.*

The accompanying map, figure 7 (after Richard), shows the extent of outcrop of the bauxite lens and its relation to the topography. Actual outcrops of the bedded ore are uncommon, but pits and borings together with the bauxite fragments in the soil show that the bed is continuous around the slope, the distance between the most widely separated exposures being 1300 feet.

In 1916 the working face, 200 yards long, cut across the end of the hill in a northeast-southwest direction. The average overburden was at least 30 feet, and the ore bed varied between 5 and 6 feet in thickness, except at the edge where it had been partly cut away by the unconformity.

At pit No. 2 a little stripping had been in preparation for starting mining. There is here from 3 to 4 feet of workable ore, overlain by plastic kaolin and grading downward into bauxitic clay.

At pit No. 3 the bauxite is also overlain by kaolin. Only 1 foot of ore is in sight; this, however, does not represent the entire thickness of the bed.

Pit No. 4 shows 4 four feet of workable ore, which is apparently not the entire thickness. The bauxite is overlain by kaolin.

Drill hole No. 2 is said to have penetrated bauxite 8 feet thick at a depth of 45 feet.

The bed of ore is horizontal and shows only slight variations in thickness. The greatest thickness in the portion of the mine already worked out was 7 feet, while the maximum reported in borings is 8 feet. The thickness in the working face when last visited was a little less than formerly, the average being about 5 feet and the maximum only 6 feet. Near the center of the face the ore thins to 4 feet on account of a rise in the underlying clay, the upper surface remaining horizontal. The mass of clay forming the rise is finely nodular and iron stained. Above it the ore shows banding, produced by iron stains, at various angles, but the red bands do not enter the nodules. This banding appears to be original, and formed by the currents which deposited the ore. The rise in the base of the ore is circular and about 100 feet in diameter. This may mark the inlet of the original source of the mineralizing solutions (hot or acid spring), but unfortunately the structure of the underlying clay can not be seen.

The ore.—The best portion of the ore makes up a bed 3 or 4 feet thick. It is hard and conglomeratic in appearance, consisting of nodules of rather irregular shape, varying in size up to 1½ inches, in a softer matrix which is locally iron stained. The volume of the nodules or pebbles is considerably greater than that of the matrix. When broken the nodules are seen to be compound, made up of hard, light gray, flinty material containing lighter colored and softer pisolites.

The bauxite grades into white kaolin both upward and downward. The upper gradational phase is thin, and the distance separating hard bauxite and plastic kaolin without nodules is only 1 to 2 feet. The lower gradational clay is more coarsely nodular and extends through a much greater distance, the clay being bauxitic for some feet below the floor of the mine.

The following series of analyses shows the gradation, from the overlying kaolin down to the base of the workable portion of the bed.

Analyses of bauxite from Sweetwater mine

Constitutents	S-109	S-110	S-111	S-112	S-113	S-114	S-115	S-116	S-117
SiO_2	34.31	23.18	16.18	9.08	5.46	6.00	8.84	14.28	22.79
Al_2O_3	44.18	49.55	54.58	57.13	58.82	58.06	58.38	55.64	51.48
Fe_2O_3	.81	2.28	.99	2.42	2.72	2.73	1.30	1.32	1.14
FeO	.29	.14	.29	.29	.14	.14	.14	.28	.14
MgO	.00	.02	.00	.04	.00	.00	.06	.00	.03
CaO	.00	.00	.00	.00	.00	.00	.00	.00	.00
Na_2O	.06	tr.	.00	tr.	.00	.00	tr.	.00	tr.
K_2O	.08	tr.	.00	tr.	.00	.00	tr.	.00	tr.
Ignition	18.16	23.28	25.58	27.75	30.26	30.21	29.25	26.84	22.58
TiO_2	1.82	1.81	2.74	3.08	2.72	3.07	1.80	1.81	1.81
Total	99.71	100.26	100.36	99.79	100.12	100.21	99.77	100.17	99.97
Moisture	.77	.72	.73	.67	.91	.40	.06	.44	.39

These samples were taken from a vertical working face at one foot intervals. Sample S-111 is from the top of the hard ore bed; S-110, from the soft but nodular clay one foot above S-111; S-109, one foot higher than S-110, is white plastic kaolin, shown by analysis to be slightly bauxitic, although it shows no trace of nodular structure. Samples S-111 to S-117 are from the face of ore as worked. The average of these samples from the ore bed is as follows:

Average analysis of seven samples from working face Sweetwater mine

Silica (SiO_2)	11.80
Alumina (Al_2O_3)	56.30
Ferric oxide (Fe_2O_3)	1.80
Ferrous oxide (FeO)	.20
Magnesia (MgO)	.02
Lime (CaO)	.00
Soda (Na_2O)	tr.
Potash (K_2O)	tr.
Ignition	27.50
Titanium dioxide (TiO_2)	2.42
	100.04
Moisture	.51

Near the edges of the deposit, where the overlying impervious bed of kaolin has been cut away by the unconformity, the ore is badly stained by iron deposited from water percolating through the red sand. In the central part of the lens, however, the bauxite shows no sign of alteration by weathering.

In the southwest end of the pit a mass of bauxite containing considerable pyrite was encountered. The pyrite occurs principally within the nodules, sometimes in crystals visible to the naked eye, but mostly so finely divided as to appear only as a gray stain. Microscopic examination shows that the pyrite occurs as small cubes and octahedra forming the nuclei of the smaller oolites, as veinlets filling fractures in the pisolites, and as very fine, disseminated grains. (See detailed description, p. 101 and Pl. X, A, B and C.)

The quantity of pyrite is sufficient in some places to give determinations of over four per cent ferric oxide, or more than is contained in the red-stained bauxite around the edges of the deposit.

The ore in the southwest part of the face is becoming more clayey, and appears to be grading into kaolin. On this account the average grade of ore is not quite so high as in the earlier part of the work.

Development and methods.—The mine and other pits have been previously described. Two trestles lead from the mine and pit No. 2 across the valley of Big Branch to the drier.

All work, both mining and stripping, is done by manual labor, although this is apparently not the most economical means of handling an overburden which averages 30 feet of soft material over a large area. A little blasting is done to loosen the overlaying kaolin, but this would probably not be necessary if steam shovels were used. The overburden is dumped into the valley of Big Branch and into the worked-out part of the pit.

A small amount of ore around the edge of the pit is mixed with the superficial sand and clay. This portion is passed over a screen of one-fourth inch mesh, that passing through the screen being rejected. Some bauxite is lost by this method, but the quantity of such ore is so small that it would not pay to install a washer. Most of the ore goes to the drier without any preliminary treatment.

All of the ore is put through a rotary drier, 30 feet long and 3 feet in diameter, which is heated by a wood fire. This removes all of the hygroscopic and a part of the combined water, bringing the percentage of alumina up to between 58 and 60 per cent.

The dried ore is hauled to the railroad with a four-ton motor truck, which is able to make, in dry weather, one round trip per hour, or ten trips a day.

Most of the ore contains less than two per cent of ferric oxide, and is used principally in the manufacture of alum and other aluminum salts. The ore carrying more than two per cent of ferric oxide is used in making aluminum.

Tonnage estimate.—The outcrop of ore has a length of 1300 feet, so the deposit may safely be assumed to have the form of a half cir-

A. SWEETWATER BAUXITE MINE AND DRIER OF THE REPUBLIC MINING & MANUFACTURING CO., SUMTER COUNTY.

B. CLOSE VIEW OF BAUXITE DRIER AND STORAGE BIN, SWEETWATER MINE.

cular lens of that diameter. Assuming an average thickness of four feet and 15 cubic feet of ore per ton, the tonnage would be 175,000. This is a reasonable estimate of the amount of ore in the deposit, but it may not all be available, because the overburden reaches a thickness of 60 feet over a part of the assumed area.

The production of the mine recently has been about 1,000 tons per month.

THIGPEN LOT
(Map locality S-2)

Lot 214, known as the Thigpen lot, lies west of lot 186. Sweetwater Creek crosses the northeastern corner of the lot, but all of the bauxite is on the south, or Sumter County, side of the creek. The Republic Mining and Manufacturing Company has the refusal of the deposit, but no mining has yet been done.

The bauxite deposit lies across the valley of Big Branch from the Sweetwater mine, and at the same altitude. There is a possibility that the two deposits may have been continuous before the valley was cut.

Outcrops or indications of bauxite in the form of nodules and boulders in the soil are found for a distance of 3,000 feet around the contour of the hill, while a straight line joining the ends of the exposures measures 1,750 feet.

Pit No. 1 (See map, fig. 7) is at the summit of a small knoll, which is covered with blocks of hard bauxite. The pit exposes 5 feet of bauxite, overlain by only a few inches of sandy soil. The ore is hard at the top, becoming softer and more clayey, with small and scattered, but hard, nodules toward the bottom. It appears to be rather badly iron-stained, on account of the lack of impervious overburden, although the iron content is really low. An average sample of the 5-foot bed was taken for analysis.

Analysis of bauxite, pit No. 1, Thigpen lot

	S-118
Silica (SiO_2)	8.30
Alumina (Al_2O_3)	57.45

Ferric oxide (Fe_2O_3)	1.77
Ignition	30.01
Titanium dioxide (TiO_2)	2.72
	100.25
Moisture	.58

Pit No. 2 is across the old plantation road, 800 feet southeast of Pit. No. 1.

Section in pit No. 2 Thigpen lot

	Feet
3. Yellow clay soil	2
2. Finely nodular white clay, like that overlying the bauxite in Sweetwater mine	1
1. Bauxite	4

The bottom of the pit was filled with water at the time of examination, so the bauxite may be thicker than indicated by the section.

Pit No. 3 is a cut in the hillside northeast of No. 1, showing 4 feet of bauxite.

Although the ore body has not been very thoroughly explored, the ore seems to be of approximately the same grade as that on lot 187. The location is more favorable for working than at the Sweetwater mine, as the maximum overburden is less than its increase on working back from the outcrop will be more gradual. The outcrop is more extensive than at the mine, but the bed seems to be thinner, and its continuity throughout the area between outcrops is somewhat doubtful.

EASTERLIN MINE

(Map locality S-3)

The property of B. F. Easterlin of Andersonville comprises nine land lots, but bauxite is known to occur only on lot 277, on the south side of Sweetwater Creek, 3½ miles from Flint River and 3.8 miles, by road, east of Andersonville, the shipping point. The deposit has been known since 1912, but continuous mining was not started until March, 1916. The mine is operated independently by Mr. Easterlin.

The bauxite outcrop is 30 feet above the level of Sweetwater

Creek, and is a little higher than the deposits on lots 187 and 214. The geologic relations are similar, the deposit being a lens of bauxite in a bed of kaolin.

On account of the hardness of the ore and lack of overburden over a considerable area, the deposit makes a great surface showing. Bauxite caps a small knoll and outcrops around the slope of a hill, as shown on the map (fig. 8), and section (fig. 9).

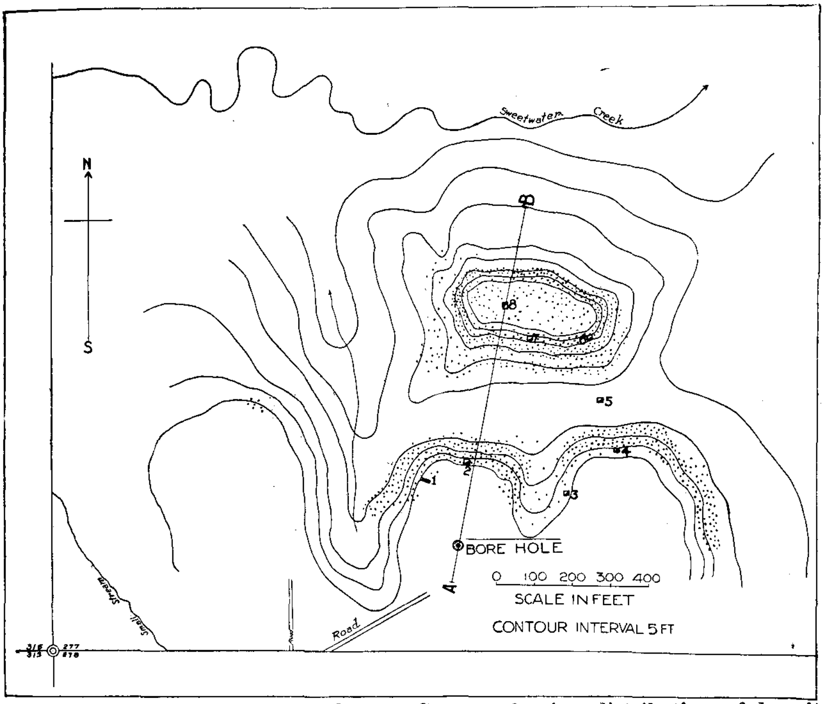


Fig. 8.—Easterlin property, Sumter County, showing distribution of bauxite deposits. Numbered pits are described in the text. *Map by L. M. Richard.*

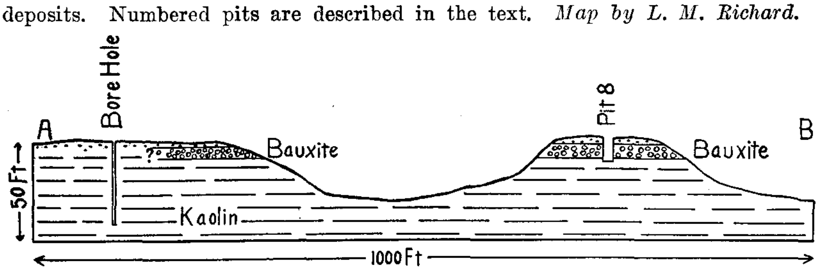


Fig. 9.—Section on Easterlin property, along line A-B, fig. 8.

Pit No. 1, from which 150 tons of ore was shipped some years ago, shows the following section:

Section in pit No. 1, Easterlin property

	Feet
3. Sandy soil	2
2. Hard, finely nodular bauxite with gray, flinty matrix	1½
1. Coarsely nodular bauxite with softer matrix, becoming clayey toward the bottom	2

Analyses of bauxite from pit No. 1, Easterlin property

	S-119	S-120
Silica (SiO_2)	7.63	19.54
Alumina (Al_2O_3)	57.67	49.52
Ferric oxide (Fe_2O_3)	2.89	4.66
Ignition	28.97	23.72
Titanium dioxide (TiO_2)	2.80	2.71
	99.96	100.15
Moisture	.22	.46

S-119—Average of bed No. 2 in above section.
S-120—Average of bed No. 1 in above section.

Pit No. 2 is 4 feet deep, cutting 2 feet of stained, coarsely nodular bauxite, which grades downward into stained, nodular clay.

Pit No. 3 exposes 2 feet of bauxite consisting of hard nodules in a soft, stained, clayey matrix. This ore would probably require washing.

Pit No. 4 shows 1 foot of material similar to that in No. 3.

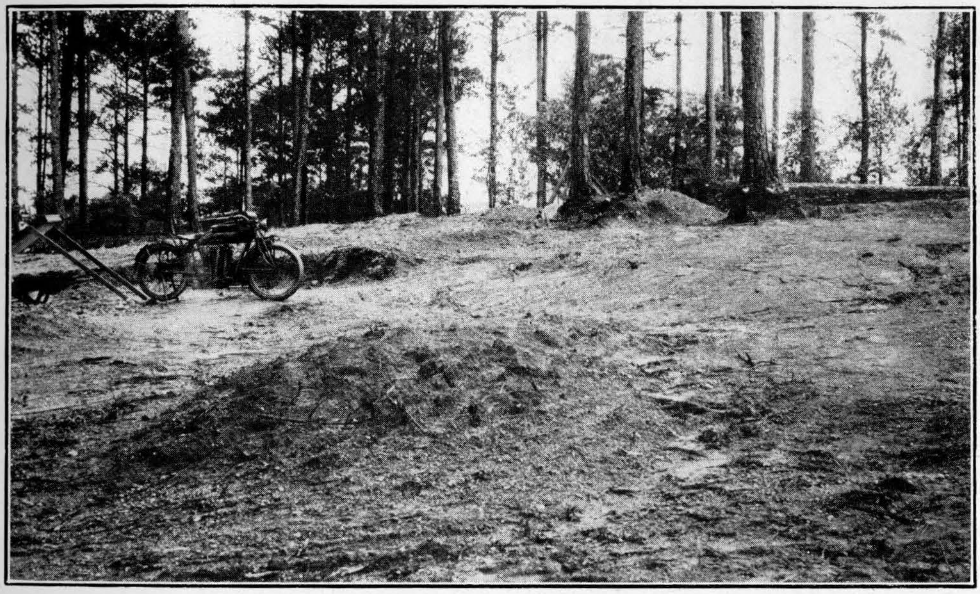
Pit No. 5 is below the bauxite horizon, and cuts only mottled, sandy clay.

Pit No. 6 on the edge of the bauxite knoll, cuts 2 feet of hard red bauxite, underlain by mealy clay of a bright maroon color. Samples were taken from the bauxite and red clay, 6 inches apart.

Analyses of bauxite from pit No. 6, Easterlin property

	S-121	S-122
Silica (SiO_2)	18.29	32.28
Alumina (Al_2O_3)	47.88	38.42
Ferric oxide (Fe_2O_3)	7.39	9.34
Ferrous oxide (FeO)	.32	.32
Magnesia (MgO)	.08	.08

A. EASTERLIN BAUXITE MINE, SUMTER COUNTY. JULY, 1916.



B. EASTERLIN BAUXITE MINE, SUMTER COUNTY. JULY, 1916.

Lime (CaO)	.00	.00
Sodium oxide (Na_2O)	.06	.14
Potassium oxide (K_2O)	.04	.12
Ignition	23.65	16.95
Titanium dioxide (TiO_2)	2.08	2.22
	99.79	99.87
Moisture	.42	.64

Pit No. 7 is also at the edge of the bauxite, showing 1 foot of ore in place, underlain by indurated, maroon colored clay.

Pit No. 8 is at the summit of the knoll, and cuts 4½ feet of workable bauxite, which grades downward into mealy, yellow clay. As in pit No. 1, the upper part of the ore is hard and finely nodular, while the lower part is coarsely nodular, with hard pisolites in a softer matrix.

A boring 200 feet southeast of pit No. 1 penetrated 40 feet of sand and clay, without cutting any bauxite, showing that the extent of the ore lens into the larger hill is small.

The overburden on the knoll is almost nothing, and on the larger hill it will not exceed 12 feet. On account of the light overburden all of the bauxite in the knoll and a large proportion of that around the slope is badly stained by iron carried down by surface water, and a part of the bed had originally high iron content, as shown in pit No. 6. There is little "alum ore," containing less than two per cent of ferric oxide in sight, and it is doubtful if any considerable amount will be found. Besides the high iron content, roots have opened up crevices in the hard ore, which have become filled with sand. This will necessitate washing or screening a large part of the ore.

Up to July 10, 1916, about 1,000 tons of ore had been mined and shipped, all of which was taken from the knoll. There was no real working face in the mine, but the difference in elevation between the highest and lowest exposures of good bauxite was 8 feet. This is greater than the thickness shown in the pit at the top of the knoll, the greater thickness around the edges being apparently due to the creep of masses of ore down the slope. Most of the ore shipped has consisted of boulders and hard nodules obtained by screening the sandy soil. It is shipped without drying or other preliminary treatment except the screening of the sandy portion.

The bauxite exposed in the workings from which the soil has been stripped is coarsely nodular or gravel ore, similar to that of the Sweetwater mine, except that its color tends more to red or yellow. An average sample of bedded ore was taken from a shallow cut in the top of the knoll, and represents approximately the grade being shipped. This ore is high grade with respect to alumina, and the iron content is by no means excessive.

Analysis of bauxite from the Easterlin mine

	S-237
Silica (SiO_2)	5.65
Alumina (Al_2O_3)	60.22
Ferric oxide (Fe_2O_3)	2.42
Ignition	29.50
Titanium dioxide (TiO_2)	1.91
	99.70
Moisture	.90

HODGES PROPERTY

(Map locality S-4)

Bauxite is reported on the property of A. F. Hodges, near the Dixie Highway bridge over Sweetwater Creek, one mile south of Andersonville. A sample, consisting principally of hard pisolites, was sent to the Survey by Mr. Hodges. The analysis is as follows:

Analysis of bauxite nodules from Hodges property

Silica (SiO_2)	4.34
Alumina (Al_2O_3)	60.49
Ferric oxide (Fe_2O_3)	1.13
Magnesia (MgO)	.00
Lime (CaO)	.00
Ignition	31.12
Titanium dioxide (TiO_2)	2.73
	99.81
Moisture	.85

MACON COUNTY

There are two groups of bauxite deposits in Macon County. One group is in the southern part of the county very close to the Sumter County line, along Boggy Branch, a tributary of Camper Creek, and the other is in the central part of the county in the valley of Buck Creek.

KALBFLEISCH CORPORATION PROPERTY

(Map locality M-1)

Two small properties purchased in 1915 by the National Bauxite Company and later transferred to the Kalbfleisch Corporation, of Chattanooga, Tenn., are situated on the south slope of Boggy Branch, 2½ miles north of Andersonville and 1½ miles from the closest point on the Central of Georgia Railway.

The bauxite exposures are found in two spurs of a hill, running north toward Boggy Branch, with a slight valley between. The altitude of the bauxite bed is 360 feet above sea level by aneroid measurement, and from 10 to 15 feet above the surface of the branch.

On the first, or northeast, spur of the hill loose nodules and large blocks of hard bauxite are found in the soil covering a part of the slope. Six test pits have been dug in a cleared field, but these are below the horizon of the bedded bauxite and cut only mealy, stained kaolin. One pit a little higher penetrates the bed of bauxite in place, showing 3 feet of ore which consists of very hard nodules or pebbles, averaging an inch in diameter, in a softer, rather clayey matrix. The composition of an average sample is as follows:

Analysis of bauxite from the National property

	S-123
Silica (SiO_2)	14.47
Alumina (Al_2O_3)	54.57
Ferric oxide (Fe_2O_3)	1.93
Ignition	26.93
Titanium dioxide (TiO_2)	1.63
	99.53
Moisture	.60

The second spur is located about 200 yards southwest. Exploration work shows that the bauxite bed extends for a distance of 200 yards around the slope. Most of the work has been done by boring, but one pit penetrates the thickness of the deposit. The ore resembles that in the Sweetwater mine, consisting of very hard, compound nodules an inch or more in diameter, in a softer matrix, and grades into mealey kaolin both upward and downward. The layer containing hard pebbles is 3 feet thick but the entire workable thickness may be as much as 4 or 5 feet. An average sample taken from 3 feet of the bed showing the best ore gave the following analysis:

Analysis of bauxite from the National property

	S-236
Silica (SiO_2)	18.08
Alumina (Al_2O_3)	52.24
Ferric oxide (Fe_2O_3)	1.62
Ignition	25.73
Titanium dioxide (TiO_2)	1.64
	99.31
Moisture	1.10

Both exposures of bauxite here described may belong to one large lens, or they may represent two smaller lenses, as the development work does not prove the continuity of the ore in the intervening depression. In any case, an area of 3 or 4 acres in the southwest deposit, and probably a little less in the other, is underlain by bauxite, whose thickness is not known to be anywhere more than 4 feet. All of the ore is low in iron but has rather high silica content. The slope of both spurs is steep, the overburden in each reaching a thickness of 40 feet about 100 yards back from the outcrop, and if the deposit is sufficiently extensive, the overburden will increase to 60 feet.

The deposit was opened by the Kalbfleisch Corporation in the spring of 1916, and about 1,000 or 1,200 tons of ore shipped.

ENGLISH PROPERTY

(Map locality M-2)

The property of Charles and Albert English lies on the north slope of Boggy Branch, just opposite the National Bauxite Company's prospects previously described.

The deposit is small, but of fair quality and favorably located with respect to transportation. Exploration work has been principally by borings, so that not much of the deposit is visible, but workable ore 4 to 6 feet thick is said to underlie an area of an acre. The following is an analysis of a sample taken from a pit near the branch, where a 2-foot bed of the best looking bauxite is exposed:

Analysis of bauxite from the English property

	S-140
Silica (SiO_2)	16.70
Alumina (Al_2O_3)	53.12
Ferric oxide (Fe_2O_3)	1.33
Ignition	26.41
Titanium dioxide (TiO_2)	1.80
	99.36

This ore is similar to that across the branch, consisting of hard pebbles in a clayey matrix.

The slope of the hill to north is gentle, and the overburden of the area likely to be underlain by bauxite is light, probably not exceeding 5 feet on the average.

KLECKLEY PROPERTY

(Map locality M-3)

The property of J. L. Kleckley is situated on the south slope of the valley of Buck Creek in the western part of Macon County, 8½ miles west of Oglethorpe and 9½ miles east of Ellaville. The exposures of bauxite are on lots 24 and 37, 29th district.

The lower slopes on these lots consist of more or less pure kaolin and fire clay, prevailingly white and containing lenses of indurated nodular clay and bauxite, mantled by a few feet of gray or red sand. The hills are capped by red sand of the Wilcox formation, which overlies the white clays unconformably.

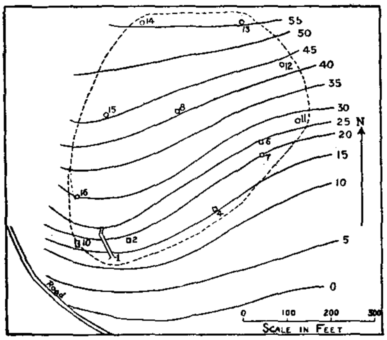


Fig. 10.—Sketch map showing bauxite exploration work on the Kleckley property, Lot 37, Macon County. Numbered pits and borings are described in the text.

The prospect on lot 37 is on a hillside sloping south, half a mile northwest of Kleckley's residence. The accompanying sketch shows the location of the exploration work and probable extent of the deposit (fig. 10).

A detailed description of the openings is as follows:

Prospect No. 1 is a trench 80 feet in length and 9½ feet deep at the head, showing the following section in the head of the cut.

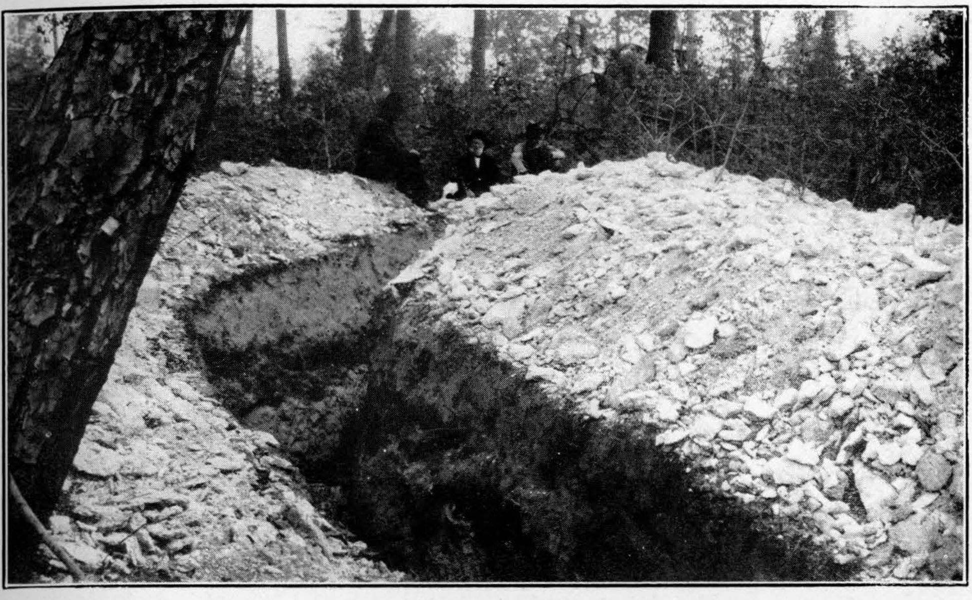
Section of prospect No. 1

	Feet
4. Sandy soil	3
3. Light-colored clayey bauxite with scattered nodules, not quite so hard as the Cretaceous "chimney rock" of Wilkinson County, which it resembles, in texture	2
2. Yellow, finely nodular, clayey bauxite, having about the same texture as the underlying pink material, which appears to weather to yellow bauxite as it approaches the surface along the strike..........	1½
1. Pink or pale maroon, finely nodular bauxitic clay. The nodules are almost white and slightly harder than the matrix..............................	3

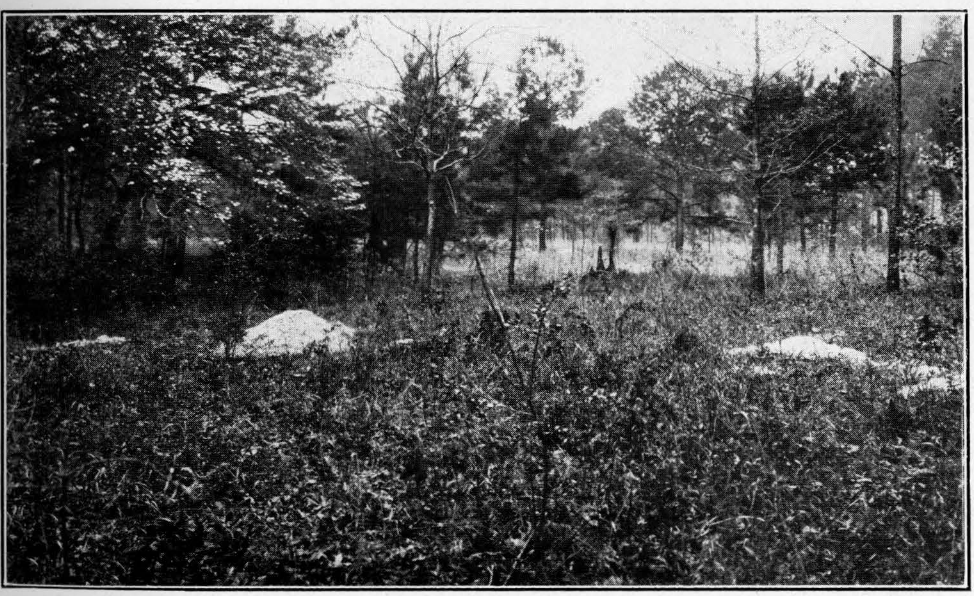
Prospect No. 2 is a pit 4 feet deep, cutting indurated clay which contains large, hard, ferruginous concretions surrounded by maroon stains.

Prospect No. 4 is a pit 2 feet deep, in sandy soil containing small pebbles and loose nodules of hard bauxite.

Prospect No. 5 is a pit 2 feet deep, in soil containing large blocks of indurated clay with scattered nodules.



A. BAUXITE EXPLORATION PIT ON THE KLECKLEY PROPERTY, MACON COUNTY.



B. BAUXITE EXPLORATIONS ON THE ENGLISH PROPERTY, MACON COUNTY.

Prospect No. 6 is a pit 10 feet deep, showing the following section:

Section in Pit No. 6

	Feet.
2. Clayey sand, lower part bright red, upper 3 feet bleached to yellow-gray	6½
(Unconformity)	
1. Bauxite, consisting of very hard nodules, mostly over one inch in diameter, in a softer matrix, with very little iron stain. In the bottom the material becomes softer and more stained so the entire workable thickness is probably penetrated. As shown by the analysis, this is the best bauxite exposed on the property	3½

Prospect No. 7 is a pit 8 feet deep, 25 feet south of No. 6. It penetrates 2 feet of sandy clay soil overlying 2 feet of bauxite similar to that of No. 6, grading downward into 2 feet of stained kaolin.

Prospect No. 8 is a pit 23 feet deep. The section is as follows:

Section in pit No. 8

	Feet
4. Clayey sand, yellow-gray at top, grading down into red	9
(Unconformity)	
3. Red-stained, plastic kaolin	2
2. Bauxitic clay containing scattered hard nodules one inch in diameter. The nodules are most abundant near the bottom; at the top the material is a white plastic kaolin	9
1. Bottom of pit filled with water at time of visit	3

The best looking material is the 6 feet just above the water level but even this contains only 44 per cent alumina.

Prospect No. 10 is a pit 7 feet deep, cutting 3 feet of sandy soil with a basal conglomerate of small pebbles of indurated clay and hard bauxite, overlying unconformably 4 feet of nodular kaolin. The nodules in the kaolin are small, hard, and ferruginous, with maroon stains in the white clay surrounding individual nodules and groups of nodules.

Prospect No. 11 is a boring which struck bauxitic material at 5½ feet.

Prospect No. 12 is a boring showing bauxitic material at 12½ feet.

Prospect No. 13 is a boring which reached white kaolin, not apparently bauxitic, at 28 feet.

Prospect No. 14 is a boring showing pink bauxitic clay at 25 feet.

Prospect No. 15 is a boring with hard bauxitic material at 18 feet.

Prospect No. 16 is a boring which struck hard material at 9 feet.

The analyses of samples from this locality are as follows:

Analyses of bauxite from lot 37, Kleckley property

Constituents	S-135	S-136	S-137	S-139
Silica (SiO_2)	14.56	23.70	43.41	33.12
Alumina (Al_2O_3)	55.47	49.08	35.99	43.62
Ferric oxide (Fe_2O_3)	1.20	2.00	2.33	.66
Ignition	26.17	22.38	14.00	18.12
Titanium dioxide (TiO_2)	2.40	2.87	2.10	2.40
	99.80	100.03	97.83	97.92

S-135—Average sample from 3½-foot bed of bauxite in the bottom of prospect No. 6.

S-136—Average sample of beds Nos. 2 and 3, prospect No. 1.

S-137—Average sample of bed No. 1, prospect No. 1.

S-139—Average sample of the lower 6 feet of bed No. 2, prospect No. 8.

The exploration work covers an area of about 4 acres, and shows that this area is underlain by a large deposit of clayey bauxite carrying 40 to 50 per cent alumina with average content of ferric oxide less than two per cent. There is apparently only a small amount of bauxite of better than 50 per cent grade, and a very little above 55 per cent. All is probably too siliceous for use as aluminum ore. On account of the rather low grade of the ore, the heavy overburden, and the haul of at least 8 miles to the nearest railroad, this deposit is hardly worth working at the present price of bauxite; but it is almost certain to be worked in the future.

The exposure of bauxite on lot 24, known as the "Stone Spring" locality, is a mile northwest of Kleckley's residence. A trench in the hillside 50 feet from "Stone Spring" exposes a thickness of 10 feet of rather soft, finely pisolitic bauxite, with nodules averaging one-sixteenth of an inch in diameter. The composition of an average sample is as follows:

Analysis of bauxite from lot 24

	S-134
Silica (SiO_2)	14.77
Alumina (Al_2O_3)	53.70
Ferric oxide (Fe_2O_3)	2.10
Ignition	23.13
Titanium dioxide (TiO_2)	1.65
	95.35

The hill slopes to north, and 200 feet south of the pit is a gully exposing 20 feet of sandy, micaceous, iron-stained kaolin above the level of the bauxite. This is overlain unconformably by 30 feet of red sand. However, the slope is gentle, so the overburden will not increase rapidly. Several borings on the slope above the bauxite exposure passed through the kaolin and struck a water-bearing sand stratum, which could not be penetrated by the auger, at about the level of the top of the bauxite bed.

As bauxite is exposed at only one point, it is impossible to make any estimate of the quantity; but the bed is much thicker and apparently more uniform in composition than that on lot 37. The aluminum content could easily be brought up to over 55 per cent by drying. The iron content is a little high for an alum ore, but it is likely that the percentage will decrease on working back into the bed. If this deposit is found to have any considerable extent along the strike it should be of more value than the apparently larger deposit on lot 37.

ROBINSON PROPERTY

The property of Mrs. Mary Robinson adjoins the Kleckley property on the south. There are indications of a small deposit of baux-it on the boundary between the two properties, the greater part of the bed lying under a hill on the Robinson property. A pit a few feet south of the boundary line cut 4 feet of sandy soil, underlain by 2 feet of stained kaolin which grades downward into 3 feet of low grade bauxite, consisting of scattered hard nodules in a matrix of kaolin. As nothing of possible commercial value is exposed no samples were taken; the locality, however, is worthy of further prospecting.

PARK PROPERTY

(Map locality M-4)

There is an occurrence of bauxite on the estate of Mrs. Josephine Park, 2½ miles southwest of the Kleckley property and 7 miles east of Ellaville, the nearest railroad station. The bauxite occurs near a small branch on the west side of lot 83, 29th district.

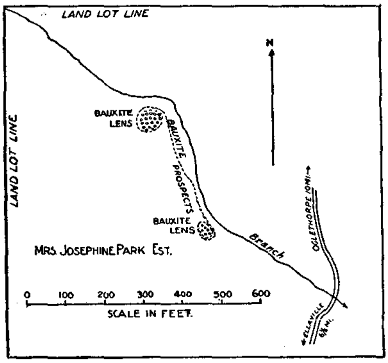


Fig. 11. Map of the Park estate, Macon County, by Maynard and Simmons, showing location of bauxite prospects.

The property has been thoroughly explored by Maynard and Simmons, of Atlanta, by means of 11 pits and trenches and 18 drill holes. The prospects extend for a distance of about 800 feet along the slope southwest of the branch, which flows southeast. The relations of bauxite to bauxitic clay are shown on the accompanying map (fig. 11).

The best bauxite is exposed in a pit near the bottom of the hill at the southeast end of the prospected area. This pit cuts 5 feet of bauxite, and a boring in the bottom showed 2½ feet additional. The material is pale yellow, with pisolites abundant but rather soft, averaging half an inch in diameter. The following is an analysis of an average sample from the 5 feet exposed:

Analysis of bauxite from Park estate

	S-138
Silica (SiO_2)	19.34
Alumina (Al_2O_3)	51.73
Ferric oxide (Fe_2O_3)	1.80
Ignition	25.02
Titanium dioxide (TiO_2)	1.40
	99.29

Four hundred feet northwest of the pit above described the kaolin comes within a foot of the surface. Several pits show indurated kaolin, with or without pisolites. One pit cuts 5 feet of hard material without pisolites, but with irregular crust-like concretions. This bed appears bauxitic, but the following analysis shows it to have the composition of an ordinary kaolin, indurated by deposition of silica.

Analysis of indurated kaolin from Park estate

	S-144
Silica (SiO_2)	41.54
Alumina (Al_2O_3)	37.21
Ferric oxide (Fe_2O_3)	1.07
Ignition	15.03
Titanium dioxide (TiO_2)	2.35
	97.20

Maynard states that the bauxite discovered consists of two very small lenses at the ends of the area of indurated kaolin. The slope of the hill is steep, so the overburden will increase rapidly. The estimated quantity of bauxite containing 50 to 52 per cent alumina is 1,000 tons, while there is a considerable amount of bauxitic clay with 40 to 50 per cent alumina. Analyses of the two best samples collected by Maynard and Simmons from this property are as follows:

Analyses of best bauxite from Park estate

Silica (SiO_2)	16.40	19.25
Alumina (Al_2O_3)	51.90	50.13
Ferric oxide (Fe_2O_3)	2.00	1.60

Ignition	29.94	27.29
Titanium dioxide (TiO_2)	1.00	1.50
	101.24	99.77

MORTON PROPERTY

Bauxite has been discovered on the property of J. S. Morton, of Byromville, Georgia. The property is lot 119, 29th district, Macon County, situated in the extreme southern part of the county, and the deposit belongs to the Camper Creek group.

Samples of nodular clay and bauxite were sent to the Survey by Mr. Morton. Analyses of these samples are given below. The bauxite resembles in texture that from other deposits along Camper and Sweetwater creeks. It consists of hard, compound pisolites up to one inch in diameter in a softer matrix. The samples appear to have been taken from surface boulders, and the extent of the deposit is not known.

Analyses of clay and bauxite from Morton property

Silica (SiO_2)	43.22	10.53
Alumina (Al_2O_3)	38.05	56.45
Ferric oxide (Fe_2O_3)	1.23	1.23
Magnesia (MgO)	.08	.08
Lime (CaO)	.04	.06
Ignition	13.82	29.21
Titanium dioxide (TiO_2)	2.73	2.34
	99.17	99.90
Moisture	.44	.72

IDEAL LOCALITIES

(Map locality M-5)

On the north side of Whitewater Creek, 2 miles northeast of Ideal, are exposures of both soft and indurated nodular kaolin, which is only slightly bauxitic. Exploration work has been done on the W. A. Aldrich and Chapman-Hardison properties. The bauxite lenses near the top of the Midway formation here cap the hills, while in the southern part of the county they are only a little above the level of the creeks.

So far nothing of economic importance has been discovered, but the indications are good, as deposits of bauxite are likely to be associated with the indurated kaolin.

SCHLEY COUNTY

STEWART PROPERTY

(Map locality Sc-1)

Bauxite is found south of Buck Creek on the property of J. T. Stewart, lot 50, 29th district, half a mile north of the Ellaville-Oglethorpe public road and 5½ miles east of Ellaville.

A plantation road crosses the bauxite area. One thousand feet west of the road an area of several acres is covered with bouders with maximum diameters of 5 or 6 feet of light red, hard, finely nodular bauxite. A test pit within the boulder area penetrated 4 feet of white, sandy clay and struck a ledge of hard, ferruginous sandstone, showing that the boulders were derived from a higher horizon. South of the boulder area is a slight rise, and a pit cuts 3 feet of sandy soil overlying 3½ feet of bauxite. The bauxite is of medium hardness, consisting of small white nodules, (average size, one-fourth inch) in a harder red matrix. Although much softer than the boulders, the latter were evidently derived from this stratum by surface hardening. The overburden increases very gently to southward, and will not exceed 10 feet over an area of several acres.

East of the plantation road a number of pits at higher level than the preceding cut only slightly bauxitic clay. One pit, 500 feet east of the road and about level with the boulder exposure cuts light yellow finely nodular bauxite. The pit was partly filled, so the thickness could not be measured, and the sample had to be taken from the material on the dump.

The following analyses indicate the grade of ore which may be expected:

Constituents	S-141	S-142	S-143
Silica (SiO_2)	12.42	19.59	13.80
Alumina (Al_2O_3)	53.32	50.64	51.05
Ferric oxide (Fe_2O_3)	4.93	3.10	2.70
Ignition	25.66	24.10	26.80
Titanium dioxide (TiO_2)	2.25	2.26	2.40
	98.58	99.69	96.75

S-141—Average sample from surface boulders of hard bauxite.

S-142—Average sample from 3½ feet of bauxite in pit south of the boulder area.

S-143—Light-colored bauxite from pit 500 feet east of the plantation road.

All of the ore is siliceous and ferruginous, but there is a considerable amount containing between 50 and 55 per cent of alumina in its natural state. Bauxite is shown up at two points, 1,500 feet apart, and there is a possibility that it is continuous throughout the intervening area. Even if not continuous, there are two lenses which may be expected to yield a considerable tonnage, while the overburden is light as compared with deposits which are being worked. The haul to Ellaville, the nearest point on the railroad, is 5.7 miles, over a good road without heavy grades, which would not be prohibitive for a good grade of ore.

HOLLOWAY PROPERTY

(Map locality Sc-2)

On the property of G. W. Holloway, situated in the southern part of Schley County, between LaCrosse and Andersonville, is an exposure of bauxitic material of unusual character. It is hard and nodular. The color is yellow, showing that the large percentage of iron occurs as yellow limonite. The bed is 4 or 5 feet in thickness, and the outcrop extends for about 100 feet around the slope of a hill.

Analysis of bauxite from Holloway property

	S-235
Silica (SiO_2)	7.18

Alumina (Al_2O_3)	34.00
Ferric oxide (Fe_2O_3)	34.48
Ignition	22.32
Titanium dioxide (TiO_2)	2.20
	100.18
Moisture	2.13

STEWART COUNTY

(Map locality St-1)

Bauxite has been reported on a property held under option by G. W. Dozier, of Dawson, Georgia. The location is 1½ miles west of Troutman's siding, in the southeastern corner of Stewart County.

The prospect has not been explored, and no analyses are available, but the occurrence indicates that bauxite may be expected in the area of outcrop of the Midway formation west of the Macon and Schley County area.

PHYSICAL AND CHEMICAL CHARACTERISTICS

PHYSICAL CHARACTERISTICS

CLASSIFICATION

The bauxites of the Coastal Plain vary greatly in color and texture. With certain modifications, the classification of the north Georgia bauxites, by Hayes,[1] also applies to the ores of the Coastal Plain.

Considered simply with reference to structure, Hayes classified the bauxite into five types: (1) pebble, (2) pisolitic, (3) oolitic, (4) vesicular, and (5) amorphous. The varieties of ore pass into one another by imperceptible gradations, and in general a single deposit will contain ore of several varieties. All of the ore is characterized by concretionary structure, the clay-like and granitic varieties reported from other localities not being found in the Coastal Plain.

The different types of bauxites are described as follows:

Pebble ore.—In this type the matrix is soft and not strong enough

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[1] U. S. Geol. Survey, Sixteenth Ann. Rept., pt. 3, p. 562, 1895.

to hold the pebbles together, so that in appearance and working qualities the ore resembles a bed of partly cemented gravel. The pebbles vary in size from half an inch to 2 inches or more in diameter, but the large boulders which are common in the north Georgia deposits are not found in those of the Coastal Plain. The smaller pebbles are usually almost spherical, while the larger are more or less irregular. Some few are single, simple nodules, but the majority are complex, consisting of small oolites in a dense, flinty matrix. The outside layer of these complex pebbles is usually flinty bauxite, from 1/64 to 1/8 inch thick, deposited after the original mass of oolitic ore had been more or less rounded by attrition. The nuclei of the sample nodules and of the oolites in the complex pebbles are usually white and powdery, and are surrounded by one, or by several concentric, layers of hard, flinty, amorphous bauxite. Doubtless the rounding of the original pebbles and the deposition of the outer coatings of compact material took place almost simultaneously, while all of the material was newly precipitated and soft, so that it may have been moved about and eroded by very gentle currents of water.

Ore of the pebble variety is typically developed in the deposits along Sweetwater Creek, Sumter County.

A different type of pebble ore is the red bauxite of Wilkinson County. The pebbles are not concretionary; they consist of massive, dark red material, a mixture of bauxite (gibbsite) and limonite, cut irregularly by minute veinlets of a white mineral. The matrix is light colored, consisting of angular sand grains with some flakes of mica imbedded in white gibbsite or kaolin. The matrix and nodules are of about the same hardness, but the adherence between the two is weak, so that the pebbles fall out in breaking.

Pisolitic and oolitic ore.—These varieties differ only on the basis of the average size of the nodules. Hayes calls the ore *pisolitic* in which the majority of the nodules vary from the size of a small pea (about 3/16 of an inch) to half an inch, while in *oolitic ore* the nodules vary from pea-size down to the smallest visible grain. In these types the nodules are usually simple, and the matrix firm and compact. Generally t ehindividual pisolites have soft nucli but occasionally they are hard throughout. Both matrix and concretions often break together with a conchoidal or hackly fracture.

The classification of the three varieties just described depends essentially on the size of the component concretions.

Vesicular ore.—This variety is merely a superficial phase of pisolitic or oolitic ore, formed by the weathering out of nodules which are softer than the matrix. Naturally, the thickness of the vesicular coating does not exceed the diameter of the nodules, as only those nodules exposed at the surface can weather out. Some of the north Georgia vesicular ore has open spaces between the hard oolites, but this type has not been found in the Coastal Plain.

Amorphous ore.—The bauxites of the Coastal Plain all possess nodular structure to a greater or less degree, no beds of the truly amorphous or clay-like ore having been found. From a microscopic viewpoint, the material of the nodules themselves is principally amorphous. The matrix of the hard varieties of ore appears amorphous to the naked eye, but under the microscope it is seen to be made up of fine oolites. The matrix of the softer pebble ores is truly amorphous, but consists very largely of kaolin. Therefore, this term can not be used as descriptive of a variety of ore of the Coastal Plain deposits.

HARDNESS

In general, the hardness of the bauxite varies with the alumina content, but this rule does not always hold, because some of the non-bauxitic or only slightly bauxitic kaolins are indurated by silicification.

The matrix and the outer layers of the nodules in the highest grade or ore, and near the surface of the deposits, have a hardness somewhat greater than calcite and about equal to flourite (four in Moh's scale). The nodules in the interior of the deposits are not quite so hard. The superficial boulders and the bedded deposits for a depth of several feet seem to have undergone ''case-hardening'' by solution and redeposition of minute amounts of silica and alumina as the material is alternately wet by rain and baked by the sun.

From the maximum hardness of four the material varies, with decrease of alumina and increase of silica content, to that of plastic kaolin, which has a hardness of about one, when dried.

COLOR

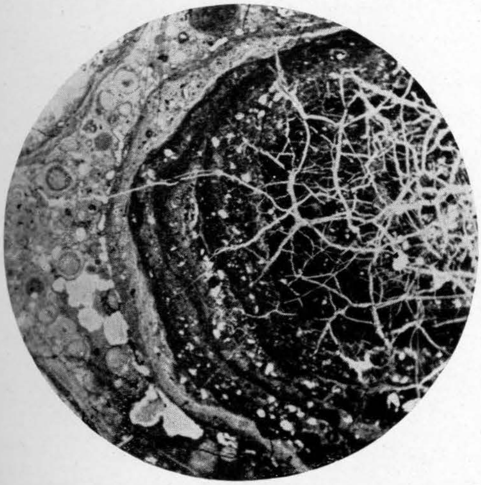
The color of the bauxite varies from tones of pale gray, buff, and brown to deep red. The color depends in a general way on the iron content, but it is not always a safe criterion for judging the percentage of iron. A given amount of iron carried in by surface water and spread as a film of limonite over the surfaces of the nodules and along fractures has a much greater coloring effect than an equal amount originally present in the ore, which is disseminated through the entire mass and probably replaces aluminum. Some of the gray ores contain minute, disseminated crystals of pyrite, so that their iron content is higher than that of other ore which is stained red by superficial coatings of iron oxide around the nodules.

Some of the deposits are stained dark gray or black near the surface by infiltration of organic matter, but such stains do not materially affect the composition.

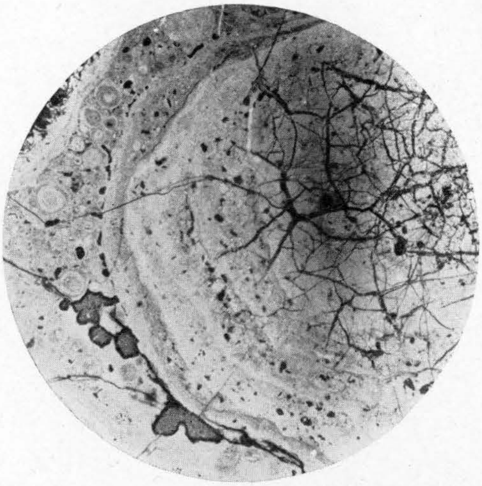
MICROSCOPIC STRUCTURE

The structure of the bauxite as revealed in thin sections under the microscope is fully as important as the megascopic features on which the preceding classification is based, particularly in its bearing on the origin of the deposits. For this reason rather detailed descriptions of slides of several types of ore are here given.

Specimen S-44.—This is a hard, high grade, pisolitic bauxite from the J. U. Parker property, Wilkinson County. The specimen probably contains over 60 per cent Al_2O_3, and approximately two per cent each of SiO_2, Fe_2O_3, and TiO_2. It has a light brownish gray color, with numerous pisolites reaching a maximum size of about 1 cm. Pisolites and matrix are of the same color and hardness, so that the whole mass breaks with a hackly fracture, and the pisolites are hardly distinguishable in the hand specimen. Some of the pisolites are hard throughout, and soft nuclei, when present, are very small.



A.

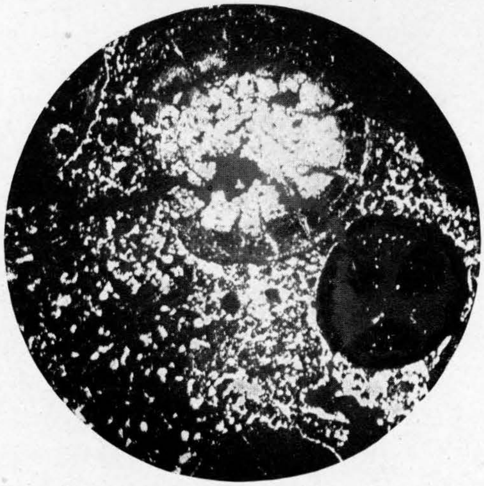


B.

A. SEC. S-44. BAUXITE PISOLITE AND OOLITIC MATRIX, WITH FRACTURES FILLED WITH AMORPHOUS MATERIAL AND CAVTIES OUTLINED BY CRYSTALLINE GIBBSITE. TRANSMITTED LIGHT. MAGNIFIED 11 DIAMETERS.

B. SEC. S-44. SAME AREA AS A. REFLECTED LIGHT.

C.



D.

C. SEC. S-232. LARGE BAUXITE PISOLITE MADE UP OF OOLITIC MATERIAL. TRANSMITTED LIGHT. MAGNIFIED 11 DIAMETERS.

D. SEC. S-75. A BAUXITE PISOLITE LARGELY RECRYSTALLIZED TO GIBBSITE. CROSSED NICHOLS. MAGNIFIED 11 DIAMETERS.

Microscopically, the ore is seen to be made up basically of amorphous, flocculent grains, and the larger structures are due to the arrangement and degree of compactness of these grains. The material is translucent, yellowish brown by transmitted light, milky white by reflected, the color being due to finely divided iron and titanium minerals.

The section cuts two large pisolites, each 8 mm. in diameter, and made up of six or eight irregularly concentric shells, varying in thickness from almost nothing to 1 mm. The outer portion of each shell is denser and more opaque than the inner, but the outer shell of each nodule is notably more transparent than the inner ones.

Scattered through the material of the nodules are angular grains made up of finely crystalline gibbsite (the crystalline form of this mineral is sometimes called hydrargillite). The largest grains noted are 0.25 mm. in length, but they are made up of numerous crystals.

The mineral identified as gibbsite is transparent, and has indices of refraction almost equal to that of Canada balsam, with moderate birefringence giving gray to yellow interference colors. The individual crystals are negatively elongated, with maximum extinction angles of about 25°. Many crystals show twinning along one set of planes, a few show two sets of twinning bands like the combined albite and pericline twinning in feldspars. A poor interference figure was observed, showing positive character, with optic angle very small, if not 0°.

The centers of the nodules are cut by numerous cracks which show some slight tendency toward radial and concentric arrangement. Almost all of them stop abruptly before reaching the outer shell of the nodule. The cracks are due to shrinkage of the soft interior of the nodule during the process of drying and cementation. In many cases these fractures cut across the areas of crystalline gibbsite, showing that the gibbsite grains formed a part of the original structure of the nodule. The fractures are filled with transparent, very fine grained, non-ferruginous material, almost amorphous, although with the highest power of the microscope portions of it shows traces of double refraction. It is evidently amorphous or cryptocrystalline gibbsite, differing from the mass of the nodule only in the absence of iron.

The matrix between the large nodules, apparently amorphous to the naked eye, is made up principally of oolites from 0.5 mm. in diameter down to exceedingly minute spherical aggregations of ore granules. Only the larger of the oolites are made up of concentric bands. Most of them have no definite nucleus, but in some cases the amorphous material has been deposited around a small mass of crystalline gibbsite, possibly an altered fragment of feldspar, or around a grain of ferro-magnesian mineral (amphibole or pyroxene).

The spaces between the oolites, once cavities, have incrustations of crystalline gibbsite, and the centers are filled with cryptocrystalline, transparent material like that filling fractures within the large nodules. The gibbsite incrustations are uniform and continuous around the walls of the cavities, and are 0.03 to 0.06 mm. in thickness, consisting of needle-like crystals elongated perpendicular to the walls.

Accessory minerals noted were apatite, zircon, muscovite, and ferro-magnesian minerals. Quartz and feldspar do not occur in the slide as determinable individuals. No titanium minerals are determinable in this or other bauxite slides, although the TiO_2 content invariably ranges from two to four or five per cent. It is most probable that the titanium exists as the alteration product leucoxene, a whitish, granular, flocculent mineral indistinguishable from the mass of amorphous aluminum hydroxide.

Apatite occurs in a few minute needles, 0.03 mm. or less in length.

Zircon occurs in water-worn, rounded to sub-angular grains, 0.03 to 0.04 mm. in diameter.

Only one small scale of muscovite was noted.

Very small, angular fragments of ferro-magnesian minerals occur, and form the nuclei of some of the smaller oolites.

Specimen S-52.—This is a typical hard, red bauxite from the property of W. A. Jones, in Wilkinson County. (See p. 55.) Its composition, shown by two analyses of samples from the property, is approximately 40 per cent Al_2O_3, 20 per cent each of H_2O and SiO_2, and 20 per cent of Fe_2O_3, TiO_2, etc.

The sample consists of well rounded, dark red pebbles up to about 1 cm. in diameter, in a light colored, sandy matrix. The slide cuts more than a dozen nodules, or pebbles, the largest of which is 6 mm. in diameter.

The pebbles are composed of amorphous, granular, bright red material, cut by numerous and irregular cracks which are filled with an isotropic, transparent mineral. Although no microscopic identification of the minerals can be made, it is evident from the analyses that the pebbles consist of hydrate of alumina, approximating the tri-hydrate in composition, colored by disseminated grains of hydrated iron oxide, or by iron replacing a part of the aluminum. The fractures are shrinkage cracks, filled by aluminum hydrate dissolved and redeposited without iron.

Only one of the pebbles in the section shows clearly concentric structure, and this has only one shell. One pebble consists of granular or brecciated fragments of the isotropic, transparent mineral, cemented by limonitic material, and has no trace of nodular structure.

Crystalline gibbsite forms incrustations around the pebbles from 0.1 to 0.2 mm. thick. The small gibbsite crystals are arranged with their long axes perpendicular to the boundaries of the nodules. There are also a few small angular areas of gibbsite within the pebbles, and the isotropic mineral filling veinlets occasionally shows traces of crystallization.

The matrix consists essentially of gibbsite, quartz, and an amorphous, isotropic mineral, evidently a hydrate of alumina, with a little oxide or hydroxide of iron in dust-like grains disseminated between crystals of the other minerals.

The gibbsite crystals in the matrix are of two generations. The older are large crystals, which have undergone partial alteration to the isotropic mineral. The latter mineral apparently recrystallizes again into gibbsite of the finely crystalline variety. The photographs

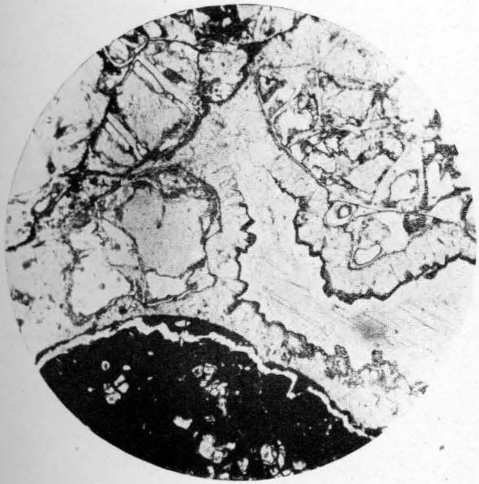
(Pl. IX, A and B) show these alterations clearly. The large, twinned crystal of gibbsite has a length of 0.85 mm. The shape and outline of the remnant proves that it has altered to the surrounding band, 0.06 mm. thick, of isotropic material. The line between the two is sharp and distinct, but as the two minerals have about the same index of refraction, it can be distinguished in ordinary light only by the ending of the cleavage lines in the gibbsite. Both minerals are free from iron stain. Finely crystalline gibbsite forms a band with an average thickness of 0.1 mm. around the isotropic mineral. The crystals have grown into the latter, apparently pushing before them the grains of iron oxide, very few of which are included in the crystals. The ends of gibbsite crystals projecting into the isotropic mass are terminated by definite crystallographic faces.

Another photograph (Pl. IX, D) shows a crystal of quartz, originally 0.3 mm. in length. The quartz is largely replaced by isotropic, amorphous material, the same in appearance as that due to alteration of the original gibbsite. The fragments of quartz remaining are optically continuous portions of one crystal. There are a few small crystals of gibbsite within the original area of the quartz crystal, but the gibbsite crystals of the surrounding crust start at the border and grow outward, there being none with crystal terminations within the area. This is an indication that there is some difference in composition or in time of formation of the isotropic material replacing quartz and that due to the alteration of gibbsite.

Besides the partially altered or replaced crystal fragments there are small areas of amorphous mineral due to entire alteration of gibbsite or replacement of quartz. The nature of the boundaries of these areas shows from which mineral they were derived.

The interstices between the nodules and the original grains of quartz and gibbsite are filled by gibbsite of later crystallization, mostly very fine, but having some elongated individuals as much as 0.6 mm. in length.

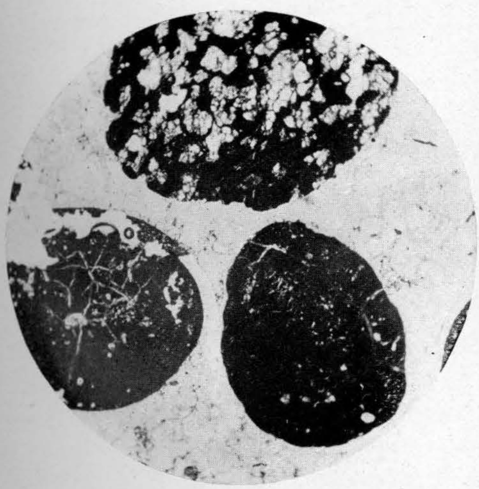
The only accessory mineral noted was zircon. Within one of the




A. B.

A. SEC. S-52. SHOWING A PORTION OF A RED PISOLITE AND A GIBBSITE CRYSTAL APPARENTLY ALTERING TO AMORPHOUS MATERIAL AND BACK AGAIN INTO CRYSTALLINE GIBBSITE. TRANSMITTED LIGHT. MAGNIFIED 37 DIAMETERS.

B. SEC. S-52. SAME AREA AS A. CROSSED NICHOLS.




C. D.

C. SEC. S-52. SHOWING STRUCTURE OF THE RED PEBBLES OR PISOLITES. TRANSMITTED LIGHT. MAGNIFIED 11 DIAMETERS.

D. SEC. S-52. SHOWING A QUARTZ CRYSTAL ALTERING TO AMORPHOUS MATERIAL. CROSSED NICHOLS. MAGNIFIED 37 DIAMETERS.

red pebbles is a sub-angular zircon fragment, with greatest dimension 0.08 mm.

Specimen S-75.—This specimen is hard, finely pisolitic ore from the outcrop of the bed at the McIntyre mine of the Republic Mining and Manufacturing Company. An analysis of a similar sample made for Veatch showed about 57 per cent Al_2O_3, 10 per cent SiO_2, and less than one per cent Fe_2O_3. The nodules are all simple, ranging in size from 5 mm. down, the majority being about 3 mm., and consist of a thin, hard shell with soft interior which has weathered out from the superficial nodules, giving the ore a vesicular appearance. The matrix is light brown, hard and flinty in appearance.

In the slide, the soft interiors of most of the nodules were lost in grinding. Evidently the material forming these soft centers approximates kaolin in composition. The matrix and outer shells of the nodules are of almost pure aluminum hydrate, and no crystalline quartz is visible, so the silica content must be principally in the nodular material.

The hard shells of the nodules are made up of the usual finely granular, amorphous material, colored yellowish brown by finely disseminated oxides of iron and titanium. As usual, no titanium minerals can be definitely identified. The small quantity of iron oxide in the ore is largely concentrated in the outer shells of the pisolites. The material of the shells is cut by small fractures which are filled with finely crystalline gibbsite, and small scattered crystals of the same mineral are very abundant. A pisolite shown in the photograph (Pl. VIII, D) is made up largely of crystalline gibbsite.

The matrix is finely oolitic, with oolites ranging in size from 0.5 mm. down. The oolites are hard and solid throughout, unlike the larger pisolites. Small fractures and inter-oolitic spaces are filled with finely crystalline gibbsite, but the isotropic, transparent material observed in other sections is absent.

The only accessory minerals noted were a few very small flakes of mica and fragments of ferro-magnesian minerals. There are a few minute plates of a mineral with very low birefringence, which is believed to be crystalline kaolinite.

Specimen S-76.—This is a typical indurated kaolin or "chimney rock," from the bed overlying the lens of bauxite on the old Adkins property, near McIntyre, Wilkinson County. It is made up of white material, showing only the faintest traces of nodular structure, with fractures and small openings stained by iron oxide. The analysis (p. 123) shows a slight excess of silica over the necessary ratio for kaolin. The hardness is considerably less than that of calcite, being readily cut with a knife.

Microscopically, the slide is made up entirely of granular, amorphous material. In appearance, this amorphous kaolin is much like the amorphous bauxite of the high grade ores, but there is no crystalline gibbsite present. The section is cut by numerous straight and curved lines of material more transparent than the mass, but probably not differing greatly in composition. Microscopic pores and larger openings are numerous in the slide.

Accessory minerals are small grains of zircon, mica, and ferromagnesian rock-forming minerals. No feldspar nor crystalline quartz is visible. It is evident that the induration is due to a small amount of hydrated silica.

Specimen S-92.—This is a compound nodule of hard, high grade bauxite from a deposit of pebble ore in the abandoned mine on the Cannon property, near Toomsboro, Wilkinson County. The pebbles are found in a matrix of white, soft, clayey bauxite. For analyses of pebbles and matrix see p. 46.

The section is cut from a compound nodule 2 cm. in diameter, and contains several pisolites up to 5 mm. The section resembles very much that of pisolitic ore from the McIntyre mine (S-75), except that the soft, clayey centers of the pisolites are smaller and the proportion of crystalline gibbsite much less. Angular cavities in the slide contain gibbsite incrustations 0.01 to 0.02 mm. in thickness, but are not completely filled, as in several other slides. Gibbsite-filled fractures are few, and the gibbsite crystals disseminated through the mass of amorphous material are very small.

The matrix between the pisolites shows imperfect oolitic structure.

Specimen S-93.—This is a speciment of hard ore from the same mine as the preceding. The matrix is of yellowish brown, flinty bauxite. The nodules are very irregular in size and shape, up to 1 cm. in diameter. Most of them have only a thin hard shell, with a soft, clayey center.

The nodular material is not shown in the slide, as it is so soft that it was lost in grinding. The matrix is made up of usual flocculent, granular material, arranged in oolites of varying shapes and sizes. As in the preceding specimen, there is very little crystalline gibbsite.

Specimen S-196.—This is a pebble ore from the pyrite-bearing portion of the deposit in Sweetwater Mine, Sumter County. The pebbles are of varying sizes up to about 5 cm. in diameter, in a softer. more clayey matrix. All of the pebbles are compound, consisting of hard, pisolitic ore. Pyrite occurs principally, if not entirely, in the pebbles. A very few of the pyrite crystals are visible to the naked eye; most of the mineral is in such fine grains that it merely gives a gray tint to the ore.

The slide is cut from a large pebble. It shows two pisolites, 1 and 2 mm. in diameter, in an oolitic matrix. The larger pisolte is made up of five distinct, concentric shells, while the smaller has oolitic interior structure. Both are cut by series of radical fracture filled with pyrite and crystalline gibbsite. (See photographs, Pl. X, A and B. The thickness of the pyrite veinlets varies from 0.03 to 0.04 mm. It is evident that the pyrite and gibbsite were deposited at about the same time, but the pyrite seems to be a little later, as at places it fills the centers of the fissures, with thin borders of gibbsite along the sides. In the larger pisolite none of the veinlets reach the outer layer of the shell, indicating strongly that they were formed before deposition was completed. In the smaller pisolite the location of the pyrite veinlets is determined by the pre-existing oolites.

The matrix surrounding the larger nodules is of finely oolitic, flocculent material with disseminated, dust-like grains and a few larger cubes, octahedra, and masses of crystals of pyrite. Many of the smaller oolites have for nuclei cubes of pyrite, and contain pyrite dust in concentric layers. Crystalline gibbsite in the matrix exists only as minute, irregularly distributed individuals.

The distribution of the pyrite shows that it was introduced after the formation of the larger pisolites, but before the consolidation of the oolitic matrix. The order of formation of the minerals and structures was as follows:

1. The larger individual pisolites were formed by accretion of newly precipitated aluminum hydrate. Some were formed by deposition around a single center, others are aggregations of oolites.

2. Before deposition on the outside of these nodules had entirely ceased, shrinkage cracks were formed in the interiors, and were filled almost immediately by crystalline gibbsite.

3. The nature of the solution changed so that pyrite crystals were formed simultaneously with the precipitation of aluminum hydrate. The solution penetrated the nodules previously formed and deposited pyrite in fractures; numerous free grains and small cubes and octahedra of pyrite were also formed in the solution.

4. The oolitic matrix was formed around the pisolites, crystals or groups of crystals of pyrite often forming the nuclei of the oolites.

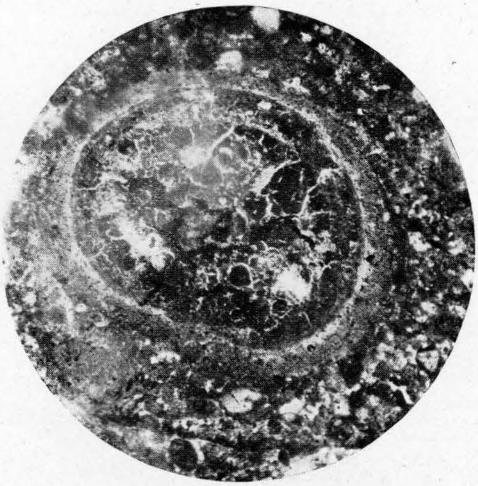
5. After becoming at least partly consolidated the mass of the ore was broken up and the pebbles rounded by attrition.

6. The mixture of amorphous aluminum hydrate and kaolin forming the clayey matrix to the pebbles was deposited.

Specimen S-232.—This is a high grade, coarsely pisolitic ore from the Cason mine of the National Bauxite Company at Toomsboro, Wilkinson County. The ore is irregularly nodular, most of the nodules appearing simple to the naked eye. (See analysis, p. 47.)

The section was cut from a sample taken near the surface, and contains more iron than the average analysis, but otherwise has about the same composition. It cuts two nodules, the larger of which is

A.

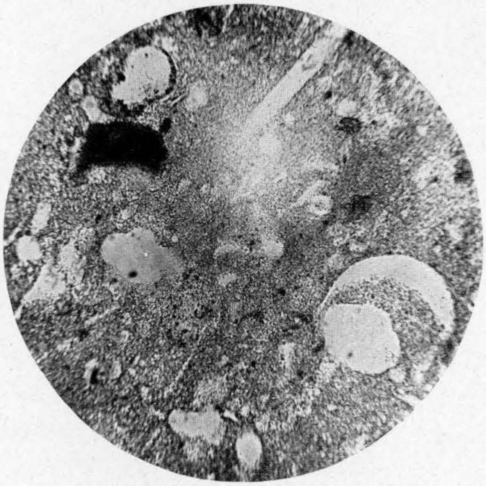


B.

A. SEC. S-196. BAUXITE PISOLITE CUT BY VEINLETS OF PYRITE. TRANSMITTED LIGHT. MAGNIFIED 37 DIAMETERS.

B. SEC. S-196. BAUXITE PISOLITE OF OOLITIC MATERIAL, WITH VEINLETS OF PYRITE BETWEEN THE OOLITES. TRANSMITTED LIGHT. MAGNIFIED 37 DIAMETERS.

C.



D.

C. SEC. S-196. BAUXITE OOLITE WITH A MASS OF FINE PYRITE CRYSTALS FOR A NUCLEUS. TRANSMITTED LIGHT. MAGNIFIED 110 DIAMETERS.

D. SEC. S-2. FULLERS EARTH, SHOWING GRANULAR AND POROUS STRUCTURE AND TRACES OF FOSSILS. TRANSMITTED LIGHT. MAGNIFIED 110 DIAMETERS.

oval in shape and 1 cm. long. The interior structure of the nodules shows concentric banding, but the bands consist of finely oolitic ore, with oolites up to 0.3 mm. in diameter. Only the outer shell of the large pisolite, 0.1 mm. thick, is really amorphous. The pisolites are not cut by shrinkage cracks or gibbsite veinlets, as is the case in most ore. The only crystalline gibbsite present is a few scattered crystals 0.03 to 0.04 mm. long.

The matrix is more coarsely oolitic than the material of the pisolites. It is much stained by iron carried in by surface waters, solutions which did not penetrate the larger nodules. There are no gibbsite veinlets, but a few small cavities are filled by crystals of a translucent red mineral, probably iron-stained gibbsite.

CHEMICAL AND MINERALOGICAL COMPOSITION

There are three generally recognized hydrates of alumina, with the following compositions:

Constituents	Diaspore Al_2O_3. H_2O	Bauxite Al_2O_3. $2H_2O$	Gibbsite Al_2O_3. $3H_2O$
Alumina (Al_2O_3)	85.01	73.93	65.41
Water (H_2O)	14.99	26.07	34.59
	100.00	100.00	100.00

I have found no analyses which correspond very closely to the formula given for bauxite, and the existence of such a mineral is denied or considered doubtful by many writers who have made a careful study of bauxite deposits. Clarke[1] says of it:

"Although many writers have regarded bauxite as a distinct mineral species, having the empirical formula Al_2O_3, $2H_2O$, few samples of it have exactly that composition. It is usually intermediate between diaspore and gibbsite; but is sometimes near one and sometimes near the other. It seems, in fact, to be a mixture of the two hydrates, but in an amorphous condition. *When solutions of sodium aluminate*

[1] Clarke, F. W., U. S. Geol. Survey Bull. 491, p. 475, 1911.

are decomposed by carbon dioxide, only the trihydrate is thrown down, at least so far as crystalline products have been observed. The ordinary, precipitated, gelatinous hydroxide has the same composition, according to E. T. Allen[1]; but at 100° it loses water and becomes a dihydrate. *The latter, in moist air, regains water readily—an order of change which renders its occurrence on a large scale as a natural mineral highly improbable. Even if a dihydrate were formed it would speedily be altered into something more nearly resembling gibbsite.*"

In this connection it is notable that all of the deposits formed in comparatively recent time by alteration of igneous rocks, or found in undisturbed stratified material, approach gibbsite very closely in composition; while those in folded beds which have undergone dynamometamorphism to a greater or less degree, such as the Baux deposits, contain a lower proportion of water.

In a tabulation of all the analyses of north Georgia bauxites available at the time of publication of his report, Watson[2] shows that all of the ore is very close to the trihydrate in composition. Wysor[3] has published analyses showing the presence of diaspore in the oolites, but not in the matrix, of the Arkansas bauxite. Some of the oolites have almost the composition of diaspore, and others are intermediate between that mineral and gibbsite, but the existence of the dihydrate as a separate mineral is not demonstrated. Leith and Mead,[4] in describing the same deposits, call the amorphous form of the trihydrate *bauxite* and the crystalline mineral of the same composition *gibbsite.* This is a variation from the older and more commonly used terminology of Dana,[5] who defines the trihydrate of alumina as *gibbsite,* with a crystalline variety, *hydrargillite.*

Laur[6] states that "the bauxites" constitute a mineralogical family, having as a basis the dihydrate of alumina ($H_4Al_2O_5$ or $Al_2O(OH)_4$) which acts as an acid in combining with iron and as a base in com-

[1] Chem. News, vol 82, p. 75, 1900.
[2] Bauxite deposits of Georgia, Geol. Survey of Ga. Bull. 11, p. 42, 1904.
[3] Wysor, D. C., Aluminum hydrates in the Arkansas bauxite deposits, Econ. Geol., vol. 11, p. 42, 1916.
[4] Leith, C. K. and Mead, W. J., Metamorphic geology, p. 27, 1915.
[5] Dana, J. D., A system of mineralogy, 6th ed., p. 254, 1893.
[6] Laur, Francis, The bauxites—A study of a new mineralogical family, Trans. Am. Inst. Min. Eng. vol. 24, p. 234, 1894.

bining with silica. In other words, the mineral always contains about 69 per cent Al_2O_3, 4 per cent accessories such as titanium oxide, and 27 per cent of H_2O, SiO_2, and Fe_2O_3 combined; and these latter substances may replace each other in widely varying proportions. He calls the dihydrate *hydrargillite,* but also refers to the trihydrate as *gibbsite,* which he says grades into clay and iron ore and is of little importance. He says of the Georgia-Alabama bauxite, "It is nothing else than amorphous hydrargillite, nearly pure, with 3 to 4 per cent of accessory constituents and 27 per cent of water." This statement is entirely erroneous, according to his usage of the word hydrargillite, yet these deposits afford his only example of the basic mineral, or "hyaline bauxite," as the French deposits are all of "mixed" types. His conclusions are not substantiated by analyses, in fact, the only analysis quoted in his paper is a monohydrate.

Phillips and Hancock[1] investigated the solubility of the Georgia-Alabama bauxite in sulphuric acid of different concentrations. They divide the alumina of bauxite into three portions: "free," which is soluble in acid of 50° B. at a temperature of 100°C. in one hour; "combined," which is soluble in concentrated acid when evaporated until fumes of SO_3 are given off; and "insoluble," which is the small amount (one or two per cent) remaining in the residue after the latter treatment. The "free" alumina is shown to exist almost entirely as trihydrate, although that of the kaolin is also slightly attacked by the weaker acid; and the "combined" comprises most of the alumina combined as kaolin. This work does not prove that the lower hydrates of alumina are absent, but it shows that if present at all they are in very small amounts. The authors conclude that the titanium oxide is in the hydrated form (leucoxene), and is almost insoluble in the 50° acid, although the concentrated acid dissolves a large proportion.

The Ferguson method, now used for the determination of available alumina in alum ores, is based on this work. In this method 50° acid

[1] Phillips, W. B. and Hancock, David, The commercial analysis of bauxite. Jour. Am. Chem. Soc. vol. 20, p. 209, 1898.

is used, and boiled for three hours with a reflex condenser to keep the volume constant. The results agree very closely with the extraction obtained in commercial practice. In all of the analyses given in this report the total alumina has been determined. In the usual type of bauxite, which has very little free silica or sand, but practically all combined in kaolin, the amount of soluble alumina available for the manufacture of alum by the acid process is approximately the total percentage of alumina minus the percentage of silica.

In the Coastal Plain deposits the alumina seems to occur almost exclusively as the trihydrate. All gradations are found from almost pure trihydrate of alumina to almost pure kaolin, the limiting analyses being as follows:

Constituents	Gibbsite $Al_2O_3 . 3H_2O$	Kaolinite $Al_2O_3 . 2SiO_2 . 2H_2O$
Alumina (Al_2O_3)	65.41	39.48
Silica (SiO_2)	.00	46.60
Water (H_2O)	34.59	13.92
	100.00	100.00

Of course, there are always present oxides of iron and titanium, with small amounts of other elements. These impurities usually make up three to five per cent in the white bauxites and kaolins. In the analyses made for this report TiO_2 varies from 0.90 to 3.26 per cent; Na_2O, 0.00 to 0.32; K_2O, 0.00 to 0.24; CaO, 0.00 to 1.13 (the latter analysis is a kaolin, and is the only one showing more than a trace); MgO, 0.00 to 0.40; S, 0.00 to 0.36; ZrO_2, 0.003 to 0.007; BaO always 0.00; and P_2O_5, always 0.00.

To show the gradation in individual deposits, the analyses of series of samples taken at one-foot intervals from the working faces in the McIntyre and Sweetwater mines have been plotted on triangular diagrams (figs. 12 and 13). In these diagrams each of the small triangles represents a single analysis: its area shows the percentage of Fe_2O_3 and miscellaneous elements: its position in the large triangle, the percentages of the three principal oxides. The distance from the base of the large triangle represents the percentage of Al_2O_3; from the left-hand side, H_2O; and from the right-hand side, SiO_2. All simple mixtures of kaolin and gibbsite would fall as points along the line connecting the two points representing the composition of those minerals.

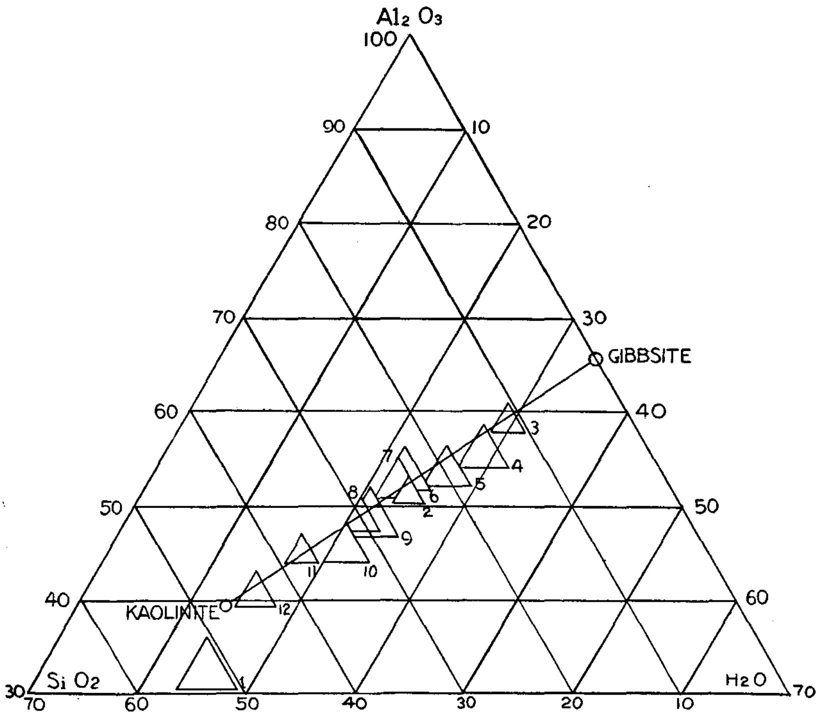


Fig. 12.—Analyses of bauxite from the McIntyre mine plotted on a triangular diagram to show gradation from gibbsite to kaolinite.

In figure 12, analysis No. 1 is the sandy, sedimentary clay of Eocene age which forms the overburden; the other analyses are all bauxite and kaolin, showing well the gradation. However, such gradation does not in this case indicate that the bauxite is a weathering product of the kaolin. Its significance will be discussed later.

The recalculated mineral compositions of the bauxites of this series are as follows: (See complete analyses, p. 37.)

Mineral composition of bauxite from the McIntyre mine

Minerals	S-109	S-110	S-111	S-112	S-113	S-114	S-115	S-116	S-117
Gibbsite	22.97	45.62	62.46	75.58	82.88	80.96	77.82	66.56	49.14
Kaolinite	73.78	49.78	34.77	19.51	11.72	12.92	18.97	30.68	48.95
Limonite	.93	2.65	1.16	2.84	3.18	3.19	1.53	1.54	1.35
TiO_2, etc.	2.25	1.97	3.03	3.41	2.86	3.21	2.00	2.09	1.98
H_2O—excess		.24							
H_2O—deficiency ...	.22		1.06	1.55	.52	.07	.55	.70	1.45

These compositions were computed by the following method:

1. All ferric oxide was computed as limonite.

2. All silica was computed as kaolinite.

3. The remaining alumina was computed as gibbsite. This sometimes requires more water than the amount available, sometimes less. The difference is stated as excess or dificiency of H_2O.

4. Titanium dioxide and small amounts of soda, potash, etc., are not computed as definite minerals.

These figures show a very close approximation to a mixture of gibbsite and kaolinite. Excess of water may be due to hydration of TiO_2; to iron replacing aluminum in gibbsite, in which case it would take up more water than in limonite; or to a higher hydrate of alumina than gibbsite, which seems to occur occasionally.[1]

It is also a known fact that some of the silica exists as sand grains, while all has been computed as kaolinite. If a correction could be made for the free silica, the alumina used in computing kaolinite would be free to combine with a higher ratio of water, as gibbsite. A deficiency of water may be explained not only by the presence of lower hydrates of alumina, but some of the alumina may be, and usually is, in the form of feldspar, mica, or other anhydrous or only slightly hydrous silicates.

The mineral composition of the samples from the Sweetwater mine (for complete analyses, see p. 70) is as follows:

[1] Wysor, D. C., Econ. Geol. vol. 11, p. 49, 1916.

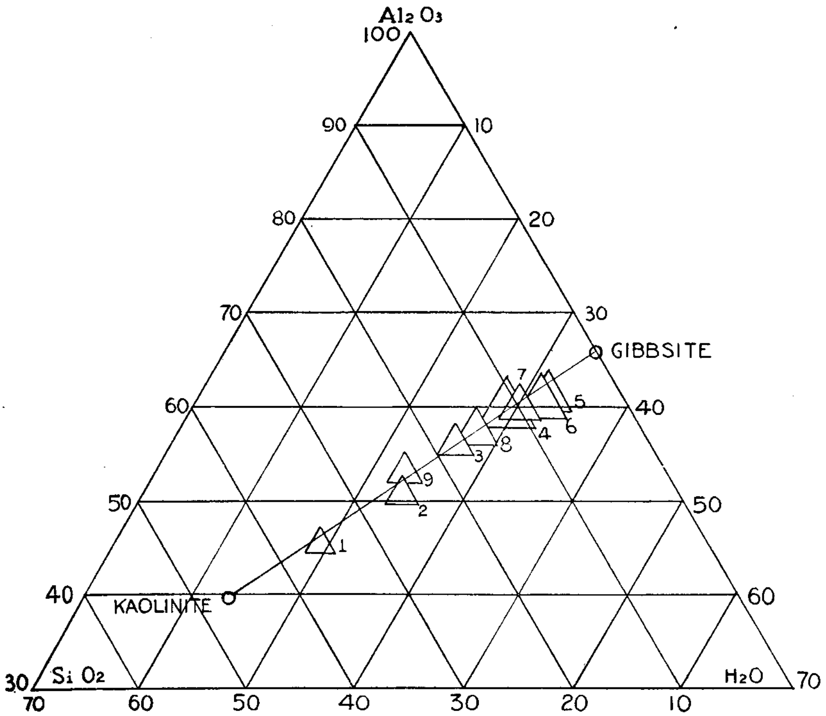


Fig. 13.—Analyses of bauxite from the Sweetwater mine plotted on a triangular diagram to show gradation from gibbsite to kaolinite.

Mineral composition of bauxite from the Sweetwater mine

Minerals	S-64	S-65	S-66	S-67	S-68	S-69	S-70	S-71	S-72	S-73	S-74
Gibbsite	45.88	74.75	64.48	55.10	49.73	46.80	34.57	36.01	26.30	20.14	4.66
Kaolinite	50.99	22.85	30.35	40.50	48.19	51.00	62.12	58.87	68.35	78.15	91,15
Limonite	1.31	1.12	1.87	2.62	3.37	3.18	2.06	2.80	1.30	1.31	1.12
TiO_2, etc.	2.38	1.65	2.44	1.83	2.08	2.31	2.26	2.10	2.34	2.17	2.75
H_2O—excess			.68	.16					1.27		.25
H_2O—deficiency ...	.08	.52			3.10	2.44	.84	.65		1.23	

Several of the richest bauxites and purest kaolins from the Coastal Plain deposits have mineral compositions as follows:

Mineral composition of Georgia bauxite and kaolin

Minerals	1	2	3	4	5	6	7
Gibbsite	89.48	94.19	92.80	89.92	.91	1.22	
Kaolinite	10.15	1.96	1.57	5.97	96.85	97.00	95.37
Limonite	.93	1.98	2.28	1.50	.69	1.01	1.01
TiO_2, etc.	.23	2.28	2.67	1.92	1.53	1.46	1.88
SiO_2							1.35
Sand					.33	.00	.31
H_2O—excess			.41	.46			.06
H_2O—deficiency	1.54	1.09			.05	.10	

1. Hard bauxite from the Underwood property, Wilkinson County, Veatch, Otto, Second report on the clay deposits of Georgia, Geol. Survey of Ga. Bull. 18, p. 436, analysis 10, 1909.
2. Hard bauxite from Wilkinson County. Veatch, op. cit., p. 436, analysis 6.
3. Hard bauxite from Wilkinson County. Veatch, op. cit., p. 436, analysis 8.
4. Bauxite nodules from Cannon mine, Wilkinson County. See p. 46 of this report.
5. Kaolin from Atlanta Mining and Clay Company pit. Veatch, op. cit. p. 133.
6. Kaolin from American Clay Company pit. Veatch, op. cit., p. 140.
7. Kaolin from L. Mandle pit. Veatch, op. cit., p. 143.

These analyses were all recalculated without moisture before computing the mineral composition. In case of the kaolins "sand" is mechanically determined, "SiO_2" in No. 7 is excess silica in the clay substance, and probably exists in hydrated form. These analyses show that even the purest of the plastic, sedimentary kaolins of the Coastal Plain frequently have an excess of alumina over that combinable with the silica as kaolin, which excess must be in the form of aluminum hydrate. Edwards[1] has shown that a large number of Georgia clays contain free hydrates of aluminum, using the fact as an argument that these hydrates are produced by weathering, but he has chosen his examples largely from sedimentary kaolins of the Lower Cretacious and from those associated with the north Georgia bauxite deposits. These clays are clearly related to the deposits of bauxite in origin, and it is evident that neither clay nor bauxite is due to ordinary weathering processes.

[1] Edwards, M. G., The occurrence of aluminum hydrates in clays. Econ. Geol., vol. 9, p. 112, 1914.

GENESIS OF DEPOS.TS

ORIGIN OF KAOLIN

The bauxite deposits of the Coastal Plain are so closely related to the larger beds of kaolin, that the origin of the latter, and of the Lower Cretaceous beds as a whole, must first be considered. The best discussion of the theory of origin and deposition of the kaolin is that of Veatch,[1] from which the following paragraphs are largely abstracted.

The greater part of the area of the Piedmont Plateau, from which the material of the Lower Cretaceous sediments was derived, is composed of granites, gneisses, and feldspathic schists, with subordinate amounts of basic intrusives. On the whole the rocks of the region are highly feldspathic.

The greater part of the Piedmont was a land surface from the close of the Cambrian period to the beginning of the Cretaceous. During this enormous time interval the region was approximately base-levelled, and was mantled by a great thickness of decomposed and kaolinized rock. Just before the beginning of the Cretaceous period the Piedmont was greatly uplifted and tilted to the southeast, forming a shore line near the present location of the Fall Line. The streams were rejuvenated, and rapidly set to work carrying the great mass of weathered rock down to the sea. On account of the steep gradient of the streams and the soft material on which they worked, the result was a rapid deposition of a great mass of sand, gravel, and clay along the coast. The streams formed deltas, which overlapped, resulting in the formation of sand flats and fresh-water delta lakes, and areas of sea water were enclosed by sand barriers, to be quickly freshened by the inflow from the land. In the quiet waters of the lakes and ponds thus formed the fine clay particles were deposited as lens-like masses of pure white kaolin; while in shallower waters and amid shifting currents the masses of cross-bedded sands and pebbles

[1] Veatch, Otto, Geol. Survey of Ga., Bull. 18, p. 97, 1909.

were laid down. Conditions did not long remain uniform, as one set of barrier lakes would fill up while another set was forming farther out. Some of the beds of sand and clay first formed were reworked by a shifting of drainage channels, forming numerous local unconformities and clay conglomerates, which have no time significance.

Marine conditions of deposition were entirely absent. No shells nor animal remains have been found in the Lower Cretaceous beds of Georgia, and for some reason plant remains are also absent except in one locality. There are no calcareous beds, nor even lime nodules, which is natural in such a formation, as the regolith of the Piedmont rocks was thoroughly decomposed and leached and the most of the rocks were only slightly calcic in the first place. Gypsum, which might indicate brackish water deposits, is absent; and the small amounts of pyrite and sulphates present are closely related to the bauxite deposits in origin.

The remarkable purity of the kaolin deposits indicates that nature operated a very efficient clay washing plant on a great scale. The separation of clay and sand particles depended on specific gravity and fineness of grain. The weathered rock of the crystalline area consisted essentially of quartz, kaolin, mica, and limonite, as the feldspars and ferro-magnesian minerals were almost entirely decomposed. The quartz and remnants of feldspar and ferro-magnesian minerals were dropped in the deltas and close to the shore line, on account of their coarseness of grain; most of the limonite was also deposited with the sand, on account of its high specific gravity and because a considerable part adhered as coatings around the sand grains. The kaolin, although it has about the same specific gravity as quartz, was so much more finely divided that it remained in suspension and was deposited in the quieter and deeper waters of the barrier lakes, forming lenses which sometimes have an extent of many acres and a thickness of 30 or 40 feet. On account of their fineness of grain, a considerable proportion of the white mica and titanium in the form of leucoxene went with the kaolin, as well as extremely fine grains of all other minerals and even of the heavy accessory minerals such as zircon.

Judging from the red soils which now cover the greater part of the Piedmont area, the whiteness of the kaolin and the prevailing light color of the sand beds of the Lower Cretaceous seems remarkable. But these red soils are only superficial, grading down into gray or white material; and their percentage of iron is much less than would be expected from a cursory examination. Forty-eight analyses of Georgia granites and gneisses by Watson[1] show a range in content of ferric oxide content from 0.71 to 3.05 per cent, with an average of only 1.45 per cent; while seventeen weathered rocks show a range from 1.22 to 6.33 per cent, with an average of 2.47 per cent. So all except the best deposits of kaolin and bauxite actually contain as large a percentage of iron as the original rocks from which they were derived.

In brief, the kaolin is a sediment derived from deeply weathered, acid igneous rocks, and deposited in shallow, fresh-water lagoons; the conditions being unusual only in that a very complete separation of sand from clay substance was attained.

The depositional conditions during that portion of Midway time in which kaolin and bauxite were formed were essentially similar to those of the Lower Cretaceous.

RELATION OF BAUXITE TO KAOLIN

There are several localities showing gradational phases between kaolin and bauxite which afford important evidence as to the origin of the bauxite; but as they can not be classed as bauxite deposits, detailed descriptions and analyses are given here rather than under the descriptions of the deposits.

"MIDDLE MINE," EDGAR BROTHERS CLAY COMPANY

(Map locality W-12)

This is a small, abandoned pit near the clay-washing plant of the Company, about one mile west of McIntyre, Wilkinson County. The pit is about 100 feet in diameter, and when visited there was 15 feet

[1] Watson, Thomas L., Geol. Survey of Ga. Bull. 9, p. 354, 1902.

of kaolin exposed above the level of the water which filled the bottom.

The contact of the kaolin with the red and yellow sand of Eocene age which overlies it is not marked by a distinct clay conglomerate. There is rather a gradational phase of a few inches, where the white clay seems to have been softened and stained before redeposition started. There are scattered rounded clay pebbles for a number of feet above the contact, and on the south side of the pit, 6 feet above the unconformity, is a distinct conglomerate layer of kaolin boulders and fine quartz gravel. Most of the kaolin pebbles in the red sand are less sandy than the kaolin in the pit, and their well-rounded condition indicates that they were transported some distance.

The kaolin is all more or less sandy, especially the middle portion of the bed. The quartz grains contained in it are mostly angular, up to one-eighth of an inch in size; and there are a number of specks of dark minerals, among which were recognized hematite flakes and cleavage fragments of green hornblende. The kaolin is white and massive, and no bedding planes can be distinguished.

On the south side of the pit the upper 18 inches of the kaolin is stained by iron along dendritic channels, but it shows no sign of change to bauxite. On the east side, where the road entered, is a mass of nodular clay of the form shown in the sketch (fig. 14). When freshly broken, the nodules may be distinguished from the matrix only by their slightly darker color, as both matrix and nodules are of the same hardness. The nodules consist of light gray, very plastic, putty-like clay, which shrinks away from the matrix on drying, and are thus easily eroded out, producing superficial honeycomb structure. They contain more ferrous iron than the matrix, and become "rusty" on weathering. The angular quartz grains and dark mineral fragments found in the massive kaolin persist in the nodular clay, and are found in both matrix and pisolites.

The upper contact of the nodular clay with the massive is marked by a band of large, soft, iron-stained clay concretions about 6 inches in diameter, while the pisolites in the mass of nodular clay average 1 inch.

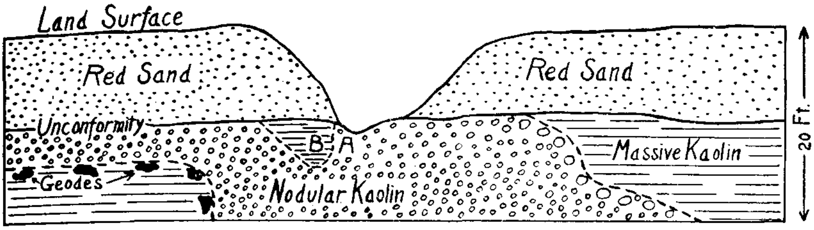


Fig. 14.—Section in Edgar Bros. Kaolin Co. Middle mine, Wilkinson County, showing relations of massive and nodular kaolin and geodes. A and B are places where samples were taken.

Along the lower contact are scattered large, irregular shaped geodes, with maximum dimensions of a foot or more. These consist of a limonitic shell about half an inch thick, with the interior partly filled with soft, dark colored material. When freshly broken the material contained in the geodes gives off for a few seconds a fetid odor resembling that of carbon bisulphide, afterwards an empyromatic odor persists for some time.

The material from the geodes consists of an unusual assemblage of minerals. The analysis is as follows:

Analysis of geode material—S-59

Constituents	Carbon bisulphide solution	Water solution	Hydro-chloric acid solu-tion	Aqua regia solution	Insoluble residue	Loss on heating
S_1O_2	.....	.....	.....	.12	9.38	.....
Al_2O_3	.....	1.60	.59	.....	2.59	.....
Fe_2O_3	.....	.60	.70	4.57	.20	.....
FeO	.....	10.28	.00	.08	.....	.....
MgO	.....	.....	.00	.03	.....	.....
CaO	.....	.....	.00	.00	.....	.....
Na_2O	.....	.....	.00	.....	.04	.....
K_2O	.....	.....	.00	.....	tr.	.....
H_2O(100°)	.....	.....	.....	.....	.....	4.65
H_2O(150°)	.....	.....	.....	.....	.....	7.38
TiO_2	.....	.....	.....	.....	.90	.....
S	2.31	.....	.....	.....	.....	.....
SO_3	.....	22.55	.78	.....	.....	.....
FeS_2	.....	.....	.....	26.37	.....	.....
	2.31	35.03	2.07	31.17	13.11	12.03
Total 95.72						

Cursory examination of the material shows that it contains crystalline sulphur; a transparent, soluble mineral, crystallized in fibrous forms and having a strongly astringent taste; and marcasite, so finely crystallized that it appears black. The heavy residue after washing with water consists principally of quartz in subangular grains and microscopic crystals of marcasite. Under the microscope the latter crystals show orthorhombic forms, with crystal faces of a very pale bronze yellow color. No pyrite crystals are present.

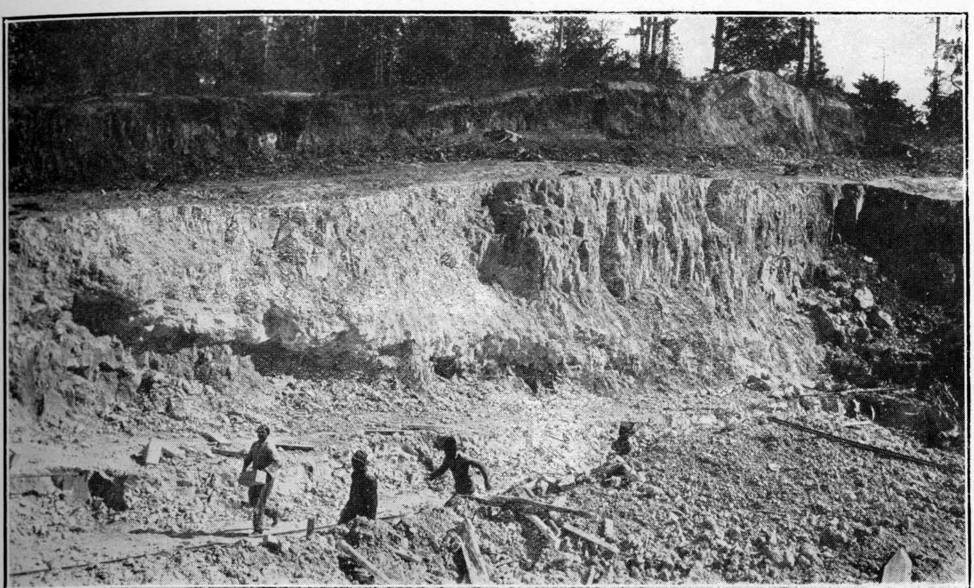
Only the crystalline sulphur is soluble in carbon bisulphide. It occurs in bunches of crystals and incrustations around other minerals, so that it appears to make up a larger proportion than is actually the case. The water-soluble mineral consists principally of ferrous sulphate (melanterite) with an admixture of ferric sulphate (coquimbite) and aluminum sulphate (alunogen). The water solution has a strongly acid reaction, and it may be seen that the sulphate radical is present in a quantity far in excess of that necessary to combine with the bases. The hydrochloric acid treatment dissolved only an unimportant quantity of material, and the insoluble residue consisted principally of quartz and kaolin. The marcasite, which is, after melanterite, the most abundant mineral, all went into the aqua regia solution. The discrepancy between the total and 100 per cent is probably due to water not lost at 150° C.

The geodes were formed contemporaneously with the surrounding clay, and have been altered little if at all by surface waters. The limonitic shells form impervious envelopes; in cases where the shell has been fractured, allowing surface water to enter, the interior material has been altered to a mass of limonite.

Samples of nodular and massive clay were taken at the points marked A and B on the sketch, at the same level and one foot on either side of the contract. The analyses are as follows:

Analyses of kaolin, from Edgar Brothers mine

	S-57	S-58
Silica (SiO_2)	45.64	45.55
Alumina (Al_2O_3)	37.54	38.07



A. CLAYMONT KAOLIN MINE, WILKINSON COUNTY. THE PROJECTING BED IS A LENS OF NODULAR, SLIGHTLY INDURATED CLAY.

B. "MIDDLE MINE" OF THE EDGAR BROS. CLAY CO., McINTYRE, WILKINSON COUNTY. THE HAMMER MARKS THE CONTACT BETWEEN MASSIVE AND NODULAR KOLIN.

Ferric oxide (Fe_2O_3)	1.45	1.12
Ferrous oxide (FeO)	.00	.00
Magnesia (Mgo)	.30	.19
Lime (CaO)	.00	.00
Soda (Na_2O)	.00	.08
Potash (K_2O)	.00	.00
Ignition	13.92	13.85
Titanium dioxide (TiO_2)	1.45	1.44
	100.30	100.30
Moisture	.40	.30

The mineral compositions are computed as follows:

Mineral composition of kaolin from Edgar Brothers mine

	S-57	S-58
Gibbsite	.00	00
Kaolinite	94.96	96.30
Limonite	1.68	1.31
Titanium dioxide (TiO_2)	1.75	1.71
Quartz	1.48	.76
Water (H_2O), excess	.43	.22

It is possible that both of these samples contain a little gibbsite, which does not show up in the recalculated analyses on account of the presence of quartz sand, which is computed as combined with alumina in kaolinite. The two analyses are almost identical, showing that kaolin may assume a distinctly bauxitic texture without any sensible variation from the massive material in composition.

CLAYMONT MINE

(Map locality W-13)

The Claymont kaolin mine of the Kaolin Mining Company is situated near the Central of Georgia Railway, 4 miles west of McIntyre.

The section in the working face in November, 1914, is shown in the sketch (see fig. 15 and Pl. XI, A). The section was as follows:

Section in Claymont mine

		Feet
Eocene		
	7. Overburden, consisting of red sand at top, grading down into yellow sand and this into greenish yellow, clayey and glauconitic sand. The lower portion contains clay pebbles, hard, weathered-out clay nodules, and boulders of indurated clay, harder than any found in place in the pit	1 to 10
	(Unconformity)	
Lower Cretaceous		
	6. Kaolin containing a little sand	9
	5. White, micaceous, clayey sand	2
	4. Brittle, gritless, jointed kaolin	7
	3. Nodular kaolin	5 to 6
	2. Firm, brittle, jointed kaolin, containing a little sand, and stained along joints by oxides of iron and manganese	4
	1. White, clayey sand	?

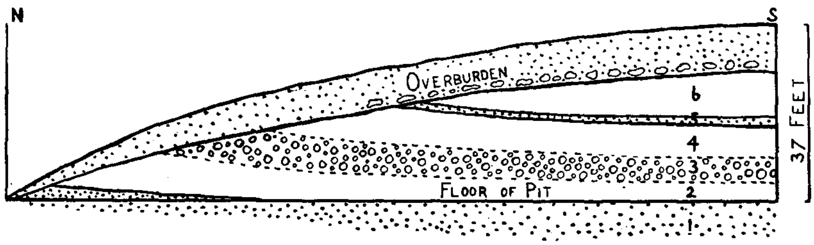


Fig. 15.—Section in the Claymont kaolin mine, Wilkinson County, showing relation of the massive and nodular kaolin.

The nodular bed, No. 3, has concretions varying in size from pisolites to over one foot in diameter. All of the material is soft and plastic enough to be worked, washed, and used as paper clay. The nodules can scarcely be distinguished from the matrix when freshly broken; but on drying the nodular material shrinks, becomes harder and darker in color than the matrix, and breaks with an intricate system of conchoidal fractures. There is a gradation downward into stratum No. 2, but the upper surface of the nodular layer is sharp.

The following are analyses of samples from the mine:

Analyses of kaolin from the Claymont mine

Constituents	S-81	S-82	S-83
Silica (SiO_2)	45.62	49.54	45.19
Alumina (Al_2O_3)	39.39	33.80	39.15
Ferric oxide (Fe_2O_3)	.49	.92	.48
Ferrous oxide (FeO)	.00	.11	.00
Magnesia (MgO)	.22	.36	.07
Lime (CaO)	.00	1.13	tr
Soda (Na_2O)	.03	tr	.04
Potash (K_2O)	.02	tr	.02
Ignition	13.19	13.21	13.87
Titanium dioxide (TiO_2)	.92	.96	1.54
	99.88	100.03	100.36
Moisture	2.21	6.50	.45

Mineral composition computed

Minerals	S-81	S-82	S-83
Gibbsite	.93	....	1.13
Kaolinite	98.00	85.48	97.15
Limonite	.56	1.08	.56
Titanium dioxide (TiO_2)	1.19	2.56	1.67
Silica (SiO_2)	....	9.77	....
Water (H_2O)—excess	....	1.14	....
Water (H_2O)—deficiency	.80	....	.15

Sample S-81 is an average sample from the nodular layer; S-82 is from the center of one of the larger nodules, about one foot in diameter; and S-83 is a massive kaolin taken 6 inches above the nodular layer. The nodular material is in such physical condition that it retains a great deal more hygroscopic water than the massive kaolin, as all of the samples were taken at the same time and had the same opportunity to dry before the analyses were made. S-82 is the only sample of Lower Cretaceous material analyzed which contains any appreciable amount of lime. The excess of silica in this sample is probably in colloidal form, as no sand grains could be detected. The nodular material contains ferrous iron, which is not found in the massive kaolin, and a little less of the alkalies and titanium.

DUPREE PROPERTY

(Map locality W-9

On the Dupree property, Wilkinson County, (see p. 52) the white, indurated clay bed which overlies the red bauxite also contains a mass of nodular clay. The irregular form of the contact between the nodular and massive clays is shown in the sketch (fig. 16). Along the contact and running off into fissures in the white, massive clay is a band of dark, greenish, non-plastic clay an inch or two in thickness.

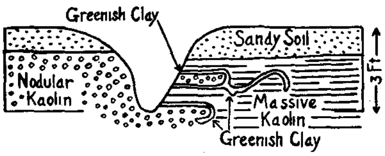


Fig. 16.—Detail of contact of massive and nodular kaolin, Dupree property, Wilkinson County.

Analyses of the massive and nodular clays from Dupree property

	S-85 (massive)	S-84 (nodular)
Silica (SiO_2)	45.75	41.19
Alumina (Al_2O_3)	36.85	34.82
Ferric oxide (Fe_2O_3)	2.14	5.14
Ferrous oxide (FeO)	.28	.15
Magnesia (MgO)	.04	.88
Lime (CaO)	.00	.00
Soda (Na_2O)	.00	.00
Potash (K_2O)	.00	.00
Ignition	13.10	16.65
Titanium dioxide (TiO_2)	2.00	.98
Manganese (NnO)	.06	.16
	100.22	99.97
Moisture	.78	7.78

The massive clay is mealy, but contains very little sand and no nodules. The bauxitic clay consists of nodules about the size of peas in a sandy matrix. Both matrix and nodules have a pale greenish color. The nodules are soft enough that they may easily be cut with a knife, and some of them show distinctly concretionary interior structure. The massive clay contains more alumina than the bauxitic material, but the higher water content of the latter indicates that it is a mixture of gibbsite and silica, while the other is a normal kaolin.

As in the Claymont mine the bauxitic clay retains a great deal of hygroscopic moisture.

ADKINS PROPERTY

(Map locality W-14)

The bauxite deposit described by Veatch as the R. W. Adkins property was bought by George Carswell, of Irwinton, and worked by the National Bauxite Company. It is situated just south of the Central of Georgia Railway, 3 miles east of McIntyre. The mine seems to be entirely exhausted, but it is of interest because it shows well the structure of the deposit and affords clues as to the origin.

The structural relations are shown in the accompanying sketch (fig. 17). On the north side of the pit Eocene red-and-blue mottled clayey sand overlies unconformably, but without basal conglomerate, a bed of indurated white clay. The claystone, which is locally known as "chimney rock," is hard and massive, but without distinct nodules. It contains slightly more combined water than most of the plastic white kaolins, but its alumina content does not indicate bauxitization. (See analysis S-76.) The bed has a maximum thickness of 2 feet and tapers out to eastward. It is underlain by a bed of less indurated clay, with indications of bedding and containing scattered pisolites one inch in diameter. This bed is more bauxitic than the preceding. (See analysis S-77.) It grades downward into roughly stratified red, yellow, blue, and white, mealy, non-plastic clay. In this bed occurred the lens of high grade bauxite, of which only small remnants are left. The bauxite was some of the best ore ever found in

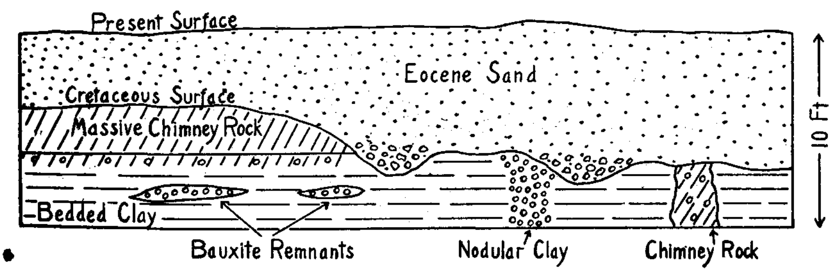


Fig. 17.—Section in Adkins bauxite mine, Wilkinson County.

this district, as it all contained over 60 per cent of alumina in its natural state. It has a light gray-brown, flinty matrix predominating over the pisolites, which are of softer white material and average a quarter of an inch in diameter.

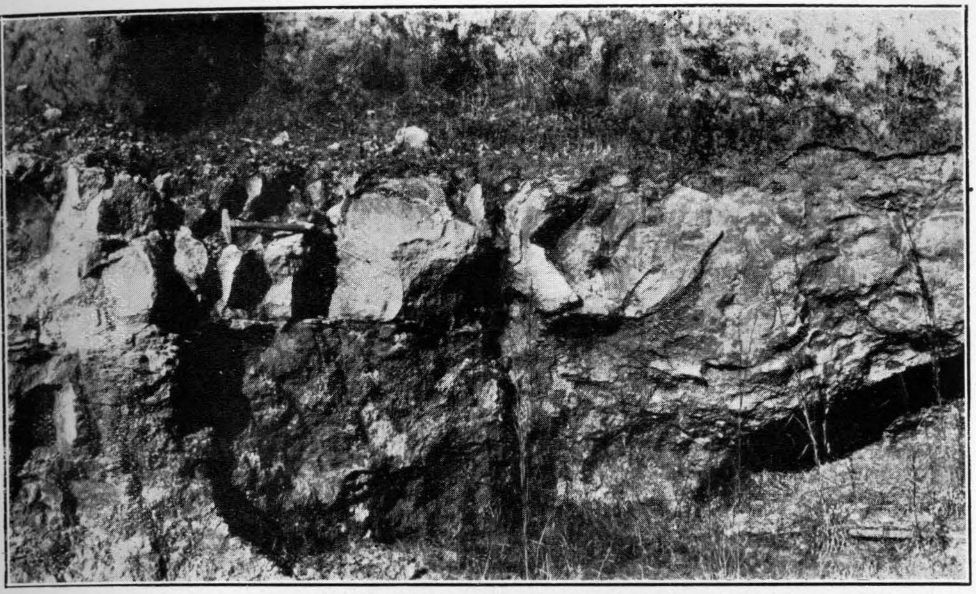
On the east side of the pit the chimney rock bed is cut away by a pre-Eocene gully. The Eocene sand here has a basal conglomerate several feet thick, with pebbles of chimney rock, bauxite, and quartz. The quartz pebbles are well rounded and average less than half an inch, the largest found being about 3 inches; showing long distance transportation. The bauxite and chimney rock fragments vary greatly in size and shape and are mostly angular, showing local erosion and redeposition.

At one point a mass or pipe of clay with pisolitic structure cuts vertically across the banded clay. The bedding of the clay runs into the nodular mass and disappears. The pisolites are white, soft, and clayey, with average diameter of 1 inch; and in volume are about equal to the softer red matrix. Although this pisolitic clay (S-78) has the bauxite texture better developed than the associated bedded clay (S-79), its alumina content is less. In the soft, pisolitic clay are found occasional very small lenses, about half an inch thick by 3 or 4 inches in diameter, of hard, flinty, light colored bauxite.

In another place a mass of indurated clay with scattered pisolites crosses the bedding in a manner similar to the soft, pisolitic clay.

The underlying material, that is, the lowest exposure in the pit, is a bluish, mealy clay with occasional sand grains, and partly with pisolitic structure. Its analysis (S-80) shows it to be still bauxitic.

A test pit south of the mine cut only soft clay, and several hundred feet east is a valley cut down to 20 feet below the level of the mine, but no bauxite nor claystone is seen on the slope. There are no indications that more high grade bauxite will be found in the vicinity, but there is available a large amount of clayey bauxite which will contain over 50 per cent of alumina after drying, and will undoubtedly come into demand some time in the future.



A. NORTH FACE OF THE ADKINS MINE OF THE NATIONAL BAUXITE CO., WILKINSON COUNTY, SHOWING "CHIMNEY ROCK" OVERLYING CLAY AND BAUXITE.

B. EAST FACE OF THE ADKINS MINE OF THE NATIONAL BAUXITE CO., WILKINSON COUNTY, SHOWING THE EOCENE BASAL CONGLOMATE ABOVE CLAY AND BAUXITE.

Analyses of clay and bauxite from the Adkins property

Constituents	S-76	S-77	S-78	S-79	S-80	A
Silica (SiO_2)............	43.02	31.30	41.92	23.47	31.57	2.37
Alumina (Al_2O_3)..........	37.70	46.37	39.16	48.90	43.54	62.39
Ferric oxide (FeO).......	1.85	1.84	1.83	2.04	3.38	1.37
Ferrous oxide (FeO(......	.14	.14	.10	.14	.14	....
Magnesia (MgO).........	tr	.05	tr	.18	.40	....
Lime (CaO)	.00	.00	.00	.00	.00	....
Soda (Na_2O)............	tr	.00	.00	.02	tr	....
Potash (K_2O)...........	tr	.00	.00	tr	tr	....
Ignition	14.80	17.85	13.98	24.04	18.30	31.45
Titanium dioxide (TiO_2)...	2.72	2.72	3.26	1.45	2.54	2.06
	100.23	100.27	100.25	100.24	99.87	99.64
Moisture	.70	.86	.78	1.02	.74	2.79

S-76. Massive claystone.
S-77. Bauxitic clay from bed just below the claystone.
S-78. Nodular clay from mass which cuts bedded clay.
S-79. Bedded clay.
S-80. Bauxitic clay from lowest exposure in pit.
A. Hard, high grade bauxite. Geol. Survey of Ga. Bull. 18, p. 443, 1909.

Mineral composition

Minerals	S-76	S-77	S-78	S-79	S-80	A
Gibbsite	1.73	30.24	5.39	44.27	25.57	92.34
Kaolinite	92.50	67.30	90.15	50.46	67.88	5.08
Limonite	2.16	2.13	2.12	2.39	3.92	1.61
Titanium dioxide (TiO_2)...	2.86	2.91	3.36	1.79	3.08	2.06
Water (H_2O)—excess......	.98	....	....	1.33	....	....
Water (H_2O)—deficiency..	....	2.31	.77	....	.58	1.45

ORIGIN OF BAUXITE

Conditions to be explained.—The brief summary given in the first part of this report indicates the diversity of form and mode of genesis of the various bauxite deposits of the earth. It is evident from the distribution, composition, and structural relations that the bauxite of the Coastal Plain of Georgia had an origin different in many respects from that of any other known deposits. The following are the conditions which must be explained by any satisfactory hypothesis of origin:

1. The deposits are horizontal, lens-like bodies, seldom if ever more than 10 feet thick and a few acres in horizontal extent.

2. The lenses are invariably underlain by sedimentary kaolin. The upper surface of the bauxite is frequently an unconformity, but in some known deposits, and probably originally in all, the bauxite is or was entirely surrounded by kaolin, having the form of a small lens of bauxite within a much larger lens of kaolin.

3. The bauxite was completely formed and indurated to almost its present condition before the end of Cretaceous time, as boulders and pebbles are found in the basal conglomerate of the overlying earliest Eocene beds.

4. There is no limestone nor any calcareous material either in or under the bauxite-bearing beds, which could have served as a reagent in precipitating the alumina.

5. The bauxite consists essentially of a mixture of gibbsite and kaolin, and contains iron and titanium in about the same proportion as the associated kaolin. Percentages of soda, potash, lime, and magnesia are lower in the bauxite than in the kaolin.

6. Nodular structure is always present in the ores, in fact, it is developed in some kaolins which contain only a minute amount of aluminum hydrate.

7. The nature of the solutions present during the formation of the bauxite was such that they were able, locally, to deposit pyrite, and to form geodes containing marcasite, sulphur, melanterite, coquimbite, alunogen and sulphuric acid.

It is obvious from conditions here stated that two unrelated phenomena were necessary for the production of bauxite deposits: first, the normal deposition of kaolin in a fresh-water lake or pond must be going on; and second, some solution having the power to form and deposit hydrate of alumina must be introduced. If any general or climatic factors were capable of producing bauxite, the large deposits would consist of bauxite instead of kaolin, so it is necessary to explain not only how the bauxite was formed, but why there is so little of it.

Only a solution containing hydrogen sulphide could have deposited pyrite and the assemblage of minerals found in geodes. The hypothesis here offered is that the bauxite is due to the action of hydrogen sulphide introduced into the lagoons in which kaolin was being deposited. This theory requires an explanation of the source of the hydrogen sulphide solution and the chemical reactions resulting in the deposition of aluminum hydrate.

Source of solutions.—During and at the close of the Triassic period occurred a period of deformation—faulting and warping, attended by igneous intrusions—in the rocks of Southeastern United States. The Jurassic was a period of erosion, but additional warping at the beginning of the Lower Cretaceous period was necessary to convert parts of the land area into localities of sedimentation. The disturbance of the rocks was great along the coast line, now the Fall Line. These movements opened up fissures and channels by which surface water could circulate through the igneous and crystalline rocks and the freshly deposited Cretaceous sediments.

Apparently all of the bauxite deposits in the Cretaceous formation are in the middle and upper portions. The lower beds near the contact with the crystalline rocks, contain considerable amounts of finely divided pyrite, which was evidently the source of hydrogen sulphide solutions.

The liberation of hydrogen sulphide from the pyrite took place by two reactions. First, descending water containing dissolved oxygen acted on the pyrite, producing ferrous and ferric sulphates and oxidizing the remaining sulphur to sulphuric acid. On penetrating below the zone of oxidation this free sulphuric acid attacked other sulphides, liberating hydrogen sulphide.[1] The hydrogen sulphide

[1] Emmons, W. H., The enrichment of sulphide ores: U. S. Geol. Survey Bull. 529, p. 91, 1913.

solutions then found outlets, forming groups of sulphur springs which were possibly, but not necessarily, thermal.

In the Lower Cretaceous period a group of such springs apparently found outlets in the Wilkinson County area and during the Midway deposition a similar group existed in Sumter and Macon counties. The distribution of the bauxite deposits indicates such an origin, as they occur in groups, with areas of barren kaolin between the individual deposits, and great areas along the strike of the beds in which no bauxitization has taken place.

There is plenty of present-day evidence that hydrogen sulphide solutions have been active, as the water of many wells and some springs throughout the Coastal Plain, and especially in the bauxite areas, is rather highly charged with hydrogen sulphide. A flowing well at Irwinton is said to have been abandoned on account of the offensive odor and unpleasant taste of the water, due to the presence of hydrogen sulphide and iron salts.[1] The water of the Toomsboro artesian wells has a decided taste and odor of hydrogen sulphide. These wells are in the center of the Wilkinson County bauxite district, and they penetrate very nearly to the crystalline basement rocks. There is a group of seven springs, known as Miona Mineral Springs, situated in Macon County a few miles north of the bauxite area. Two of the springs give water containing hydrogen sulphide.[2] Sulphureted water may also be formed from the disseminated sulphides of the crystalline rocks, as at White Sulphur Springs in Meriwether County. In that county sulphur springs and a hot spring are found within a few miles of the only deposit of bauxite known to occur in the crystalline area.

Chemical reactions and mode of deposition.—Suppose deposition of kaolin to be going on in a barrier lake (fig. 18). The streams flowing in had a steep gradient, and were rapidly cutting away the kaolinized rock which covered the slopes of the hills. The coarse sand and minerals of high density were dumped as crossbedded strata near the

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[1] McCallie, S. W., Underground waters of Georgia: Geol. Survey of Ga. Bull. 15, p. 194, 1908.

[2] McCallie, S. W., Mineral springs of Georgia: Geol. Survey of Ga. Bull. 20, p. 114, 1913.

mouths of the streams. Kaolin, mica, and other very finely divided minerals were carried out into the quiet waters of the lake, forming a bed of pure white kaolin at the deepest part. At all times the water of the lake was turbid with the considerable amount of kaolin which remained long in suspension.

Then a hydrogen sulphide spring found its outlet in the bed of the lake. When the hydrogen sulphide solution entered the aerated water of the lake the following reactions took place:

$$2H_2S + O_2 = 2H_2O + 2S$$
$$2H_2S + 3O_2 = 2H_2O + 2SO_2$$

If the supply of oxygen was limited, the former reaction occurred, with deposition of free sulphur; but in general oxygen was abundant, and the latter predominated. The sulphur dioxide united with water and oxygen by two stages, forming first sulphurous, then sulphuric acid, thus:

$$SO_2 + H_2O = H_2SO_3$$
$$H_2SO_3 + O = H_2SO_4$$

Sulphuric acid was the active agent in decomposing the kaolin. The reaction is:

$$H_4 Al_2 Si_2 O9 + 3H_2SO_4 = Al_2(SO_4)_3 + 2SiO_2 + 5H_2O$$

The aluminum sulphate was carried by circulation or diffusion to a position near the vent of the spring, where hydrogen sulphide was present and the water neutral or alkaline. Here it was hydrolized and precipitated as aluminum hydrate by the following simultaneous reactions:

$$Al_2(SO_4)_3 + 3H_2S = Al_2S_3 + 3H_2SO_4$$
$$Al_2S_3 + 6H_2O = 2Al(OH)_3 + 3H_2S$$

The hydrogen sulphide and sulphuric acid were thus regenerated and were able to act on more kaolin, so no large initial supply was necessary.

The aluminum hydrate formed in the above reaction at once accumulated into impervious, gelatinous balls and sank to the bottom,

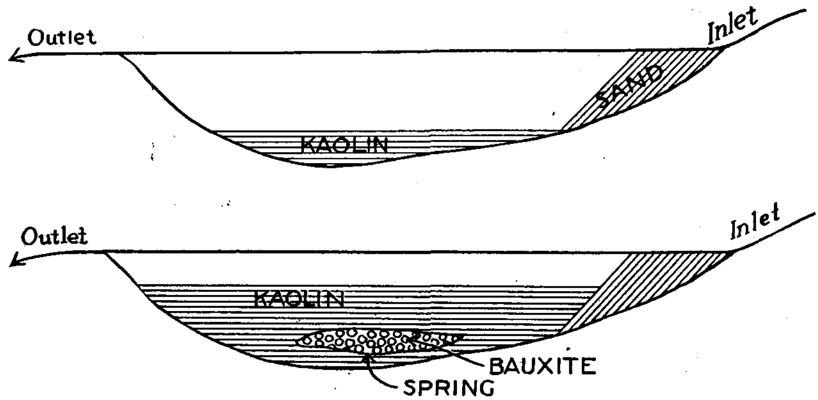

Fig. 18.—Hypothetical sketches illustrating formation f bauxite.

where it was removed from the sphere of action of the sulphuric acid, which was thus left free to attack the more stable, but finely divided, kaolin. The silica liberated was in hydrous form and remained in solution. A little was carried down with the aluminum hydrate, forming an opaline cement between the granules, but most of it was finally carried off at the outlet to the lake.

Solution of alumina and deposition of the hydrate depended on the distribution of solutions by currents and on the local active mass of sulphuric acid and hydrogen sulphide. Conditions for the decomposition of kaolin might be effective at one point, while deposition of aluminum hydrate was taking place an inch away.

Finally, the outlet to the sulphur spring became clogged or diverted to another locality, cutting off the supply of hydrogen sulphide, and deposition of kaolin continued until the lake was filled. Usually the spring seems to have died out gradually, producing a gradational phase of bauxitic clay between the pure bauxite and the kaolin.

Minor reactions and form of deposits.—Feldspar and mica fragments carried into the lake were more readily attacked by sulphuric acid than the kaolin, and the alkalies went off in solution. This explains the very minute amount of soda and potash found in the purer bauxites. Iron went through the same cycle of solution and redeposition as the aluminum, and titanium in the form of leucoxene was not affected by the solutions, so these two elements retain the same ratio to alumina in the bauxite as in the kaolin.

Aluminum sulphate may have been carried in by the water of the springs, and, if so, it was precipitated. But this hypothesis does not require the transferrence of aluminum in solution for any considerable distance, as its source is to be found in the kaolin which was constantly being supplied.

Carbonates carried into the lakes would have assisted in precipitating the alumina, but their presence was not essential. The inflowing streams were cutting into decomposed rocks, from which calcium and the alkalies had already been very thoroughly leached, and it is likely that in the early part of the Lower Cretaceous period erosion was so rapid that little soil could form and the steep slopes were almost bare of vegetation. On this account plant fossils are absent from the greater part of the formation. With the dearth of humus and lack of elements soluble as carbonates in the soil, the amount of carbonates carried down must have been negligible.

Locally, conditions were right for the deposition of the iron sulphides. In geodes the solution became concentrated and strongly acid, so marcasite was deposited; but in the dilute, neutral solution permeating the mass of freshly deposited aluminum hydroxide deposition in the form of pyrite cubes took place. Allen[1] proved experimentally that the concentration of free acid in solutions determines the precipitation of marcasite instead of pyrites on reduction of ferric salts by hydrogen sulphide. Whitman[2] produced pyrite synthetically under conditions very similar to those which must have existed during the deposition of bauxite. It would take too much space to describe the apparatus used and reactions obtained, but he concludes[3] "that pyrite can be precipitated from dilute (neutral or slightly alkaline) cold water solutions under practically atmospheric

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[1] Allen, E. T., The mineral sulphides of iron, Am. Jour. Sci., 4th Ser. No. 33, 1912.
[2] Whitman, A. R., The vadose synthesis of pyrites, Econ. Geol. vol. 8, p. 455, 1913.
[3] Op. cit., p. 468.

pressure, and that the precipitation is favored or induced by alumminous material, or by fine slimes in a reducing environment.''

The richness and form of the bauxite bodies depended on the supply of materials, both kaolin and hydrogen sulphide, and on local conditions, such as the relative positions of inlet, outlet, and spring vent, and rapidity of change of water. For the deposition of a bed of pure aluminum hydrate a nice adjustment of these various factors was necessary. The water must be very quiet, the kaolin must be fine and supplied very slowly, and sulphuric and hydrosulphuric acids must be present in sufficient amounts to attack all the kaolin and precipitate a large part of the alumina. Naturally, under such conditions the alumina was deposited in a flat-lying lens. In case the supply of kaolin was too abundant, only a small part of it was altered, and a bed of nodular clay was the result. Disturbance of the water by strong inflow from the springs or from feeding streams produced bauxitic masses of irregular shape, but in such cases there was no opportunity for complete alteration, so the irregular deposits never consist of high grade ore.

The inlets of the springs are inconspicuous and have not been certainly located in any case. In the Sweetwater mine a rise in the surface of the clay underlying the bauxite probably marks the position of the inlet, and in the Adkins mine a vertical mass or pipe of nodular clay cutting bedded clay was evidently a water channel. The sulphide water must have entered the lakes by numerous shifting channels through the freshly deposited kaolin, and, as the water had no power to alter kaolin until after it had come in contact with oxygen, with formation of sulphuric acid, the entrance channels can not easily be found and recognized.

The occurrence of pebble ores is also easily explainable. During periods of quiet deposition and slow introduction of kaolin, beds of very pure aluminum hydrate were formed, and lay as soft, gelatinous coatings on the bottoms of the lakes. Then the springs changed their points of entrance, or the waters were disturbed by storms or floods, and the amount of kaolin carried in increased for a time. The soft precipitate was broken up and rolled into pebbles by slight disturbances or shifting currents. The pebbles sometimes received fresh accretions of aluminum hydrate, in concentric layers around the older portion. Thus were formed beds of complex pebbles of very pure ore in a kaolinic matrix.

Solubility of kaolin in dilute sulphuric acid.—An experiment was made to determine the solubility of kaolin in dilute sulphuric acid. The kaolin sample used was a washed white plastic clay from the mine of the Savannah Kaolin Company near Gordon, Wilkinson County. A quantity of ten grams was placed in 500 cubic centimeters of a one per cent solution of sulphuric acid, and allowed to stand at room temperature (average 70° F) for seven days. The flask was shaken once or twice a day. It was found that even in the presence of the sulphuric acid, which, like other electrolites, has a tendency to cause kaolin to settle rapidly from suspension, the liquid did not become entirely clear in 24 hours.

Half of the solution (250 c.c.) was then filtered off and the dissolved alumina and iron precipitated with ammonia, ignited, weighed, fused with potassium bisulphate, reduced with zinc, and the iron titrated with potassium permanganate. A blank test was also made, using the same quantities of reagents, but without any kaolin, for which a correction of 0.0003 gm. had to be deducted.

The amounts taken in solution by 250 c.c. of acid acting on 5 gm. of clay, after deducting for the weight of the filter ash and the blank test on the reagents, were:

	gm.
Alumina (Al_2O_3)	.0108
Ferric oxide (Fe_2O_3)	.0029
	.0137

The original sample contained:

	Per cent
Alumina (Al_2O3)	44.28
Ferric oxide (Fe_2O_3)	.93

Therefore the percentage of the total quantity of these oxides dissolved was:

	Per cent
Alumina (Al_2O_3)	.55
Ferric oxide (Fe_2O_3)	6.23

This experiment shows that kaolin is soluble to a certain extent in cold dilute sulphuric acid, but it also indicates that a long time and very unusual conditions would be necessary for the production of bauxite deposits by any strength of acid likely to be produced by nature. However, bauxite is known to be produced by the much weaker carbonic and humic acids during rock weathering, and sulphuric is certainly a more efficient reagent than those acids.

The preceding hypothesis is presented as the best explanation of the possible origin of the deposits from materials known to have been available. It may require considerable modification if other factors favorable or unfavorable to bauxite deposition are discovered in the future.

METHODS

Mining.—The methods used in mining bauxite in the Coastal Plain are the simplest possible. Every deposit worked up to the present time has had an outcrop at some point on the slope of a hill, and mining consists simply in removing the overburden and working out the ore. The maximum known thickness of ore is about 10 feet, while overburden as heavy as 40 feet has been moved in places to get 5 or 6 feet of ore. All mining is done by manual labor, the ore and overburden being trammed to the dumps by hand or mule power. Steam shovels and drags have not been employed in any of the bauxite mines, but they are used extensively in kaolin and fullers earth mines in the vicinity. Their use in bauxite mining would certainly be economical in the larger deposits with heavy overburden. Both ore and overburden are so soft that blasting is rarely necessary.

As a rule, the upper surface of the bauxite forms a fairly sharp contact. In cases where an unconformity cuts off the top, the upper surface of the ore is rendered very irregular by pot holes and gullies, but there is no difficulty in distinguishing the place where the ore commences. The lower limit of workable ore, however, is not so easily determined, because there is usually a gradual change from bauxite to kaolin extending through a number of feet. Most of the ore is used in the manufacture of alum by treatment with sulphuric acid or 50°B., in which the alumina combined in silicates, such as kaolin, is not readily soluble. The only means of finding out just how much of the clayey material may be mined and used as ore is by keeping a check on the shipments, especially at first, by chemical analyses. The usual practice is to work far enough into the clayey bauxite so that the mixed material, when dried, will contain about 50 per cent of soluble alumina, as the alum manufacturers do not desire ore of lower grade than that.

Preparation.—The only treatment given the bauxite of the Coastal Plain previous to shipment consists in drying and, occasionally, screening. There are small quantities of bauxite which could be enriched by washing with a log washer, such as is used in the treatment of iron and manganese ores and bauxite in north Georgia, but no such washer has yet been installed.

The ore as mined contains a variable, but large, percentage of uncombined water, which adds greatly to the freight charges. It is customary, therefore, at all of the larger mines to dry the ore artificially before shipment, although that from several small deposits of high grade bauxite is simply air-dried in sheds or on board floors in the sun. The driers used are slightly inclined, rotary-cylinder kilns, about 30 feet long by 3 or 4 feet in diameter. They are usually heated by wood fires, the wet ore passing downward toward the flame. The dried ore is mechanically elevated to overhead bins, from which it is loaded on wagons or trucks by gravity. The drier at the Sweetwater mine is said to reduce the weight of the ore 10 per cent.

It is not advisable to heat the ore so highly as to drive off a large part of the combined water. Phillips and Hancock[1] carried on experiments which show that calcining reduces the solubility of the alumina in sulphuric acid of the strength used, although the effect is not great until about 80 per cent of the total combined water is removed. In the type of kiln used it is not likely that more than a very small percentage of the combined water is expelled.

A small amount of the pebble ore is screened to remove admixed sand and clay. The screens used are flat, inclined screens or revolving trommels of about three-eighths inch mesh.

Transportation.—The bauxite districts are well supplied with railroads. All of the deposits are within 10 miles of railroad connections, but none of the deposits so far worked are more than 4 miles from loading points. The ore is usually hauled to the railroad station in wagons, but one company has recently put a motor truck into service. The truck has a capacity of 4 tons, and carries 10 loads per day 3½ miles to the station.

In the Sumter and the Macon county district good sand-clay roads have been built, while in Wilkinson County the materials for constructing such roads are available but so far they are only partially improved. Sand clay roads are badly damaged by heavy hauling with wagons in very dry or very wet weather, so the use of motor trucks will render the maintenance of the roads much less expensive.

Exploration.—The known lenses of bauxite cover only a minute fraction of the area of the outcrop of the formations in which they are known to occur. There are almost certainly buried deposits which give no surface evidence of their existence, but the chances of finding them by random test holes are very small even in the most promising localities. Therefore, boring where there are no surface indications of bauxite is not advisable. When fragments of bauxite or indurated, nodular clay are found on a slope, pits or trenches should be sunk near the highest point at which such fragmental material is found. It is best to first dig pits around the edge of the ore body, in order that the workable thickness may be determined

[1] Jour. Am. Chem. Soc., pp. 220-221, 1898.

and representative samples obtained, after which a common clay auger, two or three inches in diameter, may be used to investigate the extent of the body where the overburden is heavier.

USES

The chief uses of bauxite as given by Phalen are[1]: (1) in the production of metallic aluminum; (2) in the manufacture of aluminum salts; (3) in the manufacture of bauxite brick; (4) in the manufacture of alundum (fused alumina) for use as an abrasive; (5) in the manufacture of calcium aluminate, used to give a quick set to plaster compositions.

1. The most important use of bauxite is in the production of metallic aluminum. The first step necessary is the treatment of the bauxite to obtain pure aluminum oxide. The method most commonly used is Bayer's process.[2] The bauxite is fused with sodium carbonate or sodium sulphate and lixivated; or is calcined and pulverized, mixed with a little lime and treated with sodium hydroxide under pressure. Sodium aluminate soluble in water is thus obtained. It is filtered hot, washed, and pure gelatinous aluminum hydroxide is added to the solution. The whole is then stirred continuously until the sodium aluminate is dissociated and the alumina precipitated as hydroxide. It has been discovered[3] that the alumina is precipitated first, and the silica mainly near the end of the reaction, so the process is stopped at a suitable point, before too much silica has been precipitated, the precipitated aluminum hydroxide is filtered off, and the solution containing sodium hydroxide or carbonate and some alumina is re-utilized in treating more bauxite. The hydroxide obtained by the Bayer process contains 40 per cent of water, and is easily soluble in acids. After drying it forms a white powder consisting of almost pure Al_2O_3, and is almost insoluble.

Sodium hydroxide or carbonate does not attack the iron oxides in

[1] Phalen, W. C., Bauxite and aluminum: U. S. Geol. Survey Mineral Resources for 1909, 1910, 1911, 1912, 1913, 1914, 1915.
[2] Molinari, Dr. Ettore, General and industrial chemistry, translation of 3d. ed., p. 571, 1912.
[3] McCulloch process, U. S. Geol. Survey Mineral Resources for 1914, p. 189, 1915.

the bauxite, which remain in the insoluble residue. Iron is therefore not objectionable in this process, except that it increases the bulk of material to be treated. Silica, however, goes into solution, and it is difficult to prevent its precipitation with the alumina. Silicon is reduced along with aluminum in the electric furnace, and its presence in the latter metal is very objectionable. Therefore, the principal requirement for aluminum ore is a low silica content, and iron may be considered a neutral impurity.

Aluminum is extracted from the pure aluminum oxide by the Hall or Heroult process. The two processes are essentially similar, but were developed simultaneously and independently by the two inventors. In both processes the alumina is reduced by an electric current in a bath of fused cryolite, the double fluoride of aluminum and sodium, using carbon electrodes. The cryolite is fused and powdered aluminum oxide introduced. The alumina dissolves and is electrolized, the metallic aluminum sinking to the bottom of the bath.

The uses of aluminum have become too numerous to be discussed in detail here. The new uses developed each year for the metal are described in the annual reports of the United States Geological Survey on Mineral resources. The use of aluminum is being curtailed at the present time (1916) on account of the high price, and it is reported that aluminum in actual use for electrical transmission is being replaced by copper. But when prices again reach a normal level, of something like twenty cents per pound, the former rapid increase in the demand for the metal for non-military purposes may be expected to continue.

2. The use of bauxite in the manufacture of alums and aluminum salts ranks second to its use in the production of aluminum. The base of most aluminum chemicals is the sulphate. For making iron-free aluminum sulphate, used for high grade chemicals, the aluminum hydroxide is first purified by Bayer's process; but in the manufacture of commercial grades of alum and aluminum sulphate the purification by solution as sodium aluminate is eliminated. The bauxite is pulverized and treated with sulphuric acid of 50° B. (1.53

specific gravity), which dissolves all of the aluminum trihydrate, and also slightly attacks kaolin and any lower hydrates which may be present. The solution is filtered or decanted into lead pans, where aluminum sulphate ($Al_2(SO_4)_3+18\ H_2O$) crystallizes out.

If *common alum* is desired the necessary amount of potassium sulphate must be added to the solution, and the double salt ($Al_2(SO_4)_3 . K_2SO_4+24\ H_2O$) crystallizes. Alum was first prepared from the natural mineral alunite, found near Rome, Italy, which contains both aluminum and potassium in the proper ratio; but since most alum has come to be made from bauxite it has been found that the normal aluminum sulphate will serve for most purposes as well as the more expensive potassium alum. The latter has therefore been almost entirely supplanted by aluminum sulphate.

By the acid treatment any iron oxide which may be present in the bauxite goes into solution with the aluminum; therefore only bauxites containing less than two per cent of ferric oxide are considered suitable for the manufacture of alum by this process. Silica is not dissolved, and its presence is not chemically objectionable. It must be remembered, however, that the silica in bauxite is mostly in the form of kaolin, and not only is it insoluble, but it holds in combination an approximately equal amount of alumina, which is rendered unavailable.

The principal use of aluminum sulphate is for the coagulation of impurities in water, especially for municipal supplies. It is also used as a mordant in dyeing, in tanning, etc.

3. Pure alumina melts at 2050° C, as against 1830° C for pure kaolin, so it was early suggested as a refractory material for furnace linings, but there were certain difficulties to be overcome before bauxite brick came into successful use.

Brick made of pure kaolinite would contain 46 per cent of alumina, and any addition of aluminum oxide renders the brick more refractory. Two kinds of bauxite brick are in common use, containing respectively 56 and 77 per cent of alumina, which represent the extreme proportions of alumina of value.[1] The brick containing 56 per cent of alumina is used in place of fire-clay brick, but is more refractory. The brick containing 77 per cent alumina is used as a substitute for magnesia brick for open-hearth furnaces, etc. Bauxite brick for use in basic open-hearth steel furnaces should contain less than 12 per cent silica.[2] Such bauxite brick has given good results, but normally is probably more expensive than magnesia brick.

In making the brick, the bauxite is first calcined at about 1400° C. (2500° F.). It is necessary to calcine at this great heat because the greatest shrinkage takes place between 2390° and 2500° F. The calcined mineral may be bonded with either fire-clay, sodium silicate, or lime. The brick must be carefully dried and burned at a high temperature. The brick are very hard and tough, but have a tendency to spall if suddenly cooled or heated.

4. Bauxite is used at Niagara Falls in the manufacture of the artificial abrasive, alundum. This is made by fusing calcined bauxite in an electric furnace. High grade bauxite produces alundum which is practically artificial corundum, and the ferruginous varieties give products corresponding to various grades of emery. Low silica content is required in the bauxite, but even highly ferruginous varieties are used. Alundum has a hardness of about nine in Moh's scale, and is particularly efficient in the grinding of steel.

Ground alundum, mixed with a binder and burned, makes a very refractory material for small articles such as muffles and crucibles, but it is too costly for extensive use in larger shapes.

5. Lastly, bauxite is used in the manufacture of hydraulic calcium aluminate, which is incorporated in plaster compositions to give them a quick set. This use is described in detail in the United States Geological Survey report on Mineral Resources for 1911.

The bauxite of the Coastal Plain, being prevailingly low in iron, but rather high in silica, is best fitted for use in the manufacture of alum and chemicals, and most of it is used for that purpose. Ores low enough in iron for use in the manufacture of alum by the acid

[1] Seaver, Kenneth, Bull. Am. Inst. Min. Eng., pp. 2505-2506, Dec. 1915.
[2] U. S. Geol. Survey Mineral Resources for 1913, p. 15, 1914.

process bring a higher price than aluminum ores, even thought the silica may be too high for the latter purpose.

PRODUCTION OF BAUXITE AND ALUMINUM [1]

Bauxite produced, imported, and consumed in the United States, 1889-1915, in long tons.

	PRODUCTION		IMPORTS		CONSUMPTION	
Year	Quantity	Value	Quantity	Value	Quantity	Value
1889	728	2,366	....	....	....	....
1890	1,844	6,012	....	....	....	....
1891	3,593	11,675	....	....	....	....
1892	10,518	34,183	....	....	....	....
1893	9,179	29,507	....	....	....	....
1894	11,066	35,818	....	....	....	....
1895	17,609	44,000	....	....	....	....
1896	18,364	47,338	....	....	....	....
1897	20,590	57,652	....	....	....	....
1898	25,149	75,437	1,201	4,238	25,350	[1]77,675
1899	35,280	125,598	6,666	23,768	39,916	[1]144,799
1900	23,184	89,676	8,656	32,697	30,840	[1]119,643
1901	18,905	79,914	18,313	67,107	36,218	[1]144,021
1902	27,322	120,366	15,790	54,410	43,112	175,875
1903	48,087	171,306	14,889	49,684	62,976	220,990
1904	47,661	235,704	15,374	49,257	63,035	285,961
1905	48,129	240,292	11,726	46,517	59,855	286,809
1906	75,332	368,311	17,809	63,221	93,141	431,532
1907	97,776	480,330	25,066	93,208	122,842	573,538
1908	52,167	263,968	21,679	87,823	73,846	351,791
1909	129,101	679,447	18,688	83,956	147,789	763,403
1910	148,932	716,258	15,669	65,743	164,601	782,001
1911	155,681	750,649	43,222	164,301	198,840	914,950
1912	158,865	768,932	26,214	95,431	186,079	864,363
1913	210,241	997,698	21,456	85,746	231,697	1,083,444
1914	219,318	1,069,194	24,844	96,500	244,162	1,165,694
1915	297,041	1,514,834	3,420	17,107	300,461	1,531,941

[1]Exports deducted.

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[1] Statistics taken from U. S. Geol. Survey reports on Mineral Resources.

World's production of bauxite, 1900-1914, in long tons

Year	United States	France	United Kingdom	Italy	India
1900	23,184	[1]58,530	[1]5,873	......	......
1901	18,905	[1]76,620	[1]10,357	......	......
1902	27,322	[1]96,900	[1]9,192	......	......
1903	48,087	131,781	6,128	......	......
1904	47,661	74,449	8,700	......	......
1905	48,129	101,378	7,300	......	......
1906	75,332	115,926	6,654	......	......
1907	97,776	155,512	7,480	3,445	......
1908	52,167	167,991	11,716	6,890	32
1909	129,101	128,099	9,500	3,881	32
1910	148,932	192,913	3,792	4,524	66
1911	155,618	250,818	6,007	5,600	12
1912	159,865	254,851	5,790	6,596	950
1913	210,241	304,407	6,055	6,843	1,184
1914	219,318	......	8,286	3,844	514

[1]Metric tons.

Prices.—The total production of bauxite in the United States to the end of 1915 was 1,912,122 long tons, valued at $9,016,465 at the mines; an average value of $4.72 per ton. The price has had an upward tendency during the past few years, being $4.81 in 1912, $4.75 in 1913, $4.87 in 1914, and $5.10 in 1915.

The United States now leads the nations in the production of metallic aluminum, and the rapid increase is shown in the accompanying table. These figures give production to 1900 and consumption since that year.

Aluminum produced or consumed in the United States, 1885-1915, in pounds

Year	Production
1885	283
1890	61,281
1895	920,000
1900	7,150,000
1905	11,347,000
1910	47,734,000
1911	46,125,000
1912	65,607,000
1913	72,379,000
1914	79,129,000
1915	99,806,000

PART II

FULLERS EARTH DEPOSITS

DEFINITION

Fullers earth is a variety of clay which has a high capacity for absorbing oil and grease, and also for adsorbing organic and mineral bases, including basic coloring matter, from solution in animal, vegetable or mineral oils, as well as from some other liquids, especially water. It is of commercial value when its adsorptive power is strong, and the balance between its other desirable and undesirable properties is such as to enable it to compete actively with other earths already accepted as of standard quality for refining oils.

Like other clays, fullers earth is made up essentially of hydrous silicates of aluminum; but analyses vary so greatly that the chemical composition is now known to be of almost no value in determining the efficiency of a fullers earth, or even in deciding whether a particular clay is to be classified as a fullers earth at all. However, all of the better grades of fullers earth are alike in that they show a ratio of silica to aluminum considerably higher than the ratio for the mineral kaolinite, which is supposed to form the base of common clays; and they always contain a large percentage of hygroscopic moisture which is not lost by air drying at ordinary temperatures. Some fullers earths also carry a higher percentage of combined water than ordinary clays, but this characteristic is by no means universal, and in some cases the bleaching power is not destroyed by driving off the water of composition. The bleaching efficiency of an earth is due principally to its physical characteristics, of which a high degree of porosity is most important.

HISTORICAL

The original use of fullers earth, from which it derives its name, was for removing grease and fat from woolen cloth during the process of fulling. The earliest reference to this process is by Pliny,[1] who, speaking of the "mysterie of the fuller's craft," says, "first they wash and scour a piece of cloth with the earth of Sardinia." The use of earth in fulling cloth was practiced in England during the Middle Ages, and the exportation of wool and fullers earth was prohibited in order that foreigners might not learn the secrets of the craft of woolen manufacture. The importance of this industry is evidenced by the commonness of the family name "Fuller."

Fullers earth for cleansing cloth has been almost entirely supplanted by soap and alkalies, so that use is at present of very minor importance. Its use for bleaching edible oils in the United States started about 1880. N. K. Fairbanks & Company, of Chicago, learned that in the Orient the color of olive oil is improved by agitating it with clay. A series of experiments were undertaken with cotton oil, which showed that the clay used in England for fulling cloth gave better results than any other clay then available.[2]

The first attempt to work fullers earth in the United States was made in 1890. A bed of Teritary clay marl near Alexander, Arkansas,[3] was opened and tested, but the material did not prove entirely satisfactory. The deposits near Quincy, Florida, were discovered in 1893, and the earth was soon found to be especially applicable in the refining of petroleum lubricating oils. The discovery was made accidentally.[4] An attempt was made to burn bricks from a clay found on the property of the Owl Cigar Company. The clay proved unsuitable for brick, but its resemblance to a German fullers earth was noted. The property is now held by the Floridin Company, and is one of the largest producers in the country. Other companies which have been active in Florida in recent years are the Atlantic Refining Company and the Manatee Fullers Earth Company, at Ellenton, Manatee County; and the Fullers Earth Company, at Midway, Gadsden County.

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[1] Holland, tr. of Pliny, XXXV, 17.
[2] Wesson, David, The bleaching of oils with fullers earth: Min. & Eng. World vol. 37, p. 667, 1912.
[3] Miser, H. D., Developed deposits of fullers earth in Arkansas: U. S. Geol. Survey Bull. 530, p. 208, 1911.
[4] U. S. Geol. Survey Mineral Resources for 1914, p. 36, 1915.

The most important of the Arkansas deposits, those near Benton, were discovered in 1897 by John Olsen, but that State was not added to the list of commercial producers until 1901, while Florida had been producing since 1895 and Colorado and New York since 1897. Mr. Olsen's mine and mill at Klondike, Arkansas, was still in operation in 1915, but several other mines in the vicinity, which had been operated for a time, were closed down.

The fullers earth deposits of Decatur and Grady counties, Georgia, were discovered soon after the Florida deposits, but Georgia did not become a producer until 1907, when it ranked as the third largest producing state, and since 1909 it has held second place. Almost the whole production of Georgia has come from two mines; one near Attapulgaus, Decatur County, operated by the Lester Clay Company; the other at Pikes Peak, Twiggs County, operated by the General Reduction Company.

Fullers earth is known to occur in 17 States, namely, Alabama, Arizona, Arkansas, California, Florida, Georgia, Massachusetts, Minnesota, Mississippi, Nebraska, New York, South Carolina, South Dakota, Texas, Utah and Virginia; but it was mined and marketed in 1915 in only six, Arkansas, California, Florida, Georgia, Massachusetts, and Texas. On account of the small number of producers, the figures on production by States are not given out by the United States Geological Survey, but some comparative statements have been made. Since the beginning of fullers earth mining Florida has produced two-thirds or more of the total each year. In 1915 Florida reported nearly 75 per cent of the total quantity and value, and Georgia about 20 per cent.

The industry in these two states has shown a slow but healthy growth, but in all other states production has been small and intermittent. The average price per ton has shown an upward trend. The lowest reported average was \$5.72, in 1904; the highest was \$10.21, in 1915, the latter year being the first time the price rose above \$10.00. The total annual production is now in the neighborhood of 50,000 tons, with a value of about half a million dollars. The quantity imported is normally about half the domestic production, but the value per ton of the imported earth is less than for the domestic.

OCCURENCE AND DISTRIBUTION

FOREIGN LOCALITIES

England.—Fullers earth is found in beds of Jurassic and Cretaceous age in England. The principal deposits occur in the Fullers Earth or Fullonian group of the Lower Oolites.[1]

Geikie says "The Fuller's Earth is an argillaceous deposit which, extending from Dorsetshire to the neighborhood of Bath and Cheltenham, attains a maximum depth of nearly 150 feet, but dies out in Oxfordshire, and is absent in the eastern and northeastern counties."

Searle[2] says of this formation: "Much of what the geologists term the Fuller's Earth or Fullonian series consists of limestone rocks or brown, blue, and yellow clays at the base of the Great Oolite. These are of insignificant industrial value and must not be confused with the true 'fuller's earth.' "

The series is large and thick, but the valuable portions are small and scattered. Fullers earth from this formation is mined at Midford and Wellow in Somerset, near Bath.

Fullers earth is also obtained from the Greensand formation of Upper Cretaceous age at Nutfield, Surrey, near Oxford, and at Woburn (Bedfordshire); also at Bletchingley, Reigate, and at Debtling near Maidstone. It is found occasionally in Silurian rocks, as in the Wenlock shales and Lower Ludlow beds in Shropshire. "Fullers earth rock" occurs at Thornton, Dorset, but can only be used to a limited extent, as it is deficient in some of the properties of true fullers earth. In parts of central Gloucestershire "fullers clays" lie over the solid strata of white limestone.[3]

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1 Geikie, Archibald, Text Book of Geology, 3d ed. p. 898, 1893.
2 Searle, Alfred B., An introduction to British clays, shales, and sands, p. 190, 1912.
3 Searle, A. B., op. cit., pp. 73 and 190.

Fullers earth mining has been most actively carried on in the region around Woburn Sands, on the border of Bedfordshire and Buckinghamshire. The fullers earth beds are found in the Lower Greensand formation.[1] The formation is 220 feet thick, but the fullers earth bed has a thickness of only 12 feet, and only about half of this is mined. The work is all underground, with timbered slopes and drifts. The earth is dried on iron shelves heated by flues. After drying the earth is ground in a cyclone pulverizer, and the fine material is separated by a current of air.

There are two varieties of earth, blue and yellow, the latter being considered more valuable commercially. A similar variation in color has been noted in the Georgia earths, where it is due to oxidation and leaching out of carbonaceous and calcareous material.

The product of these mines is exported for use in oil refining.

The earth from the Fullers Earth formation, mined at Midford, near Bath, was used (1898) only for fulling cloth. This earth is washed in a form of wet pan, passed into settling tanks, where it is allowed to settle for 30 days, then dried.

At present (1916) most of the earth imported from England appears to have been washed, and perhaps subjected to some other treatment. Little has been published regarding the English mines; and the details of preparation are, to a large extent, guarded as trade secrets.

AMERICAN LOCALITIES OUTSIDE GEORGIA

Arkansas.[2]—The developed fullers earth deposits of Arkansas occur in an area about 3 miles square which lies between Hot Springs and Benton.

These deposits differ from all others in the United States, as the earth does not occur in sedimentary beds, but is derived from the weathering of an igneous rock in place. The country rock of the

[1] Ries, Heinrich, The kaolins and fire clays of Europe, U. S. Geol. Survey, Nineteenth Ann. Rept., pt. 6 (cont.), pp. 408-411, 1898.

[2] Miser, Hugh D., Developed deposits of fullers earth in Arkansas: U. S. Geol. Survey Bull. 530, pp. 207-220, 1913.

area is the Ouachita shale, a black graphitic clay shale possessing slaty cleavage. The shale is cut by dikes of ouachitite, biotite monchiquite, and syenite, which are later than the period of metamorphism which produced the slaty cleavage. The time of intrusion is believed to have been late Cretaceous.

The basic dikes are weathered to a depth varying from 60 to 200 feet, according to permeability and local conditions, and the resulting clay has the properties of fullers earth. The fresher portions of the ouachitite and biotite monchiquite consist of augite, hornblende, biotite and magnetite with abundant secondary serpentine and calcite, besides limonite, chlorite, analcite, and zeolites. The weathered portion forms a decidedly plastic clay, yellowish to reddish brown near the surface and light gray to light olive-green at greater depth, which still retains the texture of the unaltered dike. If the original rock contained biotite, that mineral is present in the clay, but clays containing much biotite are not considered suitable for use as fullers earth.

The fullers earth is a decomposition product of hornblendes and augites, rather than of feldspars, as are ordinary clays. The basic dikes, which yield fullers earth, contain much augite and a large amount of hornblende, but practically no feldspar. A syenite dike in the area produces a residual clay of kaolinic character, which is not suitable for use as fullers earth, and intrusive masses of nepheline syenite a few miles east of the fullers earth district have been altered to high grade bauxite.

The basic dikes dip at steep angles, usually to the southeast, and vary from a fraction of an inch to 4½ feet in width. The mining is all underground work. A shaft is sunk and the earth is worked out in 30-foot stopes until hard rock is reached, but the upper 30 feet is not generally used.

The clay is dried in cylindrical driers, ground, and bolted or air-separated to pass 80 to 120 mesh. All is used for bleaching edible oils, as the product is not suitable for refining petroleum.

The production was 2,563 short tons in 1910, but it has since declined. In 1915 the combined production of Arkansas, California and Texas was less than 2000 tons. On account of the expensive methods necessary in mining, the Arkansas earth, even if of equally good quality, can not well compete with that of the thick bedded deposits of Georgia and Florida.

California[1].—Fullers earth is reported at several localities in California. The most important deposit is that operated by the California Fuller's Earth Company. The earth is a bedded deposit of Tertiary age, situated 18 miles north of Bakersfield. The bed is said to vary from 15 to 50 feet in thickness, with an extent of many acres, with only a thin layer of soil as overburden. The deposit was first opened in 1898, but its production has been small, and the product is used exclusively for refining animal and vegetable oils. The earth is said to compare favorably with English earth in bleaching power, but a feature of disadvantage is the wagon haul of 18 miles to the railroad.

Florida[2].—The extensive fullers earth deposits of Florida belong to the Alum Bluff formation, which forms the upper part of the Appalachicola group of late Oligocene age. The earth seems to form a continuous bed, underlying all of the upland area of Gadsden County, and outcropping on the slopes of the larger streams, near the bottoms of the valleys. The fullers earth bed also extends into the adjoining counties, Liberty and Leon, and across the State line into Decatur and Grady counties, Georgia. Fullers earth beds, apparently of the same age, are also found in Alachua and Marion counties, in central Florida, and in Manatee County, along the Gulf coast in southern Florida.

The most extensive mining operations have been carried on in

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[1] Cal. State Mining Bureau Bull. 38, pp. 273-275, 1906.

[2] Vaughan, T. W., Fullers earth of southwestern Georgia and western Florida: U. S. Geol. Survey Mineral Resources for 1901, pp. 922-934, 1902.

. . . . Fullers earth of Florida and Georgia: U. S. Geol. Survey Bull. 213, pp. 392-399, 1903.

Sellards, H. E., Fullers earth: Fla. Geol. Survey First Ann. Rept., pp. 33-35, 1908.

. . . ., Production of fullers earth in Florida during 1910-1911: Fla. Geol. Survey Fourth Ann. Rept. pp. 167-168, 1912.

. . . ., Fullers earth, Fla. Geol. Survey Sixth Ann. Rept., pp. 28-36, 1914.

. . . . and Gunter, H. Fullers earth deposits of Gadsden County, Florida, with notes on similar deposits found elsewhere in the State: Fla. Geol. Survey Second Ann. Rept., pp. 257-291, 1909.

Gadsden County, at Quincy, Midway and Jamieson, near the Georgia line. The fullers earth bed seems to be a little thicker and more persistent in Gadsden County than in Georgia, but the composition, structure, and geological relations are exactly the same. These deposits will be discussed in detail in connection with the description of the Alum Bluff earth of Georgia.

An important guide rock associated with the fullers earth in both States is a white to greenish or yellowish gray, soft, argillaceous and locally calcareous sandstone, locally called "sand rock." This rock is more resistant to erosion than the fullers earth, and often outcrops where the clay beds are entirely concealed.

Massachusetts.[1]—On the property of E. and R. M. Farnsworth, one mile north or Lancaster, Massachusetts, is a deposit of clay which has been mined for use as a fullers earth. This is a glacial silt, deposited in the Glacial Lake Nashua, and it is the only reported fullers earth of glacial origin.

The bed has a thickness, at one point, of at least 26 feet. Analysis shows that the clay resembles other fullers earths in its high content of silica and alkalies, but the percentage of combined water is very low (3.03 per cent). It is reported that all of the earth is used in fulling cloth, and its qualities as a bleaching agent for organic or mineral oils is not known.

Mississippi.[2]—Fullers earth is reported from Smith and Yalobusha counties, Mississippi, but it has never been worked on a commercial scale. That from Smith County probably comes from the Jackson formation, and it is said to have bleaching power equal to the English earth.

New York.[3]—A bed of clay at McConnellsville, 12 miles north of Rome, was worked several years ago by the New York Fullers Earth Company. It is a fine grained, dense Quartenary clay, occurring in

[1] Alden, W. C., Fullers earth and brick clays near Clinton, Mass.: U. S. Geol. Survey Bull. 430, pp. 402-404, 1910.
[2] Lowe, E. N., Soils and mineral resources of Mississippi, Miss. State Geol. Survey, Bull. 12, p. 143, 1915.
[3] Ries, Heinrich, Fullers earth, New York State Museum, Bull. 35, pp. 848-851, 1900.

layers 2 to 8 inches thick, interbedded with sand layers of equal thickness. The clay was used only for cleansing woolen goods.

South Carolina.[1]—Clays having the properties of fullers earth are widely distributed in South Carolina, occurring, according to Sloan, in the Black Mingo and Congaree phases of the Eocene, the Parachucla shales of the Oligocene, and the Hampton clays of the Lafayette formation. The fullers earth found in the vicinity of Augusta and Aiken, classed by Sloan as the Congaree phase, belongs, at least in part, to the Barnwell formation, and is areally continuous with the important deposits of Barnwell age in Georgia. This earth seems to lie at a higher horizon than the type Congaree of the Congaree River area. Sloan publishes 14 analyses,[2] showing that the clays resemble the Georgia earths in composition.

In spite of the large quantities of fullers earth present in South Carolina, mining operations have been of small importance. No production is reported since 1913.

South Dakota.[3]—The fullers earth deposits of South Dakota are fluviatile and fresh water clays, porous and lacking in plasticity, and said to be almost exact duplicates of the English earth in composition and properties. The age is Oligocene. The earth makes up a large part of the Chadron or "Titanotherium" beds at the base of the White River formation. The fullers earth formation extends from the high slopes of the Black Hills west of Fairburn and Hermosa far eastward into the Bad Lands, covering thousands of square miles.

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[1] Sloan, Earle, Preliminary report on clays of South Carolina: S. C. Geol. Survey, pp. 54-61, 1904.
. . . . Fullers earth, S. C. Geol. Survey, Bull. 2, 4th ser., pp. 339-361, 1908.

[2] Op. Cit., pp. 392-395.

[3] Ries, Heinrich, Fullers earth of South Dakota: Am. Inst. Min. Eng. Trans., vol. 27, pp. 333-335, 1898.
Darton, N. H., Preliminary description of the geology and water resources of the southern half of the Black Hills: U. S. Geol. Survey, Twenty-first Ann. Rept. part 4, pp. 588-589, 1901.
Fullers earth: U. S. Geol. Survey, Twenty-first Ann. Rept. part 6 (Cont.) p. 591, 1901.
Todd, James E., Mineral Resources of South Dakota, S. D. Geol. Survey, Bull. 3, pp. 107-108, 1902.
Darton, N. H., Geology and underground water resources of the Great Central Plains: U. S. Geol. Survey Prof. paper 32, pp. 43, 44, 175, 185, 398, 1905.
O'Harra, C. C., The Badland formations of the Black Hills region: S. D. School of Mines, Dept. of Geol., Bull. 9, pp. 65-66, 1910.
Perisho, E. C., The geography, geology, and biology of Melletto, Washabaugh, Bennett and Todd counties, south-central South Dakota: S. D. Geol. Survey Bull. 5, p. 60, 1912.

Test shipments have been made from localities near Fairburn and near Argyle, but no mining on a large scale has been done. Small samples are said to have given good results in bleaching vegetable and animal oils, but the larger test lots were not so good, owing to lack of care in selection of the material.

Texas.[1]—The fullers earth beds of Texas occur in the upper portion of the Jackson formation, of Eocene age, and in the Corrigan formation, probably Oligocene. The earth in the Jackson formation is a brown clay, occurring in beds up to 12 feet thick. Its bleaching power is greater than that of the standard English earths, and filtering properties are good.[2]

Two expensive grinding plants were erected about 1909, near Somerville (Summerville), Burleson County and near Burton, Washington County, but the production has remained very small, as the sale of the earth is severely handicapped by the cost of transportation.

Virginia.[3]—The so-called fullers earth of Virginia and Maryland consists of beds of infusorial or diatomaceous remains near the base of the Chesapeake formation of Pliocene age. The best exposures are in bluffs along the Potomac. At one time the deposits near the mouth of Pope Creek, Maryland, were worked for shipment, but no production has been reported in recent years.

TESTS FOR FULLERS EARTH

As the chemical analysis does not indicate the commercial value of a fullers earth, it is necessary to make tests of the bleaching power and other physical properties. The earths described in this report have been tested for bleaching power on cotton oil only. No tests

[1] Duessen, Alexander, Notes on some clays from Texas: U. S. Geol. Survey Bull. 470, pp. 337-343, 1910.
Phillips, Wm. B., Mineral Resources of Texas: University of Texas, Scientific Series Bull. 29, pp. 81, 97, 121, 216, 241, 1914.
Udden, Baker, Böse, Review of the geology of Texas: University of Texas, Bull. 44, p. 147, 1916.
[2] Parsons, Charles L., Fullers earth: Bureau of Mines Bull. 71, 1913.
[3] Darton, N. H., Geologic atlas of the United States, Nomini folio, No. 23, U. S. Geol. Survey, 1896.
Watson, T. L., Mineral Resources of Virginia, The Virginia Jamestown Exposition Commission, pp. 296, 297, 1907.

were made with mineral oils. In commercial practice in bleaching mineral oils percolators containing as much as 25 tons of fullers earth are used and several hundred barrels of oil are bleached in a run, making the conditions difficult to duplicate on a laboratory scale, and no standard method for comparing tests has been devised. In the case of animal and vegetable oils, however, in which the oil is agitated with a definite proportion of earth and filtered, the laboratory tests indicate accurately the results which may be expected in commercial practice, and by the use of the Lovibond color scale quantitative results may be obtained.

It is probable that the bleaching power of the various earths when applied to other animal and vegetable oils will be of the same order as with cotton oil. In bleaching mineral oils the actual bleaching efficiency should also rank about the same as for cotton oil, but for this use the physical character of the earth is of as much importance as the bleaching power. Coarsely granular earth is used, and it must have such hardness and strength that not much will be lost as dust during repeated use and revivifying.

The following methods of testing were used for all earths described in this report.

PREPARATION OF SAMPLES

Samples of 2 or 3 pounds of earth were taken, usually representing an average of all the beds in an exposure. The samples were broken down to a maximum size of half an inch, and a small sample for analysis taken out by quartering. The remainder was dried in an electric oven for 24 hours, at a temperature maintained between 100 and 110° C. The dried material was then ground in a coffee-mill until all passed through 20 mesh, and put through a small bolting machine, grading it into 20 to 40, 40 to 60, 60 to 100, and through 100 mesh sizes. A few samples were put through 200 mesh.

The bolter used was equipped with silk cloth. The average size of the openings, measured with the optical micrometer, was as fol lows:

Mesh	Distance between centers of cords of cloth	Average Opening
	Inches	Inches
20	0.05	0.0384
40	0.025	0.0192
60	0.0167	0.0115
100	0.01	0.0062
200	0.005	0.0025

BLEACH

The method used in making bleaching tests is that employed at the Picard-Law Laboratories, Atlanta, Ga.

The oil used for tests is a "prime summer yellow" cotton oil, preferably one of moderate color and capable of bleaching well. Fullers earth has no power to bleach crude cotton oil; the oil must first be refined by the usual alkali treatment, which removes free fatty acids and converts the coloring matter into basic forms. Oil from the same lot should be used for all tests of a series, as different refined oils, even if they have the same original color, differ greatly in their capability of being bleached.

Two hundred grams of oil is weighed in a beaker, and heated to 120° C. Twelve grams of earth is added, the beaker removed from the burner, and the oil is stirred for five minutes, then filtered immediately.

The preliminary heating is for the purpose of driving out any trace of water which the oil may contain, and also to drive out the hygroscopic moisture from the earth added. A small amount of extent.

water in either oil or earth prevents the bleaching action to a great

In standard tests the amount of earth used is 6 per cent of the weight of the oil; and unless otherwise stated, this proportion is always used.

If only a bleaching test is to be made a large folded filter paper may be used, but if it is desired at the same time to measure the speed of filtration and the proportion of oil remaining in the earth, in order to form an idea of the action of the earth in filter press, the filtration is made with a Buchner funnel, using suction.

The filtered oil is placed in a standard sample bottle and the color determined as soon as possible, and without exposing to light any more than absolutely necessary.

The standard sample bottles have a capacity of 4 ounces, and are exactly 5¼ inches in height, from the inside of the bottom to the base of the neck. The bottoms are ground plane and polished, as the refraction of light by an ordinary rough or curved glass surface would effect the apparent color of the oil. Some forms of color comparators have horizontal rectangular cells, but the essential feature is to have a column of oil exactly 5¼ inches in length.

The Lovibond color scale.—The Lovibond scale consists of glass plates tinted with graduated shades of the primary colors. By the use of the red, yellow, and blue series of glasses almost any color can be duplicated. As cotton oil contains no blue coloring matter, its shades can be matched with color glasses of the yellow and red series.

It is found in practice that a colum of 5¼ inches of prime yellow oil, refined but unbleached, can be best matched by using the 35 units yellow glass, then adding enough red glasses to match the tint. The number of units of red needed is more than one tenth the number of yellow units, commonly between 5 and 6. If more than 7.6 units of red are necessary to match, the oil is considered off-color.

Fullers earth has a stronger affinity for the red than for the yellow coloring matter of cotton oil; so after bleaching, it is found that a normal oil can be most accurately matched by using red and yellow glasses in the ratio of 1 to 10. This color ratio applies in all cases where the earth used is of fair efficiency; if an earth or clay with only slight bleaching power is used the red may remain more than one tenth the yellow after bleaching.

As oils vary so much in bleachability, the best results that can be secured are only comparative. The same oil used for the bleaching test on an earth of unknown value must also be bleached with a standard earth of known quality, and the results compared. The earths generally adopted as standard are the IXL brand of English earth and the Pikes Peak brand of Georgia earth. Of these the Pikes Peak brand gives a bleach several units lighter in yellow and several tenths lighter in red than the English earth.

After-bleach.—An oil bleached by fullers earth is further bleached by exposure to light. A number of the bleached samples of oil were allowed to stand for two weeks in a well-lighted room, but in a position where direct sunlight did not fall upon them, then readings were taken again.

The results indicate that the bleaching effect of light is stronger after some earths have been used than after others, but sufficient data have not been collected to show on what property of the earth the efficiency of the after-bleach depends.

The bleaching by light affects principally the yellow coloring matter of the oil. The oils after exposure to light contained only a few tenths less red than immediately after treatment with the earth, but the yellow was bleached as much as 10 units in a number of cases. This means that while exposure to light gives the oil a lighter color, the tint becomes redder.

Exposure to light has also some bleaching effect on the oil untreated with fullers earth, but when untreated the light-bleach affects principally the red coloring, as the oil can still be matcher with the 35 yellow glass and a smaller amount of red than before exposure.

The bleach produced by light is only temporary. The samples after exposure to light were placed in a dark room for two weeks. In all cases the oil was darker than when the preceding reading was made, but the tests indicate that the reversion of color is very slow, and no attempt was made to find out how long and to what extent the process would continue.

ABSORPTION OF OIL

Absorption was in most cases determined in the fullers earth residue from the bleaching tests. Filtration was made through a small Buchner funnel, using an aspirator with a gage. The maximum vacuum attained was equivalent to 25 inches of mercury, but it generally dropped to about 20 inches near the end of the suction, as the cake became more pervious to air. Suction was continued in all cases until the oil came through at the rate of one drop per minute. This, in some cases, required several hours of suction, and it would have required an unreasonably long time to have sucked the cakes entirely dry.

The entire funnel containing the oil and earth cake was weighed to 0.1 gram, then the earth was removed from the funnel and filter paper and the funnel weighed again. A hard filter paper was used, fastened around the edges with a little glue, so the earth could be easily cleaned out. The amount of oil remaining in the paper and in the bottom of the funnel was the same for both weighings, and the difference in weight represents the original 12 grams of earth plus the oil absorbed by it. The absorption is stated as the percentage of oil remaining in the cake after filtering.

The results obtained by this method are not highly accurate, the greatest source of error being the uncertainty as to the exact time at which suction should be stopped. The percentage of oil remaining in the earth after suction is about twice that left in commercial practice with the filter press, but the results are valuable as a basis for comparing the various samples.

No attempt was made to measure the time required for filtration, except to note those cases in which filtration was exceptionally rapid or exceptionally slow. In general, the very light and porous earths with high absorption filtered more slowly than denser earths, but little can be learned by laboratory tests as to the action of the earth in a filter press, because so much depends on the method of grinding and the proportion of very fine material. The earths containing calcium carbonate also filter very slowly. It seems that calcium carbonate is sufficiently alkaline to saponify a small amount of the oil, and the minute quantity of soap so formed clogs the pores in the filter paper.

SPECIFIC VOLUME

The true mineral specific gravity of all samples of fullers earth runs about the same, not differing greatly from that of ordinary clays, and varying from 1.75 to 2.50. The weight of a given volume of the dried and ground earth, however, varies greatly. The relation between weight and volume depends to some extent upon the shape of the grains, the relative proportions of coarse and fine grains, and the method of grinding, but it is principally a function of the porosity of the earth.

Most of the Georgia earth of good bleaching power is extremely light and porous, weighing approximately half as much as the English earth, and therefore requiring twice as many sacks per ton and necessitating the opening of the filter press a greater number of times in filtering a given quantity of oil, if the same proportionate weight of earth is used. On account of this great variation the quantity of earth used in large scale filtering tests should always be weighed, not measured.

The weight of equal volumes of different earths was determined under as nearly identical conditions as possible. The method consisted in taking a small Erlenmeyer flask of known weight and capacity, and filling it with the dried and ground earth, at the same time tapping the flask gently on some soft surface, until it would hold no more. The weight of the contents was then determined.

The results are comparative rather than absolute, but they are of much more value than exact determinations of specific gravity, because the latter gives no indication of the porosity and the space occupied by the ground material.

It was found that, allowing for errors in the rather rough methods used, the absorption of oil by an earth varies inversely as the density. The English earth has a density as determined by the above method, of a little over 1.0, and weighs 66 pounds per cubic foot; almost the same as a pure kaolin. The Georgia earths are all lighter, several having a density as low as 0.44, weighing 28 pounds per cubic foot. Provided the particles are of about uniform size, the fineness of grinding has little effect on the weight of a given volume of earth. Normally the portion of the earth passing through 100 mesh is a little heavier than the 20 to 40, 40 to 60, and 60 to 100 mesh grades, because the smaller particles are more irregular and have a greater relative variation in size, therefore packing closer; but in some cases the earth through 100 mesh is so light and fluffy that it cannot be packed by the same amount of tamping as the coarser grades, and is therefore a little lighter.

As a check on these determinations, the density of pure granular vein quartz, which has an actual specific gravity of 2.60, was determined by the same method. The 20 to 40 mesh size had a density of 1.41, weighing 88.5 pounds per cubic foot; and the 40 to 60 mesh, a density of 1.39, weighing 86.6 pounds per cubic foot.

The density of the Georgia earths in mass is very nearly equal to that of water. As taken from the mine the earth contains about 50 per cent of hygroscopic moisture, but after air drying it will float in water until the pores become filled. This provides an easy test for fullers earth, as a dry clay which will float is almost certain to have good bleaching power.

APPARENT ACIDITY

Fullers earth possesses the power of adsorbing inorganic bases as well as basic colors, and this affinity for basic ions causes neutral solutions to give an acid reaction on addition of fullers earth, although there is actually no free acid present in the earth.

To test an earth for apparent acidity, a two gram sample of the finely ground earth was placed in 100 c.c. of distilled water, which was then boiled to expel carbon dioxide and to thoroughly saturate the earth, and titrated with a standard $\frac{N}{10}$ solution of potassium hydroxide, using phenolphthalein as indicator. The results are stated as the number of cubic centimeters of tenth-normal alkali required to neutralize 100 grams of the earth.

Some of the earths contain pyrite, which becomes partly oxidized during drying. When placed in water these earths actually liberate sulphurous acid, and they also contain soluble sulphates of iron and aluminum, which must be precipitated by the base before an alkaline reaction can be obtained. Such earths, therefore, require a very large amount of alkali for neutralization.

In the case of earths which contain no free acid nor soluble salts the bleaching power is not directly proportional to the apparent acidity, but in general those having a high power of absorbing inorganic bases are good bleaching earths.

FULLERS EARTH DEPOSITS OF GEORGIA

FULLERS EARTH OF JACKSON AGE

GEOLOGY OF THE TWIGGS CLAY MEMBER

Areal distribution.—Outcrops of fullers earth and similar clays belonging to the Twiggs clay member of the Barnwell formation occur in a narrow belt extending more than half way across the State. The westernmost exposures are in Dooly County, and the belt continues northeastward to Savannah River near Augusta, with exposures in Houston, Crawford, Twiggs, Bibb, Bleckley, Wilkinson, Jones, Baldwin, Washington, Glascock, Jefferson, Burke, Richmond and Columbia counties. Throughout most of the area underlain by the Twiggs clay the underlying Ocala limestone and the earlier Eocene formations are absent, so the location of the outcrops is just south of the belt in which the Cretaceous strata come to the surface.

Stratigraphic relations.—The Twiggs clay member occupies a position at the base and near the northern margin of the Barnwell formation, which consists principally of glauconitic sand and marl. The clay grades downward and southward into the Ocala limestone, or into the marl and oyster shell beds of the Barnwell formation. Along the northern margin of the outcrops it is overlain with a slight unconformity by red sands of the Barnwell formation. This unconformity is exposed at Pikes Peak and Grovetown, but it evidently represents a withdrawal of the sea for only a short distance and for a short period of time, because farther south the clay member is conformable with the remainder of the Barnwell formation. Northeast of Wilkinson County the Ocala limestone is absent, and the clay rests directly on the surface of the Lower Cretaceous, or is separated from it only by a thin bed of sand, and locally tongues of the clay member overlap the Cretaceous beds entirely and rest upon the crystalline rocks of the Piedmont area. The most notable of these overlaps are at Roberts and Grovetown.

Lithologic characters.—As indicated by the name, the member consists chiefly of clay, most of which presents some characteristics of fullers earth. The earth of commercial value is a laminated to moderately thick bedded, jointed clay, which is chiefly characterized by its extreme lightness and porosity. When thoroughly air-dried it will float on water. It is brittle and lacking in plasticity, so that when a fragment of the wet clay is struck with a hammer it shatters, instead of being deformed. Such plasticity as the earth possesses is developed only by fine grinding and mixing with a large proportion of water. The earth does not slake in water, but remains firm, and pebbles are often rolled in streams for considerable distances from the outcropping beds. The layers of fullers earth are soft and unctuous to the touch, and almost free from grit, but the stratum generally contains more or less sand in lenses and pockets and has thin partings of micaceous sand between the layers or laminae.

In color the dry earth is white, drab, gray, or yellow, varying in tint from pale cream color to ocher-yellow, according to the percentage of ferric oxide. When wet the color is darker than when dry, and is characteristically gray or olive green of varying shades.

Locally in the northeastern counties of the fullers earth belt, the clay is indurated by the deposition of silica in the pores, forming a clay-stone or flint clay with approximately the hardness of an average limestone. Such clay is massive in the ground, but on exposure it breaks down in a peculiar manner into small fragments with angular and conchoidal fracture. It is distinguishable from indurated kaolins of the Lower Cretaceous, which it resembles in appearance, by its method of fracturing and by its high content of silica.

Earth of good quality seems to have been deposited only in estuaries and several miles from the shore line. On this account the deposits, while large, are discontinuous and of lens-like character. The clay along the extreme northern margin of the area of deposition is denser and more plastic than the good fullers earth, and approaches common clay in composition and characteristics. The formation has this character at Stevens Pottery and at Roberts, some of the northernmost extensions. Locally the clay deposited near the shore line is highly carbonaceous, grading into lignite, as the Chapman Lignite mine near Grovetown and at the Harbison and Walker fire clay mine near Gibson. Where carbonaceous, the clay generally contains also a considerable percentage of pyrite, which sometimes occurs in crystals visible to the naked eye.

Southward, as the water during the period of deposition became deeper, the Twiggs clay becomes more calcareous, and gradually merges into the Ocala limestone in the west and into marl and oyster shell beds in the east. As the percentage of calcium carbonate increases the clay becomes harder, until some varieties are best described as argillaceous limestones. Most of the calcareous clay varies in color from slate-blue to very dark gray when fresh and wet, but at the surface it becomes cream-colored by oxidation of the iron and leaching out of carbonaceous and calcareous matter.

At localities where the fullers earth was not deposited, and north of the limit of clay deposition, beds of yellowish-green glauconitic sand extend to the base of the Barnwell formation. Locally near the base of the formation are beds of shaly aluminous sandstone, quartzite, and completely silicified sandy limestone. These beds and the local deposits consisting largely of oyster shells represent depositional phases during the time of formation of the fullers earth member. At a few localities the basal beds of the Barnwell consist of reworked Lower Cretaceous sands and therefore resemble the latter formation, but in general the two formations may be readily distinguished by color and presence of fossils in the Barnwell.

Strike, dip and thickness.—The line of strike of the Twiggs clay member extends approximately northeast, from the vicinity of Perry, Houston County, to Grovetown, Columbia County.

Exposures along the Macon-Perry road (National and Dixie Highway) in Houston County afford data for estimating the slope of the Cretaceous surface. At 5.1 miles from Perry the unconformity between the Cretaceous and Eocene (Jackson) beds is exposed at an altitude of 360 feet, and at 13.1 miles is another exposure at an altitude of 450 feet. There are several other exposures in the intervening distance, which show that the Cretaceous surface is almost plane and has a uniform slope. The unconformity dips 90 feet in 8 miles, or 11 feet per mile, in the direction of the road, but the road is not perefectly straight, and it makes an angle of about 30 degrees with the line of dip of the beds, so the dip is steeper than indicated, and may be estimated as exceeding 12 feet, but not exceeding 20 feet, per mile. The dip of the Jackson beds is a little less than that of the unconformity, and is probably about 10 feet per mile, in a direction a little south of southeast.

In Twiggs County the slope of the upland areas, remnants of the original plain, is 9 feet per mile in the direction of the Macon, Dublin, & Savannah Railroad from Pikes Peak to Danville. No data have been secured for accurately measuring the dip of the Jackson beds, but it is a little steeper than the slope of the plain, and is probably between 10 and 15 feet per mile.

In the eastern part of the State the upper surface of the Lower Cretaceous beds is very irregular, and the angle of dip of the unconformities can not be stated with any degree of certainty. At Grovetown the fullers earth beds lie directly upon the Lower Cretaceous at an altitude of 500 feet. At Griffin Landing on Savannah River, Burke County, a bed of *Ostrea georgiana* shells in a matrix of calcareous clay of the fullers earth type rests unconformably upon blue marl of the Claiborne (McBean formation) near low water level, altitude 80 feet. The distance between these points in an air line is 36 miles, in a direction S 52° E, or almost parallel to the dip. Therefore the clay beds at the base of the Barnwell formation dip slightly more than 10 feet per mile to the southeast.

The Twiggs clay attains its maximum thickness near Pikes Peak, Twiggs County, where there are two fullers earth horizons separated by a bed of greenish, fossiliferous sand, the whole having a thickness of 100 feet. In Houston County also there are beds of fullers earth, calcareous clay and sand having a thickness of about 100 feet which may be considered as making up the Twiggs clay member. To northward the clay grades into sand, and to southward it becomes thinner as the underlying limestone thickens. Northeastward along the strike the member also becomes thinner, and in Jefferson and Columbia counties the beds of fullers earth rarely reach a thickness of 20 feet.

Physiographic expression.—The clays have no marked influence on the topography, as the outcrops are mainly in ravines, gullies and stream bluffs and on the lower slopes in valleys; localities where the overlying red sand of the Barnwell formation has been eroded. In the few localities where the fullers earth outcrops over any considerable area it forms exceedingly sticky, black clay soil.

Paleontological characters.—The Twiggs clay member is not paleontologically distinct from the rest of the Barnwell formation. The most characteristic fossil of the fullers earth horizon is *Ostrea georgiana,* which forms beds many feet in thickness, and is at some places accompanied by Bryozoa of the Rich Hill (Ocala) fauna. The westernmost of the oyster beds is near Danville, Twiggs County, and they become increasingly thick and abundant eastward, reaching their greatest development at Keys Mill, Shell Bluff and Griffin Landing, Burke County.

The fullers earth, especially the calcareous varieties, contains abundant fossil remains at some places. The animal remains are mainly molluscan casts, with the material of the shells sometimes changed to a soft, chalky material. Such fossils are very fragile and are difficult to collect and identify, but the forms are apparently the same as in the harder, silicified beds. At certain localities, plant fossils are abundant in the more or less carbonaceous varieties of clay, consisting principally of leaves and stems deposited along bedding planes, and splendidly preserved. Vertebrate remains consist of sharks teeth, which are abundant at a few localities, and bones of the Zeuglodon, *Basilosarurus cetoides* (Owen), are found in sand beds just below fullers earth near Dry Branch. For a more extensive list of the fossils see Bulletin 26, Geological Survey of Georgia.

DESCRIPTIONS OF INDIVIDUAL DEPOSITS

TWIGGS COUNTY

As previously stated, the important clay member of the Jackson group reaches it maximum thickness and is best exposed in Twiggs County, from which the name "Twiggs clay member" is derived.

Ocmulgee River forms the western boundary of the county, and its valley is cut down into the Lower Cretaceous beds and the sand members of the Upper Cretaceous Ripley formation as far south as a point between Adams Park and Westlake. Big Sandy Creek, which crosses the northeastern corner of the county, has also cut through the Tertiary beds and into the Lower Cretaceous, while the Upper Cretaceous strata are not exposed in Big Sandy Valley nor at any place farther east within the State of Georgia. The upland area forming the central and southern portions of the county is underlain by red sand, fullers earth, and limestone of Jackson age. In the extreme southern part chert bearing fossils of Vicksburg (Oligocene) age is found in the red sand, and although there is no paleontological evidence farther north, it is possible that the red sand capping the hills and locally overlying the clay member unconformably as far north as Pikes Peak also belongs to the Vicksburg formation.

Topographically the county forms a part of the Fall Line Hills belt. Only Ocmulgee River and Big Sandy Creek have formed broad valleys with well-developed river swamps or flood plains, while the remainder of the county is a plateau dissected by deep narrow valleys with precipitous sides. The steep valley slopes are cut by many deep gullies, largely formed since the deforestation of the land, in which may be observed geologic sections often totaling over 100 feet of freshly exposed strata.

The Lower Cretaceous beds consist of light-colored arkosic and kaolinic sands with prominent lenses of sedimentary kaolin, which is extensively mined in the vicinity of Dry Branch. The Upper Cretaceous, of which only the Cusseta and Providence sand members of the Ripley formation are exposed in the county, consists dominantly of light-colored kaolinic sand. Fossils, calcareous materials, and clays of ordinary composition are lacking in all the Cretaceous formations, and the character of the beds is so different from the Eocene deposits that there is never any possibility of mistaking the Cretaceous or Eocene age of the strata.

The Ocala limestone, which underlies the fullers earth beds throughout the greater part of the area of Twiggs County, has the same character as in other counties to the southwest. It consists almost entirely of bryozoan fossils, and *Pecten perplanus* and *Periarchus pileus-sinesis* are very abundant. The maximum thickness is 45 to 50 feet in the southwestern part of the county, but it becomes thinner to the north and east.

The Twiggs clay member changes considerably in character from north to south within the county. In the northern part, near Pikes Peak, there are two well defined beds of fullers earth in a horizon having a total thickness of 100 feet. The lower bed is about 45 feet thick, the upper over 20 feet, and the two are separated by a bed of greenish-yellow fossiliferous sand which reaches a thickness of 50 feet. The earth in this vicinity is not calcareous except near the base, where it grades into limestone. Where leached and oxidized by surface water it has a pale yellow to cream color, and is extremely light and porous; but below the zone of oxidation it is usually dark gray, and contains organic matter and pyrite. Farther south, for instance, in the vicinity of Danville and Westlake, the fullers earth bed becomes thinner as the underlying limestone thickens, and the clay becomes more and more calcareous. The calcareous earth is blue or gray where unoxidized, but becomes cream or yellow at the surface. It is much less pervious than the non-calcareous variety, so the zone of leaching and oxidation frequently extends less than an inch from the surface, while in the northern part of the county the material is usually oxidized to a depth of many feet.

The structure is simple, as the beds are almost in their original position, and dip slightly to the southeast. The only evidence of folding is seen in the railroad cut at Pikes Peak station, where there is a local anticline with limbs dipping 4 degrees southeast and 3 degrees northwest. The slope of the upland areas, remnants of the original plain, is 9 feet per mile, as the altitude decreases from 625 feet on the hill tops near Pikes Peak to 460 feet at Danville, a distance of 18 miles. The dip of the beds is a little steeper than the slope of the plain, and is probably between 10 and 15 feet per mile.

PIKES PEAK LOCALITIES

GENERAL REDUCTION COMPANY PROPERTY

(Map locality T-1)

The General Reduction Company was incorporated in 1908, and mining operations were commenced by Mr. James E. Carlton about that time. A great deal of experimental work was done before finding a satisfactory method of drying and grinding the earth, but the difficulties have been overcome and the plant is now operating steadily and profitably. At present Mrs. L. H. Carlton is president of the company and Mr. K. R. Slocum is manager. The post-office address is Dry Branch, Georgia.

Location.—The General Reduction Company owns about 1300 acres of land in the vicinity of Pikes Peak station on the Macon, Dublin & Savannah Railroad. The mine is 12 miles from Macon, and half a mile northeast of Pikes Peak station.

The locations of the exposures described are shown on the topographic sketch map, figure 19.

Geologic relations.—The following section is exposed in and near the fullers earth mine (Map locality A).

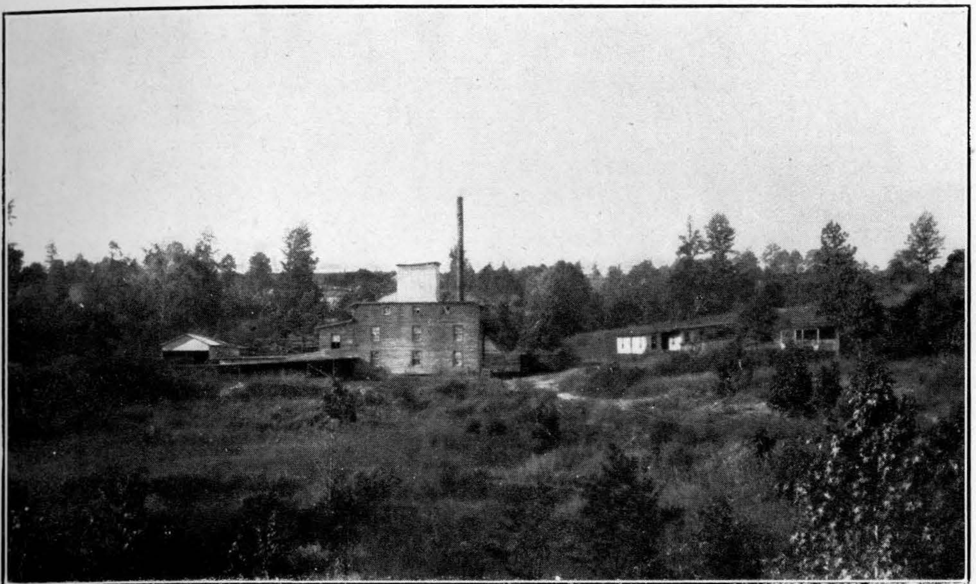
Section in fullers earth mine of the General Reduction Company

Oligocene or Eocene
Vicksburg formation or Jackson group
Barnwell formation?

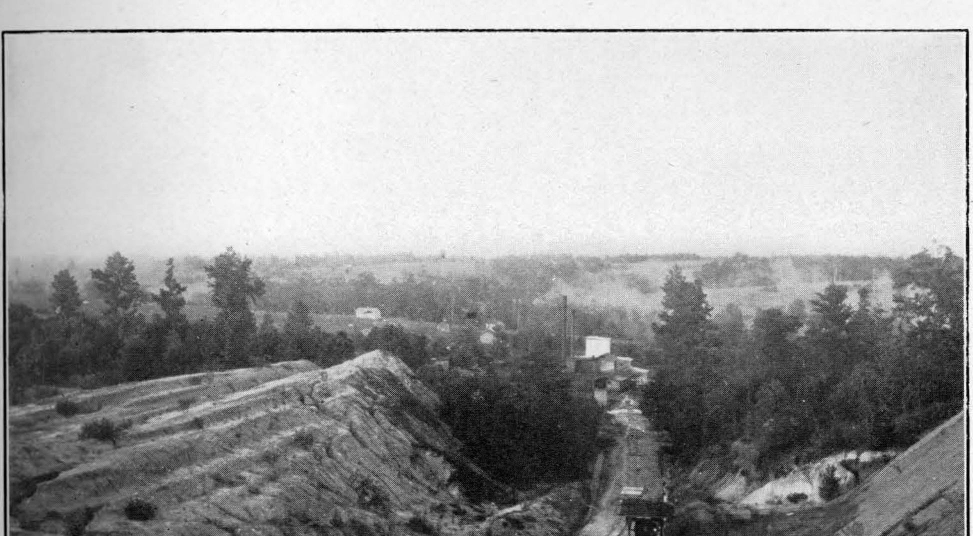
	Feet
8. Massive, dark red, argillaceous sand...............	17
7. Quartz sand and fine gravel, indistinctly bedded....	10
6. Varicolored sands with laminae and lenses of tough, plastic clay, locally called "gumbo." Some layers of the sand are slightly indurated...............	8
(Unconformity)	

Eocene
Jackson group
Barnwell formation (Twiggs clay member)

5. Light cream-colored fullers earth, almost white when dry. The lower portion is thin-bedded, with fine sandy partings. Toward the top the earth becomes more massive, and the beds are several feet thick between partings. The material along the partings consists of fine quartz sand and flakes of mica (damourite or partly weathered muscovite) stained yellow by oxides of iron. The whole mass of fullers earth is cut by numerous joints in all directions, and along the joints, as well as the sand partings, iron-and manganese-bearing solutions have penetrated, locally depositing oxides of manganese in dendritic forms. Some of the joints and partings are slickensided, showing that slight movements, probably caused by shrinkage, have occurred. This unit is uniform in texture and composition, and is very light and porous, constituting the commercially valuable fullers earth	17
4. Dark-colored fullers earth, almost black when wet, but becoming light gray on drying. The dark color is probably due to fine particles of carbonaceous matter, and the clay also contains visible crystals of pyrite, and gives off a strong odor of	



A. FULLERS EARTH MILL OF THE GENERAL REDUCTION CO., PIKES PEAK, TWIGGS COUNTY.



B. INCLINED TRAMWAY AND MILL OF THE GENERAL REDUCTION CO., FROM THE FULLERS EARTH MINE, PIKES PEAK, TWIGGS COUNTY.

sulphur dioxide when dried at 100° C. It also contains scattered concretionary masses of hard, siliceous material. The dark layer is separated from the light-colored earth above and below by a sharp line of contact, but it gradually thins to north and west; that is, the contour of its upper surface follows the contour of the hill. The line of contact is sharp and even, but there is no visible change in texture, no tendency to split along the contact, and the line of contact was observed to cut obliquely across the sand partings (bedding planes). It is evident that the light-colored earth has been derived from the dark variety by leaching and oxidation of pyrite and carbonaceous matter	5
3. Yellow-drab fullers earth. The lower part of the bed is mottled and banded with grains and layers of dark colored oxides of iron and manganese. Contains numerous fossil rhizopods, determined as *Orbulina universa* D'Orbigny and Nodosaria, some of which are replaced by black oxides of manganese	1
2. Greenish-yellow sand containing some poorly preserved fossils. This bed is shown in borings in the floor of the mine and in wells near the mill......	50
1. Pale yellow fullers earth, shown in wells near the mill	?
	108

The lower fullers earth stratum is a thick bed of good looking earth, but no attempt has been made to work it. The exposures are at depths of 12 to 15 feet in several wells near the office and mill, 600 feet northwest of and 40 feet below the floor of the mine. The exact thickness is not known.

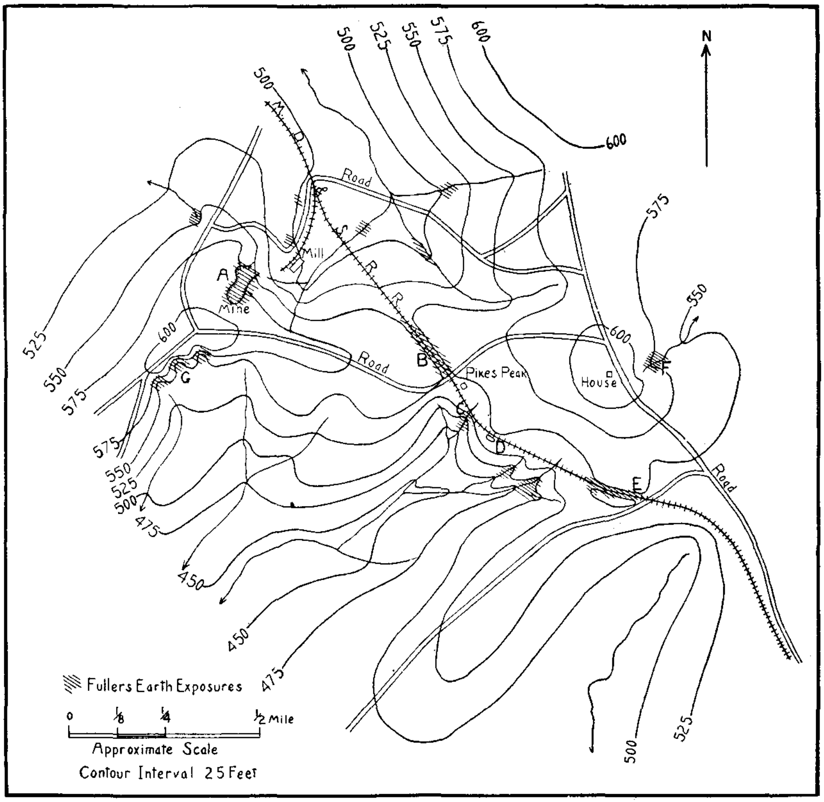


Fig. 19.—Topographic map of the property of the General Reduction Co., Pikes Peak, Twiggs County, showing the distribution of fullers earth exposures. Based on a survey by the company. Letters A to G refer to points described in the text.

The upper surface of the fullers earth in the mine is irregular and pitches to north and east, while the sand beds overlying it have a dip of 4 degrees in an easterly direction. This relation indicates an unconformity, and the same unconformity, which may be only local, is seen in the railroad cut at Pikes Peak station between the red sand and fullers earth beds.

The fullers earth beds are exposed in the Macon, Dublin & Savannah Railroad cut near Pikes Peak station (map locality B). A ridge extends from this point to the mine, and borings have shown that the deposit is continuous throughout the intervening distance, over half a mile.

Section in railroad cut at Pikes Peak station

Oligocene or Eocene	
Vicksburg or Jackson	
Barnwell formation?	
6. Red sand, which caps the ridge. At the base of the stratum is a bed of fine gravel 1 to 2 feet in thickness, containing quartz pebbles up to ½ inch in diameter	10
(Unconformity)	
Eocene	
Jackson group	
Barnwell formation (Twiggs clay member)	
5. Varicolored sands; red, yellow, and white interbedded	7
4. Thin-bedded and rather impure fullers earth. The upper 4 or 5 feet of the bed is a greenish, somewhat plastic clay, which was apparently affected by weathering previous to the deposition of the overlying red sand and has not the properties of a good grade of fullers earth	12
3. Yellow limonitic sand	0.2
2. Light-colored olive-drab fullers earth. The lower part is thin-bedded and contains a considerable amount of iron and manganese oxides along partings; toward the top the bedding becomes thicker	9
1. Light-colored, greenish-gray clayey sand, fossiliferous and locally iron stained. Exposures above track level	3
	41.2

The yellow sand stratum, No. 3, is persistent along the southwest side of the cut, where it shows a slight anticline with limbs dipping four degrees southeast and three degrees northwest. Between beds Nos. 5 and 6 there is a decided unconformity, although the exact line of contact is at most places obscured by weathering. The fullers earth beds are cut down below the track level at the station, southeast end of the cut. At the northwest end of the cut, on the northeast side of the track, the bank is made up of massive, red-and-white-mottled clayey sand; while across the cut fullers earth is exposed at the same level. Along a level to the southeast the base of the sand formation is reached. Just below the sand beds is several feet of a structureless plastic clay mixed with limonite and red sand. The upper surface of the clay is very irregular, with bosses projecting up into the sand formation. This plastic clay appears to be a residual soil formed by decomposition of the fullers earth before the deposition of the mottled sand.

The structural relations are shown on the accompanying sketch (fig. 20). The altitude of the track at Pikes Peak station is 534 feet.

Several hundred yards southeast of the station a small gully heads northeast of the track (map locality C). The intermittent stream passes under the railroad 13 feet below grade, and flows southward.

Section in gully southeast of Pikes Peak station

	Feet
Eocene	
Jackson group	
Barnwell formation	
12. Sandy soil	3
11. Iron-stained plastic clay	1.5
10. Red sand	1.5
9. Light red sandstone, containing casts of small shells	1
8. Plastic clay	1
(Railroad level)	
7. Indurated, dark red sand	0.6
6. Softer red sand	2.6
5. Fine, soft, yellow sand	2
4. Interbedded red and yellow sand, with thin clay beds near base	8
3. Interval mostly concealed. There are some outcrops of red-and-white-mottled argillaceous sand	23
(Unconformity?)	
Twiggs clay member	
2. Structureless, iron-stained, plastic clay, probably a residual soil derived from fullers earth	2
1. Light-colored fullers earth, base of bed not exposed	15+

The upper surface of the fullers earth at this point is 50 feet lower than the top of that exposed in the cut about an eighth of a mile distant, while the stained clay and mottled sand overlying both are similar, indicating an unconformity of considerable importance.

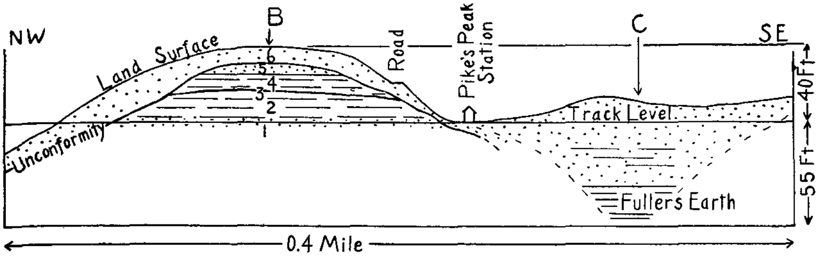


Fig. 20.—Section along the Macon, Dublin & Savannah Railroad near Pikes Peak station, showing structural relations between points B and C, fig. 19.

In a cut a quarter of a mile southeast of the station (map locality D), 20 feet of slightly indurated red, yellow, and white clayey sand is exposed. At the southeast end of the cut a gully heads south of the railroad, and in this gully a 25-foot bed of fullers earth outcrops. The top of the bed is 32 feet below the level of the track.

Two hundred yards beyond the cut is a second valley heading south of the railroad, in which the fullers earth is exposed 28 feet below track level. The bed of earth is 45 feet thick (by aneroid measurement) and apparently of good quality, although rather thin bedded. It is underlain by bluish-gray, clayey and calcareous sand. The effect of the fullers earth bed on the topography is notable. Intermittent streams have cut gorges 15 to 20 feet deep with frequent small falls and rapids in the resistant earth. On reaching the underlying sand strata the gradient of the streams become flatter and the valleys broaden greatly.

At the 13 mile post (map locality E) is a deep cut in which the fullers earth beds are again exposed above the track level.

Section in cut at 13 mile post, Macon, Dublin & Savannah Railroad

Oligocene or Eocene

Vicksburg formation or Jackson group

	Feet
5. Coarse, massive red and white sands, with a layer of fine gravel at the base........................	20

(Unconformity?)

Eocene	
Jackson group	
Barnwell formation	
4. Slightly indurated, red and yellow, bedded sand....	5
Barnwell formation (Twiggs clay member)	
3. Greenish, rather plastic clay......................	5
2. Fullers earth, thin bedded and containing much manganese oxide along partings....................	10
1. Talus to track level.............................	3

In a valley south of the track just southeast of the cut no trace of fullers earth is seen down to 80 feet below the railroad grade. In gullies near the wagon road just north of the cut 20 feet or more of massive red sand overlies coarse yellow and white crossbeded sand. There is no fullers earth, although it outcrops at this level in the cut.

East of Pikes Peak station is the hill known as Pikes Peak, said to be the highest point between Macon and the coast, although it overtops the other elevations in the vicinity by only a few feet. East of the residence of K. R. Slocum, which is on the summit of the hill, a good workable deposit of fullers earth outcrops in a gully (map locality F). A 30-foot stratum of thick-bedded earth, which is partly pale yellow and partly blue, is exposed, on a level with the upper bed in the railroad cuts and in the mine. Four feet from the base of the exposure is a three-inch bed of fossiliferous argillaceous limestone. The underlying material is not exposed. The overburden consists of 40 feet of red sand to the head of the gully and 60 feet to the level of the house on the hill top. This exposure is on the Oconee River side of the divide, so that, unless working can be started on the opposite side of the hill, it will require a long deep cut or a tramway over the ridge to carry the earth to the railroad. As the upper surface of the fullers earth horizon in this hill is evidently very irregular, systematic exploration by drilling will be necessary to determine the quantity of earth and its relation to overburden.

Half a mile southwest of the fullers earth mine near the public road, a number of large gullies have been washed in the sand strata (map locality G).

Section in a gully ½ mile southwest of the fullers earth mine

Eocene
Jackson group
Barnwell formation

	Feet
10. Massive red argillaceous sand	35
9. Indurated maroon-colored sand	0.5
8. Coarse and pure red, white, and yellow sands. Grains are well rounded, averaging one-sixteenth of an inch in diameter	4.5
7. Very tough plastic dark gray and white clay	1
6. Coarse red sand	2
5. Tough plastic yellow clay interbedded with coarse sand. Exposures not continuous	10
4. White sandstone containing numerous fossils, mostly casts of pelecypods	0.5
3. Unconsolidated yellow sand	1
Barnwell formation (Twiggs clay member)	
2. Pale yellow fullers earth	22
1. Fine, light gray sand, containing some clay	?

The preceding section was measured in the gully presenting the best exposures. Fullers earth is also exposed in other washes about 60 feet below the hill top, or almost level with the bed of the mine. There is good reason for believing that a bed of fullers earth of good quality and more than 20 feet in thickness underlies the whole of the flat-topped hill southwest of the mine, with a maximum overburden of 60 feet of sand and clay. The upper surface of the earth here does not show such irregularity as it does at the station, half a mile east.

Considering the property as a whole, the higher portion, above the level of the Macon, Dublin & Savannah Railroad, is underlain in part by the upper bed of fullers earth, maximum thickness 30 feet, and maximum overburden 60 feet. Almost the entire area of the property is underlain by a lower bed of fullers earth, below the level of the railroad. This bed is thicker than the upper horizon, but the greater part of it is not available because of the overburden of 100 feet or more. Also, the lower bed contains more calcareous layers than the upper, and is not so uniform in composition and bleaching power.

The earth.—Analyses of samples of fullers earth collected by the writer in September, 1914, are as follows:

Analyses of fullers earth from the General Reduction Company's mine

Constituents	S-1	S-2	S-3
Silica (SiO_2)	69.62	72.95	73.08
Alumina (Al_2O_3)	14.34	12.65	9.48
Ferric oxide (Fe_2O_3)	3.90	3.56	2.68
Ferrous oxide (FeO)	.31	.47	1.22
Magnesia (MgO)	1.01	.57	.76
Lime (CaO)	.80	1.00	1.13
Soda (Na_2O)	.43	.28	.54
Potash (K_2O)	.80	.68	.84
Ignition	6.77	7.02	7.62
Carbon dioxide (CO_2)	.00	.00	.00
Titanium dioxide (TiO_2)	.72	.50	.63
Phosphorus pentoxide (P_2O_5)	.58	.36	.27
Sulphur (S)	.79	.00	1.17
	100.07	100.04	99.42
Moisture	7.29	5.77	4.74

S-1 Commercial fullers earth, Pikes Peak brand.
S-2 Light-colored earth, average sample of 17-foot stratum in the mine.
S-3 Dark-colored earth, average sample of 5-foot stratum in the mine.

Analyses of samples previously collected from the General Reduction Company's property

Constituents	1	2	3	4	5
SiO_2	67.80	83.43	73.54	75.06	71.58
Al_2O_3	16.04	5.75	11.64	6.86	14.05
Fe_2O_3	5.40	.33	5.63	.55	3.91
FeO	.75	2.82	.....	4.54	.....
MgO	1.25	.55	1.70	1.48	2.01
CaO	.06	.17	.77	1.72	.20
Na_2O	.31	.20	.16	.15	.34
K_2O	.56	.33	.30	.37	.52
Ignition	6.90	4.16	4.69	7.98	6.74
TiO_2	.56	.49	1.05	1.10	.88
P_2O_5	.12	.09	.....	.....	.....
S	.42	1.94	.00	.88	.....
MnO	tr	.00	tr	.00	.10
	100.17	100.26	99.48	100.69	100.33
Moisture	19.87	8.43	14.59	9.42	8.65
Soluble FeO	.....	.....	.00	1.69	.....
Soluble SO_3	.....	.....	.00	2.90	.....

1. Light-colored earth, November, 1912.
2. Dark-colored earth, November, 1912.
3. Light-colored earth, November, 1913.
4. Dark-colored earth, November, 1913.
5. Sample collected by Otto Veatch for burning tests. Described in Bull. 18, Geol. Survey of Ga., p. 371, 1909.

Rational analysis of No. 5

Feldspar	1.34	Sand	17.36
Quartz	9.92		
Mica	6.10		
Ferric oxide			3.47
Clay substance			79.17
			100.00

The preceding analyses, as well as all other analyses of fullers earth in this report, have been recalculated to the determined total without the hygroscopic water. All fullers earth samples retain large and varying amounts of moisture, so analyses stated as percentages of the material dried at 100° C are much more useful in showing chemical relations and mineralogical composition than those in which the moisture is included in the total.

These analyses show considerable variations, especially in the percentages of the minor constituents, but all are alike in their high content of silica and low content of alumina, as compared with ordinary clays, while the one rational analysis available shows that the greater part of the silica exists in combined form. The differences in composition of the light and dark earths are of such character that they may be easily explained by oxidation and leaching of the latter.

When the sample of commercial earth (S-1) was taken a portion of the bed of dark earth was being mined and mixed with the light earth in the mill. The use of the dark bed has since been discontinued, so samples from the present production may be expected to contain less sulphur, ferrous iron, and soluble salts, and to have slightly better bleaching power, as the tests show that the dark earth is a poor bleaching agent.

Tests.—The following tables include all tests made on fullers earth samples from the General Reduction Company mine. For comparison, the results of tests on an English fullers earth, IXL brand, obtained from the Picard-Law Laboratories, Atlanta, are also stated.

Bleach

Sample used	Original bleach		After two weeks in light		After two weeks in dark	
	Yellow	Red	Yellow	Red	Yellow	Red
Oil used	35	4.8	35	4.0	35	4.4
IXL English	21	2.1	15	1.9	16	2.0
S-1 (commercial)	19	1.9	15	1.9	17	2.1
S-2 (20-40 mesh)	28	2.8	20	2.4	20	2.6
S-2 (40-60 mesh)	23	2.3	16	2.0	20	2.6
S 2 (60-100 mesh)	21	2.1	15	1.9	16	2.2
S-2 (Through 100 mesh)	18	1.8	..	...	..	...
S-2 (Through 200 mesh)	18	1.8	14	1.8	16	2.0
S-3 (20-40 mesh)	33	3.3	26	3.0	28	3.4
S-3 (40-60 mesh)	30	3.0	23	2.7	23	2.9
S-3 (60-100 mesh)	25	2.5	19	2.3	21	2.7
S-3 (Through 100 mesh)	23	2.3	..	...	..	...
S-3 (Through 200 mesh)	22	2.2	18	2.2	20	2.4

To determine the bleaching power of proportions of earth smaller than the standard quantity of 6 per cent of the weight of the oil the following series of tests were made. These indicate that the bleaching efficiency increases rapidly up to 4 per cent, after which the addition of more earth produces only a slightly better bleach.

	Yellow	Red
S-1 (1%)	32	3.2
S-1 (2%)	28	2.8
S-1 (3%)	23	2.3
S-1 (4%)	21	2.1
S-1 (5%)	20	2.0
S-1 (6%)	19	1.9

Absorption of oil

IXL English	21.2%
S-1 (commercial)	38.4
S-2 (20-40 mesh)	45.5
S-2 (40-60 mesh)	45.9
S-2 (60-100 mesh)	44.4
S-2 (Through 100 mesh)	45.1

S-2 (Through 200 mesh)	49.1
S-3 (20-40 mesh)	44.3
S-3 (40-60 mesh)	43.2
S-3 (60-100 mesh)	42.0
S-3 (Through 100 mesh)	43.0
S-3 (Through 200 mesh)	43.9

Specific volume

Sample used	Specific Gravity	Lb. per cu. ft.
IXL English	1.05	66.0
S-1 (commercial)	.61	38.2
S-2 (20-40 mesh)	.47	29.4
S-2 (40-60 mesh)	.47	29.6
S-2 (60-100 mesh)	.48	30.2
S-2 (Through 100 mesh)	.48	30.2
S-3 (20-40 mesh)	.45	28.2
S-3 (40-60 mesh)	.46	28.5
S-3 (60-100 mesh)	.47	29.6
S-3 (Through 100 mesh)	.52	32.6

Apparent acidity

	$\frac{N}{10}$ Alkali for 100 gm. earth
IXL English	19.6 c.c.
S-1	163.0*
S-2	69.2
S-3	326.1*

* Contain free acid and soluble sulphates due to oxidation of pyrite.

These tests lead to certain important conclusions concerning the properties of the earth, which may be summarized as follows:

1. If the oil is treated with earths for a fixed period of time, the bleaching power increases rapidly with the fineness of grinding up to the point where all of the earth will pass through 100 mesh. Finer grinding has little effect on bleaching power. It is possible that the coarser grades of earth would bleach better if allowed to remain longer in contact with the oil.

2. Fineness of grinding has no sensible effect on the absorption of oil, except that the extremely fine material, passing through 200 mesh, holds a little more oil. Even this is probably due to clogging of the pores of the filter paper rather than to inherently greater absorption by the earth.

3. Fineness of grinding has only a slight effect on the specific volume of the earth, so long as the particles are of approximately the same size and shape. There is some tendency for the finer grades to pack closer, and therefore to show greater density, on account of the greater relative variations in size and shape of the particles when finely ground.

4. Earths with high apparent acidity, or power of adsorbing inorganic bases, tend to have stronger bleaching power than those of low apparent acidity; but the presence of free acid and soluble salts lessens the bleaching power, as shown by sample S-3.

5. The after-bleach, or bleaching effect of light on an oil after treatment with fullers earth, is not entirely dependant on the original bleach, but varies after the use of different earths. Thus, with the particular sample of cotton oil used, the IXL earth does not produce as good an original bleach as the commercial Pikes Peak earth, but after standing in the light for two weeks the two oil samples assume the same tint.

A summary of the comparative tests on Pikes Peak and English earth made by Charles L. Parsons[1] is given below. The methods of testing used by Parsons were essentially the same as those employed in testing the preceding samples.

[1] Parsons, Charles L., Fullers earth: U. S. Bureau of Mines Bull. 71, 1913.

Bleach

Sample used	After two weeks in light		After two weeks in dark	
	Yellow	Red	Yellow	Red
Oil used	35	6.2		
English earth received in lump form	20	2.0	15	1.5
English earth, IXL brand	20	2.0	16	1.6
Sample from Pikes Peak	14	1.4	9	0.9
Pikes Peak brand, General Reduction Co.	12	1.2	10	1.0

Specific volume

	Specific Gravity	Lb. per cu. ft.
English earth received in lump form	1.07	68
English earth, IXL brand	1.20	75
Sample from Pikes Peak	.56	35
Pikes Peak brand, General Reduction Company	.64	40

Apparent acidity

	$\frac{N}{10}$ Alkali for 100 gm. of earth
English earth received in lump form	15
English earth, IXL brand	60
Sample from Pikes Peak	175
Pikes Peak brand, General Reduction Company	230

Conditions affecting mining.—The relations of topography and overburden to the fullers earth bed have previously been discussed under the heading of "*Geologic relations.*" The locations of the mine and mill are the most favorable which could be chosen. The mine is high and well drained, and the earth is transported to the mill by gravity. The mill is reached by a short spur track from the Macon, Dublin & Savannah Railroad.

The greatest overburden which has been handled is about 40 feet, but it is not likely that the mine will be worked back farther into the hill for some time. It is planned to work to northwest around the slope of the hill until the public road is reached, then work may be continued along the slope to southeast toward the railroad cut. By this means enough earth to supply the mill for a number of years may be obtained, and besides having light overburden, the useless dark and unoxidized part of the fullers earth bed may be avoided.

No plans have been made for working the fullers earth from the lower horizon, and it is not likely that this will be worked so long as the more homogeneous and more accessible earth from the upper bed is available.

Mining methods.—The principal expense in mining the earth is the handling of overburden. This is removed by a self-dumping drag shovel designed by Mr. Slocum, and is dumped in the valley north of the mine or in abandoned parts of the pit.

The earth is worked with pick and shovel, loaded in tram-cars, and carried to a storage shed at the mill, where a sufficient amount of earth is kept to run for several days, so that no work need be done in the mine in wet weather. The tramway is so arranged that a descending loaded car pulls an empty car up to the level of the mine.

Preparation for market.—Preparation of the earth for the market consists in drying and grinding.

The most difficult and expensive operation is the drying. The earth as mined contains about 50 per cent of moisture, and it is desirable to drive off as much of the hygroscopic water as possible without raising the earth to a temperature high enough to expel any of the combined water. To meet these requirements steam-heated tunnel driers are used.

The earth from the first storage shed is briquetted in an ordinary brick machine, and the bricks are stacked on trucks in such a manner that air may circulate freely between them. The trucks are then pushed into the drying tunnels. Each day about four trucks of earth are removed from one end of a tunnel and four more added at the other end, each truck taking three or four days to pass through the tunnel. The air entering the tunnels is heated by passing over steam coils, exhaust steam from the engine being used when the mill is in operation. The temperature is usually maintained at about 120° F. but can be raised as high as 180° F.

The dried earth as shipped still contains a considerable percentage of moisture, as shown by sample S-1, which contained 7.29 per cent. The percentage is probably less as the earth comes from the mill, but it gains and loses moisture readily with changes in the humidity of the atmosphere.

The dried briquets are carried by a spiral conveyor and elevator to a storage bin. The conveyor serves as a preliminary breaker, reducing the material to walnut size.

From the storage bin the earth is fed to a four-roll Raymond pulverizer, and when ground sufficiently fine the earth is carried up by a current of air, from which it is precipitated by a Cyclone separator. The air separation is so adjusted that 95 per cent of the finished product passes through a 100 mesh screen. A screen analysis of the dry commercial earth, made with a small flour bolting machine, is given below, with an analysis of the IXL brand of English earth for comparison. (The IXL sample from the Picard-Law Company is specially ground and prepared for laboratory tests, and is finer than the commercial product.)

Screen analyses of fullers earth

Screen used	Pikes Peak (S-1)	IXL English
On 20 mesh	.00	.00
On 40 mesh	.00	.12
On 60 mesh	.56	.05
On 80 mesh	1.49	.04
On 100 mesh	2.43	.04
On 150 mesh	14.68	.14
On 200 mesh	13.96	2.29
Through 200 mesh	66.88	97.32
	100.00	100.00

The plant has an annual capacity of 10,000 tons of prepared earth.

Uses.—The Pikes Peak earth sold in the United States is used almost entirely in the refining of vegetable and animal oils, especially cotton oil and linseed oil. Before the European war a large quantity of the earth was exported to Germany. The exact uses made of the exported earth are not known, except that a part was used in refining edible oils. Parsons[1] makes the following statement, which probably refers to earth from this deposit: "Certain finely ground and nearly white clays of high adsorptive power have been imported from Germany to be used in the production of clay pigments as a basis for color printing on wall papers. While these samples of imported clay can not be positively identified, certain brands strongly resemble samples from one or two American deposits of fuller's earth, and there is every reason to believe that the material was exported and after specially fine grinding was reimported into this country."

No serious attempt has been made to introduce this earth for refining of mineral oils. The dried earth from the Pikes Peak deposits is softer than that from the Alum Bluff formation of south Georgia and Florida and offers less resistance to crushing and attrition, so it would probably not prove so satisfactory as the latter for this purpose.

LOCALITIES NORTH OF PIKES PEAK

North and northwest of the General Reduction Company property, along the Macon, Dublin & Savannah Railroad between Pikes Peak and Dry Branch, are the kaolin mines of the Georgia Kaolin Company, American Clay Cömpany, John Sant Clay Company, and the abandoned mine of the Atlanta Mining and Clay Company. All of the clay pits, as well as numerous gullies, expose fullers earth of varying grade and thickness.

ATLANTA MINING AND CLAY COMPANY

The kaolin mine of the Atlanta Mining and Clay Company is half a mile east of Winthröp and 2 miles north of Pikes Peak.

[1] Parsons, Charles L., op. cit. p. 33.

Section at south end of Atlanta Mining and Clay Company pit

Eocene	
Jackson group	
Barnwell formation	Feet
7. Sand and soil containing quartz pebbles	7-10
(Unconformity?)	
6. Yellow and red-and-gray-mottled plastic clay	2-5
5. Bedded red and black sand	1.5
4. Yellow sand	3.5
3. Yellow clay and sand, interbedded	1
2. Yellowish-gray sand	10
(Unconformity)	
Lower Cretaceous	
1. White kaolin, varying from very pure to sandy and micaceous	12+

The clay of bed No. 3 is non-plastic and resembles fullers earth in appearance, so this thin bed must represent the fullers earth horizon. Its altitude is 465 feet.

AMERICAN CLAY COMPANY PROPERTY

The kaolin mine of the American Clay Company is situated about half a mile northeast of Winthrop and a mile south of Dry Branch.

Section on north side of American Clay Company pit

Eocene	
Jackson group	
Barnwell formation	
	Feet
7. Slightly indurated red and yellow sand	10
6. Plastic clay, red-and-gray-mottled, containing some sand	12
5. Red, yellow and black bedded sand	4
4. Fullers earth horizon. The earth exposed is very impure. It is sandy, iron-stained, and more plastic than earth of good quality	2
3. Yellow argillaceous sand	10
(Unconformity?)	
Lower Cretaceous	
2. White kaolin, almost free from grit	12
1. Sandy white kaolin	15

The altitude of the top of the Cretaceous beds is about 430 feet.

At the west end of the kaolin pit the fullers earth bed pinches out, but in a well 100 yards north of the pit fullers earth of considerably greater thickness and better quality than shown in the preceding section was cut.

On the same property, south of the mine, is a gully which heads near the store on the public road. In this gully a good section is exposed.

Section in gully south of the American Clay Company mine

	Feet
Eocene?	
6. Greenish argillaceous sand, weathering to bright red. Overlies the fullers earth bed with a slightly irregular contact, which is marked by an inch or two of carbonaceous clay	20
(Unconformity?)	
Eocene	
Jackson group	
Barnwell formation (Twiggs clay member)	
5. Fullers earth horizon. About 10 feet from the base is a sand stratum some feet in thickness, and there are other rather sandy beds, but as a whole the formation is light-colored and apparently of good quality. A few feet of earth at the top of the bed is fossiliferous and slightly indurated	45
4. Fossiliferous sandstone	0.5
3. Yellow argillaceous sand	1.
2. Argillaceous limestone	0.5
1. Yellow sand	?

PROPERTY OF MRS. F. M. THARPE

(Map locality T-2)

The property of Mrs. F. M. Tharpe, on which the kaolin mine of the John Sant Clay Company is located, adjoins the property of the American Clay Company on the west.

Geologic relations.—A section of the lower beds of the Jackson formation is exposed as overburden in the pit of the John Sant Clay Company.

Section in John Sant Clay Company pit

Eocene	
Jackson group	
Barnwell formation	
	Feet
5. Soil and clayey sand	5
4. Massive red and yellow sand	4
3. Fullers earth horizon, here represented by olive-gray clay, iron-stained and more plastic than good fullers earth	1.5
2. Light colored sand, partly argillaceous	10
(Unconformity)	
Lower Cretaceous	
1. White kaolin	15

The Tharpe residence is situated on a ridge about half a mile west of the clay pit, and 50 feet above the surface of the kaolin in the pit. A well near the house is said to have struck fullers earth with 18 feet overburden. It passed through one bed of fullers earth, then through a sand bed, and ended in fullers earth at a depth of 60 feet. Other wells along the ridge have also encountered fullers earth.

In gullies on both sides of the public road, which follows the ridge south of the Tharpe house, fullers earth is exposed. In a gully west of the road are discontinuous exposures of fullers earth through a vertical range of over 30 feet, with a thin bed of hard limestone about the middle of the section.

In a gully east of the road light-colored, thick-bedded fullers earth outcrops almost continuously for a thickness of 30 feet. An average sample (S-16) was taken from the exposure. The overburden above this deposit apparently consists entirely of red argillaceous sand, and has a thickness of 40 feet to the top of the ridge followed by the road.

Between the house and the kaolin mine is another gully in which a considerable thickness of fullers earth is exposed, but this earth contains sandy fossiliferous beds, and is not of as good quality as that where the sample was taken.

The earth.—This occurrence is near the northern limit of the area of deposition of the fullers earth beds, and therefore the earth has more of the characteristics of ordinary clay than the Pikes Peak deposits. As shown by the tests, the Tharpe earth is denser and absorbs less oil than the Pikes Peak earth, approaching the English earth in these characteristics. Its original bleaching power is not especially high, but after standing in the light the oil bleached with this earth becomes as light in color as that bleached with the standard earths. It is more plastic than the Pikes Peak earth, and when dried is harder and appears finer in grain.

Tests.—All tests of sample S-16 were made on earth ground in a coffee-mill to pass through a 100 mesh screen. As usual, the tests on IXL and Pikes Peak commercial earths are stated for comparison.

Bleach

Sample used	Original bleach		After two weeks in light		After two weeks in dark	
	Yellow	Red	Yellow	Red	Yellow	Red
Oil used	35	4.8	35	4.0	35	4.4
IXL	21	2.1	15	1.9	16	2.0
Pikes Peak	19	1.9	15	1.9	17	2.1
S-16 (Through 100 mesh)	22	2.2	15	1.9	16	2.0

Absorption of oil

IXL	21.2%
Pikes Peak	38.4
S-16	36.5

Specific volume

	Specific gravity	Lb. per cu. ft.
IXL	1.05	66.0
Pikes Peak	.61	38.2
S-16	.82	51.4

Apparent acidity

	N/10 alkali per 100 gm. earth
IXL	19.6 c.c.
Pikes Peak	163.0
S-16	49.4

GEORGIA KAOLIN COMPANY PROPERTY

(Map locality T-3)

The mine of the Georgia Kaolin Company is located 2 miles north of that of the Atlanta Mining and Clay Company and 1½ miles east of Dry Branch. The altitude of the post-Cretaceous surface of unconformity in the mine is about 400 feet.

Geologic relations.—The beds of the fullers earth formation, which form the overburden on the Lower Cretaceous kaolin deposits, show great local variation in thickness and composition, but the following section, measured at the south end of the clay pit in March, 1916, is typical.

Section in pit of the Georgia Kaolin Company

	Feet
Eocene?	
7. Red sand capping the hill east of the pit, about....	80
Eocene	
Jackson group	
Barnwell formation (Twiggs clay member)	
6. Fullers earth. The earth near the surface has been affected by weathering, making it denser and more plastic than usual, and is stained along the numerous joints by oxides of iron and manganese and organic matter. The extreme lower portion is sandy and calcareous, and the stratum contains partings and thin beds of fossiliferous sand or sandy earth up to 1 foot thick. The top of the bed is obscured by weathering and creep of the red sand, so the thickness may be more than indicated	20
Ocala limestone	
5. White argillaceous bryozoan limestone, grading up into the fullers earth bed. This bed pinches out	

100 feet north of the point where the section was measured, its place being taken by sand....	5
4. Coarse sand, stained by organic matter, and containing small lenses of black mud. Bones of the Zeuglodon were collected from this bed. It is a swamp deposit, and its contact with the overlying limestone is slightly irregular, apparently representing a local unconformity..............	2.5
3. Yellow to red medium coarse sand, irregularly bedded	12
2. Gray sandstone with calcareous cement, loaded with casts of molluscs. This bed, like No. 5, pinches out to the north, where the kaolin is overlain by green sandy clay............................	2
(Unconformity)	
Lower Cretaceous	
1. Massive white kaolin...........................	20

No exploration work has been done to determine the extent of the fullers earth beds, but there are natural exposures in gullies indicating that it underlies all of the higher land to the east of the kaolin mine.

The earth.—The sample of earth from this property (S-11) was taken from the best portion of the stratum exposed in the section described above, and represents an average of a thickness of 10 feet of beds. The lower 6 or 8 feet of the fullers earth stratum is useless on account of its content of sand and calcium carbonate, and the upper part of the exposure has been affected by weathering, but the thickness of beds of the best quality of earth will evidently increase on working back into the hill.

The earth is very similar to that on the Tharpe property, previously described. It is more plastic and denser than the Pikes Peak earth, therefore absorbing less oil. While its immediate bleaching power on cotton oil is not exceptionally good, the after-bleach makes the treated samples even lighter than the Pikes Peak and English earths.

Tests.—All tests of sample S-11 were made on earth ground in a coffee-mill to pass through a 100 mesh screen. Tests on commercial earths are stated for comparison.

Bleach

Sample used	Original bleach		After two weeks in light		After two weeks in dark	
	Yellow	Red	Yellow	Red	Yellow	Red
Oil used	35	4.8	35	4.0	35	4.4
IXL	21	2.1	15	1.9	16	2.0
Pikes Peak	19	1.9	15	1.9	17	2.1
S-11	22	2.2	14	1.8	15	1.9

Absorption of oil

IXL	21.2%
Pikes Peak	38.4
S-11	32.2

Specific volume

	Specific gravity	Lb. per cu. ft.
IXL	1.05	66.0
Pikes Peak	.61	38.2
S-11	.88	52.9

Apparent acidity

	$\frac{N}{10}$ alkali per 100 gm. earth
IXL	19.6 c.c.
Pikes Peak	163.0
S-11	49.4

Conditions affecting mining.—The fullers earth constitutes overburden on a valuable deposit of sedimentary kaolin, and must therefore be moved. It is being wasted at present, so if the material can be put to any use the cost of mining may be considered as nothing.

SAVAGE PROPERTY

(Map locality T-4)

A piece of land adjoining the property of the Georgia Kaolin Company on the west, and lying one-half to one mile east of Dry

Branch, has been purchased by H. W. Savage. The property is said to contain workable deposits of both kaolin and fullers earth. Several carload samples of fullers earth have been mined and shipped for tests, but work on a commercial scale has not been started.

Geologic relations.—The location of prospect pits are shown on the sketch map (fig 21).

There is a one-foot bed of fossiliferous sandstone in the valley at "A," although the kaolin of the Lower Cretaceous extends 20 feet higher at the house to the east. The gully above "A" shows red sand with kaolin pebbles at the base. Above this is fullers earth inter-laminated with sand, grading upward into massive fullers earth. The horizon of the fullers earth beds exposed in the branches of the gully has a thickness of 20 feet, but most of it is sandy, plastic and of poor quality.

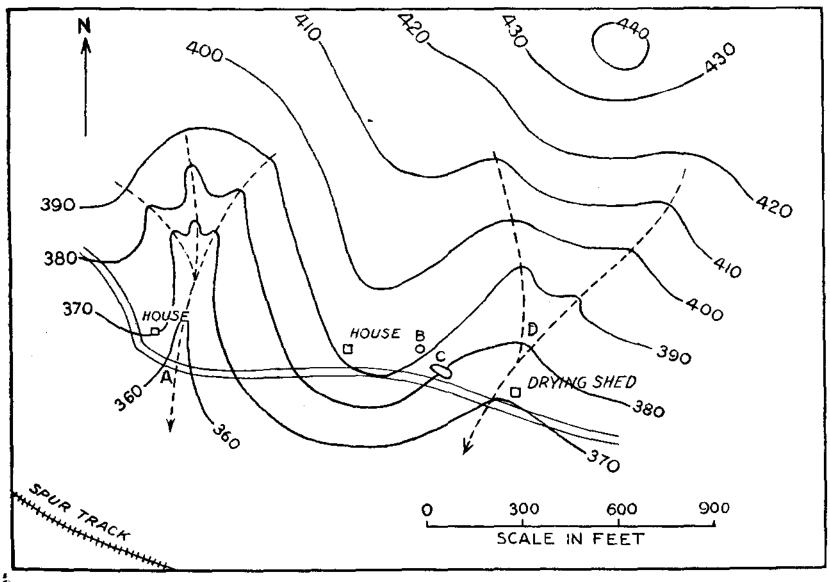


Fig. 21.—Sketch map of the fullers earth prospects on the Savage property, Twiggs County. Letters A to D refer to localities described in the text.

A pit at "B" cut 33 feet of fullers earth. The upper part of the bed is light-colored, thick-bedded, and apparently of good quality but near the base the earth is calcareous and contains nodules of chalk (finely granular calcium carbonate).

The large pit at "C" cut a thickness of 18 feet of fullers earth overlain by 8 feet of sandy plastic clay and soil.

This pit was filled with water when examined, but the earth taken from it was stored in the drying shed, and an average sample (S-197) was taken from there.

In gullies at "D" above the drying shed are exposures of fullers earth. The beds are a few inches to several feet thick, with much sand interbedded.

The better part of the fullers earth deposit seems to fill an erosion depression in the Lower Cretaceous surface, because in the surrounding hills kaolin and kaolinic sands are found at higher elevation than the base of the fullers earth beds. There is undoubtedly plenty of fullers earth on the property for working on a commercial scale, but the distribution is irregular, and much of the earth is unsuitable, so it would be desirable to do considerable exploration work before mining is started.

The earth.—The earth on the Savage property is almost identical in composition and properties with that on the adjoining property of the Georgia Kaolin Company. It has considerably higher specific gravity, with correspondingly lower oil absorption, than the Pikes Peak earth. The following analysis shows no unusual characteristics, except that this earth contains slightly more alumina and slightly less silica than most of the lighter varieties.

Analysis of fullers earth from Savage property

	S-197
Silica (SiO_2)	67.72
Alumina (Al_2O_3)	17.86
Ferric oxide (Fe_2O_3)	3.69
Ferrous oxide (FeO)	.15
Lime (CaO)	.68
Magnesia (MgO)	1.14
Soda (Na_2O)	.57
Poatsh (K_2O)	.57
Ignition	6.43

Carbon dioxide (CO_2)	.00
Titanium dioxide (TiO_2)	.79
Phosphorus pentoxide (P_2O_5)	.33
Sulphur (S)	.00
	99.93
Moisture	8.91

Tests.—All tests of sample S-197 were made on earth ground in a coffee-mill to pass a 100 mesh screen. These tests show very good bleaching power and high apparent acidity for an earth of so great density. The absorption of oil by this sample was not determined. Tests on commercial earths are stated for comparison.

Bleach

	Yellow	Red
Oil used	35	6.1
IXL	25	2.5
Pikes Peak	23	2.3
S-197	22	2.2

Specific volume

	Specific gravity	Lb. per cu ft.
IXL	1.05	66.0
Pikes Peak	.61	38.2
S-197	.71	44.4

Apparent acidity

	$\frac{N}{10}$ alkali per 100 gm. earth
IXL	19.6 c.c.
Pikes Peak	163.0
S-197	131.

LOCALITIES WEST AND SOUTH OF PIKES PEAK

East of the Macon, Dublin & Savannah Railroad in the vicinity of Pikes Peak the valley of Big Sandy Creek is cut down below the fullers earth horizon, but west and south of the railroad is a large upland area underlain by the beds of the Barnwell formation. Fullers earth is to be found on almost every property within 5 miles west and south of Pikes Peak station, but only a few of the best exposures are here described in detail.

CRUMP PROPERTY

(Map locality T-E)

The property of J. D. Crump, of Macon, adjoins the American Clay Company and General Reduction Company properties on the west, and comprises an area of 380 acres north of Stone Creek Church.

Geologic relations.—The best exposures of fullers earth on the property is in a deep gully at Stone Creek Church.

Section in gully on Crump property, at Stone Creek Church

	Feet
Eocene?	
4. Red sand with thin beds of plastic clay, forming overburden on the fullers earth. Maximum thickness, to the level of the church	45
Eocene	
Jackson group	
Barnwell formation (Twiggs clay member)	
3. Fullers earth, light-colored and thick-bedded, but contains occasional sand partings over an inch in thickness	13
2. Hard sandstone bed, forming a small waterfall	0.5
1. Yellow sand and fullers earth interbedded, in about equal quantities	6.5

In another gully a quarter of a mile northwest of the church the fullers earth horizon is represented by rather plastic yellow and purple-stained clay interbedded with an equal volume of sand. This exposure and that at the church show that the formation can change in a short distance from a thick-bedded stratum of good fullers earth to a mixture of impure sands and clays.

Near a house in the valley, half a mile north of Stone Creek Church, and 100 feet below the level of the church, is a pit 3 feet deep, cutting yellow fossiliferous marl containing nodules of pure white chalk, thin beds of hard limestone, and laminae of pale yellow calcareous clay resembling fullers earth in appearance. The marl represents the gradation between the fullers earth and the underlying Ocala limestone. Several pits and borings on the slopes 15 to 20 feet above the house have shown fullers earth, but the thickness and quantity are not known.

The earth.—An average sample (S-56) was taken from the bed, 13 feet thick, in the gully near Stone Creek Church. The earth is not calcareous and is very light and porous, resembling the light-colored earth in the General Reduction Company mine. It absorbs a large percentage of oil, and while the original bleach is not especially good, the after-bleach by action of light makes the oil very light in color.

Earth from other exposures on the property varies greatly in composition and physical properties.

Tests.—All tests of sample S-56 were made on earth ground in a coffee-mill to pass through a 100 mesh screen. Tests on commercial earths are stated for comparison.

Bleach

Sample used	Original bleach		After two weeks in light		After two weeks in dark	
	Yellow	Red	Yellow	Red	Yellow	Red
Oil used	**35**	**4.8**	**35**	4.0	35	4.4
IXL	21	2.1	15	1.9	16	2.0
Pikes Peak	19	1.9	15	1.9	17	2.1
S-56	22	2.2	12	1.7	13	1.8

Absorption of oil

IXL	21.2%
Pikes Peak	38.4
S-56	47.8

Specific volume

	Specific gravity	Lb. per cu ft.
IXL	1.05	66.0
Pikes Peak	.61	38.2
S-56	.55	34.2

Apparent acidity

	$\frac{N}{10}$ alkali per 100 gm. earth
IXL	19.6 c.c.
Pikes Peak	163.0
S-56	64.2

DORSEY PROPERTY

E. F. Dorsey owns the property south of Stone Creek Church, separated from the Crump property by the public road.

At a spring a quarter of a mile west of the church, is an outcrop of good thick-bedded fullers earth, overlain by red sand. The section is not well exposed, so the exact thickness of the earth could not be determined. Although not much fullers earth is in sight on the property the prospects are very good, as it is entirely surrounded by properties on which thick beds of earth are exposed.

ABANDONED RAILROAD

(Map locality T-6)

One and one-fourth miles southwest of Stone Creek Church the public road crosses the right-of-way of the Macon and Augusta Railroad, which was abandoned after a considerable amount of grading had been done.

For a quarter of a mile north of the road crossing fullers earth is exposed in cuts and in gullies below grade level. The thickness of the horizon is 60 feet, but no continuous section is exposed. The earth is pale yellow, and resembles the Pikes Peak earth in appearance, but some beds are calcareous and contain lenticular nodules several inches in diameter of pure, white, finely granular calcium carbonate. At the top of the highest exposure of fullers earth is a one-foot bed of yellow ocher color, similar to the underlying beds in texture, but containing much more ferric oxide and no calcium carbonate. The fullers earth in the cuts above the railroad grade is overlain by red sand with apparent unconformity.

A mile south of the road crossing fullers earth, containing calcium carbonate nodules in some beds, is exposed in a cut, while in a gully south of the right-of-way the underlying bryozoan limestone is exposed. The lower beds of the fullers earth stratum are highly calcareous, and grade downward into the limestone.

The fullers earth beds at this locality contain so much calcareous material, and the situation is so far from present railway transportation that economic development in the near future is unlikely.

Tests.—To determine the effect of a large percentage of limonite in fullers earth, a sample (S-20) was taken from the one-foot bed of ocher-colored earth at the top of the fullers earth horizon. The tests indicate this to be an earth of good bleaching power, and no bad effects due to the excess of iron oxide were noticed.

All tests of sample S-20 were made on earth ground in a coffee-mill to pass through a 100 mesh screen. Tests on commercial earths are stated for comparison.

Bleach

Sample used	Original bleach		After two weeks in light		After two weeks in dark	
	Yellow	Red	Yellow	Red	Yellow	Red
Oil used	35	4.8	35	4.0	35	4.4
IXL	21	2.1	15	1.9	16	2.0
Pikes Peak	19	1.9	15	1.9	17	2.1
S-20	20	2.0	12	1.8	13	1.9

Absorption of oil

IXL	21.2%
Pikes Peak	38.4
S-20	43.9

Specific volume

	Specific gravity	Lb. per cu. ft.
IXL	1.05	66.0
Pikes Peak	.61	38.2
S-20	.56	35.2

Apparent acidity

	$\frac{N}{10}$ alkali per 100 gm. earth
IXL	19.6 c.c.
Pikes Peak	163.0
S-20	200.?*

* End point of titration could not be determined accurately on account of the color of the earth.

WALL PROPERTY

The property of Lowe Wall lies 2 miles south of Pikes Peak, along a road which leaves the Macon-Jeffersonville road on the hill top just west of the General Reduction Company mine. In a gully east of the public road and a quarter of a mile southeast of the Adam Burkett residence a good section of the fullers earth horizon is exposed.

Section in gully on Lowe Wall property

	Feet
Eocene?	
6. Red sand capping the ridge, probably reaching a thickness of	60
Eocene	
Jackson group	
Barnwell formation (Twiggs clay member)	
5. Light-colored fullers earth	20
4. Yellowish, fossiliferous, argillaceous limestone	10
3. Fullers earth, light-colored and thick-bedded, but partly calcareous	35
Ocala limestone	
2. Bryozoan limestone	15
1. Plastic clay and mottled argillaceous sand	15

Half a mile north of this exposure, and probably on the property of Mrs. E. F. Dorsey, a thickness of 40 feet of fullers earth beds is shown in a gully just east of the public road.

The Lowe Wall and adjoining properties should be able to supply a large quantity of fullers earth if the demand becomes great enough and transportation facilities are provided. The latter would not present any great difficulty, as the distance in a straight line to the nearest point on the Macon, Dublin & Savannah Railroad is little more than a mile.

DELZEL

(Map locality T-7)

Fullers earth is exposed near the old Delzel post-office in a gully parallel to the road to Bond's Mill, which is situated a mile northwest of Delzel.

In the bottom of the gully is an exposure of 13 feet of bryozoan limestone of Ocala age, the elevation of the top of the limestone bed being 445 feet. The limestone bed is immediately overlain by yellowish fullers earth. The exposure shows 55 feet of thick-bedded earth, calcareous near the base, where it grades into the limestone. The massive earth bed is overlain by 45 feet of fullers earth interbedded with sand, and 25 feet of red argillaceous sand caps the hill. Other gullies in the vicinity show varying thicknesses of limestone and fullers earth. At Bond's Mill both limestone and fullers earth are absent, and kaolin of Lower Cretaceous age is overlain by red sand with beds of plastic clay.

The Delzel fullers earth is denser than that from Pikes Peak, with correspondingly lower bleaching power and lower oil absorption. Although the bed is very thick, its economic importance is small, on account of the very heavy overburden and distance of at least 5 miles to either the Southern or the Macon, Dublin & Savannah Railroad.

Tests.—Sample S-17 represents an average from a thickness of about 50 feet of the best beds of the fullers earth horizon in the Delzel gully. All tests of this sample were made on earth ground in a coffee-mill to pass through a 100 mesh screen. Tests of commercial earths are stated for comparison.

Bleach

Sample used	Original bleach		After two weeks in light		After two weeks in dark	
	Yellow	Red	Yellow	Red	Yellow	Red
Oil used..............	35	4.8	35	4.0	35	4.4
IXL	21	2.1	15	1.9	16	2.0
Pikes Peak............	19	1.9	15	1.9	17	2.1
S-17	23	2.3	16	2.0	18	2.2

Absorption of oil

IXL	21.2%
Pikes Peak..................................	38.4
S-17	34.0

Specific volume

	Specific gravity	Lb. per cu. ft.
IXL	1.05	66.0
Pikes Peak......................	.61	38.2
S-17	.84	52.7

Apparent acidity

	$\frac{N}{10}$ alkali per 100 gm. earth
IXL	19.6 c.c.
Pikes Peak..................................	163.0
S-17	138.2

JOHN THARPE ESTATE

The John Tharpe estate is on the Macon-Marion public road near the boundary between Twiggs and Bibb counties, 1½ miles south of Bond's Store, Bibb County, and 10 miles southeast of Macon.

The following section, measured in gullies above and below the level of the Macon-Marion road, is given by Veatch and Stephenson[1]:

[1] Geol. Survey of Ga. Bull. 26, p. 283, 1911.

Section in gullies on John Tharpe estate

Eocene	
Jackson group	
Barnwell formation	
	Feet
11. Fine red sand	50
Barnwell formation (Twiggs clay member)	
10. Thick-bedded fullers earth, partly concealed by the "creep" of the overlying sand	15
9. Alternating thin layers of fullers earth and fine sand	10
8. Heavy-bedded fullers earth	5
7. Fullers earth with sand partings	15
6. Thick-layered jointed fullers earth	5
5. Interval concealed } 4. Thin layers of clay, sand partings } 3. Thick layers, sandy }	20
2. Concealed interval of a few feet	?
Lower Cretaceous	
1. White clay and sand	?

The fullers earth contains casts of fossils, leaf impressions, and bits of lignitized wood.

On account of the distance from a railroad, heavy overburden, and the large amount of interbedded sand in the fullers earth horizon, the possibility of working this deposit on a commercial scale is small.

The following are analyses of earth collected from this property by Otto Veatch for burning tests:

Analyses of fullers earth from the John Tharpe estate

Silica (SiO_2)	75.45	81.48
Alumina (Al_2O_3)	12.64	8.84
Ferric oxide (Fe_2O_3)	2.64	3.40
Magnesia (MgO)	1.30	1.16
Lime (CaO)	.55	tr
Soda (Na_2O)	.04	.12
Potash (K_2O)	.42	.03
Ignition	6.49	4.55
Titanium dioxide (TiO_2)	.64	.66
Phosphorus pentoxide (P_2O_5)	.18	....
Sulphur (S)	.00	....
Manganous oxide (MnO)	tr	tr
	100.35	100.24

Moisture		7.10	13.88
Sand	Feldspar	tr	
	Quartz	4.93	3.48
	Mica	.00	
Ferric oxide (Fe_2O_3)		2.34	2.93
Clay substance and soluble silica		92.73	93.59
		100.00	100.00

LOCALITIES NEAR FITZPATRICK

The gullies heading near the Macon, Dublin & Savannah Railroad between the 13 milepost, on the General Reduction Company property, and Fitzpatrick, 15½ miles from Macon, were explored but no exposures of fullers earth were found. There are, however, a number of good outcrops in the vicinity of Fitzpatrick and along the railroad between Fitzpatrick and Jeffersonville.

SOLOMON PROPERTY

(Map locality T-8)

The property of Dr. J. C. Solomon lies north of the Macon, Dublin & Savannah Railroad just northwest of Fitzpatrick station. The property has been explored to some extent by H. W. Savage, and several carload samples of fullers earth were shipped for tests.

Geologic relations.—A small branch flows east about parallel to the railroad, and fullers earth exposures are seen in at least three tributary gullies.

In the gully south of the branch and nearest Fitzpatrick station the following section is exposed:

Section in gully on Solomon property

Eocene
Jackson group
Barnwell formation

	Feet
8. Red sand to railroad level	70
7. Thick-bedded fullers earth	10+
6. Blue, sandy, fossiliferous marl	2
5. Interval concealed	5
4. Hard sandstone	0.3

3. Argillaceous limestone	3
2. Interval concealed	30
1. Tenacious, blue, sandy clay mottled with iron stains	?

Across the branch from this gully is another exposure of fullers earth. A shallow pit has been dug, showing the earth to be thick-bedded and free from grit, but the section is so poorly exposed that the thickness can not be measured. The overburden here is light.

In another gully south of the branch and half a mile west of the first described the best section of the fullers earth horizon is shown.

Section in gully on the Solomon property

Eocene
Jackson group
Barnwell formation

	Feet
4. Red sand to railroad level. At the base is a conglomerate layer consisting of small clay fragments in a sand matrix	65
3. Tough, plastic yellow clay	2
2. Sand and clay, not well exposed	10
1. Pale yellow, thick-bedded fullers earth	15

All the fullers earth on this property is a considerable distance below the railroad grade, and belongs to the lower stratum of fullers earth horizon shown at Pikes Peak.

The earth.—The pit from which Savage obtained earth for test shipments is in the first gully above described, near the top of the fullers earth bed. The earth in the pit is light greenish-yellow when wet, almost white when dry, and is fine grained and free from grit, but contains sand laminae along bedding planes and beds up to an inch in thickness of black manganiferous and carbonaceous material. The lower beds of the fullers earth stratum are partly blue and calcareous. On the whole, the fullers earth of this exposure is much less uniform in composition and properties than that of the upper stratum at Pikes Peak, but it resembles the latter in its low density and strong bleaching power.

Sample S-7 represents an average of the earth from the test pit and from the shallow pit on the opposite side of the branch. The following analyses show the composition of this sample and of another sample from the property sent in by Dr. Solomon in 1910.

Analyses of fullers earth from Solomon property

	S-7	Solomon's sample
Silica (SiO_2)	69.09	71.20
Alumina (Al_2O_3)	16.33	15.85
Ferric oxide (Fe_2O_3)	3.02	3.84
Ferrous oxide (FeO)	.78	....
Magnesia (MgO)	.54	1.98
Lime (CaO)	.90	.00
Soda (Na_2O)	.24	.25
Potash (K_2O)	.62	.40
Ignition	7.86	5.99
Carbon dioxide (CO_2)	.00	....
Titanium dioxide (TiO_2)	.62	.62
Phosphorus pentoxide (P_2O_5)	.20	....
Sulphur (S)	.12	....
Manganous oxide (MnO)	....	tr
	100.32	100.13
Moisture	7.05	10.83

Tests.—All tests of sample S-7 were made on earth ground in a coffee-mill to pass through a 100 mesh screen. Tests of commercial earths are stated for comparison.

Bleach

	Yellow	Red
Oil used	35	4.8
IXL	21	2.1
Pikes Peak	19	1.9
S-7	19	1.9

Absorption of oil

IXL	21.2%
Pikes Peak	38.4
S-7	41.0

Specific volume

	Specific gravity	Lb. per cu. ft.
IXL	1.05	66.0

Pikes Peak	.61	38.2
S-7	.68	42.8

Apparent acidity

	$\frac{N}{10}$ alkali per 100 gm. earth
IXL	19.6 c.c.
Pikes Peak	163.0
S-7	135.9

KENNINGTON PROPERTY

Fullers earth is exposed on a property owned by Dr. J. N. Kennington of Dry Branch, and others. The location is a mile east of Fitzpatrick station.

The elevation of the Kennington residence is 540 feet, the same as the station at Fitzpatrick. A well near the house struck fullers earth at a depth of 25 feet. On the slope of the hill several hundred yards east of the house fullers earth exposures extend down to 450 feet, showing a thickness of 65 feet for the fullers earth horizon. Half a mile farther east is another section along the public road and in a gully, showing fullers earth through a range of 70 feet.

The lower portion of the fullers earth horizon is more or less calcareous, while the upper part contains a considerable amount of interbedded sand. However, there are beds 10 to 15 feet thick of light-colored, thick-bedded earth containing little sand and apparently of good quality. The earth is all below the level of the Macon, Dublin & Savannah Railroad, and probably belongs to the lower fullers earth stratum in the Pikes Peak section.

LOCALITIES BETWEEN FITZPATRICK AND JEFFERSONVILLE

From Fitzpatrick to Jeffersonville, 15½ to 23 miles from Macon, the Macon, Dublin & Savannah Railroad follows the divide between Oconee and Ocmulgee rivers. The ridge is capped by red argillaceous sand, but numerous gullies, in which good sections are exposed, head near the track on both sides.

SIXTEEN-MILEPOST

Near the 16-milepost is a gully northeast of the track, exposing the following section:

Section in gully near 16-milepost, Macon, Dublin & Savannah Railroad

Eocene
  Jackson group
    Barnwell formation

	Feet
4. Red sand to track level	35
3. Fullers earth, exposed in a cliff. The earth is light-colored and appears to be of good quality, although the outcrop is stained by iron	10
2. Interval concealed; beds probably consist of fullers earth	15
1. Light colored fullers earth	3+

The base of the fullers earth bed is not exposed, and it may be considerably thicker. The deposit is easily accessible, as it is only 200 feet from the railroad, and the maximum overburden does not exceed 40 feet.

In another gully, 16½ miles from Macon, a complete section of the beds is exposed, but the fullers earth consists only of several thin, sandy beds.

EIGHTEEN-MILEPOST

In a gully southwest of the railroad near the 18-milepost the following section is exposed:

Section in gully near 18-milepost, Macon, Dublin & Savannah Railroad

Eocene
  Jackson group
    Barnwell formation

	Feet
7. Red sand to track level	45
6. Red and gray plastic clay	5
Barnwell formation (Twiggs clay member)	
5. Argillaceous sand, containing pockets of black carbonaceous material and laminae of yellow fullers earth	25
4. Concealed interval	10

3. Dark-colored, slate-blue fullers earth, containing some sand layers a few inches thick	10
2. Gray and yellowish argillaceous sand	5
1. Fullers earth	2+

NINETEEN-MILEPOST

(Map locality T-9)

A good section of the fullers earth beds is exposed in a gully southwest of the railroad near the 19-milepost.

Section in gully near 19-milepost, Macon, Dublin & Savannah Railroad

	Feet
Eocene	
Jackson group	
Barnwell formation	
6. Red sand to track level	30
5. Red-and-gray-mottled, plastic, sandy clay	10
Barnwell formation (Twiggs clay member)	
4. Interval is not entirely exposed, but the beds consist principally of light-colored argillaceous sand with one bed of fullers earth several feet thick	20
3. Dark-colored, slate-blue fullers earth	15
2. Pale yellow fullers earth	2.5
1. Light-colored gray and yellow sand with laminae of light-colored fullers earth up to several inches thick	4.5

The earth.—The beds of dark and light-colored earth are well exposed in a cliff. Samples S-27 and S-28 were taken from beds Nos. 3 and 2, respectively, in the preceding section. As in the General Reduction Company mine, the contact between light and dark earth is sharp, but does not seem to be a bedding plane. The lower part of the bed of dark-colored earth is dark at the surface, but above, where weathering has had more chance to act, it has been bleached to a depth of a few inches. At this locality the light earth lies below the dark, a relation which may be explained by the fact that the former was leached and oxidized by water circulating through the underlying sand bed.

Tests.—The dark earth from this locality, while stained by organic matter, does not seem to contain any pyrite. Both samples were taken from natural exposures and were somewhat weathered. Neither shows especially good bleaching power. All tests of samples S-27 and S-28 were made on earth ground in a coffee-mill to pass through a 100 mesh screen. Tests on commercial earths are stated for comparison.

Bleach

Sample used	Original bleach		After two weeks in light		After two weeks in dark	
	Yellow	Red	Yellow	Red	Yellow	Red
Oil used	35	4.8	35	4.0	35	4.4
IXL	21	2.1	15	1.9	16	2.0
Pikes Peak	19	1.9	15	1.9	17	2.1
S-27	22	2.2	13	1.9	14	2.0
S-28	23	2.3	16	2.0	18	2.2

Absorption of oil

IXL	21.2%
Pikes Peak	38.4
S-27	35.8
S-28	35.8

Specific volume

	Specific gravity	Lb. per cu. ft.
IXL	1.05	66.0
Pikes Peak	.61	38.2
S-27	.76	47.4
S-28	.79	49.4

Apparent acidity

	$\frac{N}{10}$ alkali per 100 gm. earth
IXL	19.6 c.c.
Pikes Peak	163.0
S-27	14.8
S-28	2.5

LOCALITIES NEAR JEFFERSONVILLE

The town of Jeffersonville is situated on an upland plain capped by red sand, at an altitude of 526 feet. There are no exposures of the underlying formations in the immediate vicinity, but to east and west, where erosion has proceeded farther, good sections are exposed. Toward the west, the road to Bullards descends from the upland 4 miles from Jeffersonville. On the slope a fullers earth horizon 60 feet thick is encountered, 65 feet by aneroid reading below Jeffersonville station. The earth is thin-bedded and badly iron stained, and contains many laminae and beds of sand. The deposit is probably too impure to have any commercial value, even if means of transportation were available. Farther west, in the vicinity of Bullards and Adams Park, the land surface is cut down below the 400-foot level, so no fullers earth is to be expected.

There are a number of gullies within 2 or 3 miles north, south, and east of Jeffersonville, where good sections of the strata of the fullers earth horizon are shown, but none of the deposits are likely to have commercial value, as the fullers earth beds are usually very thin and interbedded with a great amount of sand.

FOUR MILES NORTHEAST OF JEFFERSONVILLE

(Map locality T-10)

Four miles northeast of Jeffersonville is a deep gully parallel to the public road. An excellent section is exposed.

Section in gully four miles northeast of Jeffersonville

	Feet
Eocene?	
11. Red sand capping hill	45
Eocene	
Jackson group	
Barnwell formation (Twiggs clay member)	
10. Tough, plastic yellow and white clay interbedded, partly sandy	5
9. Olive-yellow clay, resembling fullers earth, but rather plastic	4

8. Black-mottled sandy clay containing well rounded quartz grains up to an eighth of an inch in diameter	1
7. Clay of fullers earth character, light yellow, thin-bedded, and containing much sand along partings	7
6. Thick-bedded greenish fullers earth, of high specific gravity	3
5. Bluish and yellow sandy fullers earth	10
4. Hard, fine-grained limestone	1
3. Interval concealed except for a small outcrop of pale blue argillaceous sand	20
2. Hard, fine grained limestone, maximum	1
1. Soft, argillaceous, fossiliferous marl	?

The earth of bed No. 6 is denser than any other Georgia earth discovered, and resembles the English earth very much in most physical properties. For this reason a sample (S-33) was taken for testing, but its bleaching power was found to be unsatisfactory.

Tests.—All tests of sample S-33 were made on earth ground in a coffee-mill to pass through a 100 mesh screen. Tests of commercial earths are stated for comparison.

Bleach

Sample used	Original bleach		After two weeks in light		After two weeks in dark	
	Yellow	Red	Yellow	Red	Yellow	Red
Oil used	35	4.8	35	4.0	35	4.4
IXL	21	2.1	15	1.9	16	2.0
Pikes Peak	19	1.9	15	1.9	17	2.1
S-33	26	2.6	17	2.1	19	2.3

Absorption of oil

IXL	21.2%
Pikes Peak	38.4
S-33	23.6

Specific volume

	Specific gravity	Lb. per cu. ft.
IXL	1.05	66.0
Pikes Peak	.61	38.2
S-33	1.04	65.3

Apparent acidity

	$\frac{N}{10}$ alkali per 100 gm. earth
IXL	19.6 c.c.
Pikes Peak	163.0
S-33	42.0

LOCALITIES NEAR DANVILLE

Danville has an altitude of 460 feet and is situated on the upland plain capped by sand and chert of Vicksburg age, but there are exposures of the beds of the Barnwell formation along the valley of Turkey Creek. These localities are far south of the northern limit of fullers earth deposition and the earth shows signs of a gradation into limestone, being mostly calcareous and interbedded with impure, fossiliferous marls.

HILL PROPERTY
(Map locality T-11)

Fullers earth is exposed on the property of Robert Hill (colored), just south of the Macon, Dublin & Savannah Railroad bridge over Turkey Creek, 1½ miles northwest of Danville. The elevation of the creek at this point is 365 feet, and the following section starts about 5 feet above creek level.

Section on Hill property

Eocene
Jackson group
Barnwell formation (Twiggs clay member)

	Feet
4. No outcrops, but the slope is covered with boulders of hard argillaceous limestone	?

3. Light yellow, slightly calcareous fullers earth, exposed in a wash	4
2. Sandy and indurated fullers earth	1
1. Light yellow, indurated calcareous fullers earth or argillaceous limestone	2

Tests.—Sample S-37 was taken from bed No. 3 of the preceding section. In spite of the content of lime, this earth bleaches fairly well, but filtration is slow. All tests were made on earth ground in a coffee-mill to pass through a 100 mesh screen. Tests on commercial earths are stated for comparison.

Bleach

Sample used	Original bleach		After two weeks in light		After two weeks in dark	
	Yellow	Red	Yellow	Red	Yellow	Red
Oil used	35	4.8	35	4.0	35	4.4
IXL	21	2.1	15	1.9	16	2.0
Pikes Peak	19	1.9	15	1.9	17	2.1
S-37	21	2.1	14	2.0	15	2.1

Absorption of oil

IXL	21.2%
Pikes Peak	38.4
S-37	38.5

Specific volume

	Specific gravity	Lb. per cu. ft.
IXL	1.05	66.0
Pikes Peak	.61	38.2
S-37	.71	44.2

Apparent acidity

	$\frac{N}{10}$ alkali per 100 gm. earth
IXL	19.6 c.c.
Pikes Peak	163.0
S-37	0.0

PORTER PROPERTY

(Map locality T-12)

On the property of J. F. Porter, about a mile downstream from the Macon, Dublin & Savannah Railroad bridge over Turkey Creek, is an exposure locally known as "Kaolin Spring." The exposure consists of 5 feet of calcareous fullers earth, above which is several feet of hard argillaceous limestone. Both hard and soft varieties are dark slate-blue when fresh, but have weathered to a light olive-gray color to a depth of an inch or more from the surface.

The earth.—The earth at this locality is highly calcareous. A sample (S-36) was taken from the beds below the hard limestone ledge, principally for the purpose of determining the effect of a large percentage of lime on the bleaching power and other properties, but the results show that it has not very strong bleaching power. The analysis is as follows:

Analysis of earth from Porter property

	S-36
Silica (SiO_2)	25.93
Alumina (Al_2O_3)	6.94
Ferric oxide (Fe_2O_3)	.87
Ferrous oxide (FeO)	.45
Magnesia (MgO)	.34
Lime (CaO)	34.94
Soda (Na_2O)	.37
Potash (K_2O)	.12
Ignition (Less CO_2)	3.51
Carbon dioxide (CO_2)	25.50
Titanium dioxide (TiO_2)	.28
Phosphorus pentoxide (P_2O_5)	.10
Sulphur (S)	.44
	99.79
Moisture	3.08

Tests.—All tests of sample S-36 were made on earth ground in a coffee-mill to pass through a 100 mesh screen. Tests on commercial earths are stated for comparison.

Bleach

Sample used	Original bleach		After two weeks in light		After two weeks in dark	
	Yellow	Red	Yellow	Red	Yellow	Red
Oil used	35	4.8	35	4.0	35	4.4
IXL	21	2.1	15	1.9	16	2.0
Pikes Peak	19	1.9	15	1.9	17	2.1
S-36	23	2.3	16	2.2	17	2.3

Absorption of oil

IXL	21.2%
Pikes Peak	38.4
S-36	33.3

Specific volume

	Specific gravity	Lb. per cu. ft.
IXL	1.05	66.0
Pikes Peak	.61	38.2
S-36	.81	50.7

Apparent acidity

	$\frac{N}{10}$ alkali per 100 gm. earth
IXL	19.6 c.c.
Pikes Peak	163.0
S-36	0.0

HUGHES PROPERTY

(Map locality T-13)

Two and a half miles west of Danville, on the property of Dudley Hughes, a good section is exposed in a small branch which flows north into Turkey Creek.

Section along branch on Hughes property

	Feet
Eocene?	
7. Apparently all red argillaceous sand to road level..	60
Eocene	
Jackson group	
Barnwell formation (Twiggs clay member)	
6. Chert ledge	2
5. Hard limestone	1
4. Pale yellow fullers earth, resembling the Pikes Peak earth in appearance, although slightly calcareous	10+
3. Hard to soft, fossiliferous, blue, clayey and sandy marl. Analysis shows only about 25 per cent of calcium carbonate	25
2. Calcareous, blue fullers earth-like clay resembling that at ''Kaolin Spring'' on the Porter property	5?
1. Blue clayey and calcareous sand..................	5?

The earth.—An average sample (S-38) was taken from the good-looking earth of bed No. 4 of the preceding section. In spite of several per cent of calcium carbonate which it contains, this is a good bleaching earth, but its oil absorption is very high and it filters with difficulty. The analysis is as follows:

Analysis of earth from Hughes property

	S-38
Silica (SiO_2)	71.60
Alumina (Al_2O_3)	10.62
Ferric oxide (Fe_2O_3)...........................	5.13
Ferrous oxide (FeO)...........................	.47
Magnesia (MgO)	.04
Lime (CaO)	2.47
Soda (Na_2O)	.25
Potash (K_2O)	.70
Ignition (less CO_2)...........................	4.67
Carbon dioxide (CO_2).........................	1.37
Titanium dioxide (TiO_2)........................	.59
Phosphorus pentoxide (P_2O_5).....................	1.75
Sulphur (S)	.12
	99.78
Moisture	7.95

Tests.—All tests of Sample S-38 were made on earth ground in a coffee-mill to pass through a 100 mesh screen. Tests on commercial earths are stated for comparison.

Bleach

Sample used	Original bleach		After two weeks in light		After two weeks in dark	
	Yellow	Red	Yellow	Red	Yellow	Red
Oil used	35	4.8	35	4.0	35	4.4
IXL	21	2.1	15	1.9	16	2.0
Pikes Peak	19	1.9	15	1.9	17	2.1
S-38	19	1.9	12	1.8	13	1.9

Absorption of oil

IXL	21.2%
Pikes Peak	38.4
S-38	49.0

Specific volume

	Specific gravity	Lb. per cu. ft.
IXL	1.05	66.0
Pikes Peak	.61	38.2
S-38	.51	32.2

Apparent acidity

	$\frac{N}{10}$ alkali per 100 gm. earth
IXL	10.6 c.c.
Pikes Peak	163.0
S-38	9.9

LOCALITIES SOUTH AND WEST OF DANVILLE

South of Danville the fullers earth beds dip below the Vicksburg and younger formations. West and southwest of Danville, in the vicinity of old Marion and Tarversville, and between Tarversville and Westlake, numerous sections of the Twiggs clay member are exposed. None of the fullers earth deposits of southwestern Twiggs County are likely to be of commercial importance, as most of them are several miles from any railroad, and the beds of earth of sufficient thickness and extent for working are sandy and calcareous.

One of the best exposures is at the locality known as "Chalk Hill" on the Burton property, 3 miles west of Tarversville, where a 30-foot bed of cream-colored, highly calcareous fullers earth overlies bryozoan limestone, while 60 feet of calcareous earth is shown in gullies near by. Other exposures of more or less calcareous fullers earth were noted on the Bradberry property near Richlands Church; on the Marchman place, 3½ miles southwest of Tarversville; on the Minter Wimberly place, 1½ miles north of Tarversville; on the Irwin Fitzpatrick place, 2½ miles northeast of Westlake; and on the Carter place, 1½ miles northeast of Westlake.

BLECKLEY COUNTY

As the outcrops of the Jackson beds in Bibb and northern Twiggs counties are typical of the shoreward phase of deposition, those of northern Bleckley County are typical of the deeper water deposits now found near the southern limit of exposure of the Jackson group. The Jackson beds in this county are almost entirely calcareous, consisting of blue clay of the fullers earth type, sandy marl, and bryozoan limestone, overlain by red sand which belongs largely to the Vicksburg formation. The fullers earth exposures are confined to a narrow belt along the northern boundary of the county.

DEESE PROPERTY

(Map locality B-1)

Calcareous fullers earth is well exposed on the property of J. T. Deese, situated on the southeast side of Shellstone Creek, 10 miles north of Cochran.

Geologic relations.—The beds of the Twiggs clay member are exposed in a number of gullies, and the exposures show local variations, but the following section, measured in a gully near the Deese residence, is typical.

Section on the Deese property, near Shellstone Creek

Probably Oligocene	
9. Red sand with chert ledges, to the flat summit of the hill	50
Eocene	
Jackson group	
Barnwell formation (Twiggs clay member)	
8. Blue calcareous fullers earth, thin-bedded, fossiliferous, and more sandy than the underlying beds	3
7. Thin bed of hard impure fossiliferous limestone, probably	2
6. Blue calcareous fullers earth.....................	20
5. Blue calcareous fullers earth, containing harder and more calcareous layers.........................	10
4. Blue calcareous fullers earth, almost free from grit	20
3. Concealed interval	10
2. Interbedded massive blue argillaceous limestone and blue calcareous fullers earth. (These are varying phases of the same formation, the hardness depending on the percentage of calcium carbonate)	5
1. Rotten fossiliferous limestone....................	5

This section is above the horizon of the typical Ocala bryozoan limestone, but the latter formation is exposed in the Shellstone Creek escarpment, 1½ miles northwest of the section just described.

The earth.—The exposures on the property indicate a thickness of at least 50 feet of fullers earth, but all is calcareous and contains interbedded layers of limestone and marl. Most of the exposures are in recently eroded gullies, so the earth is comparatively fresh and unweathered. At the surface and for a depth varying from an inch to several feet the earth is altered by leaching out of the calcium carbonate and oxidation of the iron. After this alteration it is pale yellow or cream colored and very light and porous, resembling the Pikes Peak earth.

Sample S-183 represents an average of bed No. 4 of the section described, a 20-foot exposure of fresh, blue, calcareous earth. The analyses of this sample and of two others sent to the State Geological Survey by Mr. Deese in 1912 are as follows:

Analyses of earth from the Deese property

Constituents	S-183	No. 1	No. 2
Silica (SiO_2)	43.88	56.50	52.87
Alumina (Al_2O_3)	10.55	10.90	11.21
Ferric oxide (Fe_2O_3)	2.00	2.12	1.79
Ferrous oxide (FeO)	.61	.30	.27
Magnesia (MgO)	1.58	.22	.16
Lime (CaO)	18.56	12.58	13.19
Soda (Na_2O)	.75	.91	.80
Potash (K_2O)	.24	1.89	1.97
Ignition	5.76*	13.65	16.38
Carbon dioxide (CO_2)	13.75	......	......
Titanium dioxide (TiO_2)	.69	.58	.64
Phosphorus pentoxide (P_2O_5)	.108	.15	.13
Sulphur (S)	.81	.17	.15
Manganous oxide (MnO)	.00	.13	.11
	100.288	100.10	99.67
Moisture	5.32	7.64	5.94

* Loss on ignition less CO_2.

Tests.—All tests of sample S-183 were made on earth ground in a coffee-mill to pass through a 100 mesh screen. In spite of the high content of calcium carbonate, the earth is equal to the English in bleaching power. The absorption of oil was not determined. Tests on commercial earths are stated for comparison.

Bleach

	Yellow	Red
Oil used	35	6.1
IXL	25	2.5
Pikes Peak	23	2.3
S-183	24	2.4

Specific volume

	Specific gravity	Lb. per cu. ft.
IXL	1.05	66.0
Pikes Peak	.61	38.2
S-183	.72	44.6

Apparent acidity

	$\frac{N}{10}$ alkali per 100 gm. earth
IXL	19.6 c.c.
Pikes Peak	163.0
S-183	25.

AINSLIE

Beds of calcareous fullers earth at least 20 feet in thickness are exposed at Ainslie, on the Southern Railway, and on the Weatherly place, 1½ miles east of Ainslie, in the escarpment on the east side of Shellstone Creek. The earth at both these localities overlies the Ocala bryozoan limestone.[1] The earth exposed is cream-colored but highly calcareous. It has evidently undergone weathering to a sufficient extent to oxidize the iron, but not enough to remove the calcium carbonate, and may be expected to become blue and more calcareous in depth.

HOUSTON COUNTY

The greater part of the area of Houston County is underlain by beds of Jackson age. The fullers earth member, however, outcrops only in a belt across the county south of Perry, passing between Tivola and Grovania and swinging southwestward into Dooly County, the best exposures being in the steep escarpment along the south side of the valley of Indian Creek and its tributaries. North of Perry the upland areas are underlain by red sand of the Barnwell formation, while the larger streams have cut their valleys down into the light-colored sand and clay of the Upper Cretaceous formations, but it is evident that the fullers earth beds have been removed from this

[1] Brantly, J. E., Geol. Survey of Ga. Bull. 21, pp. 65-67, 1916.

area by erosion, since an erosional outlier of limestone and fullers earth is found farther north, at Rich Hill, Crawford County.

In the belt south of Indian Creek the Ocala limestone is exposed on the lower slopes of the hills, and is overlain by almost 100 feet of beds referable to the Twiggs clay member of the Barnwell formation, while the hills are capped by red sand of late Eocene or early Oligocene age. The clay member consists of fullers earth interbedded with much limestone and marl. The earth is almost entirely calcareous, but is always light yellow at the surface, due either to weathering or to original deposition without the carbonaceous matter which characterizes the calcareous earth of Bleckley and Twiggs counties.

ROSS HILL

(Map locality H-1)

The most complete and typical section of the Twiggs clay member in Houston County is that exposed at Ross Hill on the Perry-Elko public road, 3 miles south of Perry. The following section was measured in an old limestone quarry and gullies west of the road.

Section west of the Perry-Elko public road, Ross Hill, 3 miles south of Perry

	Feet
Oligocene or Eocene	
Vicksburg or Barnwell	
15. Residual red sand with flint fragments to the top of the hill	30
Eocene	
Jackson group	
Barnwell formation (Twiggs clay member)	
14. Fullers earth and glauconitic clay, apparently interbedded, poorly exposed. The earth is yellowish-green, rather coarse grained, and is stained by iron, manganese and organic matter, but it is only slightly or not at all calcareous	15
13. Glauconitic clay-marl, yellow-green in color, containing poorly preserved fossils	2.5
12. Fullers earth, with pockets or masses of glauconitic clay in the upper 2 feet. The lower part is almost white, thick-bedded, fine-grained, and not calcareous	7.5

11. Bed or lens of limestone. The rock is hard and dense, and contains abundant but poorly preserved molluscs, no Bryozoa	1
10. Fullers earth, more or less impure, but not highly calcareous	5
9. Hard, massive argillaceous limestone, without fossils	1
8. Calcareous fullers earth	15
7. Hard gray limestone, with fossil molluscs abundant but poorly preserved	0.5
6. Calcareous fullers earth, containing nodules of soft white chalk, which do not occur in the fullers earth beds higher in the section	3.5
5. Gray fossiliferous limestone, soft at the base, but containing harder masses toward the top	3
4. Calcareous fullers earth. A cream-colored clay, becoming more calcareous and containing more abundant chalk nodules as the bottom is approached. There are several hard beds, more calcareous than the remainder, which show up strongly in the wash topography, and several ferruginous layers a few inches thick. The lower portion of the unit contains Bryozoa	35
Ocala limestone	
3. Soft, argillaceous bryozoan limestone	7
2. Hard and soft bryozoan limestone	17
1. Concealed interval to the level of Mill Creek	40
	182

The beds of the Twiggs clay member in Houston County are all calcareous and contain much interbedded limestone, so it is not likely that any of the material will find use as bleaching earth and no samples were tested.

CRAWFORD COUNTY

RICH HILL

(Map locality C-1)

The Jackson beds extend into the southern part of Crawford County, overlapping the Upper and Lower Cretaceous almost to the edge of the crystalline area. An outlying exposure of Ocala limestone and fullers earth occurs 5 miles southeast of Roberta, on the slopes of Rich Hill, which is a conspicuous topographic feature rising 150 feet above the valleys to north and south.

The beds exposed in the Rich Hill gullies show great variations in thickness and character within distances of a few hundred feet, but the following section, measured in a large gully on the south side of the hill, is typical.

Section on south side of Rich Hill

	Feet
Eocene	
Jackson group	
Barnwell formation	
8. Dark red argillaceous sand, with thin beds of plastic clay near the base	40
Barnwell formation (Twiggs clay member)	
7. Fullers earth. The clay is light greenish-yellow in color, very slightly calcareous at the top, but becomes more so toward the base	10
6. Hard, massive argillaceous limestone	3
5. Soft, massive argillaceous limestone, with few if any fossils	7
Ocala limestone	
4. Bryozoan limestone of varying hardness	10
3. Sandy marl (gradational phase)	0.5
2. Unconsolidated light yellow sand	25
(Unconformity)	
Lower Cretaceous	
1. Kaolinic sand with lenses of massive kaolin	100+

The earth.—An average sample (S-184) was collected from the **10-foot** bed, No. 7 of the preceding section. The analysis is as follows:

Analysis of earth from Rich Hill

	S-184
Silica (SiO_2)	53.32
Alumina (Al_2O_3)	8.49
Ferric oxide (Fe_2O_3)	2.86
Ferrous oxide (FeO)	.30
Magnesia (MgO)	1.36
Lime (CaO)	14.80
Soda (Na_2O)	.14

Potash (K_2O)	.71
Ignition (less CO_2)	6.45
Carbon dioxide (CO_2)	11.06
Titanium dioxide (TiO_2)	.82
Phosphorus pentoxide (P_2O_5)	.120
Sulphur (S)	.11
Manganous oxide (MnO)	.00
	100.540
Moisture	4.27

Tests.—The tests on sample S-184 show very slight bleaching power. All tests were made on earth ground in a coffee-mill to pass through a 100 mesh screen. Tests on commercial earths are stated for comparison.

Bleach

	Yellow	Red
Oil used	35	6.1
IXL	25	2.5
Pikes Peak	23	2.3
S-184	34	3.4

Specific volume

	Specific gravity	Lb. per cu. ft.
IXL	1.05	66.0
Pikes Peak	.61	38.2
S-184	1.03	64.5

Apparent acidity

	$\frac{N}{10}$ alkali per 100 gm. earth
IXL	19.6 c.c.
Pikes Peak	163.0
S-184	0.0

WILKINSON COUNTY

The geology of Wilkinson County is very similar to that of Twiggs. The upland areas are underlain by beds of Jackson age, while Oconee River and Commissioners and Big Sandy creeks have cut their valleys down into the Lower Cretaceous strata. The Jackson exposures cover the southern part of the county and form a narrow tongue along the ridge between Big Sandy and Commissioners creeks and an elongated erosional outlier between Commissioners Creek and Oconee River, both of the latter areas extending beyond the northern boundary of the county. Chert of Vicksburg age is found along the southern county line, and there is a possibility, as in Twiggs County, that a part of the red sand farther north is also of that age.

The Ocala limestone bed, which is nearly 50 feet thick in Houston and Twiggs counties, pinches out before the Oconee is reached, and throughout Wilkinson County it is thin and impure, and is absent at many localities. The fullers earth member in this county is also less persistent and less pure than in Twiggs, and the material is generally too sandy or calcareous to serve as a commercial fullers earth. Locally both limestone and fullers earth are absent, and the Jackson consists entirely of red sand with a few thin beds of plastic clay, or gumbo.

LOCALITIES NEAR GORDON

A section typical of the beds in the northern part of Wilkinson County is exposed in a pit of the Savannah Kaolin Company, a mile south of Gordon.

Section in pit of the Savannah Kaolin Company

	Feet
Eocene	
Jackson group	
Barnwell formation	
5. Red and mottled argillaceous sand to the top of the hill	60
Barnwell formation (Twiggs clay member)	
4. Greenish yellow fullers earth, rather sandy and containing chalk nodules and a few fossils. Apparently too impure to be of commercial value	10
Ocala limestone	
3. Sandy bryozoan limestone	3
2. Argillaceous, glauconitic sand, filling erosion depressions in the Cretaceous surface	0-2
(Unconformity)	
Lower Cretaceous	
1. Massive white kaolin	30

A bed of fullers earth at least 25 feet thick is exposed on the property of J. W. Batchelor, Jr., 3½ miles south of Gordon. The earth on this property is of high specific gravity, resembling that of the localities near Dry Branch, Twiggs County.

DUPREE PROPERTY
(Map locality W-1)

Fullers earth is exposed on the property of J. T. Dupree, 4½ miles northwest of Irwinton. The earth overlies bauxite and bauxitic clays of the Lower Cretaceous. The best exposures consists of 10 feet of beds outcropping in a gully a quarter of a mile south of the Dupree residence. The exposure is 60 feet below the summit of the ridge on which the house is situated, and 10 feet above an outcrop of bauxitic kaolin. Sample S-86 represents an average of the fullers earth beds. The earth from this bed is not calcareous.

No exploration work has been done to determine the extent and thickness, which may exceed the 10 feet seen in the natural exposure. In the gully above the deposit of red bauxite (see section, p. 53) the fullers earth horizon has a thickness of 45 feet, most of which consists of earth of apparently good quality.

Tests.—The earth from the Dupree property is slightly denser than the Pikes Peak earth, and therefore absorbs less oil. While its immediate bleaching power is not especially strong, the after-bleach by exposure to light makes the oil very light in color. All tests of sample S-86 were made on earth ground in a coffee-mill to pass through a 100 mesh screen. Tests on commercial earths are stated for comparison.

Bleach

Sample used	Original bleach		After two weeks in light		After two weeks in dark	
	Yellow	Red	Yellow	Red	Yellow	Red
Oil used	35	4.8	35	4.0	35	4.4
IXL	21	2.1	15	1.9	16	2.0
Pikes Peak	19	1.9	15	1.9	17	2.1
S-86	22	2.2	12	1.7	13	1.8

Absorption of oil

IXL	21.2%
Pikes Peak	38.4
S-86	35.1

Specific volume

	Specific gravity	Lb. per cu. ft.
IXL	1.05	66.0
Pikes Peak	.61	38.2
S-86	.80	49.7

Apparent acidity

	$\frac{N}{10}$ alkali per 100 gm. earth
IXL	19.6 c.c.
Pikes Peak	163.0
S-86	44.4

HALL AND TOLER PROPERTIES

(Map locality W-2)

Fullers earth is exposed along the public road on the southwest slope of Big Sandy Creek near Sand Bed bridge, 3 miles south of Irwinton. The following section was measured along the road. The property east of the road belongs to Marvin Hall; that west of the road, to N. H. Toler.

Section near Sand Bed bridge, on the southwest slope of Big Sandy Creek

	Feet
Eocene?	
6. Red, yellow, and mottled argillaceous sand, containing some thin beds of plastic clay	40
Eocene	
Jackson group	
Barnwell formation (Twiggs clay member)	
5. Thin bed of plastic clay, not well exposed	5?
4. Fullers earth. Contains some partings of yellow sand up to an inch thick, but the greater part is thick-bedded, light-colored earth	25
3. Very plastic bluish clay, several feet exposed, but the top and bottom of the bed are concealed	5?
2. At bottom, red sand with laminae of fullers earth-like clay; above, red-and-blue-mottled clayey sand	25
(Unconformity)	
Lower Cretaceous	
1. Massive white kaolin	15

The bed of fullers earth exposed on these properties is apparently workable, but is about 6 miles from Wriley, the nearest railroad station.

Tests.—Sample S-45 represents an average of the 25-foot bed of fullers earth, No. 4 of the preceding section. All tests of this sample were made on earth ground in a coffee-mill to pass through a 100 mesh screen. Tests on commercial earths are stated for comparison.

Bleach

Sample used	Original bleach		After two weeks in light		After two weeks in dark	
	Yellow	Red	Yellow	Red	Yellow	Red
Oil used	35	4.8	35	4.0	35	4.4
IXL	21	2.1	15	1.9	16	2.0
Pikes Peak	19	1.9	15	1.9	17	2.1
S-45	22	2.2	12	1.7	13	1.8

Absorption of oil

IXL	21.2%
Pikes Peak	38.4
S-45	38.5

Specific volume

	Specific gravity	Lb. per cu. ft.
IXL	1.05	66.0
Pikes Peak	.61	38.2
S-45	.72	44.8

Apparent acidity

	$\frac{N}{10}$ alkali per 100 gm. earth
IXL	19.6 c.c.
Pikes Peak	163.0
S-45	128.4

STEPHENSVILLE

(Map locality W-3)

The best exposure of the fullers earth formation in the southern part of Wilkinson County is at Stephensville, 9 miles south of Toomsboro. The following section is exposed in a gully along the public road on the south slope of Big Sandy Creek.

Section on south slope of Big Sandy Creek at Stephensville

	Feet
Eocene?	
5. Red sand capping the hill to the south	100
Eocene	
Jackson group	
Barnwell formation (Twiggs clay member)	
4. Fullers earth interbedded with much sand and plastic clay	15
3. Light-colored, thick-bedded fullers earth, not calcareous, and apparently of fair quality	20
2. Impure, sandy fullers earth	15
1. Concealed interval to the level of Big Sandy Creek	50

The deposits in this vicinity, even if of good quality, are too far from railroad transportation and have too much overburden to be of present commercial value.

TOOMSBORO

In the immediate vicinity of Toomsboro no limestone or fullers earth is exposed, and the Jackson seems to consist entirely of red sand. Three miles west of the station, on the property of the General Bauxite Corporation, which formerly belonged to Dr. N. T. Carswell, there are exposures of sandy and calcareous fullers earth, overlying the kaolin and bauxite beds of the Lower Cretaceous. The earth is evidently too impure to be of commercial value.

JONES COUNTY

ROBERTS

(Map locality J-1)

Several small areas of Jackson beds extend into the southern part of Jones County. The most interesting exposures are in the cuts of the Georgia Railroad near Roberts. The following is the section in the cut a mile northeast of the station, near the overhead crossing of the Central of Georgia Railway.

Section in cut 1 mile northeast of Roberts

	Feet
Eocene	
Jackson group	
Barnwell formation	
6. Loose red sand, containing a few scattered quartz pebbles	10
Barnwell formation (Twiggs clay member)	
5. Greenish and drab laminated fullers earth	12
4. Laminated sandy fullers earth containing white chalk nodules and casts of fossils. The upper 2 feet of the bed is very fossiliferous	8
3. Bluish, fossiliferous mud or marl	8
Crystalline basement	
2. Concealed	5?
1. Crystalline igneous rock	?

Bed No. 5 of the above section is typical of the fullers earth deposited near the northern limit of the formation. It is denser than the Pikes Peak earth, and may therefore be expected to have lower absorption of oil, but also less bleaching power.

BALDWIN COUNTY

So far as known, there is only one tongue of Jackson beds entering the southern part of Baldwin County. The Jackson material, consisting of fossiliferous marl and impure fullers earth of high density, forms the overburden in the fire-clay pits of Stevens Brothers & Company at Stevens Pottery. The section presented is very similar to that at Roberts, Jones County.

HALL PROPERTY

(Map locality Ba-1)

The best fullers earth exposures seen in Baldwin County are on the property of W. A. Hall, which consists of 190 acres, lying east of the Central of Georgia Railway, a mile south of Stevens Pottery station.

The fullers earth bed, having a thickness of 15 to 20 feet, underlies the hill on which the Hall residence is situated. The earth outcrops in several gullies in the hillside and is cut by the well at the house. The maximum overburden is about 40 feet, and the earth itself forms the overburden on an extensive deposit of white kaolin or fire-clay.

The earth.—The earth from the Hall property is not calcareous, and is much denser than most varieties of Georgia earth, resembling the English fullers earth closely in physical properties, but its bleaching power is not strong. An analysis of a sample sent to the State Geological Survey by Hall in 1914 is as follows:

Analysis of earth from the Hall property

Silica (SiO_2)	61.76
Alumina (Al_2O_3)	18.26
Ferric oxide (Fe_2O_3)	3.15
Ferrous oxide (FeO)	1.43
Magnesia (MgO)	2.12
Lime (CaO)	.05
Soda (Na_2O)	2.10

Potash (K_2O)	2.14
Ignition	7.35
Titanium dioxide (TiO_2)	1.14
Manganous oxide (MnO)	.11
	99.61
Moisture	7.35

Tests.—Sample S-99 represents an average of a 15-foot bed of fullers earth exposed in a gully north of the Hall residence. All tests of this sample were made on earth ground in a coffee-mill to pass through a 100 mesh screen. Tests on commercial earths are stated for comparison.

Tests for bleaching power and acidity were also made on sample S-97, which is a nodular, very slightly bauxitic kaolin collected below the fullers earth exposure and in the same gully. The kaolin has much stronger bleaching power than the fullers earth from this property but when mixed with oil it forms a sticky mass which filters very slowly. The high oil absorption is caused not so much by the porosity of the kaolin as by the difficulty in sucking the cake dry.

Bleach

Sample used	Original bleach		After two weeks in light		After two weeks in dark	
	Yellow	Red	Yellow	Red	Yellow	Red
Oil used	35	4.8	35	4.0	35	4.4
IXL	21	2.1	15	1.9	16	2.0
Pikes Peak	19	1.9	15	1.9	17	2.1
S-99	25	2.5	15	2.0	16	2.1
S-97	21	2.1	12	1.7	14	1.9

Absorption of oil

IXL	21.2%
Pikes Peak	38.4
S-99	25.0
S-97	33.0

Specific volume

	Specific gravity	Lb. per cu. ft.
IXL	1.05	66.0
Pikes Peak	.61	38.2
S-99	1.00	62.2

Apparent acidity

	$\frac{N}{10}$ alkali per 100 gm. earth
IXL	19.6 c.c.
Pikes Peak	163.0
S-99	148.2
S-97	19.8

WASHINGTON COUNTY

Washington County includes most of the area of outcrop of the Jackson beds between Oconee and Ogeechee rivers. The beds have much the same character as in eastern Wilkinson County, but they differ greatly from those of Twiggs and Houston counties.

The most persistent bed is the fullers earth of the Twiggs clay member of the Barnwell formation. The fullers earth deposits are discontinuous and lens-like in form, but the horizon may be traced by a belt of outcrops in a northeasterly direction across the county from Oconee to Chalker.

The Ocala limestone formation is absent in Washington County, and the Eocene beds underlying the fullers earth average about 50 feet in thickness, consisting principally of calcareous clay and sand. The portions which were originally more calcareous are largely silicified, and contain numerous fossils typical of the Barnwell formation. North of the limit of fullers earth deposition the Barnwell formation consists entirely of red sand, which unconformably overlies the light colored sands and clays of the Lower Cretaceous.

The clay member is overlain by a considerable thickness of red sand and by a bed of limestone which outcrops in a belt south of, and stratigraphically above, the fullers earth, extending from Wring Jaw Landing on Oconee River a little south of the Washington

County line to Sunhill, passing between Sandersville and Tennille. The portion of the county south of the Central of Georgia Railway is covered with residual sands and clays, probably belonging to the Alum Bluff formation of Oligocene age.

BUFFALO CREEK

The course of Buffalo Creek is almost due south, 9 to 10 miles west of Sandersville. The area west of the creek is comparatively low, and the Barnwell material consists only of red sand capping the hills, but the east slope of the valley is a steep escarpment, and good sections of the Barnwell beds are exposed along the public roads east of Sheppard's bridge and Turnpike bridge, 3 and 8 miles, respectively, north of the mouth of the creek.

Section along road east of Sheppard's bridge

	Feet
Eocene	
Jackson group	
Barnwell formation	
9. Red sand with plastic clay laminae toward the base	70
Barnwell formation (Twiggs clay member)	
8. Plastic, laminated yellowish-green clay............	12
7. Porous, light yellow, non-plastic fullers earth.....	5
6. Gray plastic clay, more or less sandy............	14
5. Massive, gray, argillaceous sand with casts of fossils	6.5
4. Interbedded fullers earth and sand...............	7.5
3. Gray, very plastic, sandy clay, becoming more sandy toward the top. The upper portion contains poorly preserved fossils	27
2. Gray sand, mottled with red, containing quartz pebbles up to 1½ inches long near the top........	6
(Unconformity)	
Lower Cretaceous	
1. Crossbedded kaolinic sand, from the level of Buffalo Creek. This unit may include the basal beds of Barnwell formation, as the position of the unconformity can not be exactly determined.........	70
	218

Section along Sandersville-Milledgeville road east of Turnpike bridge.

(Map locality Wa-1)

	Feet
Eocene	
Jackson group	
Barnwell formation	
9. Red sand	35
Barnwell formation (Twiggs clay member)	
8. Greenish, plastic, laminated, sandy clay	10
7. Fullers earth. The exposures are not quite continuous, and there is a possibility of interbedded sand strata in the covered intervals. All the earth in sight, however, appears to be of sufficient purity for use as a bleaching earth. It is light greenish-yellow, fine grained, non-plastic, non-calcareous, and is somewhat iron-stained on account of proximity to the surface, but contains very little sand	40
6. Concealed interval, beds probably of the same character as the stratum below. A spring emerges near the top of the unit	20
5. Dark gray sandy clay	5
4. Greenish, slighty plastic clay, resembling fullers earth in appearance, containing considerable sand and a few fossils	25
3. Sandy and calcareous clay, containing fossil corals	3
2. Gray sandy clay at base, grading up into gumbo or pipe clay	12
——Unconformity——	
Lower Cretaceous	
1. Light-colored sand containing lenses of white kaolin, from the level of Buffalo Creek	70
	220

The earth.—The preceding sections are very similar, except that the fullers earth bed is much thicker at Turnpike bridge. A bed of fullers earth of varying thickness is likely to be found on all properties along the east slope of Buffalo Creek at an elevation of 130 to 140 feet above the creek.

An average sample, S-176, was taken from all good exposures of the 40-foot fullers earth horizon in the Turnpike bridge section. The analysis is as follows:

Analysis of earth from the Sandersville-Milledgeville road east of Turnpike bridge

	S-176
Silica (SiO_2)	68.18
Alumina (Al_2O_3)	16.08
Ferric oxide (Fe_2O_3)	4.21
Ferrous oxide (FeO)	.15
Magnesia (MgO)	1.09
Lime (CaO)	.82
Soda (Na_2O)	.48
Potash (K_2O)	.76
Ignition	7.04
Carbon dioxide (CO_2)	.00
Titanium dioxide (TiO_2)	.79
Sulphur (S)	.04
Phosphorus pentoxide (P_2O_5)	.24
	99.88
Moisture	8.49

Tests.—All tests of sample S-176 were made on earth ground in a coffee-mill to pass through a 100 mesh screen. Tests on commercial earths are stated for comparison.

Bleach

	Yellow	Red
Oil used	35	6.1
IXL	25	2.5
Pikes Peak	23	2.3
S-176	22	2.2

Specific volume

	Specific gravity	Lb. per cu. ft.
IXL	1.05	66.0
Pikes Peak	.61	38.2
S-176	.78	48.8

Apparent acidity

	$\frac{N}{10}$ alkali per 100 gm. earth
IXL	19.6 c.c.
Pikes Peak	163.0
S-176	78.0

IRWIN PROPERTY

(Map locality Wa-2)

A good exposure of fullers earth is found on the property of Andrew J. Irwin, at the head of a branch of Little Keg Creek, 3 miles south of Warthen and 6 miles north of Sandersville.

Section on Irwin property, 3 miles south of Warthen

	Feet
Eocene	
Jackson group	
Barnwell formation	
5. Massive red sand. This bed overlies the clay with a sharp contact, showing no sign of gradation, which may represent a local unconformity.......	40
Barnwell formation (Twiggs clay member)	
4. Greenish plastic clay and indurated sandy clay....	2
3. Fullers earth, light yellowish gray when dry, laminated, brittle, and free from grit	8
2. Plastic greenish clay, with a tendency to crumble on drying	15
1. Greenish, sandy, non-plastic clay of fullers earth character, containing thin beds of sand and plastic clay.	

At this exposure the bed of good earth is only 8 feet thick and the overburden would increase rapidly, but it is possible that exploration might show up earth of greater thickness and more favorably situated. The locality is hardly more than a mile from the Augusta Southern Railroad.

The earth.—Sample S-179 is an average of bed No. 3 of the preceding section. The analysis is as follows:

Analysis of earth from the Irwin property

	S-179
Silica (SiO_2)	70.91
Alumina (Al_2O_3)	14.71
Ferric oxide (Fe_2O_3)............................	4.37
Ferrous oxide (FeO)............................	.31
Magnesia (MgO)	.50
Lime (CaO)	.69
Soda (Na_2O)	.63

Potash (K_2O)	.58
Ignition	6.66
Carbon dioxide (CO_2)	.00
Titanium dioxide (TiO_2)	.49
Sulphur (S)	.00
Phosphorus pentoxide (P_2O_5)	.24
	100.09
Moisture	7.95

Tests.—All tests of sample S-179 were made on earth ground in a coffee-mill to pass through a 100 mesh screen. Tests of commercial earths are stated for comparison.

Bleach

	Yellow	Red
Oil used	35	6.1
IXL	25	2.5
Pikes Peak	23	2.3
S-179	21	2.1

Specific volume

	Specific gravity	Lb. per cu. ft.
IXL	1.05	66.0
Pikes Peak	.61	38.2
S-179	.65	40.4

Apparent acidity

	$\frac{N}{10}$ alkali per 100 gm. earth
IXL	19.6 c.c.
Pikes Peak	163.0
S-179	166.

CHALKER

Near the 65-milepost on the Augusta Southern Railroad, 1¼ miles southwest of Chalker, a lens of sandy kaolin of Lower Cretaceous age is worked and used in the manufacture of common pottery. The kaolin extends 8 feet above the railroad level and is overlain unconformably by 6 feet of yellow and white sand of the Barnwell formation, the fullers earth being absent. A quarter of a mile southwest of the pottery pit there is about 10 feet of more or less indurated fullers earth exposed above railroad level, but below the top of the kaolin in the pit.

From half a mile to a mile southwest of the pottery, fullers earth is exposed in the railroad cuts. There is not more than 3 or 4 feet vertically exposed at any one point, but the exposures have a range of 20 feet. The earth in the upper part of the horizon is interbedded with sand, but there is apparently 10 feet of earth of good quality in the lower part. The earth varies from gray through pale yellow to ocher yellow in color, and is soft and rather plastic on account of weathering. It would be necessary to dig pits to determine the extent and thickness of the bed and to secure fairly representative samples.

A mile south of Chalker, where the road to Sandersville ascends from the Ogeechee valley to the upland plain, a section is exposed which shows well the character of the Barnwell formation.

Section along Sandersville road, 1 mile south of Chalker

	Feet
Eocene	
Jackson group	
Barnwell formation	
10. Massive red and mottled sand to the top of the hill	30
9. Red sand with laminae of white and purple clay...	17
8. Yellow and mottled sand........................	16
Barnwell formation (Twiggs clay member)	
7. Greenish laminated fullers earth, stained and somewhat plastic on account of weathering..........	11
6. Coarse yellow sand.............................	11
5. Greenish laminated fullers earth, free from sand...	1
4. Concealed interval	10
3. Fullers earth containing a little sand............	4
2. Sand with laminae of fullers earth...............	4
(Unconformity)	
Lower Cretaceous	
1. White sand with kaolin lenses, from the level of Chalker station	55
	159

It is not impossible that workable deposits of fullers earth may be found in the vicinity of Chalker, but the natural exposures indicate that the beds are generally thin, with heavy overburden.

GLASCOCK COUNTY

The geological formations of Glascock County are a continuation of those of northern Washington County. There is a granite outcrop in the bed of Rocky Comfort Creek 1.4 miles north of Gibson, and the Lower Cretaceous beds are thin, although their outcrop covers a considerable proportion of the area of the county. At the base of the Barnwell formation is a thin but rather persistent bed of highly fossiliferous sandy limestone, locally silified to a very hard rock. This is overlain by lenses of clay of the Twiggs clay member, above which is the red sand which caps the hills in the southern part of the county.

The exposures seen indicate no fullers earth of possible commercial importance in the county, as all beds are thin and impure. Typical exposures are on the slope of Jumping Gully Creek, Gibson-Mitchell road, 2 miles west of Gibson, where the fullers earth horizon is represented by several lenses of earth 2 or 3 feet thick interbedded with white, fossiliferous, calcareous sand; and at the Harbison and Walker fire-clay mine near Rocky Comfort Creek, 2 miles east of Gibson, where the Lower Cretaceous fire-clay is overlain by several feet of shaly and lignitic clay.

JEFFERSON COUNTY

Jefferson County is almost entirely underlain by beds of Jackson age. Their outcrop covers all of the county except near the northern boundary, where several streams have cut their valleys down into the Lower Cretaceous beds, and south of Louisville, where the upland areas are capped by sand of Alum Bluff (Oligocene) age. However, the character of the Jackson beds has changed greatly since passing Ocmulgee River. The Ocala limestone and the fossiliferous sand beds which take its place at the base of the group farther east have disappeared, so that the fullers earth lies almost immediately on the Cretaceous surface.

The fullers earth of the Twiggs clay member is thin but fairly persistent, and shows up in a line of exposures across the northern part of the county. In general, the earth of this county is whiter than the deposits farther west, on account of its lower iron content. Some of it is soft and very light and porous, but on going eastward a larger proportion is indurated by deposition of silica in the pores, forming a rather hard rock. Some of the silicified fullers earth resembles the indurated Cretaceous kaolins found in the same area, but may be distinguished from them by analysis, as it has a much higher ratio of silica to alumina. Southward from the border of the Jackson deposits the earth grades into calcareous clay, marl, and oyster shell beds, which have few of the characteristics of a true fullers earth.

The upper part of the Jackson group is made up of a considerable, but undetermined, thickness of red sand, containing thin beds of plastic clay, locally silicified layers of sandstone, which is sometimes fossiliferous, and thin beds of fossiliferous chert.

WRENS

(Map locality Je-1)

Fullers earth is exposed at a number of localities in the vicinity of Wrens, and has been cut by many wells in and around the village. The earth is almost white, non-plastic and non-calcareous, and shows various degrees of induration. A section is exposed on the north slope of Brushy Creek, on the Louisville road, a mile south of Wrens.

Section 1 mile south of Wrens

	Feet
Eocene	
Jackson group	
Barnwell formation	
4. Yellow sand with interlaminated clay, conformable with the underlying fullers earth	20
Barnwell formation (Twiggs clay member)	
3. Slightly indurated fullers earth, porous, laminated, greenish when wet, but becoming pure white on drying. Contains laminae and beds up to several feet thick of greenish sand	20

2. Light greenish, argillaceous sand, slightly indurated	5
1. Concealed interval from the level of Brushy Creek..	5
	50

The best looking fullers earth found in the vicinity of wrens is that from a well on the property of Dinah Hines, three quarters of a mile southeast of the station. This earth is light and porous, almost white, contains flakes of mica but very little sand, and is only slightly harder than the Pikes Peak earth. The thickness of the bed is not known, but must be considerable. A sample, S-163, was collected from the pile of material taken from the well. The analysis is as follows:

Analysis of earth from Dinah Hines property, Wrens

	S-163
Silica (SiO_2)	78.59
Alumina (Al_2O_3)	10.08
Ferric oxide (Fe_2O_3)	3.16
Ferrous oxide (FeO)	.31
Magnesia (MgO)	.90
Lime (CaO)	.00
Soda (Na_2O)	.40
Potash (K_2O)	.36
Ignition	4.65
Carbon dioxide (CO_2)	.00
Titanium dioxide (TiO_2)	.58
Sulphur (S)	.00
Phosphorus pentoxide (P_2O_5)	.47
	99.50
Moisture	6.14

Tests.—All tests of sample S-163 were made on earth ground in a coffee-mill to pass through a 100 mesh screen This sample is among the most powerful bleaching earths found, but on account of the great porosity the absorption of oil would evidently be high, although it has not been determined. Tests on commercial earths are stated for comparison.

Bleach

	Yellow	Red
Oil used	35	6.1

IXL	25	2.5
Pikes Peak	23	2.3
S-163	19	1.9

Specific volume

	Specific gravity	Lb. per cu. ft.
IXL	1.05	66.0
Pikes Peak	.61	38.2
S-163	.50	31.3

Apparent acidity

	$\frac{N}{10}$ alkali per 100 gm. earth
IXL	19.6 c.c.
Pikes Peak	163.0
S-163	186.

HATCHER'S MILL

At R. R. Hatcher's mill on Reedy Creek, 5.2 miles north of Wrens, indurated fullers earth of the Twiggs clay member of the Barnwell formation immediately overlies the Lower Cretaceous. The unconformity is exposed by the roadside on the north slope of Reedy Creek, 15 feet above water level. The Cretaceous consists of white, mealy, slightly sandy kaolin. The unconformity where observed is almost horizontal, but irregular in detail. The lower 5 feet of the Barnwell formation consists of interlaminated aluminous sandstone and indurated clay, the latter being silicified so that it has almost the hardness of an average limestone. This basal bed contains fragments of lignitized wood and leaf impressions, and also fragments of kaolin from the underlying bed, but the fragmental kaolin is inconspicuous on account of the similarity in color and texture of fragments and matrix. The bed of laminated sandy clay is overlain by 10 feet or more of massive silicified fullers earth, practically free from grit, which is best exposed in the road just south of the mill. The stratum shows almost no trace of bedding, and on weathering breaks into small irregular pieces with angular and conchoidal fracture. The clay is bluish when fresh, but becomes white on weathering. It resembles the associated Cretaceous kaolin, from which it may be distinguished by its characteristic mode of fracture or by chemical analysis, as the indurated fullers earths have a high ratio of silica to alumina, while for the Cretaceous kaolins, unless very sandy, the ratio is rarely higher than 45 to 35 per cent.

The following partial analysis of a sample from the Hatcher's mill exposure is typical of the composition of the indurated fullers earth, which is found at a number of other localities in Jefferson, Richmond, and Columbia counties.

Partial analysis of indurated earth from Hatcher's Mill

	S-233
Silica (SiO_2)	67.48
Alumina (Al_2O_3)	18.74
Ferric oxide (Fe_2O_3)	1.45
Ignition	10.71
Titanium dioxide (TiO_2)	.72
	99.10
Moisture	.30

LOUISVILLE

South of the line of the Augusta Southern Railroad the fullers earth beds dip beneath the red sand of the Barnwell formation, and grade into plastic clay and marl. In the vicinity of Louisville no earth of possible commercial value was seen. One of the best sections of the upper part of the Barnwell formation is exposed in a gully on the east slope of Rocky Comfort Creek, three quarters of a mile west of Louisville. In this section the fullers earth member seems to be represented by 3 feet of laminated but rather plastic clay, intermediate between fullers earth and common pipe clay in properties, which is underlain by calcareous and fossiliferous sand.

At Warren's mill, on Big Creek, 3 miles east-northeast of Louisville a bed of rock containing large *Ostrea georgiana* shells was excavated from below water level and used in building a dam. Above water level is exposed 3 feet of blue calcareous fullers, which drys and weathers white. This grades up, by interbedding, into yellow argillaceous sand containing laminae of fullers earth and fragments of oyster shells.

BURKE COUNTY

The Barnwell formation in Burke County is of very much the same character as in southern Jefferson County. The beds of true fullers earth outcrop in Richmond and Columbia counties, north of the Burke County line, so in this county the formation consists of calcareous clay, marl, and oyster shell beds, overlain by red sand with ledges of fossiliferous chert. The underlying McBean formation of the Claiborne group is exposed in the valleys of Savannah River and McBean Creek, while in the southern part of the county the higher land is underlain by beds of Alum Bluff (Oligocene) age, and there is good evidence that the Alum Bluff beds extend as far north as Greens Cut.

At Keys Mill, 3 miles northwest of St. Clair, near the northwestern corner of Burke County, a bed of fullers earth 7 feet thick overlies a thick *Ostrea georgiana* bed, and is overlain by 50 feet of red and yellow sand. The earth is light greenish-yellow in color and not highly calcareous, but it contains a considerable amount of greenish sand interbedded and in irregular pockets. The thinness of the bed and the heavy overburden preclude its having any commercial value.

At Griffin Landing, on Savannah River, the marl of the McBean formation dips below water level, and is overlain by a 10-foot bed of *Ostrea georgiana* shells in a matrix of greenish calcareous clay. Above the oyster bed is a non-persistent stratum of pale yellow, laminated, calcareous clay of fullers earth type, nowhere exceeding 5 feet in thickness.

RICHMOND COUNTY

The greater part of the area of Richmond County is underlain by beds of Lower Cretaceous and Claiborne age. The Barnwell formation caps the hills north of McBean Creek, overlying the McBean formation, but in the absence of beds of fullers earth or chert it is almost impossible to distinguish one formation from the other. No fullers earth deposits of present commercial value are known in the county, but in the western part the Barnwell formation contains at its base beds of indurated fullers earth, which directly overlie the Lower Cretaceous. A long narrow outlier of the Barnwell formation caps the ridge between Butler and Spirit creeks, extending northwest into Columbia County, where it overlaps the Lower Cretaceous beds to the edge of the crystalline area.

MOUNT ENON

Mount Enon is an isolated hill, a remnant of the original plain, situated near the Dean's Bridge road, 14 miles southwest of Augusta and about 3 miles northeast of Bath. A good section of the lower beds of the Barnwell formation is exposed near a spring on the north slope of the hill.

Section on the north slope of Mount Enon

	Feet
Eocene	
Jackson group	
Barnwell formation	
8. Apparently all red sand to the top of the hill. Near the top are fragments of dense, banded cherty sandstone	60
Barnwell formation (Twiggs clay member)	
7. Soft white fullers earth; top of the bed not exposed, so may be thicker than indicated	3
6. Argillaceous sandstone, with abundant but poorly preserved fossils and casts, and rounded quartz pebbles up to an inch in diameter	1
5. Coarse yellow sand	11
4. Light drab indurated fullers earth, with angular and conchoidal fracture on weathering	11
3. Gray plastic clay	1
(Unconformity)	
Lower Cretaceous	
2. Indurated sandy kaolin or flint clay	10
1. Kaolinic sand, etc., not measured in detail	?

Bed No. 4. is similar to the indurated fullers earth at Hatcher's mill. Jefferson County. On account of the hardness, it would not serve as a bleaching earth, and the only probable commercial use would be in the manufacture of portland cement. The following is an analysis of a sample sent to the State Survey by J. Miller Walker:

Analysis of indurated fullers earth from Mount Enon

Silica (SiO_2)	76.59
Alumina (Al_2O_3)	13.59
Ferric oxide (Fe_2O_3)	2.16
Magnesia (MgO)	.82
Lime (CaO)	tr.
Soda (Na_2O)	.24
Potash (K_2O)	.38
Ignition	5.59
Titanium dioxide (TiO_2)	.39
Manganous oxide (MnO)	.04
	99.80
Moisture	7.42

At Bath about 25 feet of indurated fullers earth is exposed in the slope above the spring and bath house on the Walker property, and the bed is seen at several other points in the vicinity, but at Hephzibah, 6 miles farther east, the fullers earth formation is absent. In the pit of the Albion Kaolin Company, near Hephzibah, the Cretaceous kaolin is overlain by 100 feet of red and yellow argillaceous sand without any conspicuous clay beds.

COLUMBIA COUNTY

The Barnwell formation of Columbia County consists only of several tongues which extend into the southern part near Grovetown, Forrest and Harlem, but some of the exposures of fullers earth are of interest and importance. The calcareous beds found in the Barnwell farther south and west are here lacking, and the formation consists of fullers earth, clay, shale, or lignite lying immediately above the Lower Cretaceous, and overlain by red sand. An unconformity between the clay member and the red sand was noted at several places and is probably of general occurrence throughout the county. There are also indications of local unconformities within the red sand. As the beds are all of shallow water origin, these unconformities may have been produced by very slight oscillations in the level of the land, and do not necessarily represent any considerable interval of time.

Some varieties of leached and partly weathered earths from Columbia County have stronger bleaching power than any other samples tested. Among the fresh and unweathered earths from this county no calcareous material has been found, but the earth is usually dark in color and contains a considerable amount of carbonaceous matter and pyrite. The latter mineral is in such finely divided form that it readily oxidizes on drying, producing sulphur dioxide and soluble sulphites and sulphates, which diminish the bleaching power to a great extent, and probably also have a deleterious effect on the oil bleached. Therefore, in mining, care must be taken to avoid the dark-colored, pyritiferous and carbonaceous earths and to use only the light-colored varieties.

Locally the carbonaceous earth grades over into lignite and lignitic clay. Such material occupies the fullers earth horizon at the Chapman lignite mine, 3 miles south of Grovetown, where it was formerly mined for use as a fertilizer filler, but was sufficiently carbonaceous to be used as a fuel under the boiler at the grinding plant.

PHINIZY GULLY

(Map locality Co-1)

There is a good exposure showing the relation of the Barnwell beds to the Lower Cretaceous in a gully in the abandoned Augusta-Wrightsboro public road, a mile northeast of Grovetown, on the Phinizy property. The relations of the beds may be seen in the following sketch (fig. 22) and section:

Section in Phinizy Gully, 1 mile northeast of Grovetown

Eocene
Jackson group
Barnwell formation

	Feet
6. Yellow to red argillaceous sand, coarse and pebbly near the base. Caps hill east of the gully...	50+
5. Laminated, plastic greenish clay.................	0-3

4. Conglomerate of vari-colored kaolin pellets in red sand. Contains some fragments of lignitized wood 0-2

(Unconformity?)

Barnwell formation (Twiggs clay member)

3. Laminated, shaly fullers earth, containing leaf impressions along bedding planes. The bedding dips west at a smaller angle than the unconformity below 0-6

(Unconformity)

Lower Cretaceous

2. Silicified white sandy kaolin or flint clay, has been described as "argillaceous sandstone." The bedding dips 10° east, the unconformity above dips 15° west in the head of the gully.............. 12

1. Soft plastic white kaolin interbedded with white and yellow sand, with some kaolin conglomerate near the bottom of the exposure.................... 12

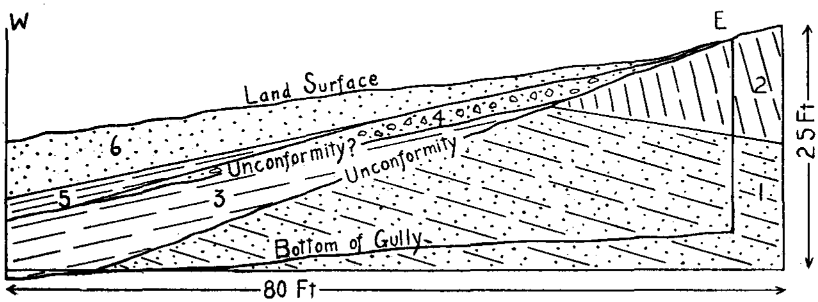


Fig. 22.—Section in Phinizy Gully, Columbia County. Numbers correspond to beds described in the text.

The earth.—An average sample, S-102, was collected from bed No. 3 of the preceding section. The earth exposed is thoroughly leached, and contains no sulphur or carbonates, but is considerably iron stained. This is the best bleaching earth of all samples tested, and at the same time its absorption of oil is not excessive, but filtration is extremely slow. The locality, however, is not favorable for working, as the bed is not known to exceed 6 feet in thickness and the overburden would be very heavy. The analysis is as follows:

Analysis of earth from Phinizy Gully

	S-102
Silica (SiO_2)	65.97
Alumina (Al_2O_3)	17.39
Ferric oxide (Fe_2O_3)	3.81
Ferrous oxide (FeO)	tr.
Magnesia (MgO)	2.38
Lime (CaO)	.31
Soda (Na_2O)	.36
Potash (K_2O)	.60
Ignition	8.44
Carbon dioxide (CO_2)	.00
Titanium dioxide (TiO_2)	1.14
Phosphorus pentoxide (P_2O_5)	.112
Sulphur (S)	.00
Manganous oxide (MnO)	.00
	100.512
Moisture	3.20

Tests.—All tests of sample S-102 were made on earth ground in a coffee-mill to pass through a 100 mesh screen. Tests of commercial earths are stated for comparison.

Bleach

Sample used	Original bleach		After two weeks in light		After two weeks in dark	
	Yellow	Red	Yellow	Red	Yellow	Red
Oil used	35	4.8	35	4.0	35	4.4
IXL	21	2.1	15	1.9	16	2.0
Pikes Peak	19	1.9	15	1.9	17	2.1
S-102	17	1.7	11	1.6	12	1.7

Absorption of oil

IXL	21.2%
Pikes Peak	38.4
S-102	44.4

Specific volume

	Specific gravity	Lb. per cu. ft.
IXL	1.05	66.0
Pikes Peak	.61	38.2
S-102	.59	36.6

Apparent acidity

	$\frac{N}{10}$ alkali per 100 gm. earth
IXL	19.6 c.c.
Pikes Peak	163.0
S-102	177.9

GROVETOWN

Fullers earth is exposed in the railroad cut at Grovetown station, extending 4 feet above track level, and overlain unconformably by red sand. The large cut south of the station shows 20 feet of cross-bedded red and white sand, overlying the fullers earth horizon. The altitude of the station is 495 feet, so the highest exposure of fullers earth is very nearly 500 feet.

Fullers earth was mined some years ago on the property formerly owned by W. M. Fiske, about a quarter of a mile east of the station. When visited the pit was filled with water, but according to the section given by Veatch and Stephenson,[1] it penetrated 10 to 12 feet of fullers earth which lay immediately above white clay of Lower Cretaceous age.

The earth was not a commercial success for bleaching, on account of the amount of pyrite it contains. Its bleaching power is not good, as shown by the tests on sample S-103. This sample was taken from sacks of ground earth remaining in the old storage shed.

The fullers earth bed is cut by a well at Usry Brothers' cotton gin, only a few feet from the railroad near the station. The section is as follows:

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[1] Geol. Survey of Ga. Bull. 26, p. 269, 1911.

Section in well at Usry Brothers' gin

	Feet
Jackson group	
Barnwell formation	
4. Loose gray sand	2
3. Argillaceous sand	2
Barnwell formation (Twiggs clay member)	
2. Fullers earth, very massive and thick-bedded, cut by widely spaced joints in various directions. Dark gray when fresh and wet, but becomes light in color on drying and weathering. Contains flakes of mica, small crystals of pyrite, and fragments of lignitic material	12
1. Argillaceous sand	1

Sample S-106 represents an average of bed No. 2 of the preceding section.

The earth.—All of the earth from the deposits in the immediate vicinity of Grovetown station contains a considerable precentage of carbonaceous matter and pyrite, except a little near the top of the beds, where it has been leached and oxidized by surface water.

Sample S-103 shows the highest apparent acidity of any sample tested (1156.1 c.c. of tenth-normal alkali per 100 gm. of earth). To determine how much of this apparent acidity is due to free acid and soluble salts, a portion of the earth was boiled with water and filtered. The filtrate gave an acid reaction, and qualitative tests showed a large amount of sulphates and a trace of chlorides. Potassium hydroxide gave a light colored precipitate, consisting principally of aluminum hydrate, and 841.9 c.c. of a tenth-normal was required for the titration of the solution from 100 gm. of the earth. The ferric and aluminum oxides (principally the latter) in the solution amounted to 2.30 per cent of the weight of the original earth.

Sample S-106 is a better bleaching agent than S-103, although it also contains over one per cent of pyrite. But S-106 was collected from an exposure in place in the well, where all soluble salts were leached out and the pyrite had not much time to oxidize before testing, while S-103 had remained in the storage shed for a number of years, giving the pyrite time to oxidize, and the soluble salts formed were not carried away.

Analysis of earth from well at Usry Brothers' gin

	S-106
Silica (SiO_2)	**73.85**
Alumina (Al_2O_3)	15.28
Ferric oxide (Fe_2O_3)	1.06
Ferrous oxide (FeO)	.59
Magnesia (MgO)	.06
Lime (CaO)	tr
Soda (Na_2O)	.25
Potash (K_2O)	.55
Ignition	7.15
Carbon dioxide (CO_2)	.00
Titanium dioxide (TiO_2)	.51
Phosphorus pentoxide (P_2O_5)	.25
Sulphur (S)	.74
Manganous oxide (MnO)	.00
	100.29
Moisture	5.40

Tests.—All tests of samples S-103 and S-106 were made on earth ground in a coffee-mill to pass through a 100 mesh screen. Sample S-103 had been previously ground, but had become reconsolidated by standing. Tests of commercial earths are stated for comparison.

Bleach

Sample used	Original bleach		After two weeks in light		After two weeks in dark	
	Yellow	Red	Yellow	Red	Yellow	Red
Oil used	35	4.8	35	4.0	35	4.4
IXL	21	2.1	15	1.9	16	2.0
Pikes Peak	19	1.9	15	1.9	17	2.1
S-103	27	2.7	21	2.5	22	2.6
S-106	19	1.9	13	1.7	14	1.8

Absorption of oil

IXL	21.2%
Pikes Peak	38.4
S-103	38.8
S-106	43.4

Specific volume

	Specific gravity	Lb. per cu. ft.
IXL	1.05	66.0
Pikes Peak	.61	38.2
S-103	.73	45.3
S-106	.55	34.2

Apparent acidity

	$\frac{N}{10}$ alkali per 100 gm. earth
IXL	19.6 c.c.
Pikes Peak	163.0*
S-103	1156.1*
S-106	291.5*

* All of these samples contain free acid and soluble salts from oxidation of pyrite.

FISKE ESTATE

(Map locality Co-2)

Several years ago Messrs. E. J. O'Connor and W. M. Fiske worked a deposit of fullers earth on a property belonging to the latter. The property, of about 100 acres, is situated north of the Georgia Railroad and a quarter of a mile southwest of Forrest. The material was not used commercially for bleaching oil, but was sold for pigment or ocher.

The pit is in a small valley, 20 or 30 feet below the railroad level and about 300 yards from the track. At this point is the best exposure on the property, showing the following section:

Section in O'Connor paint mine

	Feet
4. Red argillaceous sand	2
3. Gray plastic clay	0.5
2. Yellow ocher fullers earth	3
1. White and drab fullers earth	9

About a quarter of a mile west of the mine is an old pit which is said to have cut 12 feet of white earth, but it had caved in so that only 4 feet was visible. The earth on the dump is pale yellow to light gray, free from grit, and without taste of alum. Across the valley, a quarter of a mile north of this exposure, is another pit which penetrates white fullers earth. These pits are on hill slopes where the overburden is almost nothing and surface waters have had opportunity to leach the earth. It is probable that the earth with more overburden will be found to contain carbon and pyrite, as in the mine.

The earth.—The earth from the base of bed No. 1 in the mine is drab when dry and almost black when wet. This grades upward into earth which is chalk white when dry and light drab when wet. The difference in color is due to carbonaceous matter, which is present in considerable amount in the lower portion, but has been removed from the upper beds of oxidation. Besides the carbonaceous matter the lower beds contain over one per cent of pyrite in minute crystals. On exposure to the air the pyrite oxidizes rapidly, setting free acid which reacts with the other minerals present to form iron sulphate and alum. The gray earth in the face of the mine, and especially that in the drying sheds, where it has been exposed to the atmosphere for several years, tastes very strongly of acid and alum, while the yellow and white earths are tasteless.

Samples S-104, S-153, and S-105 represent, respectively, the fresh drab earth, leached white earth, and yellow ocher earth. The difference in composition of the white and drab earths is due to weathering, but the yellow earth was probably deposited with a higher percentage of iron.

Analyses of earth from O'Connor paint mine

Constituents	S-104	S-153	S-105
Silica (SiO_2)..........	68.69	72.42	64.25
Alumina (Al_2O_3).......	15.33	16.72	15.00
Ferric oxide (Fe_2O_3)..	2.20	1.21	11.38
Ferrous oxide (FeO)...	.76	.45	.10
Magnesia (MgO)......	.00	.00	.00
Lime (CaO)...........	.00	.00	.00
Soda (Na_2O)..........	.26	.28	.37
Potash (K_2O).........	.67	.58	.56
Ignition	9.94	7.77	7.09
Titanium dioxide (TiO_2)	.76	.68	.85
Sulphur (S)...........	.95	.03	.00
Manganous oxide (MnO)	.12	.03	.00
	99.68	100.17	99.60
Moisture	5.16	6.63	4.34

Tests.—In June, 1913, while the paint mine was being operated, tests were made on the yellow ocher earth by the Southern Cotton Oil Company, at Savannah.[1] In laboratory tests it gave a better bleach than Pikes Peak earth. In factory tests the bleach was about the same as with Pikes Peak earth, but the absorption with ordinary steaming of the filter press was 32.7 per cent and with longer steaming showed 25.9 per cent absorption, while the Pikes Peak earth under similar conditions had about 13 per cent absorption and English and Texas earths only about 10 per cent. On account of the high absorption no more of the earth was used for bleaching.

Tests of samples S-104 and S-105 were made in the Survey laboratory, using earth ground in a coffee-mill to pass through a 100 mesh screen. Tests of commercial earths are stated for comparison.

[1] Letter from J. H. Eve, Superintendent, to G. C. Hulbert, District Chemist.

Bleach

Sample used	Original bleach		After two weeks in light		After two weeks in dark	
	Yellow	Red	Yellow	Red	Yellow	Red
Oil used	35	4.8	35	4.0	35	4.4
IXL	21	2.1	15	1.9	16	2.0
Pikes Peak	19	1.9	15	1.9	17	2.1
S-104	27	2.7	22	2.6	23	2.7
S-105	18	1.8	11	1.6	12	1.7

Absorption of oil

IXL	21.2%
Pikes Peak	38.4
S-104	40.3
S-105	37.4

Specific volume

	Specific gravity	Lb. per cu. ft.
IXL	1.05	66.0
Pikes Peak	.61	38.2
S-104	.58	36.4
S-105	.72	44.7

Apparent acidity

	$\frac{N}{10}$ alkali per 100 gm. earth
IXL	19.6 c.c.
Pikes Peak	163.0*
S-104	553.3*
S-105	291.5†

* Contain free acid and soluble salts from oxidation of pyrite.

† End point could not be accurately determined on account of the color of the earth.

In the preceding tests the yellow ocher earth (S-105) does not show excessive absorption, but it filters slowly and it would probably be difficult to blow the oil from the press.

Conditions affecting mining.—The quantity of the yellow ocher material is too small for working as a fullers earth, because all that is in sight is a bed 3 feet thick over a limited area. The white, leached earth in the mine reaches a thickness of about 5 feet, and its thickness may be expected to vary, depending on topography and drainage. There is not here, as at Pikes Peak, a sharp line between the leached and unleached earth, but the one passes into the other by insensible gradations. The yellow and white varieties only are worthy of consideration as bleaching earths, while the gray, pyrite-bearing earth must be carefully avoided. Therefore, careful prospecting would be necessary to determine the amount of leached earth. Transportation would present no difficulty, as the deposits are within a quarter of a mile of the railroad, and the only earth worth mining would be that which has small overburden.

HARLEM

Beds of shaly, more or less indurated, and locally carbonaceous fullers earth outcrop at a number of places in the vicinity of Harlem, which is situated on the divide between Brier Creek and the direct tributaries of the Savannah, at the northern extremity of a tongue of Barnwell strata.

At the point where the August-Atlanta public road crosses under the Georgia Railroad, 2.5 miles west of Harlem station, is an exposure of the contact between the Lower Cretaceous and the Barnwell. This exposure is chiefly of scientific interest, as the fullers earth is indurated, like that at Hatcher's Mill and Mount Enon. The fullers earth reaches a maximum thickness of 10 to 15 feet. It rests unconformably upon kaolin of Lower Cretaceous age, and is unconformably overlain by red sand of the Barnwell formation, while 10 feet above the fullers earth another unconformity within the Barnwell was recognized.

At Phillip's Falls, 1½ miles south of Harlem, is an exposure of

24 feet of fullers earth beds. The earth is thin-bedded, hard and shaly and contains sand along the partings. The lower part is dark gray, containing many fragments and lenses of carbonized wood, while the upper portion is more or less completely leached and oxidized, and is light drab in color, with some beds stained yellow by limonite.

At "Chalk Spring," 1½ miles southwest of Harlem, is an exposure of 13 feet of thin-bedded, shaly, sandy fullers earth. This earth is similar to that at Phillip's Falls, except that oxidation has proceeded farther, and the earth exposed contains no carbonaceous matter.

FULLERS EARTH OF THE ALUM BLUFF FORMATION

GEOLOGY OF THE ALUM BLUFF FORMATION[1]

Areal distribution.—The Alum Bluff formation outcrops throughout a large area in south-central Georgia. The limit of the deposits as they exist today is approximately marked on the north by Waynesboro, Tennille, and Vienna; on the west by the escarpment along the east side of the Flint River valley, and on the east by a line extending from Savannah River near the mouth of Buck Creek through Sylvania, Reidsville, and Blackshear to the western edge of Okefenoke Swamp.

The formation of the upland areas between the valleys of the larger streams was called "Altamaha grit" by Dall.[2] Veatch and Stephenson[3] in 1911 used the name "Altamaha (Lafayette?) formation" which they questionably referred to the Pliocene, although they recognized that the formation included strata ranging in age from Oligocene to Pleistocene. In the later report by the same authors[4] these areas are mapped as "Undifferentiated Oligocene to Pleistocene inclusive," and they make the following statement:

"The investigations of recent years have led to the conclusion that the bulk of the deposits included by Harper, Veatch, and Stephen-

[1] Largely abstracted from report on Underground Waters of the Coastal Plain of Georgia by L. W. Stephenson and J. O. Veatch, U. S. Geol. Survey Water-Supply Paper 341, pp. 89-94, 1915.
[2] Dall, W. H., U. S. Geol. Survey Bull. 84, p. 82, 1892.
[3] Report on the Geology of the Coastal Plain of Georgia: Geol. Survey of Ga. Bull. 26, 1911.
[4] U. S. Geol. Survey Water-Supply Paper 341, p. 91, 1915.

son in the Altamaha formation are of Oligocene age and are probably contemporaneous with a part of the Alum Bluff formation."

The inland boundary of the Alum Bluff formation has not been accurately determined, nor has the seaward boundary between it and the Miocene been definitely traced. The inaccuracy of the mapping is due to the lithologic similarity of several other formations, and to the mantling of the surface by residual materials and Pleistocene sand deposits.

Stratigraphic relations.—The Alum Bluff formation is named from the type locality at Alum Bluff on Apalachicola River, Liberty County, Florida. It is defined in Florida as including the beds between either the Chattahoochee or the Hawthorne formation and the overlying Miocene marls and limestones.[1] At the type locality the formation consists of the Chipola marl member, overlain by the Oak Grove sand member, but this division can not be traced into Georgia.

The Alum Bluff formation conformably overlies the Chattahoochee formation, and the boundary between the two is in places drawn arbitrarily, for there is neither abrupt lithologic nor faunal change from the one to the other. Locally there are apparent unconformities due to solution and weathering of the Chattahoochee limestone near the contact. On Savannah and Altamaha rivers the Alum Bluff formation is separated from the overlying Miocene by an erosion unconformity, probably of minor importance. Throughout the greater part of the area underlain by the Alum Bluff formation its weathered products, in places perhaps overlain by more recent deposits, are believed to form the surface material; but in southeastern Georgia it is overlain by lithologically similar undifferentiated deposits, ranging in age from Miocene to Pleistocene. In narrow areas along the larger streams the Alum Bluff formation is overlain by thin terrace deposits of Pleistocene age.

Local unconformities within the Alum Bluff formation are of rather common occurrence, especially in the coarse sands and grits

[1] Matson, G. C. and Clapp, F. G., A preliminary report on the geology of Florida, Fla. Geol. Survey 2d. Ann. Rept. p. 91, 1909.

of the upper portion. At the fullers earth mine of the Lester Clay Company, near Attapulgus, there is one certain and another probable unconformity above the fullers earth bed, and in the Alum Bluff section an apparent unconformity is mentioned 26 to 28 feet above river level.[1] Local unconformities have been noted at a number of other localities in Florida. These unconformities were formerly believed to separate the Alum Bluff beds from the Altamaha or Lafayette, but the evidence at present available indicates that they occur within the Alum Bluff, and are of slight time significance.

Lithologic characters.—The Alum Bluff formation consists entirely of beds of shallow water origin, but it presents a number of different lithologic phases.

The beds near the base of the formation are calcareous and contain marine fossils, the Chipola marl forming the basal member in Florida. In the southern Georgia counties a part of the fullers earth and underlying beds are calcareous, and calcareous beds are reported as far north as House Creek Bluff, Wilcox County, on Ocmulgee River and Hudson Landing, Screven County, on Savannah River.

The fullers earth beds seem to occupy a position in the lower part of the formation, but above the marl member, where that is present. The fullers earth is associated with coarse, light greenish-gray to white argillaceous sands, often showing crossbedding, and more or less greenish plastic clay, known locally as "pipe clay." On Allapaha and Suwanee rivers are phosphatic sands which are believed to lie directly upon the Chattahoochee formation. The light colored argillaceous sand of the fullers earth horizon is frequently indurated, forming a soft sandstone, which in Florida serves as a guide rock in locating fullers earth deposits. Sellards and Gunter[2] say of it: "A guide rock associated with and indicating the presence of fullers earth is recognized and described. This guide rock consists of a greenish to gray or yellowish sand or sandstone. This sandstone is, in Gadsden County, a part of the fullers earth series and its presence in this

[1] Sellards, E. H. and Gunter, Herman, The fullers earth deposits of Gadsden County, Florida: Fla. Geol. Survey, 2d. Ann. Rept. pp. 275, 276, 1909.
[2] Fla. Geol. Survey 2d. Ann. Rept., p. 255, 1909.

section indicates the place of the fullers earth. The rock is in places indurated and resistant to decay. It thus often stands out and is exposed where the fullers earth itself is entirely covered." Similar indurated sand beds are associated with the fullers earth beds in the southern tier of Georgia counties.

The upper portion of the Alum Bluff formation is the so-called Altamaha grit, an extensive deposit of irregularly bedded sands, clays and gravels, locally indurated. The indurated sands and the conglomerates contain a peculiar greenish or greenish-gray disseminated clay and are described as "gray or greenish aluminous grits." The pebbles are predominately subangular, many of them lath shaped, and the sands are invariably harsh or in sharp angular grains. Feldspar is abundant, and phases may be described as "feldspathic grits." The materials are very coarse grained, even at points 100 miles from their northern margin. The beds that have been locally indurated to sandstones, conglomerates, and claystones do not differ essentially in composition from the non-indurated materials. A negative peculiarity is the total absence of calcareous and fossiliferous materials.

The weathered residual loams from the grit beds are mottled and splotched in red, yellow, purple, and gray tints, due to unequal weathering, oxidation, and distribution of ferruginous materials. Mottled sandy clays are produced by weathering of other Coastal Plain formations, and are even found in the Piedmont area, but the Alum Bluff materials are characterized by purple tones and especially brilliant reds. Iron oxide nodules are in many places abundant in the soil, forming "pebble" or "pimple" lands, but these also occur locally in soils derived from the older Coastal Plain formations.

The clays of the upper beds of the Alum Bluff formation are fairly uniform in texture and composition throughout the area of their occurrence. They are greenish or drab, very fine grained and plastic, are everywhere more or less sandy, and have rather low specific gravity. They occur as irregular pockets or thin lenticular beds, nowhere persisting over any large area. In the southwestern part of the State, near Whigham and Cairo, in Grady County, the sands are interlaminated with layers of light-colored plastic clay approaching the composition of sedimentary kaolin.

The fullers earth is a gray, drab or greenish, laminated clay of very low specific gravity. It occurs as local lenses or discontinuous beds, all of which seem to be at about the same horizon within the formation. The maximum thickness of fullers earth observed in a single section in Florida is 15 feet,[1] but north of the Georgia line the beds are thinner and less continuous than in Florida, and none of the deposits are known to reach so great a thickness. The earth at Quincy, Florida, where protected by 12 or 14 feet of overburden, becomes calcareous and contains residual masses of argillaceous limestone. This fact, and the physical structure of the earth, indicates that the earth of bleaching quality may have been produced by leaching of an originally calcareous clay.

The fullers earth deposits are generally overlain by a variety of clay locally known as "short bread" or "false fullers earth." This is non-plastic, and resembles the fullers earth in color and physical properties, but it is not laminated and crumbles into irregular grains on drying. The "short bread" usually grades up into greenish, very plastic "pipe clay." It is probable that these varieties of clay represent stages in the weathering of the fullers earth.

The Alum Bluff earth differs somewhat in character from that of the Barnwell formation in central Georgia. It appears finer in grain and is more unctuous to the touch when wet. When dry it is harder, so that granular grades stand up well when used for bleaching mineral oils, but when wet is less resistant to weathering and erosion, and is therefore rarely seen in natural outcrops. The Alum Bluff earth is prevailingly more thinly bedded, and the deposits do not reach so great a thickness. It is lighter and less variable in color, and although corresponding calcareous phases are found under heavy overburden in both formations, pyrite and carbonaceous matter do not occur in appreciable amounts in any of the Alum Bluff earth.

The fullers earth phase of the formation has in places been silici-

[1] Fla. Geol. Survey 2d. Ann. Rept. p. 94, 1909.

fied to such an extent that it has been converted into a very hard claystone, and has lost its characteristic properties. Such clay is especially well exhibited along Withlacoochee River south of Ousley. By infiltration of opaline silica the earth has become dense, compact, vitreous, and agatized. The clay is about three in the scale of hardness and it requires a strong blow of the hammer to break it. Fissures and cavities are filled by opaline silica.

Other clay beds, argillaceous sands, and gravels have likewise been locally silicified, forming claystones, quartzites, and conglomerates. In fact, alteration by silica carried in solution in circulating waters has taken place in some degree throughout the greater part of the formation.

Strike, dip, and thickness.—The Alum Bluff formation has a low southward and southeastward dip, certainly much less than that of the underlying Eocene formations. On Savannah River the dip does not exceed 4 or 5 feet per mile, and near the Florida line the beds must be almost horizontal, for the streams have cut through them, exposing the underlying formations. There is evidence that a broad anticline exists in the southern part of the State, and some indication of minor folding has been found in Florida.

The maximum thickness of the Alum Bluff formation in Georgia is estimated to be 150 to 200 feet. The full thickness is not seen at any natural exposure, and the estimate is based chiefly on well records. Records at Lumber City, Telfair County, indicate a thickness of over 200 feet. Some of the natural exposures on Savannah River and in Decatur County reveal a thickness of 70 or 80 feet.

Physiographic expression.—The area in which the lower, fullers earth-bearing beds of the Alum Bluff formation outcrop is relatively small, although in the southern part of the State west of Lowndes County a relatively broken and hilly topography has been produced by its weathering. The higher divides and uplands underlain by the upper grit beds of the formation present a peculiar topography. Part of this area constitutes the Altamaha upland, one of the major topographic divisions of the Coastal Plain of Georgia, an area of low hills with gentle slopes and softened outlines, of shallow saucer-shaped valleys, many of which are not more than 40 or 50 feet deep, of sluggish clear-water streams bordered by swamps and sand hammocks, and of "bays" and cypress ponds. Altamaha, Oconee, and Ocmulgee rivers have cut deep valleys, and the precipitous bluffs along their courses form an exception to the general type of topography of the area. The low hills and gentle slopes of the main area present a notable contrast to the broken and hilly areas near the Fall Line, to the lime-sink topography to the west, and to the flat sand-coated plains to the southeast.

Paleontological characters.—As a whole, the Alum Bluff formation is poorly fossiliferous. Fossils are entirely lacking in the upper beds of grit, and the sands and clays generally contain only poorly preserved casts and impressions. Vaughan obtained a number of species from "Gastropod Gully" and other localities near Bainbridge,[1] and a well-preserved oyster, *Ostrea mauricensis,* is found at a number of localities. The formation seems to mark the disappearance of the species of Orbitoides which are so common in the Vicksburg and Chattahoochee formations. Among the characteristic fossils are *Turritella alcida* Dall, Carolia, and *Pecten madisonius* var. *sayanus* Dall.

DESCRIPTIONS OF INDIVIDUAL DEPOSITS

FULLERS EARTH MINES OF GADSDEN COUNTY, FLORIDA

Fullers earth in America was first discovered at Quincy, Florida. At present two of the largest fullers earth mines and grinding plants in the country are operated by the Floridin Company at Jamieson, on the main line of the Georgia, Florida & Alabama Railway, 2 miles south of the Georgia line and at Quincy, 6 miles from the Georgia line. As the deposits at these localities are practically identical with the Georgia deposits in geologic relations and quality of earth, brief descriptions are here included. The writer is indebted to W. L. MacGowan, Vice-President and General Manager of the company, for permission to visit the mines and plants and for other assistance.

[1] Geol. Survey of Ga. Bull. 26, p. 347, 1911.

Jamieson mine.—East of the Georgia, Florida & Alabama Railway at Jamieson a bed of fullers earth with an average thickness of 13 feet underlies a flat area of many acres, the average overburden being 17 feet. The section in the workings in September, 1915, was as follows:

Section in Jamieson mine of the Floridin Company

	Feet
Age?	
5. Coarse, unconsolidated sand, light-colored at top, at base back and carbonaceous. Seems to be a swamp deposit of comparatively recent age............	8
(Unconformity)	
Oligocene	
Alum Bluff formation	
4. Very plastic yellow clay........................	1
3. Crumbly, non-plastic greenish clay (short bread) at base, grading up into plastic pipe clay. The pipe clay and short bread are similar in structure, and the difference in plasticity may be due to weathering	8
2. Fullers earth. The earth of exposure is firm and not very distinctly laminated and is blue instead of greenish when wet, due probably to a minute amount of carbonaceous matter. It dries almost white	10
1. Greenish argillaceous sand forming floor of pit.....	?

Quincy Mines.—There are several mines on the property of the Floridin Company, as pits have been abandoned when the overburden became too heavy or the calcium carbonate content of the earth too high. The following is the section in the Magnolia Grove mine, a mile north of Quincy, where work was being done in November, 1914:

Section in Magnolia Grove mine of the Floridin Company

	Feet
Oligocene	
Alum Bluff formation	
6. Yellow argillaceous sand........................	15
5. Short bread clay...............................	1-3
4. Greenish laminated fullers earth..................	6
3. Greenish sand parting..........................	0.5-2
2. Greenish laminated fullers earth..................	6
1. Greenish argillaceous sand forming floor of pit....	?

At this exposure the pipe clay, which usually overlies the fullers earth, is absent.

The earth.—The earth from the two Floridin mines is practically identical in properties. Samples for testing were taken only from the Jamieson mine. S-125 is the commercial product, 15 to 30 mesh, and S-124 is an average sample of the greenish earth taken near the edge of the deposit. As shown by the analyses, the commercial earth contains a small percentage of lime, but all had been leached from the bed at the point where the other sample was collected.

Analyses of earth from the Jamieson mine

	S-124	S-125
Silica (SiO_2)	66.06	58.10
Alumina (Al_2O_3)	15.46	15.43
Ferric oxide (Fe_2O_3)	3.45	4.95
Ferrous oxide (FeO)	.31	.30
Magnesia (MgO)	.09	2.44
Lime (CaO)	1.84	1.75
Soda (Na_2O)	.52	.27
Potash (K_2O)	1.01	.66
Ignition (less CO_2)	8.70	14.04
Carbon dioxide (CO_2)	.00	.84
Titanium dioxide (TiO_2)	.19	.72
Phosphorus pentoxide (P_2O_5)	1.44	.724
Sulphur (S)	.38	.15
Manganous oxide (MnO)	.00	.00
Total	99.45	100.374
Moisture	7.13	4.59

The above analyses show that there are considerable variations between the average commercial product and samples selected from limited portions of the bed, and the samples also show variations in physical properties.

These samples, like all of the South Georgia and Florida earths, are almost white when dry, and although firm and of fine texture, they are extremely light and porous, for which reason the absorption of oil is very high. S-124 is the lightest of all samples tested.

It has been found in bleaching cotton oil that the very porous earths with extremely high oil absorption are likely to take fire by spontaneous combustion when the filter presses are blown with air. According to reports, only the South Georgia and Florida earths give trouble in this manner, although some of the central Georgia earths require careful handling and start to burn soon after removal from the press. On this account, as well as because of the high absorption, very little of the Alum Bluff earth has been used in bleaching vegetable or animal oils. Practically all is used in refining petroleum, in which process there is no danger of spontaneous combustion, and the absorption is not of great importance, since the oil held in the earth is recovered.

Tests.—Although little of the Floridin earth is used for bleaching vegetable oils, tests were made on cotton oil. The market standards for fullers earth used in bleaching petroleum have been fixed by years of practice, but satisfactory laboratory tests on a small scale are not easy to make, while the tests on cotton oil serve as a basis for comparing the properties of the earth with those of earths from other localities. Sample S-124 was ground in a coffee-mill and bolted into four grades for testing. Sample S-125, which was already sized 15 to 30 mesh, was reground in a coffee-mill, and tests were made on the product which passed through 100 mesh. Tests of other commercial earths are stated for comparison.

Bleach

Sample used	Original bleach		After two weeks in light		After two weeks in dark	
	Yellow	Red	Yellow	Red	Yellow	Red
Oil used	35	4.8	35	4.0	35	4.4
IXL	21	2.1	15	1.9	16	2.0
Pikes Peak	19	1.9	15	1.9	17	2.1
S-124 (20-40 mesh)	25	2.5	....	....	....	....
S-124 (40-60 mesh)	22	2.2	....	....	....	....
S-124 (60-100 mesh)	21	2.1	....	....	....	....
S-124 (through 100 mesh)	18	1.8	....	....	....	....
S-125 (through 100 mesh)	20	2.0	15	1.9	16	2.0

Absorption of oil

IXL	21.2%
Pikes Peak	38.4
S-124 (20-40 mesh)	42.6
S-124 (40-60 mesh)	44.7
S-124 (60-100 mesh)	45.7
S-124 (Through 100 mesh)	47.6
S-125 (Through 100 mesh)	44.6

Specific volume

	Specific gravity	Lb. per cu. ft.
IXL	1.05	66.0
Pikes Peak	.61	38.2
S-124 (20-40 mesh)	.51	31.7
S-124 (40-60 mesh)	.50	31.0
S-124 (60-100 mesh)	.50	31.4
S-124 (Through 100 mesh)	.44	27.9
S-125 (Through 100 mesh)	.55	34.5

Apparent acidity

	$\frac{N}{10}$ alkali per 100 gm. earth
IXL	19.6 c.c.
Pikes Peak	163.0
S-124	9.9
S-125	24.7

Mining methods and preparations for market.—At both the Floridin mines the overburden is removed by steam "dredges" with orange-peel buckets. At Jamieson the earth is worked with a steam shovel, but at Quincy the two thinner beds of earth must be removed separately and the work is done by manual labor.

The earth is broken to about one-inch size and passed through revolving cylindrical driers heated by crude petroleum. The cylinders are 30 to 40 feet long and 5 to 6 feet in diameter, and the clay requires 15 to 20 minutes to pass through the cylinder. The earth is ground in Abbé mills and bolted into various grades for shipment. Some standard sizes are 15-30, 30-60, 20-60, 60-100 mesh, and through 100 mesh. The coarser grades bring the higher prices, because, on account of the uses made of the earth, there is some difficulty in disposing of the large quantity of fine material which is necessarily produced by any method of grinding.

The new plant of the Floridin Company at Quincy, completed in 1915, is the largest and best equipped in the United States.

DECATUR COUNTY

The area of Decatur County southeast of Flint River is almost entirely underlain by the Alum Bluff formation. There are thin beds of fullers earth exposed along the escarpment southeast of Flint River, but the deposits of possible commercial importance seem to be confined to the valleys of Attapulgus and Little Attapulgus creeks, in the extreme southeastern corner of the county. The upland areas are covered by red and mottled argillaceous sands of upper Alum Bluff age or later.

LESTER CLAY COMPANY

(Map locality D-1)

The only operating fullers earth mine in southern Georgia is that of the Lester Clay Company of Jacksonville, Florida. The mine is located on the west side of Little Attapulgus Creek, a quarter of a mile southwest of Attapulgus station. The company owns or controls about 800 acres west of the Georgia, Florida & Alabama Railway and 300 acres east of the railway.

Geologic relations.—The following section was measured in the workings in September, 1915. The relations of the beds are shown in the accompanying sketch (fig. 23).

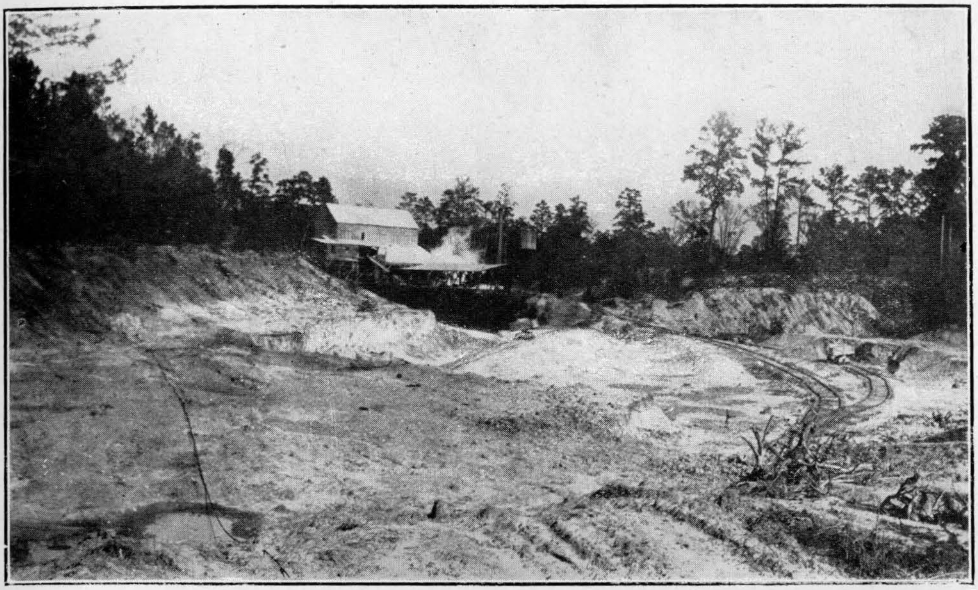
Section in Lester Clay Company mine

Oligocene

Alum Bluff formation

	Feet
6. At base is sandy pipe clay and light colored argillaceous sand, locally indurated to "sand rock," which is hard and sometimes requires dynamite for removal, but disintegrates quickly on exposure to the atmosphere. The upper portion is weathered material, consisting of mottled argillaceous sand. Maximum thickness..........................	25

(Unconformity)



A. FULLERS EARTH MINE AND MILL OF THE LESTER CLAY CO., ATTAPULGUS, DECATUR COUNTY.

B. WORKING FACE IN THE FULLERS EARTH MINE OF THE LESTER CLAY CO., ATTAPULGUS, DECATUR COUNTY.

5. Slightly laminated, greenish, slightly plastic clay. It is said to have the properties of fullers earth, but on account of its plasticity it balls up in the drier and cannot be used. The bed pinches out or grades into the plastic pipe clay which overlies the fullers earth where the overburden is light......	3
4. Light greenish clayey sand, overlying the fullers earth with a slightly irregular contact...........	2
(Unconformity)	
3. Unlaminated, crumbly fullers earth } 2. Laminated fullers earth }	11
1. White or pale green indurated argillaceous sand, or sand rock, forming the floor of the pit.........	?

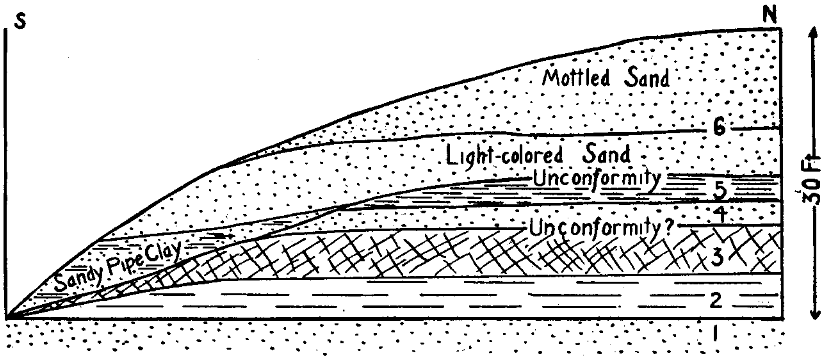


Fig. 23.—Working face in the fullers earth mine of the Lester Clay Company, Decatur County. Numbers correspond to beds described in the text.

The floor of the mine is 15 feet above water level in Little Attapulgus Creek, and the hill west of the mine rises about 90 feet above creek level. The mine is situated at the east end of a ridge. The working face is over 1000 feet long, and at one point the overburden reached 30 feet, but the later work has been continued around the slope to the south, where the overburden is less.

There are no natural outcrops of fullers earth on the property, but pits have been dug north of the mine, showing that the bed extends for a considerable distance in that direction, and borings have shown that fullers earth underlies the hills east of the railroad, but has there heavy overburden. Vaughan[1] states that in preliminary

[1] Vaughan, T. Wayland, Fullers earth deposits of Georgia and Florida: U. S. Geol. Survey Bull. 213, p. 392, 1903.

exploration work Mr. J. D. Lester sunk 10 pits, all of which struck fullers earth varying from 2½ to 9 feet in thickness.

The earth.—The lower portion of the fullers earth bed in the mine is distinctly laminated, but the upper portion is massive and crumbly, resembling the short bread clay of the Florida mines. In Florida the short bread is removed with the overburden, but at this locality the entire thickness is worked as fullers earth. The bed is thin around the edge of the hill, where the weathered material is plastic and resembles common pipe clay, but both crumbly and laminated beds increase in thickness on working back until the maximum of 11 feet is reached. The earth is minutely joined, and near the top and edges of the deposit it is stained along joint planes by iron, manganese and carbonaceous matter, but as the overburden increases the staining becomes less. Where the overburden is heavy the lower part of the bed contains lens-like masses of hard argillaceous limestone, and shell-like fissure fillings of pure, crystalline calcite about an eighth of an inch thick. This calcareous material is avoided as much as possible in mining.

Sample S-127 represents an average of the working face in the mine in November, 1914, including both laminated and crumbly varieties. Besides the analysis of this sample, two analyses from Vaughan's report and one from Veatch's report on the clay deposits of Georgia are included in the table below. All have been recalculated to a dry state.

Analyses of earth from the Lester Clay Company property

Constituents	S-127	1[1]	2[1]	3[2]
Silica (SiO_2)	70.85	61.70	62.95	59.44
Alumina (Al_2O_3)	13.25	13.70	20.15	14.32
Ferric oxide (Fe_2O_3)	2.90	2.65	2.06	4.49
Ferrous oxide (FeO)	.15	....	....	....
Magnesia (MgO)	.06	8.97	1.17	6.44
Lime (CaO)	1.29	1.10	2.84	.99
Soda (Na_2O)	.36	....	....	.20
Potash (K_2O)	1.41	....	....	.54
Ignition	8.08	11.60	10.33	12.00
Carbon dioxide (CO_2)	.00	....	....	....
Titanium dioxide (TiO_2)	.29	....	....	1.11
Phosphorous pentoxide (P_2O_5)	.56	....	....	....
Sulphur (S)	.25	....	....	....
Manganous oxide (MnO)	....	....	....	.12
	99.45	99.72	99.50	99.65
Moisture	6.27	9.40	9.00	8.97

[1] H. Ries, analyst, U. S. Geol. Survey Bull. 213, p. 393, 1903.
[2] Geol. Survey of Ga. Bull. 18, p. 317, 1909.

Rational Analysis of No. 3

Feldspar	1.73
Quartz	3.63
Mica	4.69
Ferric oxide	4.02
Clay substance	85.93
	100.00

Tests.—Sample S-127 was ground in a coffee-mill and bolted into four grades, each of which was tested on cotton oil. Tests on commercial earths are stated for comparison.

Bleach

Sample used	Yellow	Red
Oil used	35	4.8
IXL	21	2.1
Pikes Peak	19	1.9

S-127 (20-40 mesh)	31	3.1
S-127 (40-60 mesh)	27	2.7
S-127 (60-100 mesh)	23	2.3
S-127 (Through 100 mesh)	20	2.0

Absorption of oil

IXL	21.2%
Pikes Peak	38.4
S-127 (20-40 mesh)	36.1
S-127 (40-60 mesh)	36.1
S-127 (60-100 mesh)	38.2
S-127 (Through 100 mesh)	40.3

Specific volume

	Specific gravity	Lb. per cu. ft.
IXL	1.05	66.0
Pikes Peak	.61	38.2
S-127 (20-40 mesh)	.60	37.4
S-127 (40-60 mesh)	.59	36.6
S-127 (60-100 mesh)	.57	35.8
S-127 (Through 100 mesh)	.54	33.6

Apparent acidity

	$\frac{N}{10}$ alkali per 100 gm. earth
IXL	19.6 c.c.
Pikes Peak	163.0
S-127	0.0

Sample S-127 gives a distinctly alkaline reaction with phenolphthalein, and is the only sample tested which gives such a reaction, although some of the calcareous earths are neutral. A qualitative test by Everhart showed that the alkaline reaction is due to the presence of soluble potassium phosphate.

Conditions affecting mining and mining methods.—The fullers earth deposit is situated above the drainage level and within a quarter of a mile of the railroad, with a spur track extending to the plant. The only mining problem is the handling of overburden, and by working around the slope this will not become excessive for a long time. It is probable that the earth under overburden more than 20 or 30 feet will become too calcareous to be of much value. The overburden is handled by steam drags, and the earth is carried to the plant in tram cars drawn by a small locomotive.

Preparation for the market.—The earth is dried in revolving cylindrical driers heated by crude oil blast. It is ground in Abbe mills, of which there are eight, two to each set of Wolf bolters. Silk bolting cloth of 16, 30, 60 and 100 mesh is used in grading the earth.

The principal use is in refining petroleum.

GIBSON PROPERTY

(Map locality D-2)

William Gibson and relatives own land on either side of the Georgia, Florida & Alabama Railway about a mile south of Attapulgus station. The railroad cut south of bridge A 77 shows only sand, but a two-foot boring with a post-hole auger beside the track reached good fullers earth. Sample S-131 was taken from this hole. Fullers earth was also reached by boring in the cut between bridges A 77 and B 77. The thickness of the fullers earth bed is not known, but it apparently underlies a considerable area, with overburden not much over 10 feet.

The earth.—Sample S-131 is nearly white, resembling the earth from the Lester and Floridin mines in color and texture. Tests showed it to be a powerful bleaching earth, but it is very light and has extremely high oil absorption. The analysis is as follows:

Analysis of earth from Gibson property

	S-131
Silica (SiO_2)	61.93
Alumina (Al_2O_3)	16.61
Ferric oxide (Fe_2O_3)	5.01
Ferrous oxide (FeO)	tr
Magnesia (MgO)	1.03
Lime (CaO)	.56
Soda (Na_2O)	.43
Potash (K_2O)	.78
Ignition (less CO_2)	12.11
Carbon dioxide (CO_2)	.32
Titanium dioxide (TiO_2)	.82
Phosphorus pentoxide (P_2O_5)	.360

Sulphur (S)	.00
Manganous oxide (MnO)	.00
	99.960
Moisture	5.98

Tests.—Sample S-131 was tested for bleaching power on cotton oil. All tests were made with earth ground in a coffee-mill to pass through a 100 mesh screen. Tests of commercial earths are stated for comparison.

Bleach

Sample used	Original bleach		After two weeks in light		After two weeks in dark	
	Yellow	Red	Yellow	Red	Yellow	Red
Oil used	35	4.8	35	4.0	35	4.4
IXL	21	2.1	15	1.9	16	2.0
Pikes Peak	19	1.9	15	1.9	17	2.1
S-131	19	1.9	12	1.7	13	1.8

Absorption of oil

IXL	21.2%
Pikes Peak	38.4
S-131	52.8

Specific volume

	Specific gravity	Lb. per cu. ft.
IXL	1.05	66.0
Pikes Peak	.61	38.2
S-131	.48	29.8

Apparent acidity

	$\frac{N}{10}$ alkali per 100 gm. earth
IXL	19.6 c.c.
Pikes Peak	163.0
S-131	27.2

SMITH PROPERTY

(Map locality D-3)

Fullers earth is exposed along the public road a quarter of a mile west of Laingkat, about 2 miles south of Attapulgus, on the property of W. E. Smith. The section along the road is as follows:

Section along public road west of Laingkat

Oligocene
Alum Bluff formation

	Feet
5. Yellow, red, and mottled argillaceous sand	12
4. Blue argillaceous sand and pipe clay	4
3. Crumbly, non-plastic clay or short bread	2
2. Laminated fullers earth. Grades up into short bread. Base of the bed is not exposed, so it may be thicker than indicated	5
1. Concealed to water level, Little Attapulgus Creek	20

The strata dip one degree west, one of the few indications of local folding found in South Georgia. Mr. Smith states that by boring he found the fullers earth bed to be 8 feet thick. The area underlain by fullers earth is probably large, but south of the public road the overburden will become heavy, probably 30 or 40 feet.

The earth.—Sample S-132 represents an average of the exposure along the road, bed No. 2 of the preceding section. The earth resembles that of the mines in the vicinity, but it a little denser, with less bleaching power and lower absorption of oil. As the samples was taken from a superficial exposure, these variations in the properties may be due to weathering. The analysis is as follows:

Analysis of earth from Smith property

	S-132
Silica (SiO_2)	60.97
Alumina (Al_2O_3)	17.30
Ferric oxide (Fe_2O_3)	3.63
Ferrous oxide (FeO)	.32
Magnesia (MgO)	4.51
Lime (CaO)	1.54
Soda (Na_2O)	.28
Potash (K_2O)	.55
Ignition	9.50

Carbon dioxide (CO_2)	.00
Titanium dioxide (TiO_2)	.49
Phosphorus pentoxide (P_2O_5)	1.42
Sulphur (S)	.04
	100.55
Moisture	8.52

Tests.—Sample S-132 was tested for bleaching power on cotton oil. All tests were made with earth ground in a coffee-mill to pass through a 100 mesh screen. Tests of commercial earths are stated for comparison.

Bleach

Sample used	Original bleach		After two weeks in light		After two weeks in dark	
	Yellow	Red	Yellow	Red	Yellow	Red
Oil used	35	4.8	35	4.0	35	4.4
IXL	21	2.1	15	1.9	16	2.0
Pikes Peak	19	1.9	15	1.9	17	2.1
S-132	21	2.1	15	1.9	15	2.0

Absorption of oil

IXL	21.2%
Pikes Peak	38.4
S-132	45.2

Specific volume

	Specific gravity	Lb. per cu. ft.
IXL	1.05	66.0
Pikes Peak	.61	38.2
S-132	.58	35.9

Apparent acidity

	$\frac{N}{10}$ alkali per 100 gm. earth
IXL	19.6 c.c.
Pikes Peak	163.0
S-132	0.0

AMSTERDAM AND WATAGA

On the Attapulgus-Amsterdam road 2 miles southeast of Attapulgus is a small exposure of fullers earth. The section exposed is as follows:

Section on Attapulgus-Amsterdam road, 2 miles southeast of Attapulgus

	Feet
Oligocene	
Alum Bluff formation	
4. Yellow and red sand capping hill, probably reaches a thickness of	100
3. Greenish, plastic pipe clay	10
2. Fullers earth, laminated, iron stained, and slightly indurated, grading up into pipe clay	1
1. Indurated greenish argillaceous sand	?

The railroad fill on the Atlantic Coast Line 1½ miles northwest of Amsterdam shows fragments of laminated fullers earth. The material for the fill was dug up from the swamp by the roadside. It is possible that there is a considerable amount of fullers earth underlying the swampy bottom of Attapulgus Creek between Amsterdam and Wataga, but if so, it is below water level, can only be located by boring, and would be difficult to work.

GRADY COUNTY

In Grady County the limestone of the Chattahoochee formation is exposed along Ochlockonee River in the southern part of the county and in Big Slough and several limesinks north of Whigham. The Alum Bluff formation outcrops over all the remainder of the county, but the fullers earth beds near the base of that formation seem to be thin and discontinuous, and natural exposures are rare.

WHIGHAM

The only properties where prospecting for fullers earth has been done are those belonging to E. L. Lester and Mr. Chapman, situated in the valley of Tired Creek north of the Atlantic Coast Line, 2 miles east of Whigham, and the Roddenberry place, between Cairo and Whigham.

The Chapman property was formerly owned by R. A. Connell. Vaughan[1] states that a pit a mile south of the Connell residence showed 6½ feet of fullers earth with 19½ feet of overburden, and other pits on Sears and Wolffs creeks showed several feet of fullers earth with 5 to 8 feet of overburden. At the time of the writer's visit all of the pits had caved, and no earth was in sight. A sample sent in by Connell was tested by Dr. Everhart, who states that it bleached cotton oil fairly well.

On the Lester property bluish, sandy clay is exposed along the lower courses of branches of Tired Creek. Fullers earth, if present, should be a short distance below this clay, but it would be below drainage level and working would present great difficulties.

In a railroad cut 1¼ miles east of Whigham the fullers earth horizon is exposed, consisting of interbedded fullers earth and greenish sand in layers an inch or less in thickness.

T. M. Parker, of Moultrie, collected samples of fullers earth from the Roddenberry place. He states that two strata of fullers earth of varying thickness were found. The maximum thickness of the upper is 4 feet and of the lower 9 feet, and they are separated by 3 feet of sand rock. A sample of the earth was sent to the Proctor & Gamble Company, but it was rejected because it produced spontaneous combustion in the filter press.

THOMAS COUNTY

The Alum Bluff formation covers all of Thomas County except narrow strips along the streams in the southern part, where the Chattahoochee limestone is exposed, but most of the area consists of the upper sandy beds of the formation and weathered residual materials.

A well on the property of the Flowers Ice Cream Company, a quarter of a mile east of Thomasville station, cut a bed of fullers earth, apparently of good quality, at a depth of about 100 feet. The

[1] U. S. Geol. Survey Bull. 213, p. 393, 1903.

altitude of the station is 250 feet above sea level. A complete log of the well could not be obtained, but limestone, probably belonging to the Chattahoochee formation, was struck a short distance below the fullers earth.

BROOKS COUNTY

The Alum Bluff is the surface formation over all of Brooks County except strips along the streams in the southern part, where the Chattahoochee limestone is exposed. As in Thomas County, the surface is largely covered by weathered residual material, and exposures of the lower beds of the formation are poor. Some of the most interesting exposures are along Withlacoochee River, and will be described under Lowndes County.

At Devils Hopper, 2 miles northeast of Barwick, there is a large irregular limesink, about 60 feet deep, in a flat piney woods area. The section has been described by Brantly.[1] The exposure of Alum Bluff beds, about 30 feet thick, shows irregularly bedded material, varying considerably in different gullies leading into the sink. It consists principally of slightly indurated, greenish, argillaceous sand, resembling the sand rock of Lester fullers earth mine. The hardest part is at the base, toward the top it becomes softer and mottled and contains lenses of greenish plastic pipe clay, non-plastic or slightly plastic clay of the fullers earth type, both lamited and massive, and yellow plastic clay. The fullers earth is of poor quality, small in quantity, and of no economic importance.

LOWNDES COUNTY

The Alum Bluff formation outcrops throughout the area of Lowndes County, excepting a narrow strip along Withlacoochee River, where the Chattahoochee limestone is exposed. The lower beds of the Alum Bluff formation, which carry the fullers earth deposits, are exposed only along the valley of Withlacoochee River.

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[1] Geol. Survey of Ga. Bull. 21, p. 197, 1916.

WITHLACOOCHEE RIVER

(Map locality L-1)

Silicified fullers earth is exposed in bluffs along Withlacoochee River from the Atlantic Coast Line bridge near Ousley southward to Stony Lake and Knights Ferry. The following typical section was measured in a small gully in the east slope of the river, 150 yards downstream from the wagon bridge on the Quitman-Valdosta public road.

Section on east slope of Withlacoochee River near Quitman-Valdosta road

	Feet
Pleistocene	
6. Loose gray sand	10
(Unconformity)	
Oligocene	
Alum Bluff formation	
5. Fullers earth breccia. The fragments are hard, flinty, silicified fullers earth, and some of the larger ones when broken show concentric, agate-like banding in shades of brown and green. The matrix is partly sandy, partly a clay with apparently about the same composition as the fragmental material, but it becomes white and weathers more rapidly than the pebbles	2
(Unconformity?)	
4. Indurated fullers earth, with nodules of very hard, cherty, silicified earth in a softer greenish matrix. The bed is partly calcareous, and contains rounded, nodular masses of argillaceous limestone	3
3. Hard, fine-grained white limestone, containing nodules of gray chert	1
2. More or less indurated fullers earth, partly soft enough to be scratched with the finger nail. Color is bluish when fresh, weathered to greenish yellow at the surface	2
(Unconformity?)	
Chattahoochee formation	
1. Hard, white, fine-grained limestone at and below water level	?

The indurated earth from this locality is described by Veatch and

Stephenson[1] as follows: "Samples of silicified clays from Withlacoochee River, 7 miles east of Quitman, were examined in the laboratory. They vary from bluish to light greenish and dove color, are hard, brittle, and break with a conchoidal fracture; the rock is dense and compact, and the cracks are filled with opaline silica. Some of the rocks are slightly phosphatic. There are phases which might be termed opalized clay conglomerates or breccias; originally this conglomeratic rock consisted of fragments of clay, either pebbles of clay or angular fragments, in a matrix of very sandy, lighter colored clay or argillaceous sand, the matrix often containing oyster shells. By the infiltration of opaline silica, the rock has become dense, compact, and in places vitreous or glassy to such an extent that the sand grains are no longer recognizable. The clay is about three in the scale of hardness and it requires a strong blow with the hammer to break it. The lime of the oyster shells has been replaced by silica, and they are opalized and agatized."

The structure of the siliceous fillings of cavaties and fisures is shown by the microphotographs (Pl. XV, A and B) taken with crossed nichols.

The following is the analysis of a sample collected by Otto Veatch from the exposure at Stony Lake, 5½ miles southeast of Quitman. Except for the unusually high silica content the composition is much like that of other fullers earths from the same formation.

Analysis of silicified fullers earth from Stony Lake

Silica (SiO_2)	83.40
Alumina (Al_2O_3)	7.45
Ferric oxide (Fe_2O_3)	2.21
Magnesia (MgO)	.84
Lime (CaO)	tr
Soda (Na_2O)	.16
Potash (K_2O)	.32
Ignition	4.84
Titanium dioxide (TiO_2)	.45
	99.67
Moisture	7.69

[1] Geol. Survey of Ga. Bull. 26, p. 344, 1911.

This silicified fullers earth is not suitable for bleaching and has no apparent uses, but it indicates the position of the fullers earth horizon, and unindurated deposits may be found at the same level.

OLD TROUPVILLE

(Map locality L-2)

There is an interesting exposure of the Alum Bluff beds near the site of Old Troupville, on Little River half a mile above the junction of that river with the Coochee to form the Withlacoochee. The following section is exposed a few hundred feet downstream from the wagon bridge.

Section on east side of Little River at Old Troupville

	Feet
Pleistocene	
4. Coarse, sharp white sand	10
Oligocene	
Alum Bluff formation	
3. Hard, greenish sandy limestone. There is said to have been an old limekiln here, but the rock is very impure	6
2. Greenish nodular clay. This seems to be a slightly bauxitic phase of the fullers earth. The nodules are soft, and they shrink and drop out of the matrix, as do those of the slightly bauxitic kaolins of the Lower Cretaceous and Midway formations. The matrix is sandy and harder than the nodules	4
1. Greenish argillaceous sandstone, above river level	4

ECHOLS COUNTY

Echols, like the other counties along the Florida line, is almost entirely within the terrane of the Alum Bluff formation, but the Chattahoochee limestone is exposed along Allapaha River north and south of Statenville. Most of the county is a plain covered by loose sand deposits, but Allapaha River has cut a narrow valley 50 feet or more in depth, and it is only in the valley slopes and bluffs that exposures of beds in place are seen.

ALLAPAHA RIVER

Under the bridge at Statenville and for about half a mile upstream the basal bed of the Alum Bluff formation, a coarse, cross-bedded, argillaceous sandstone, extends down below water level. (When the examination was made, in October, 1915, the river was at an unusually low stage.) Farther upstream the limestone of the Chattahoochee formation appears, at some places extending 6 or 8 feet above river level. For about 2 miles above Statenville the limestone is overlain unconformably by the Alum Bluff argillaceous sandstone.

Farther north the latter bed changes to coarse yellow sand with laminae of yellowish clay of the character of fullers earth and this soon grades into blue, slightly calcareous fullers earth with only thin partings of sand. The fullers earth reaches a maximum of 8 feet, and maintains an average thickness of about 6 feet for a distance of half a mile, then it pinches out, being overlain and supplanted by greenish plastic clay. The section at the best exposure of fullers earth, about 2 miles upstream from the bridge, is as follows:

Section on east side of Allapaha River, 2 miles north of Statenville

	Feet
Pleistocene	
4. Loose gray sand	10
Oligocene	
Alum Bluff formation	
3. Fullers earth	8
2. Sandy and pebbly clay, forming a basal conglomerate and grading up into fullers earth, not over	0.5
(Unconformity)	
Chattahoochee formation	
1. Sandy limestone, top ranges from a few inches below to a few inches above water level	?

The earth of bed No. 3 is thick-bedded, almost massive, and free from grit. It is very slightly calcareous, dark blue when wet and drab when dry. It is soft and rather plastic, resembling certain phases of the Jackson fullers earth more than any other of the Alum Bluff deposits. Sample S-192 represents an average from the best part of the exposure.

The bed maintains this thickness and quality for a distance of 200 or 300 yards. Toward the south it becomes thinner bedded and harder, with an increasing quantity of sand, until it grades into the argillaceous sandstone. To the north the bed becomes thinner, and half a mile farther upstream the section is as follows:

Section on west side of Allapaha River 2½ miles north of Statenville

	Feet
Pleistocene	
7. Loose gray sand	8
Oligocene	
Alum Bluff formation	
6. Laminated, greenish, plastic clay	2
5. Sandy fullers earth	2
4. Conglomerate of coarse limestone pebbles	1
3. Interbedded argillaceous limestone and coarse argillaceous sand	2
2. Coarse argillaceous sand	1
(Unconformity)	
Chattahoochee formation	
1. Sandy limestone, exposed above water level	2-3.5

Tests.—Tests of sample S-192 were made on earth ground in a coffee-mill to pass through a 100 mesh screen. Tests of commercial earths are stated for comparison. These tests indicate an earth which, although not exceptionally light, has great bleaching power and very high apparent acidity.

Bleach

	Yellow	Red
Oil used	35	6.1
IXL	25	2.5
Pikes Peak	23	2.3
S-192	19	1.9

Specific volume

	Specific gravity	Lb. per cu. ft.
IXL	1.05	66.0
Pikes Peak	.61	38.2
S-192	.70	43.6

Apparent acidity

	$\frac{N}{10}$ alkali per 100 gm. earth
IXL	19.6 c.c.
Pikes Peak	163.0
S-192	214.

APPLING AND TOOMBS COUNTIES

The topography of these counties is flat or gently rolling, and the surface is deeply mantled by residual gray sand of Alum Bluff or later age. The only natural exposures of importance are in the bluffs along Altamaha River, which forms the boundary between the two counties.

GRAYS LANDING BLUFF

(Map locality A-1)

One of the best exposures is in the bluff at Grays Landing, on the north side of the river, 10 miles below the junction of Ocmulgee and Oconee rivers and a mile below Mann's Ferry.

Section at Grays Landing Bluff

Oligocene
Alum Bluff formation

	Feet
6. Greenish gray feldspathic sandstone or grit	8
5. Greenish argillaceous sand, upper part containing more clay than the lower	15
4. Sand with laminae of fullers earth-like clay	5
3. Slightly indurated greenish sand	1
2. Fullers earth, containing much sand interlaminated and in irregular pockets	4
1. Laminated fullers earth, pale greenish color when wet, dries white, contains only occasional pockets of sand. Exposed above water level	2

The section was measured at the west end of the bluff. Further east the grit bed, No. 6, reaches a thickness of 30 feet, and is locally so coarse as to be almost a conglomerate. It is overlain by mottled clayey sand formed by weathering, and the upland is capped by loose gray sand. The greatest height of the bluff is between 60 and 70 feet.

The fullers earth of bed No. 1 is identical with that of Decatur County, Georgia, and Gadsden County, Florida, in appearance, and the following analysis of a sample collected by Otto Veatch shows that its composition is almost the same:

Analysis of fullers earth from Grays Landing

Silica (SiO_2)	67.38
Alumina (Al_2O_3)	12.85
Ferric oxide (Fe_2O_3)	4.50
Magnesia (MgO)	3.75
Lime (CaO)	1.68
Soda (Na_2O)	.11
Potash (K_2O)	.24
Ignition	9.32
Titanium dioxide (TiO_2)	.40
	100.23
Moisture	9.42

When this exposure was visited the river was about 5 feet above its normal level, so the thickness of the bed of good earth could not be measured. There is almost no possibility of working the deposit, since most of the earth is below water level. This exposure is of importance, however, in showing the great areal extent of the Alum Bluff fullers earth and indicates that deposits may occur in any of the counties south of Altamaha and Ocmulgee rivers.

The lithological similarity of the beds to those near the Florida line is further shown by the section at Red Bluff, on the south side of Altamaha River, just below Mann's Ferry. The section is as follows:

Section at Red Bluff

Oligocene

Alum Bluff formation

	Feet
4. Red sandy clay, produced by weathering of bed No. 3	5
3. Greenish sandy clay	4

2. Silicified fullers earth breccia in a sandy matrix, exactly like the rock along Withlacoochee River in Brooks and Lowndes counties.................	0.5
1. Soft, sandy fullers earth, exposed above water level	1

Fullers earth was also exposed a few inches above water level at Piney Bluff, about 5 miles downstream from Gray's Landing.

SCREVEN COUNTY

Along Ogeechee River, about a mile south and west of Rocky Ford, there are exposures of coarse greenish sandstone or grit and greenish argillaceous sand lithologically very similar to the Alum Bluff beds of southwestern Georgia. The beds contain laminae and small lenses of clay similar to the fullers earth beds in appearance and properties. However, no fullers earth deposits large enough to have any possible commercial importance are known in any of the counties northeast of Altamaha and Oconee rivers.

FULLERS EARTH OF THE WILCOX AND CLAIBORNE FORMATIONS

In the Wilcox and Claiborne formations in Randolph and Clay counties there are beds of clay which have been described as fullers earth. One sample for testing was taken from the clay of each formation, but they were found to have only slight bleaching power, so only brief descriptions are included.

Sample S-242 was collected from a 10-foot bed of fullers earth-like clay of the Wilcox formation exposed on the Upper Cuthbert-Lumpkin road, 5 miles north of Cuthbert, Randolph County. (Map locality R-1.)

Sample S-243 is from an average of 85 feet of clay of the undifferentiated Claiborne beds, exposed along the Lower River road, three quarters of a mile south of Fort Gaines, Clay County. (Map locality Cl-1.)

Both of these clays are light-colored, laminated, and more plastic than most earth of good bleaching quality. Their density is high, and they evidently approach kaolin rather than fullers earth in composition.

Tests.—Tests of samples S-242 and S-243 were made on earth ground in a coffee-mill to pass through a 100 mesh screen. Tests of commercial earths are stated for comparison.

Bleach

	Yellow	Red
Oil used	35	6.1
IXL	25	2.5
Pikes Peak	23	2.3
S-242	31	3.1
S-243	31	3.1

Specific volume

	Specific gravity	Lb. per cu. ft.
IXL	1.05	66.0
Pikes Peak	.61	38.2
S-242	1.00	62.6
S-243	1.01	63.1

Apparent acidity

	$\frac{N}{10}$ alkali per 100 gm. earth
IXL	19.6 c.c.
Pikes Peak	163.0
S-242	131.
S-243	50.

PHYSICAL AND CHEMICAL CHARACTERISTICS

PHYSICAL PROPERTIES

The properties of fullers earths have been described to a certain extent in the sections on tests and descriptions of individual deposits. Certain desirable and undesirable properties and their causes are here briefly discussed. All statements here made, unless otherwise specified, refer only to Georgia fullers earths, as English and other fullers earths, some of which differ greatly from the Georgia earths in composition and properties, have not been studied.

BLEACHING POWER

Theories as to bleaching power.—Porter[1], after a series of tests on fullers earths in their natural state and after treatment with various solvents, reached the following conclusions to explain their peculiar properties:

"1. Fullers earth has for its base a series of hydrous aluminum silicates.

"2. These silicates differ in chemical composition.

"3. They are, however, similar in that they all possess an amorphous colloidal structure.

"4. The colloidal structure is of a rather persistent form and is not lost on drying at a temperature of 130° C., or possibly higher.

"5. These colloidal silicates possess the power of absorbing [adsorbing] and retaining organic coloring matter, thus bleaching oils and fats.

"I have used the word colloidal in this statement in its broadest sense—to cover the whole range of conditions expressed by the words colloid, pectoid, and hydrogel. It is my opinion that the word pectoid would most properly express the condition of the active constituents of fullers earth, but it is not impossible that these may go into partial solution in oil and thus become true colloids."

Dana[2] states that fullers earth has for its base the mineral smectite, and possibly also malthacite, inferring that he considered these minerals the cause of the bleaching power. Both these minerals have in the neighborhood of 30 per cent of combined water, and Porter[3] has shown that they can not be important constituents of American fullers earths, which, as may be seen from the analyses in this report, rarely contain as much as 10 per cent of combined water.

The presence of hydrous silica and extreme fineness of grain have also been considered as causes of the bleaching action, but Parsons

[1] Porter, John T., Properties and tests of fullers earth: U. S. Geol. Survey Bull. 315, pp. 268-290, 1907.
[2] Quoted by Ries in U. S. Geol. Survey Seventeenth Ann. Rept., pt. 3, p. 876, 1896.
[3] Op. cit. p. 277.

showed that hydrous silica in itself has no bleaching power, and various fine powders gave negative results.

The work of Porter, Parsons[1], Cameron and Bell[2], and the later investigations of Ashley[3] have shown that the bleaching action of fullers earth is due to the physical phenomenon of adsorption of basic ions by the colloidal matter or gels of the earth.

Adsorption.—Adsorption is a phenomenon dependent on surface tension, that is, on the difference in density or concentration of a liquid in films adjacent to bounding mediums and the density or concentration of the mass of liquid. Haskin[4] defines it as follows:

"Suspensoid particles attract ions of opposite electrical charge and hold them, so that when the colloid is precipitated the ions are carried down also. This holding is not chemical union, but condensation of a substance at the surfaces of contact and is called *adsorption*. So also two colloids of opposite electrical charge will hold one another by adsorption and precipitate together.

"Adsorption can occur independently of electrical considerations. In this case it is to be explained solely by the concentration of the adsorbable substance at the colloidal surfaces and the lowering of the surface tension of the liquid about the colloidal particles.

"The use of animal charcoal to remove coloring matters and certain other substances from solutions is a case of adsorption."

The application of adsorption to the fine mineral particles of clays has been treated by Ashley. He used the adsorption of brilliant green and malachite green by various clays as a measure of their relative colloid content, and attempted to rank them in order of plasticity by the same means. However, the plasticity was found to be dependent on colloid content only for clays of common origin.[5] The one sample of fullers earth tested, described as "Eimer and Amend," was found to adsorb the dyes much more completely than any other

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[1] Parsons, C. L., Fullers earth and its application to the bleaching of oils: Jour. Am. Chem. Soc., p. 598, Nov. 1906, vol. 29 (1907).

[2] Cameron, F. K. and Bell, J. M., Mineral constituents of the soil solution: Bureau of Soils Bull. 30, p. 42, 1905.

[3] Ashley, H. E., The colloid matter of clay and its measurement: U. S. Geol. Survey Bull. 388, 1909.

[4] Haskins, D., Organic chemistry, 2d ed. p. 71, 1914.

[5] Op. cit. p. 45.

clay sample, and therefore may be concluded to have a much higher proportion of colloids. The relation of plasticity to colloid content in Georgia earths is discussed under the heading "Plasticity." (See p. 297.)

Forms of colloids.[1]—Colloids exist in two characteristic forms (1) as a homogeneous suspension in a liquid, called a "sol" or "colloid;" and (2) as a continuous jelly with pore walls (and pores) filled with a liquid, called a "gel" or "pectoid." The terms sol and gel are considered preferable to colloid and pectoid since the word colloid is used in a general sense and may be extended to include all amorphous substances. Solids are included as a limiting case under gels.

Colloids are classified as reversible and irreversible, according to whether they will pass from sol to gel and back to sol, or whether, having passed into the gel form, they cannot be reconverted into the sol. The process of passing from sol to gel is called coagulation; from gel to sol, peptinization. When granular matter also is present as is the case with clays, the terms flocculation and deflocculation are used. When coagulation is permanent and irreversible it is called setting.

In setting, a chemical change is usually produced in the molecule. Therefore, more than a physical change of conditions is required to reverse it.

Charcoal is an example of a set gel free from solvent, therefore an amorphous solid. "It results from a very complete decomposition of organic gels by heat, and its structure depends on theirs. Liquids are probably not *absorbed* into the substance of its pore walls, but dissolved substances (solutes) or suspended substances (sols) are readily attached to the surfaces of its pore walls (adsorption). All of the external and internal surfaces are wetted by the liquid."

The action of fullers earth.—The action of fullers earth in bleaching oils is very similar to the adsorption of colors, gases, etc, by charcoal. The colloid matter of the earth is in finely divided and porous condition, presenting an enormous amount of surface, but, if not a

[1] Abstracted from Ashley, op. cit. pp. 14-16.

completely set gel or amorphous solid mineral, it is in such a condition that it is not readily deflocculated or peptinized in water or oil solutions.

The colloid matter of fullers earth has the power of adsorbing basis ions, that is, ions carrying a negative charge, or anions. It therefore affects basic dyes, in which the color is due to the negative ion. Crude cotton oil is not bleached, but fullers earth exerts its bleaching power only after the oil has been refined by treatment with an alkali, which process converts the coloring matter into sodium or potassium salts of the basic dyes. But not enough work has been done along this line to state to what extent the bleaching action depends on electrical charges, and to what extent it is independent of such considerations, and corresponds to the adsorption of gas molecules by charcoal or platinum black. Also, no clear explanation seems available for the fact that fullers earth, which acts as a negative sol in water solution should adsorb ions of like charge rather than those of opposite charge.

While the *power* to bleach evidently depends on the presence of colloidal clay substance, the *efficiency* of the bleach, in the absence of soluble salts and coarse mineral grains, which act merely as diluents, shows a very direct dependence on the porosity of the earth, which in turn may be measured by the specific volume. Thus the following tests show that Georgia sedimentary kaolins, having density and porosity about equal to the English fullers earth, *have equally good bleaching power,* and apparently the only factor which should prevent the substitution of kaolin for the English earth is that its physical constitution is such that it forms a sticky mass with oil, and would therefore not work well in the filter press. Sample S-97 is a slightly indurated and apparently very slightly bauxitic kaolin from the W. A. Hall property, Baldwin County. It is very fine grained and smooth in texture, the only evidence of bauxitization being scattered soft nodules, which have almost the same composition and character as the matrix. Sample S-108 is a slightly carbonaceous kaolin from the pit of the Georgia Vitrified Brick and Clay Company, at Campania. It is bluish in color when fresh, but burns almost white, and is a little lighter and more porous than the average kaolin, although it does not approach the Georgia fullers earth in these respects. Besides these tests, a bleaching test on a sample of bauxite from the Midway formation in Sumter County is stated. The bauxite is denser than the average kaolin, but it contains a considerable proportion of silica combined as kaolin. This test shows that while bauxite has some bleaching power, aluminum hydrate in that form is not a very efficient bleaching agent, so no further tests on it were made.

Bleaching Tests

Sample used	Original bleach		After two weeks in light		After two weeks in dark	
	Yellow	Red	Yellow	Red	Yellow	Red
Oil used	35	4.8	35	4.0	35	4.4
IXL Fullers earth	21	2.1	15	1.9	16	2.0
S-97 (Kaolin) through 100 mesh	21	2.1	12	1.7	14	1.9
S-108 (Kaolin) through 100 mesh	22	2.2	14	1.9	15	2.0
Bauxite through 100 mesh	30	3.0	20	2.5	21	2.6

Specific volume

	Specific gravity	Lb. per cu. ft.
IXL earth	1.05	66.0
S-97	.94	58.6
S-108	.84	52.5

Fullers earth, as shown by Ashley's work,[1] has the power of adsorbing basic dyes and bleaching water as well as oil solutions, but the adsorptive power varies with the solvent. Thus, the coloring matter

[1] U. S. Geol. Survey Bull. 388, 1909.

adsorbed from oil by fullers earth can be redissolved by alcohol after the excess of oil is removed by ether or gasoline. In judging the commercial value of a fullers earth, until much more work has been done in determining the physical chemistry of the bleaching process, not too much dependence should be placed on bleaching tests made with any other dye and solvent than those with which the earth is to be used.

AFTER-BLEACH AND REVERSION OF COLOR

The bleaching action of light on oils after treatment with fullers earth and the reversion of color when kept in the dark are subjects which have been little studied. Parsons[1] makes the statement:

"The question of color reversion is deemed important by certain refiners and these claim that with certain American earths the color tends to come back to cotton seed oil in the treatment after bleaching. This is a quality inherent in the earth, and if extensive would be fatal to its use."

The fact that the bleach by light varies after the use of different earths has been frequently noted. The tests made by the writer indicate that the presence of soluble salts (principally aluminum and iron sulphates) and of calcium carbonate makes the bleach by light less efficient, but in the absence of these substances the order of the after-bleach is about the same, whether the original bleach was good or bad. With nine samples bleached by earths containing appreciable amounts of soluble salts, exposure to light for two weeks effected a further lightening of the color averaging 6 Lovibond units of yellow and 0.2 unit of red. With six samples bleached by earths containing determinable carbon dioxide, the average after-bleach amounted to 6.5 units yellow and only 0.16 unit red. But with 21 samples bleached by earths carrying neither lime nor alum, the average after-bleach was 8 units yellow and 0.31 unit red.

There is also more apparent tendency for the color of the oil to revert after bleaching with earths containing soluble salts. Thus

[1] Jour. Am. Chem. Soc., vol. 29, p. 604, 1907.

in the case of oil bleached with the Pikes Peak commercial earth produced in 1914, the red tint was higher after standing two weeks in the light and two weeks in the dark than when first bleached. (In justice to the Company, it should be stated that the earth containing soluble salts is no longer worked.)

PLASTICITY

Fullers earth is generally described as non-plastic, but Porter[1] states that samples tested by him were most decidedly plastic. According to F. F. Grout's[2] definition that "Plasticity may be considered as involving two variable factors: (1) amount of possible flow before rupture; (2) resistance to flow or deformation," which corresponds to the usual conception of plasticity, Georgia fullers earth is very slightly plastic. A fragment of the wet earth as taken from a mine or natural exposure is not deformed, but shattered, by a blow of the hammer, and its resistance to deformation is such that pebbles of the earth are often rolled for considerable distances by streams before being worn away or broken up. A great deal of the earth is hard enough to be described as "shale." However, after drying, grinding, and mixing with water, fullers earth, like many shales, develops plasticity, and some samples become very sticky. Evidently Porter made his tests with dried and ground material.

The work of Ashley[3] has shown that while the plasticity of clay depends on the presence of colloid gels, the quantity of colloid having adsorptive power has no bearing on the relative plasticity, excepting for groups of clays of similar origin and which have undergone similar metamorphic changes. Indeed, there is no reason why plasticity should depend on the proportion of adsorbent colloids, because gels may vary in consistency from gelatinous pastes to the completely set form found in charcoal, which has high adsorbent power, but is not at all plastic.

The gels in fullers earth are evidently set to a greater degree

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[1] U. S. Geol. Survey Bull. 315, pp. 273 and 284, 1907.
[2] Quoted by Porter, op. cit., p. 273.
[3] U. S. Geol. Survey Bull. 388, 1909.

than those of ordinarily plastic clays or kaolins. They can be deflocculated to a certain extent by fine grinding, and especially by the presence of a minute amount of alkali.[1] Another evident cause of the lack of plasticity of fullers earth is the fact that it contains some, and usually a large amount of hydrous or opaline silica, which probably forms a sponge-like skeleton structure, supporting the grains of softer colloids.

The only conclusions which can be stated as to the effect of plasticity on fullers earth are: (1) plasticity in itself has no evident effect on bleaching power but (2) if a clay is very plastic the porous structure will be broken down and less bleaching surface presented to the oil and (3) a plastic clay causes slow filtration, although it may not retain a large percentage of oil.

HARDNESS

Hardness may be considered a desirable property of fullers earth. If the earth is hard the particles are not crushed so much in agitation and filter pressing, therefore filtration is easier and more rapid. Hardness is especially desirable for use with mineral oils, as the earth must keep its coarsely granular form in the large percolators used, and the harder the earth the less is lost as dust during revivifying by heating.

The hardness of the earth seems to be due to cementation of the softer clay particles by water-deposited silica. It is advantageous up to the point where the deposition of silica has been so great that it starts to fill up the pores.

POROSITY AND DENSITY

As previously mentioned, the bleaching power of fullers earth depends directly on the porosity. The pore space in Georgia earths in many cases exceeds 50 per cent of the volume, as shown by the determinations of specific volume. The same is indicated by examination of thin sections, which show visible pores of various sizes and

[1] Porter, J. T., U. S. Geol. Survey Bull. 315, pp. 278 and 287, 1907.

shapes, besides which there must be a large aggregate volume of sub-microscopic pore space.

It is probably the case that bleaching efficiency is directly dependent on the surface presented to the oil, the mineral composition and proportion of adsorbent colloids being approximately the same in all earths. The total porosity, however, is only a rough measure of the active surface, since a fine grained and finely porous earth may present a much greater surface than one of the same density which is coarse grained and coarsely porous. With some of the best bleaching earths, such as S-102 and S-131 (see pp. 250 and 276), in addition to being very light, the extreme fineness of grain is apparent to the naked eye. On the other hand, some of the Barnwell earths formed near the northern margin of the area of deposition are much heavier and the mineral grains are obviously coarser. This may explain why the fine grained kaolin from the W. A. Hall property, S-97 (see p. 232) has stronger bleaching power than the coarse grained fullers earth, S-99, from the same locality, although both have approximately the same density and total volume of pores.

The efficiency of the IXL English earth may be explained by the fact that, in spite of its high density, it is extremely fine grained and finely porous, thus presenting more bleaching surface than an ordinary clay of the same density.

Porosity is a desirable property in that it increases the bleaching power, but undesirable in that it increases the oil absorption, and for bleaching any particular oil a balance of these properties leading to good quality with the greatest possible economy is to be sought.

ABSORPTION OF OIL

The absorption of oil, as well as the bleaching power is a direct function of the porosity. The oil fills the sub-microscopic pores and coats the walls of the larger openings, where it is held so firmly by surface tension that it is not removable by any ordinary process of suction, blowing or pressing.

The absorption is a quality inherent in the earth. It does not depend to any considerable extent upon the coarseness of the particles nor upon the method of grinding, although these factors may have a great effect upon the ease of filtration. The absorbed oil is held principally within the pores of the fullers earth fragments, and not to any great extent on the exterior surfaces or between the fragments, and the grain and porosity of the earth is so fine that by the finest practicable methods of grinding the particles are still sponge-like masses with interior pore surfaces greatly exceeding the exterior surface. From the nature of the phenomenon, it seems impossible that any treatment of an earth could decrease its absorption, because anything which would close up the pores would also destroy the bleaching power, while to press out the oil would require a pressure sufficient to break down the structure of the earth and to close even the sum-microscopic pores.

Some interesting facts concerning the absorption of mineral oils are shown by the work of Gilpin and Cram[1] and Gilpin and Bransky[2]. Mixtures of oil and fullers earth in the ratio of one cubic centimeter of oil to one gram of earth were made, and the oil was displaced from the earth by the addition of water. The quantity of oil retained in the earth was about one-third of the oil used. A pressure of 200 tons per square inch extracted very little oil from the earth after the water treatment. Heating to 165° caused more oil to distil out, and another portion was extracted by ether. But pressure, heat, and extraction with ether together yielded only about half the amount of oil which the earth contained. In the later work the amounts of oil retained by the earth after displacement with water varied from 40 to 55 per cent of the amounts supplied, depending on the specific gravity and chemical composition of the oil. The earth used in these tests was supplied by the Atlantic Refining Company, of Philadelphia, and was evidently an earth from the Alum Bluff formation of south Georgia or Florida.

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[1] Gilpin, J. E. and Cram, M. P., The fractionation of crude petroleum by capillary diffusion: U. S. Geol. Survey Bull. 365, 1908.
[2] Gilpin, J. E. and Bransky, O. E., The diffusion of crude petroleum through fullers earth: U. S. Geol. Survey Bull. 475, 1911.

SPONTANEOUS COMBUSTION

A cause for the rejection of some American fullers earths has been that they caused spontaneous combustion when the filter presses were blown out with air, thus causing delays and ruining the filter cloths. So far as could be learned from statements in the literature and conversation with producers, this applies only to the earth of the Alum Bluff formation. With the Barnwell earths from central Georgia there is said to be no danger when handled by experienced men.

The Alum Bluff earth is very fine grained and very porous, therefore a film of oil is spread over an enormous surface. When air is blown through or over any oxidizable oil there is naturally some rise in temperature, and when the oil is spread in a thin film over so large a surface the heat may reach the point of combustion. The action may be compared with the ignition of a jet of hydrogen by a platinum sponge. With earths of slightly coarser grain or less porosity the danger is greatly decreased.

APPARENT ACIDITY

When a quantity of neutral fullers earth entirely free from any acid or soluble salts, is suspended in water the mixture has an acid reaction toward phenolphthalein and other indicators, and a considerable amount of alkali must be added to affect apparent neutralization. This is a property of almost all clays and soils as well as of fullers earth, but fullers earth samples show especially high apparent acidity.

The phenomenon is evidently due to the adsorption of hydroxyl ions by the colloidal clay substance, leaving an excess of hydrogen ions in solution, then alkali sufficient to make up the deficit of hydroxyl ions must be added before neutrality is shown by the phenolphthalein, which is the indicator generally used.

The relation between apparent acidity and bleaching power is not very definite, but it may be noted that the earth with highest bleaching power, that from Phinizy Gully, Columbia County, had higher apparent acidity than any other earth sample free from soluble salts.

The quantity of tenth normal potassium hydroxide solution required to neutralize 100 grams of this earth was 177.9 cubic centimeters. The quantity of alkali required by other earths varied from this maximum value down to zero. Some of the earths containing considerable amounts of calcium carbonate gave neutral reactions, although their bleaching power was fairly strong, and in one case an earth of good bleaching power gave an alkaline reaction, on account of the presence of a trace of soluble phosphate.

English fullers earth and the kaolins tested require about 20 cubic centimeters of alkali for 100 grams of earth. Most of the Barnwell earths, unless calcareous, require much larger quantities. The Alum Bluff earths, although they are very porous and bleach well, take only small quantities of alkali, but most of them contain some calcium carbonate and a considerable percentage of phosphorus, a trace of which in the form of soluble phosphates has a tendency to neutralize the apparent acidity or even to give an alkaline reaction.

Closely allied to the apparent acidity of fullers earth is the property of adsorbing basic analine dyes from water solution. This property has been investigated by Ashley.[1] It leads to the use of earth saturated with dyes in the production of pigments known as ''lakes.''

FRACTIONATION OF PETROLEUM

When crude petroleum is allowed to diffuse upward through tubes filled with fullers earth the lighter constituents rise more rapidly than the more viscous oils, and the oil displaced from the earth contained in different parts of the tube varies greatly in properties. A similar fractionation may be effected by mixing crude oil and fullers earth, then displacing the oil by successive small additions of water. These phenomena have been investigated by Day, Gilpin, Cram, and Bransky.[2]

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[1] U. S. Geol. Survey Bull. 388, 1909.

[2] Gilpin, J. E. and Cram, M. P., under supervision of Day, D. T., The fractionation of crude petroleum by capillary diffusion: U. S. Geol. Survey Bull. 365, 1908.

Gilpin, J. E. and Bransky, O. E., The diffusion of crude petroleum through fullers earth, with notes on its geologic significance: U. S. Geol. Survey Bull. 475, 1911.

The fractionation is independent of any properties of the fullers earth except its porosity, and is explained as follows:[1] "The fractionation is effected entirely by capillarity; oils with different surface tensions rise with different velocities through the capillary openings, such as the fine interstices and minute pores of the fullers earth.

"Any medium, therefore, sufficiently fine grained and porous to afford capillary spaces, causes a separation of the constituents of any mixture, provided they possess different surface tensions."

MICROSCOPIC STRUCTURE

A few thin sections of various types of earth were examined and notes on the slides are given below.

Specimen S-2.—Light-colored fullers earth from the mine of the General Reduction Company, Twiggs County.

The pore space visible under the microscope amounts to almost 50 per cent of the area of the slide. The pores are of all shapes and sizes. Many are irregular or elongated, seeming to represent the space left by the solution of minute shells or fragments of shells. A number of the pores are perfectly circular in section and 0.2 mm. or less in diameter. The structure is shown by the photograph (Pl. X, D).

The clay substance is not resolvable into distinct mineral grains by a magnification of 375 diameters, but it consists principally of crystalline material, and shows a distinct aggregate polarization with the slow ray parallel to the bedding planes. The index of refraction is a little higher than that of balsam. Probably much of the "ground mass" consists of cryptocrysalline quartz, deposited with the long axes of the crystals parallel to the bedding.

Quartz occurs in angular or subangular grains, of which the maximum dimension is only 0.065 mm., showing the extreme fineness of the sediment when deposited. Zircon grains up to 0.09 mm. were noted. The slide shows a number of granules of green glauconite, up to 0.05 mm. in diameter, made up of interwoven crystalline laminae.

[1] U. S. Geol. Survey Bull. 475, pp. 8-9, 1911.

Flakes of white mica are present in the mass of the earth, but are much larger and more abundant along partings, where flakes 1 mm. in diameter are seen. The small optic angle of the mineral shows it to be hydro-mica or damourite.

One small grain of orthorhombic pyroxene, probably hypersthene, was noted.

Specimen S-3.—Dark-colored fullers earth from the mine of the General Reduction Company, Twiggs County.

The structure and mineral composition as shown in the section are the same as S-2, but in addition the earth contains abundant brown to black carbonaceous matter in disseminated grains and numerous small opoque crystals of pyrite, mostly less than 0.01 mm. in diameter. This section also shows aggregate polarization, and it seems to contain more glauconite than S-2.

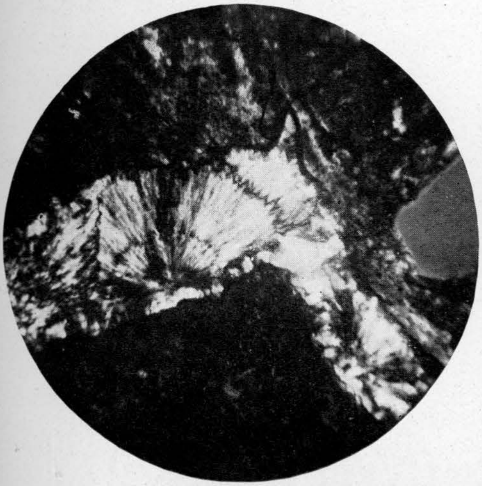
Specimen S-124.—Fullers earth from the Jamieson mine of the Floridin Company, Gadsden County, Florida.

This is a typical specimen of the Alum Bluff fullers earth. It is decidedly finer in grain than the Pikes Peak earth, and the clay substance is so fine and uniform that it appears almost transparent and glassy under high power by transmitted light. With crossed nichols it is seen to have almost entirely crystalline structure, and shows strong aggregate polarization with the slow ray parallel to the bedding planes. The only determinable mineral present in quantity is quartz, which occurs in small angular grains, with maximum dimensions very rarely exceeding 0.2 mm.

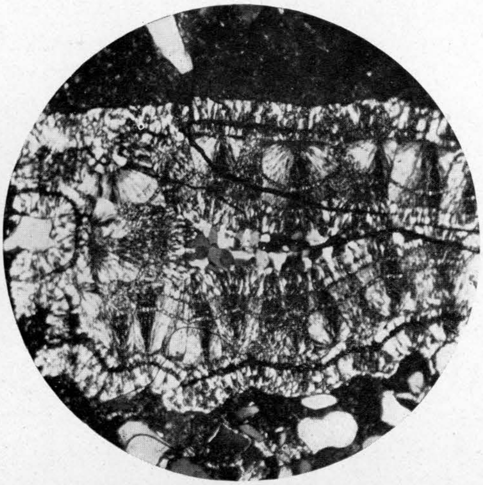
The porosity of the specimen is less apparent under the microscope than in the Pikes Peak earths. The section examined was rather thick and the pores must be largely less than the thickness of the section, if not sub-microscopic in size.

Specimen S-133.—Silicified fullers earth from Withlacoochee River below Atlantic Coast Line bridge, boundary of Brooks and Lowndes counties.

This is a silicified sandy fullers earth of the Alum Bluff formation, similar to that described megascopically on p. 283. The microscope



A.



B.

A. SEC. S-133. SILICA (CHALCEDONITE OR PSEUDOCHALCEDONITE) FILLING A FISSURE IN INDURATED FULLERS EARTH. CROSSED NICHOLS. MAGNIFIED 110 DIAMETERS.

B. SEC. S-133. SPHERULITIC SILICA (CHALCEDONITE OR PSEUDOCHALCEDONITE) FILLING A CAVITY IN INDURATED FULLERS EARTH. CROSSED NICHOLS. MAGNIFIED 37 DIAMETERS.

C. BAUXITE MINE OF THE REPUBLIC MINING & MANUFACTURING CO., NEAR WARM SPRINGS, MERIWETHER COUNTY, SHOWING CONTACT OF BAUXITE AND KAOLIN.

shows that it consists of quartz grains, angular to well rounded, with maximum dimensions up to 0.5 mm., in a cryptocrystalline matrix showing aggregate polarization. A pear-shaped cavity, 1.2 by 2.7 mm., is filled by spherulitic silica of the structure shown by the photograph (Pl. XV, B), and similar silica fills fractures in the mass. (See Pl. XV, A.) Although the silica in cavities and fractures has been described as opaline, no amorphous opal is seen in the sections. The fibers of the spherulitic mineral have negative elongation, and are therefore chalcedonite or pseudochalcedonite. The aggregate polarization of the ground mass would indicate that all of the silica exists in crystalline form.

Specimen S-154.—Indurated fullers earth from Mount Enon, Richmond County. This specimen is typical of the indurated fullers earth which is abundant in the Barnwell formation from Washington County northeastward to Savannah River.

The material is porous, but much less so than S-2. Its granular structure is much coarser than that of the bleaching earths, and, although grains of crystalline minerals are abundant, there is no aggregate polarization. The slide shows cell-like and fibrous structures which are evidently of organic origin.

Angular and subangular quartz grains are abundant. Most of the grains are very small, but a few are over 1 mm. The cementing material in this earth is very probably amorphous silica.

Specimen S-163.—Light colored fullers earth from Dinah Hines property, Wrens, Jefferson County.

This earth is very fine grained and finely porous, and consists almost entirely of amorphous clay substance. The only determinable particles of crystalline minerals are quartz grains, which rarely exceed 0.01 mm. in diameter. There is no aggregate polarization.

Specimen S-184.—Calcareous fullers earth from Rich Hill, Crawford County.

The earth consists of a mass of amorphous clay substance with only a few very small grains of quartz and mica, but calcite is very abundant in small irregular grains less than 0.02 mm. in maximum dimensions. A few glauconite granules were noted. The porosity visible under the microscope is small, as is to be expected, since the section was cut from the harder, denser, and more calcareous earth near the base of the bed. It shows no aggregate polarization, and the induration seems to be due to cementation by calcite rather than silica.

CHEMICAL AND MINERALOGICAL COMPOSITION

It has frequently been stated that the chemical composition is no criterion for judging the value of a fullers earth for bleaching and such was found to be the case with the samples examined in preparation of this report. In fact, the fullers earths show no decided peculiarities in chemical composition, and the analyses of good bleaching earths may be duplicated among alluvial and residual clays of no value for bleaching purposes.

Below are assembled the analyses of commercial earths tested, with analyses of average clays and shales for comparison.

Analyses of fullers earth, clay and shale

Cons'ts	IXL	S-1	S-2	S-3	S-124	S-125
SiO_2	60.65	69.62	72.95	73.08	66.06	58.10
Al_2O_3	14.43	14.34	12.65	9.48	15.46	15.43
Fe_2O_3	6.74	3.90	3.56	2.68	3.45	4.95
FeO	.50	.31	.47	1.22	.31	.30
MgO	3.44	1.01	.57	.76	.09	2.44
CaO	2.49	.80	1.00	1.13	1.84	1.75
Na_2O	.15	.80	.28	.54	.52	.27
K_2O	.52	.43	.68	.84	1.01	.66
Ignition *a*	8.73	6.77	7.02	7.62	8.70	14.04
CO_2	1.81	.00	.00	.00	.00	.84
TiO_2	.89	.72	.50	.63	.19	.72
P_2O_5	.15	.58	.36	.27	1.44	.72
S	.09	.79	.00	1.17	.38	.15
MnO	.00	....	....	....	....	.00
	100.59	100.07	100.04	99.42	99.45	100.37
Moisture .	11.70	7.29	5.77	4.74	7.13	4.59

Constituents	S-127	A	B	C	D
SiO_2	70.85	54.48	57.09	60.69	56.62
Al_2O_3	13.25	15.94	17.24	16.59	14.14
Fe_2O_3	2.90	8.66	5.07	4.08	4.08
FeO	.15	.84	2.30	2.93	1.78
MgO	.06	3.31	2.17	2.34	2.73
CaO	1.29	1.96	2.04	1.42	6.09
Na_2O	.36	2.05	1.05	1.02	1.84
K_2O	1.41	2.85	2.25	3.63	2.73
Ignition *a*	8.08	7.04	7.18	3.86	3.52
CO_2	.00	....	....	1.47	4.72
TiO_2	.29	.98	1.27	.77	.47
S	.25	....	.13	.58*c*	.80*c*
P_2O_5	.56	.30	.21	.15	.20
MnO	....	1.21*b*	.12	tr	tr
	99.45	99.62	98.12	99.53	99.72
Moisture	6.27	....	....	.89	2.11

a Loss on ignition, less CO_2 when present.
b MnO_2
c SO_3
IXL—English fullers earth from Picard and Law laboratories.
S-1, S-2, S-3 } General Reduction Company, Pikes Peak brand fullers earth.
S-124, S-125 } Floridin fullers earth, Jamieson mine.
S-127—Lester Clay Co. fullers earth.

A—Composite of 51 samples of marine "red clay." G. Steiger, analyst. Clarke, F. W., The data of geochemistry: U. S. Geol. Survey Bull. 491, p. 490, 1911.

B—Composite of 52 marine "terrigenous clays," namely, 4 "green muds" and 48 "blue muds," G. Steiger, analyst. Clarke, op. cit., p. 490.

C—Composite of 51 Paleozoic shales, by H. N. Stokes. Clarke, op. cit., p. 522.

D—Composite of 27 Mesozoic and Cenozoic shales, by H. N. Stokes. Clarke, op. cit., p. 522.

It may be noted that the sample of English earth used for comparison in the tests is very similar to the Georgia earths in chemical composition, although many of the analyses of English earths cited in the literature contain much less silica and much more combined water. The IXL earth differs from the average of the Georgia commercial earths only in that it contains a little more ferric iron, magnesium, calcium, and carbon dioxide. As a whole, the fullers earths differ from the average marine clays in their higher content of silica and lower content of all of the bases, especially soda and potash. However, their composition is in no way abnormal, as compared with other marine or even terrestrial clays. They differ from the average shales in the same respects as from the clays, and also in containing more combined water.

The one distinguishing chemical characteristic of the commercial fullers earth is that, aside from any sand grains which may be present, the ratio of silica to alumina is much higher than in clays of the kaolin type. The silica in excess of the kaolin ratio may be combined with alumina, or it may be free and in an amorphous or cryptocrystalline state. The tests, however, do not indicate that the excess of silica has any direct effect on the bleaching power, but it serves to preserve the physical texture of the earth, while clays with a larger proportion of alumina are too plastic and the grains have not enough firmness to filter well. Sloan[1] has noted this, and says:

"It is observed that where the alumina exceeds one-fifth of the amount of silica present the critical point is approximated beyond which an increase in the densely bedding aluminous material prejudices filtration. The silica therefore serves to maintain the required porosity."

Attempts have been made to compute the mineral composition of fullers earth from analyses, but such computations show little of practical importance. In short, fullers earth, like soils and other sedimentary clays, is likely to contain any of the common rock-forming minerals, besides any or all of the series of hydrous aluminum silicates or clay minerals. A complete list of these minerals has been published by Porter,[2] and need not be repeated here. The minerals of the clay series most likely to be present are those with a higher

[1] Sloan, Earle, Preliminary report on the clays of South Carolina, p. 59, 1904.
[2] Porter, J. T., properties and tests of fullers earth: U. S. Geol. Survey Bull. 315, pp. 269, 270, 1907.

SiO_2: Al_2O_3 ratio than kaolin ($Al_2O_3.2SiO_2.2H_2O$); namely, smectite ($Al_2O_3.7SiO_2.12H_2O$), malthacite ($Al_2O_3.7SiO_2.16H_2O$), razoumoffsskine ($Al_2O_3.4SiO_2.7H_2O$), montmorillonite ($Al_2O_3.3Sio_2.3H_2O$), pyrophyllite ($Al_2O_3.4SiO_2.H_2O$), and cimolite ($2Al_2O_3.9SiO_2.6H_2O$). It is probable that much of the amorphous or colloidal clay substance of the earth consists of hydrated oxides of silica and alumina combined without any definite molecular ratio.

The minerals known to affect the bleaching power of the earth unfavorably are soluble salts and the sulphides, pyrite and marcasite, which by oxidation during drying lead to the production of free acid and sulphates. Calcium carbonate is also objectionable if more than a small percentage is present.

GENESIS OF DEPOSITS

Porter[1] and others present arguments favoring an origin of fullers earth from basic rocks, of which augites and hornblendes are the prominent minerals, rather than from acidic or feldspathic rocks. In the case of the Georgia earths, however, the source of material was exactly the same as for the formation of the Lower Cretaceous kaolin deposits, and the causes of the peculiarities in composition and texture of the earths must be sought in depositional conditions and subsequent metamorphic changes.

The material for the kaolins was eroded from the surface of the Piedmont area after conditions of base-leveling had permitted the accumulation of a deep mantle of thoroughly weathered residual material, and the clays were deposited in fresh water lagoons (see pp. 111-113 of this report). In the later Eocene time, when the deposition of the fullers earth beds commenced, the residual mantle of the Piedmont had been swept away, fresher rocks were exposed to erosional activity, and deposition took place under shallow water marine conditions, along the shore line or in bays.

The nature of the Barnwell and Alum Bluff deposits depends on the kind and quantity of detrital material supplied. When and

[1] U. S. Geol. Survey Bull. 315, p. 268, 1907.

where the supply was abundant and coarse the extensive beds of glauconitic sands and feldspathic grits were laid down; finer sediments led to the formation of fullers earth and other clays; and in the absence of much clastic material organic depositional factors predominated, and beds of limestone or marl were formed.

As the fullers earths are clays of normal composition, deposited under ordinary marine conditions, a discussion of the genesis of the deposits requires only an explanation of the cause of the porous texture.

From the field relations, it is at once apparent that most of the Georgia fullers earth was deposited as a calcareous clay. The leaching out of the calcium carbonate left a large volume of openings, while the silica originally present, together with that deposited from solution, formed a framework strong enough to hold the pores open. The abundant joints and sandy partings in the beds of earth provided channels for the circulation of solutions.

At many localities near the southern or off-shore limit of the area of fullers earth deposition the alteration of the very calcareous clay or argillaceous limestone to a light, porous, non-calcareous clay may be observed. Farther north, where the clay was originally less calcareous, the alteration extends to greater depths. Along the northern margin, where the original sediments of the fullers earth horizon were coarse grained and very slightly, if at all, calcareous, the resultant earth is dense and compact and has little bleaching power. In the deposits of Alum Bluff age it has been noted at several localities that the fullers earth beds become calcareous where the overburden exceeds about 15 feet.

Although the production of porous earths from calcareous clays at some localities is a recent phenomenon which is still going on, at other localities the leaching out of lime appears to have been nearly contemporaneous with the deposition of the clay. Thus at Pikes Peak and near Grovetown the earth which has been affected by recent weathering is light colored, while that below the zone of oxidation is dark, containing organic matter and pyrite, but no calcium carbonate.

However, the dark earth contains determinable casts of molluscs, showing that calcareous material was present during deposition, and besides the whole shells there must have been a much larger amount of fragmental shell material. The water must have had the power to dissolve this lime almost immediately, but the siliceous matter present preserved a certain degree of porosity. The recent weathering has increased the porosity of such earths by the removal of organic matter, pyrite, and the material dissolved by acids generated by oxidation of the pyrite.

The production of fullers earth by weathering of the ferro-magnesian silicates, as noted in the Arkansas[1] deposits, may depend on a somewhat similar condition. In the alteration of the basic minerals a considerable amount of calcite is produced, which later is leached out, leaving a porous clay, but in weathering of feldspathic rocks little or no calcite is formed.

METHODS

Mining.—All fullers earth in Georgia is worked by pits or open cuts. The overburden is best moved by steam shovels or steam drags, and in some cases the earth also may be mined with steam shovels. Water is a cause of difficulty in mining, and even well drained mines are not usually workable for a day or more after a heavy rain. The earth is carried to the drying and grinding plants in tram cars moved by gravity or by steam locomotives.

Preparation.—The methods of preparation have been discussed under the descriptions of plants. In brief, earth for bleaching vegetable oils is dried at a temperature which will not drive off any of the combined water, while that for use on mineral oils may be dried at a somewhat higher temperature, but the temperature must not in any case rise above the fusing point of any of the minerals of the earth.

The grinding machinery employed should be such as will break

[1] Miser, H. D., Developed deposits of fullers earth in Arkansas: U. S. Geol. Survey Bull. 530, pp. 208-216, 1911.

down the particles of earth to the required fineness, but will produce a minimum of extremely fine dust. Abbè mills have been found most satisfactory for grinding earth which is to be graded by bolting, but in case only one fine grade of earth is desired roller mills are used, and the ground earth is carried up from the mill by a current of air. Tube and ball mills are not satisfactory, on account of the lightness of the material and the large amount of fine dust produced.

Bolting machines similar to those used in flour mills are employed for grading the granular earth. From the bolters or air separators the earth passes to storage bins, and is weighed and sacked before shipment.

USES

The original use of fullers earth, that of removing grease from woolen cloth in fulling, is now of little importance, as other effective methods of freeing the cloth from grease have been found. At present the greater part of the earth produced is used in refining petroleum. Second in importance is the use in bleaching animal and vegetable oils, fats and greases. Minor uses are in the manufacture of pigments for wall paper, for detecting artificial coloring in food products, as a substitute for talcum powder[1], and in medicine as a poultice and as an antidote for alkaloid poisons.[2]

Petroleum refining[3].—The fullers earth of the grade chosen is placed in a cylindrical percolator, some 15 feet in height, and holding 18 to 25 tons to a charge. Te oil is forced through under pressure. When crude, dark-colored oil is introduced into the cylinders the first portion to pass through is water-white and of much lower viscosity and specific gravity than the original oil. As percolation continues the depth of color, viscosity, and specific gravity progressively increase, until finally the oil passes through the percolator unchanged. The quantity of oil decolorized by a charge of ful-

[1] Bur. Mines Bull. 71, p. 19, 1913.

[2] Fantus, Bernard, Fullers earth; its adsorptive power, and its antidotal value for alkaloids: Jour. Am. Med. Assoc. vol. 64, pp. 1838-1845, May 29, 1915.

[3] Abstracted from Bur. Mines Bull. 71, pp. 26-29, 1913.

lers earth varies with the quality of the oil and the degree of bleach desired. The maximum quantity exceeds 700 barrels to 25 tons of earth, while the minimum is less than 150 barrels to the same charge.

Fullers earth is used for various purposes, such as removing the "floc" which causes turbidity of kerosene on cooling, and for decolorizing such products as vaseline, paraffin, petrolatum, and spindle and lubricating oils. The grades of earth most used are 15 to 30, 30 to 60, and 60 to 80 mesh. The grade of earth used, and filtering cold or preliminary heating of the oil depends on the viscosity of the oil to be treated and the character of the product desired.

When the earth becomes useless for further decolorization the percolator is blown out with air and the residue washed with naphtha to remove as much as possible of the adhering oil, then the percolator is blown out with steam to remove the naphtha. The naphtha is recovered by distillation and the dissolved oil is re-treated.

The spent fullers earth from the percolator is revivified by igniting at a low red heat in a rotary kiln, after which it is ready for use in the percolator again. Ordinarily the earth is used 10 to 16 times, gradually losing its decolorizing power. The heating seems to have no effect on the bleaching power of the earth, so long as the point of incipient fusion is not reached.

With the earths commonly used in refining mineral oils about 3 per cent of the material treated is lost as dust during each ignition in the rotary kilns. With the softer varieties of earth the loss would be greater, so such earths would evidently be less satisfactory.

Bleaching of cotton oil.—After the refining of petroleum products, the next most important use of fullers earth is in the bleaching of cotton oil. The following is the method employed:

The crude oil is refined by saponifying out the fatty acids with sodium hydroxide. It is found that in addition to the alkali required for neutralization of the free fatty acids, a considerable excess must be added to change the coloring matter of the oil into the form of basic salts which can be acted upon by fullers earth.

The refined oil is pumped to the bleaching vat, and heated to about the boiling point of water, temperatures varying from 180 to 220° F. being used. Oil to be bleached with Georgia earth is not heated to so high a temperature as when English earth is to be used, on account of the danger of spontaneous combustion with the former. The required quantity of fullers earth is added and agitated with the oil for 10 minutes. The proportion of earth used varies from 1½ to 6 per cent of the weight of the oil, depending on the effectiveness of the particular earth used, the bleachability of the oil, and the lightness of the product desired. One Atlanta refinery uses 3 per cent of Pikes Peak earth, which seems to be about the average amount, but Parsons[1] states that at one plant as much as 10 per cent of earth is used at a very low temperature for bleaching oils of special quality. It is important that the oil should be dry before bleaching, on account of the strong affinity of fullers earth for water.

The mixture of oil and earth is pumped to the filter press, and after pressing, air is blown through at a pressure of about 15 pounds per square inch. The press is then blown with steam and again with air, the oil recovered by these last blowings going back to the refinery. Care is necessary during the final blowing with air, which is stopped as soon as an acrid odor indicates rising temperature. The earth from the presses is dumped at a safe distance from the plant, as it usually starts to burn within a few hours.

All varieties of fullers earth have the property of imparting to the bleached oil a disagreeable taste and odor. The exact cause is not known, but those earths of highest bleaching efficiency generally give the strongest taste and odor. The taste and odor are removed by blowing dry steam through the oil, which is heated to a temperature above the boiling point of water.

The principal use of the bleached cotton oil is for mixing with hardened oil in the manufacture of various brands of shortening, used as substitutes for lard.

The processes of bleaching other vegetable and animal oils vary in detail, but are essentially similar to the bleaching of cotton oil.

[1] Bur. Mines Bull. 71, p. 20, 1913.

In American refinery practice fullers earth is used but once in bleaching cotton oil, and the residue thrown on the dump carries from 10 to 20 per cent by weight of valuable oil. According to Parsons[1] the earth may be revivified and the oil recovered by treating with an oil solvent such as naphtha, benzol or carbon tetrachloride, an acid to convert the basic coloring matter into salts, and alcohol to dissolve the coloring matter. By mixing the solvent, alcohol and acid the process may be carried on at one operation, and the earth bleaches as effectively as at first. The objection to applying this process on a commercial scale is the fact that most individual refineries use such small quantities of earth it would not pay to install a recovering and revivifying plant, while the used earth with the oil in it can not be stored or shipped on account of the danger of spontaneous combustion.

Manufacture of pigments.—Fullers earth saturated with basic dyes is employed to some extent as a pigment, especially for printing on wall paper. Such colors correspond to the "lakes" formed by precipitating dye stuffs with aluminum hydroxide. They may be very brilliant, but are lacking in permanence, on account of the character of dyes used.

The use of natural yellow, gray, and white fullers earth as a pigment in place of ocher has been mentioned (see p. 254). On account of its lightness and porosity, fullers earth should serve well for this purpose, and it is likely that the market could be developed.

Detecting coloring matter.—In the laboratory fullers earth is used for detecting certain artificial coloring matter added to butter, whisky and vinegar. This application is based on the fact that the artificial colors used are more readily absorbed by fullers earth than the coloring naturally present in such products.

Talcum powder.—Fullers earth is used as an ingredient in some, if not all, commercial "talcum powders." On account of its strong affinity for moisture and fats, fullers earth is well suited to this use, and perhaps it could advantageously be employed entirely in place

[1]Bur. Mines Bull. 71, p. 22, 1913.

of powdered talc, except where the latter is desired primarily as a lubricant.

Medical uses.—On account of its strong absorptive power, fullers earth is claimed to have value as a poultice for ulcers, burns, and sores.

In 1910, John Uri Lloyd discovered that the addition of fullers earth to alkaloids diminished or abolished their bitter taste and that alkaloids could be quantitatively removed from solutions by it.[1] He first prepared "Lloyd's reagent," which consists of the finer particles of fullers earth, separated from the coarser material by elutriation. Bernard Fantus[2] published the results of tests with Lloyd's reagent and various other earths, showing that fullers earth, especially when administered with tartaric acid or sodium dihydrogen phosphate, has antidotal value in morphin, cocain, and ipecac poisoning, and less value in strychnin and aconitin poisoning.

PRODUCTION

The production of fullers earth in the United States, as stated in the United States Geological Survey Mineral Resources for 1915 is as follows:

[1] Lloyd, J. U., Lloyd's reagent—preliminary announcement: Jour. Am. Pharm. Assoc., p. 625, May, 1914.
[2] Jour. Am. Med. Assoc. vol. 64, pp. 1838-1845, May 29, 1915.

Fullers earth marketed in the United States, 1895-1915

Year	Quantity (short tons)	Value	Average price per ton	Year	Quantity (short tons)	Value	Average price per ton
1895	6,900	$ 41,400	$ 6.00	1906	32,040	$265,400	$ 8.28
1896	9,872	59,360	6.01	1907	32,851	291,773	8.88
1897	17,113	112,272	6.56	1908	29,714	278,367	9.37
1898	14,860	106,500	7.17	1909	33,486	301,604	9.01
1899	12,381	79,644	6.43	1910	32,822	293,709	8.95
1900	9,698	67,535	6.96	1911	40,697	383,124	9.41
1901	14,112	96,835	6.86	1912	32,715	305,522	9.34
1902	11,492	98,144	8.54	1913	38,594	369,750	9.58
1903	20,693	190,277	9.20	1914	40,981	403,646	9.85
1904	29,480	168,500	5.72	1915	47,901	489,219	10.21
1905	25,178	214,497	8.52				

In recent years Georgia has contributed about 20 per cent of the total production.

The amounts imported, almost entirely from England, have been as follows:

Fullers earth imported for consumption into the United States, 1897-1915

Year	Quantity (short tons)	Value	Average price per ton	Year	Quantity (short tons)	Value	Average price per ton
1897 *a*	4,980	$ 34,320	$ 6.89	1907	16,406	$122,221	$ 7.45
1898	9,356	71,044	7.59	1908	12,166	93,413	7.68
1899	11,558	69,640	6.03	1909	12,752	101,151	7.93
1900	9,154	64,797	7.08	1910	16,857	132,545	7.86
1901	12,058	80,697	6.69	1911	18,224	143,594	7.88
1902	15,134	102,580	6.78	1912	19,109	145,337	7.61
1903	17,100	120,671	7.06	1913	18,628	146,001	7.84
1904	10,222	74,006	7.24	1914	24,977	195,083	7.81
1905	14,563	105,997	7.28	1915	19,441	152,493	7.84
1906	14,825	108,695	7.33				

a July to December.

APPENDIX A

BAUXITE DEPOSITS OF MERIWETHER COUNTY

In 1915 bauxite was discovered on the property of W. Howard Smith, at the foot of the north slope of Pine Mountain, 3 miles west of Bullochville, Meriwether County. This deposit is of particular interest on account of its situation in the area of crystalline rocks of the Piedmont Plateau, where no other bauxite has ever been discovered. The property, now owned by Wynne and Large, was developed by the Republic Mining & Manufacturing Company in July, 1916. About 1000 tons of ore were obtained.

Geologic relations.—Pine Mountain is a ridge of resistant, more or less schistose quartzite, which attains an elevation of over 1300 feet above sea level, while the land in the areas to north and south has an average elecation 800 and 900 feet. South of Bullochville and Warm Springs the trend of the ridge is east and west.

South of Pine Mountain, in the vicinity of Shiloh, there are exposures of mica and hornblende gneiss, but in the ridge and for some miles north no igneous rock was found. The mountain is made up of interbedded quartzite and mica schist. Along the Southern Railway south of Bullochville the prevailing dip of the beds is east and northeast, but farther west it changes to north and northwest. The quartzite layers show many minor folds, while in the schistose layers the bedding is not generally determinable, but the schistosity dips at high angles. North of the ridge is an area of sedimentary schist of varying composition; micaceous, ferruginous and graphitic. The prevailing dip of the schistosity is north to northwest at various angles.

The deposits.—The known deposits consist of two small lenses or masses, one of red and one of white bauxite. These occur at the north end of a spur running down from the mountain, at an altitude of about 1000 feet. The relative size and position of the deposits is shown in the accompanying sketch (fig. 24).

The small knoll at the north end of the spur is covered with large blocks and boulders of red bauxite. The area entirely covered by the fragments is 200 feet long, from east to west. The south (upper) boundary of the area is sharp, but smaller boulders have rolled down into the valley to the north, covering a considerable area. Scattered boulders of bauxite are found southwest around the slope to the location of the white bauxite deposit.

It is impossible to determine whether the large masses of red bauxite are real outcrops or large boulders as no openings have been made. However, it is certain that the material is very nearly in place, and it is probably the outcrop of a vertical lens or pocket similar in form to the mass of white ore. At the east end of the knoll, just below the bauxite area, is an outcrop of mealy, dark-red clay without nodules.

Four hundred feet south of the red bauxite outcrop a deep gully in the hillside exposes white, red, cream-colored and mottled kaolin. The clay is fairly plastic, and shows no evidence of structure, excepting a small mass which has bedding or banding dipping N 20° E at an angle of 40°. The kaolin is overlain with marked unconformity by a recent superficial formation, locally 15 feet thick, of red argillaceous sand containing pebbles and boulders, both angular and rounded, of Pine Mountain quartzite, together with a few boulders of dark gneiss.

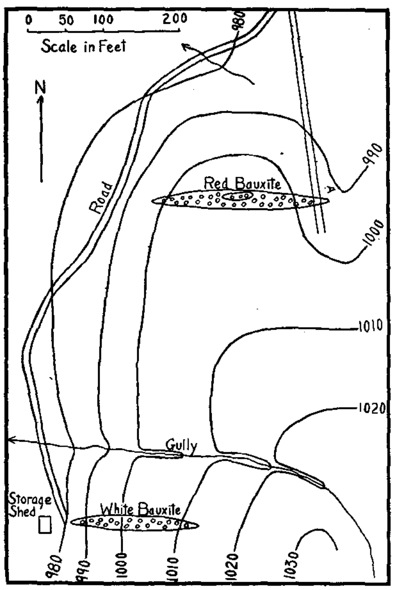
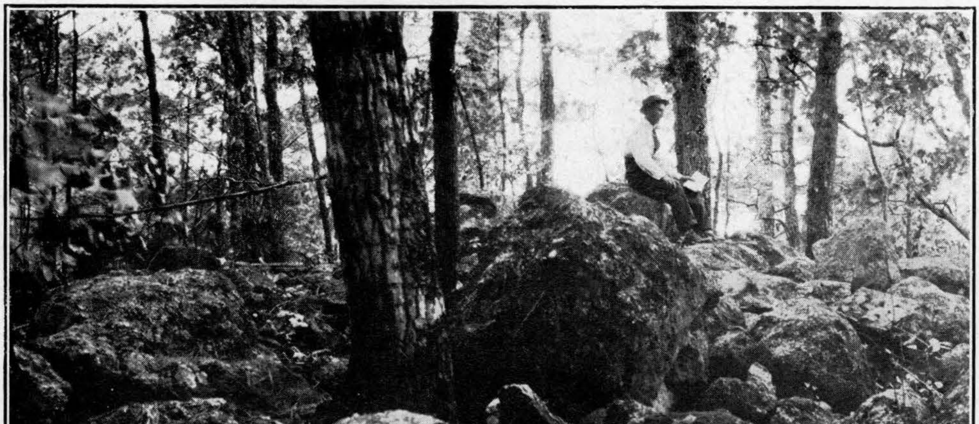


Fig. 24.—Sketch map of the bauxite deposits of Meriwether County.

The deposit of white bauxite, which has been in a measure, if not entirely worked out, was a lens-like mass striking N 85° E and dipping 80° N. The length was 150 feet, and the greatest thickness was 12 feet near the center, but the ore pinched out to east and west and downward.

A. BAUXITE MINE OF THE REPUBLIC MINING & MANUFACTURING CO., ON THE PROPERTY OF WYNNE AND LARGE, NEAR WARM SPRINGS, MERIWETHER COUNTY, SEPTEMBER, 1916.



B. EXPOSURE OF RED BAUXITE ON THE PROPERTY OF WYNNE AND LARGE, NEAR WARM SPRINGS, MERIWETHER COUNTY.

The structural relations and methods of working may be seen in the photographs, (see Pl. XV, C and Pl. XVI, A), which were taken in September, 1916. The ore body was entirely surrounded by kaolin, which was first removed from narrow cuts along both sides of the lens, after which the projecting mass of bauxite was removed.

The ore in the center of the mass was of the coarsely nodular gravel type, consisting of hard, compound pebbles over an inch in diameter in a clayey matrix, and practically identical in appearance with that of the Sweetwater and other mines in the Coastal Plain of Georgia. Toward both sides it became more clayey and more finely nodular. The ore was almost white, but locally there were light red bands up to 4 inches thick dipping 15°S, that is, almost at a right angle to the dip of the lens. The body was cut by several vertical, slickensided faults, but the throw along them was probably inconsiderable.

The south, or foot wall, of the ore body was kaolin with a slightly yellowish tint. There was a gradation between bauxite and kaolin, and small soft pisolites occurred for several feet out into the clay.

The north, or hanging wall, was principally a dark, maroon-colored clay, the color evidently being due to iron and a little manganese. The bauxite graded into white kaolin, which formed a sharp contact with the maroon clay, while bands or veins of white clay cut through the red. A close view of the contact is shown in the photograph, (Pl. XV, C).

The ore.—The bauxite from the mine is white and exceptionally low in iron content, but contains a considerable percentage of combined silica and some sand grains. The red bauxite from the north exposure, on the other hand, is highly ferruginous but less siliceous. The fresher portions of the red bauxite consist of soft red pisolites, from very minute to half an inch in diameter, in a hard brownish-gray matrix. The soft material of the pisolites is usually surrounded by a thin, hard, white shell. In some portions the matrix is stained dark red, due apparently to surface alteration. Some of the boulders show distinctly slickensided surfaces.

The following are analyses of typical samples:

Analyses of bauxite from Meriwether County

Constituents	1	2	3	S-248
Silica (SiO_2)	16.06	5.50	8.40	19.05
Alumina (Al_2O_3)	54.76	52.36	51.95	51.28
Ferric oxide (Fe_2O_3)	.93	7.06	8.26	.48
Ignition	26.75	28.80	27.46	26.71
Titanium dioxide (TiO_2)	1.66	2.83	2.23	1.71
	100.16	96.55	98.30	99.23
Moisture				.10

1. White bauxite from surface boulders, collected by S. W. McCallie.

2 and 3. Red bauxite from surface exposures, collected by S. W. McCallie.

S-248. Average sample across the working face, 12 feet in width, in September, 1916.

Origin.—Surrounding the bauxite deposits is an area of white or stained clay similar to the sedimentary kaolins of the Coastal Plain. The mica schist of the vicinity weathers to a red or mottled clay, similar in general appearance to some of the clays associated with the bauxite, but such weathered schist may be distinguished by the abundance of mica, traces of schistose structure, and pockets and stringers of quartz in parallel orientation.

Clays derived from schist are seen along the public road from Bullochville to a point a quarter of a mile beyond the bauxite occurrence. The clay from the gully between the bauxite lenses however, shows no trace of ever having been schistose. This clay contains little mica and no bunches or stringers of crystalline quartz. The residue, after washing and treating with hydrochloric acid, consists of sand grains of various sizes, mostly angular, but some well rounded. Similar clay is seen in gullies across the small valley east of the bauxite outcrops, and along the road which runs north and south half a mile farther east.

Half a mile west of the bauxite an area south of the public road is covered with boulders of ferruginous sandstone, not schistose. Some of the boulders contain well-rounded quartz pebbles, others are masses of brecciated quartz cemented by limonite. This material resembles the limonite-cemented sand beds which are common in the Cretaceous and Eocene formations of the Coastal Plain.

A mile west of the bauxite deposits is an elevation known locally as "Chalk Hill." In the road near the base of the hill on the east side is an outcrop of kaolinic sand, made up of coarse, rounded grains, and showing no trace of schistosity. A little higher is a pit from which about a cubic yard of kaolin was taken. The kaolin is almost white and contains very little grit. Like the Cretaceous kaolins, it is massive and shows no bedding nor other structure, but half way up the east slope of the hill is an exposure of bedded kaolinic sand dipping 45° NW. At the summit and on the west slope of the hill, however, there are exposures of weathered mica schist, which strikes northeast and dips almost vertical.

Structurally and lithologically, the small areas of unmetamorphosed sediments lying north of Pine Mountain, and associated with the bauxite deposits, are identical with the Lower Cretaceous sediments of the Coastal Plain, which approach most closely at Geneva, Talbot County, 23 miles south. The bauxite, kaolin, and all varieties of associated clay and sand can be duplicated at numerous points in the belt just south of the Fall Line.

A possible explanation of these deposits seems to be that the Lower Cretaceous starta once covered the area. In the post-Cretaceous uplift this area of the formation was folded sufficiently to give the bedding and bauxite lenses a steep dip to the north, and slickensided surfaces in the bauxite were produced along minor faults. Lying in a protected position north of the ridge of Pine Mountain, the beds have escaped erosion; while all Cretaceous and later sediments have been removed from the surrounding region.

Unfortunately, the actual contact of the unmetamorphosed materials with the schists could not be found, so this theory can only be considered as hypothetical. However, the form of the deposit of white bauxite, except for the nearly vertical altitude, and the character of the ore and associated clays, resemble the Coastal Plain deposits much more than those of the Paleozoic formations of north Georgia, Alabama and Tennessee. The form and relations of the red bauxite can not be determined in the absence of underground work, but the body is apparently a lens similar to the white bauxite. There is no limestone, dolomite, nor shale associated with the Meriwether County deposits, although these sediments surround and underlie the north Georgia deposits, and according to Hayes's theory, are necessary for the genesis of bauxite deposits of the Paleozoic type.

If the bauxite and associated clays of Meriwether County are really of Lower Cretaceous age, the origin is the same as that of the deposits of the Wilkinson and Sumter County areas. The presence of a thermal spring (Warm Springs) and a sulphide spring (White Sulphur Spring) within 5 miles of the bauxite deposits indicates that dynamic activity in the region has been comparatively recent, and suggests the possibility that such springs may have played a part in the formation of the bauxite, although no definite relationship between springs and bauxite deposits is evident.

APPENDIX B

NOTES ON THE BAUXITE DEPOSITS OF NORTH GEORGIA

MINING OPERATIONS IN 1917

The amount of bauxite mined in the Paleozoic area of northwest Georgia has steadily declined for a number of years, and even the increased demand since the beginning of the European war has not stimulated mining to any great extent.

Watson,[1] in 1904, listed 39 deposits in the Hermitage district, of which 18 had been worked; 44 deposits in the Bobo district, of which two had been worked; five deposits in the Summerville district, of which three had been worked; and two isolated deposits. Very few deposits of importance have been discovered since the publication of Watson's report, and the decline of mining operations indicates that the deposits of good bauxite in easily accessible localities are almost exhausted. However, more or less good ore has been left in most of the abandoned pits, and there are large amounts of low grade bauxite and bauxitic clay which will undoubtedly come into demand as the higher grade ores are exhausted. Many deposits which would otherwise have been worked remain undeveloped on account of the rapid increase in production of the Arkansas and Coastal Plain fields, while in other cases the mining companies have been unable to reach an agreement with the property owners in regard to terms and royalties. It is probable that the field will continue to produce a comparatively small quantity of ore for a number of years.

In the fall of 1916 the Republic Mining & Manufacturing Company was drying and shipping an occasional carload of ore from Hermitage, and the same company was operating the Booger Hollow and Merrimac mines. Later in 1916 or early in 1917 a mine was opened 2½ miles east of Cave Spring by Asbury and Sparks, the product being a red bauxite said to be used in the manufacture of aluminum.

[1] Watson, T. L., A preliminary report on the bauxite deposits of Georgia: Geol. Survey of Ga. Bull. 11, 1904.

Recently, I am advised, D. E. Chisolm, of Boston, Massachusetts, has begun the shipment of bauxite from the old Warner mine which is in Bartow County about 2 miles east of Halls Station.

The production of the Alabama and Tennessee districts has also declined. The Perry mine of the National Bauxite Company, at East Chattanooga, Tennessee, was abandoned in 1916, as the pit had a depth of about 150 feet and clay slides proved troublesome and expensive. In Alabama the Monahan, Indian and Klondike mines of the Republic Mining & Manufacturing Company were in operation in 1916.

Hermitage mines.—In 1916 the average shipments from Hermitage, Floyd County, are said to have been only two or three cars per month. Actual mining operations were not carried on, but ore previously extracted from the Stockade and Hardee mines was washed, dried and shipped, and some prospecting was done in the area north and east of Hermitage. The local opinion is that there is still a large amount of ore held in reserve. The Republic Mining & Manufacturing Company controls practically all of the deposits near Hermitage.

Merrimac mine.—The Merrimac mine, 3.1 miles by road east of Halls Station, Bartow County, was worked some years ago by B. P. Curtis, and reopened in 1916 by the Republic Mining & Manufacturing Company. When visited, in October, 1916, the work in the old mine consisted principally in stripping, as a cave-in of the walls had covered the ore to a depth of 20 feet. A hundred yards east of the old mine a new opening about 50 feet in diameter and 30 feet deep had been made.

The ore from both mines has low iron content, but runs rather high in silica. It consists largely of "block ore," which is nearly amorphous. Wells in both pits have cut some finely pisolitic bauxite, indicating that the best ore is deep in the deposits. There is no "dornick ore," but occasional boulders are encountered.

Booger Hollow mine.—The Booger Hollow mine was worked about 1910, and was reopened by the Republic Mining & Manufacturing

Company in February, 1916. It is in the Bobo district, Floyd County, near the Polk County line, and 4.9 miles from Cunningham on the Southern Railway, which is the shipping point. When visited, in October, 1916, the mine was producing about a car of ore a day.

The new pit measured 20 by 30 feet on the surface, and the greatest depth was 30 feet, of which 15 feet was in ore. The ore varies considerably in appearance. A part consists of a hard, light-brown matrix with irregular nodules, some of which are highly ferruginous, part consists of light-brown pisolites in a soft white matrix, and part is a complex c. c. pebble ore, stained by iron carried in by surface water. Although the ore in the face appears red, the iron content is not very high, and by avoiding the worst parts the shipments can be kept below two per cent ferric oxide, while the alumina content of all shipments has been over 52 per cent.

The deposit is known to the large, extending into the Bobo property, which lies north of the mine. The portion of the deposit on the Bobo lot has been prospected, but not worked. A well near the property line cut 39 feet of bauxite, and a boring is said to have penetrated 50 feet of ore.

COMPARISON OF THE PALEOZOIC AND THE COASTAL PLAIN BAUXITE DEPOSITS

Although the bauxite deposits of the Paleozoic area differ so greatly from those of the Coastal Plain in form and mode of origin, the similarity between the ores and associated kaolins of the two regions is remarkable.

The Paleozoic ores show perhaps a wider range in composition and physical structure, and "aluminum ore" containing a low percentage of silica and a considerable amount of iron is more abundant than in the Coastal Plain, although the proportion of such ore is small in both regions. The typical "dornick ore," consisting of complex boulders several feet in diameter of hard, high-grade bauxite imbedded in a softer or clayey matrix is not found in the Coastal Plain, but the complex pebble ores, which differ from "dornick ore" only in the size of the hard masses, are found in both regions. Porous or vesicular bauxite occurs principally in the Paleozoic region. Some samples from north Georgia consist of pisolites adhering only at the points of contact, leaving vacant spaces between the individual nodules, but in all Coastal Plain bauxites examined the spaces between pisolites are completely filled with a matrix of amorphous bauxitic or clayey material.

Chemically, both Paleozoic and Coastal Plain bauxites consist of a mixture of trihydrate of alumina with kaolin. The most notable difference is the higher titanium content of the Paleozoic ores, which frequently carry 5 to 10 per cent of titanium dioxide, while this constituent in the Coastal Plain ores rarely exceeds 2 or 3 per cent.

The residual kaolins in which the Paleozoic bauxite deposits are imbedded are entirely similar, chemically and physically, to the sedimentary kaolins associated with the Coastal Plain deposits. All varieties of white, stained, mottled, nodular, indurated, and plastic clays are found in both regions, and in both the kaolin seems always to entirely surround the bauxite pockets or lenses, except where cut away by the present surface or by unconformities.

Although the Coastal Plain deposits are distinctly stratified and the Paleozoic in the form of irregular pockets, showing a great difference in conditions of origin, the similarity in chemical and physical characteristics of the two types of ore deposits and the associated clays leads to the conclusion that the solutions which deposited them must have been almost identical. According to Hayes's[1] theory, which is the most satisfactory explanation of the origin of the Paleozoic deposits ever presented, the bauxite was precipitated from aluminum sulphate solutions, the source of the material being principally the underlying Cambrian shales. According to the theory of origin of the Coastal Plain deposits here presented (see pp. 123-132), those deposits also were formed by precipitation from sulphate solutions. Calcareous material, which is supposed to have acted as a precipitant of the material of the Paleozoic deposits, was absent in the

[1] U. S. Geol. Survey Sixteenth Ann. Rept. pt. 3, pp. 587-591, 1895.

Coastal Plain, but whether precipitated from solution by carbonates, by hydrogen sulphide, or by hydrolysis, the alumina might be expected to have about the same composition and to assume the same nodular or pisolitic structure.

In age, the Paleozoic and Coastal Plain deposits do not differ greatly. Watson[1] concludes from the elevations of the deposits and their relation to the topography that the bauxite of the Paleozoic area was formed near the close of the Eocene period. The Coastal Plain deposits of the Lower Cretaceous were formed and indurated during Cretaceous time, as shown by the fragmental material in the basal conglomerate of the Eocene formations. Conditions for the formation of bauxite, however, persisted well into Eocene time, when the Midway beds were laid down.

[1] Geol. Survey of Ga. Bull. 11, p. 130, 1909.

APPENDIX C

NOTES ON HALLOYSITE

Halloysite is a hydrated silicate of aluminum having the theoretical composition $Al_2O_3.2SiO_2.3H_2O$, that is, 43.5 per cent silica, 36.9 per cent alumina, and 19.6 per cent water. It contains one more molecule of combined water than kaolinite, and the elements seem to be less closely combined than in kaolins and ordinary clays. The alumina of halloysite is readily soluble in sulphuric acid, therefore deposits of halloysite, if sufficiently extensive, are possible sources of alum and other aluminum salts, as well as metallic aluminum.

The North American Chemical Company.—The North American Chemical Company, H. H. Shackelton of Rome, Georgia, president, for a time mined halloysite, and an experimental plant with a capacity of 15 tons of alum per 24 hour day was erected at Urbana, Ohio. Treatment with sulphuric acid of 60° Be. extracted 760 pounds of alumina from one ton of halloysite, or one ton of halloysite would yield about two tons of aluminum sulphate with 17.25 per cent alumina.

The mine is on the east slope of Taylor Ridge, 5 miles north of Gore, the terminus of the Rome and Northern Railroad. There are probably several thousand feet of workings.

The halloysite is soft and waxy in appearance, with a pale greenish tint, and contains masses of harder, brownish halloysite, of flinty appearance, but soft enough to be easily cut with a knife. Running through the halloysite masses are dendritic veinlets of black material, which the analyses indicate consists largely of oxides of cobalt, nickel and manganese.

The halloysite is overlain by massive chert (Fort Payne chert?) and underlain by plastic yellow clay (weathered Chattanooga shale?). It occurs as irregular seams and pockets, just below the chert and often surrounding angular fragments of chert. The underlying yellow clay is locally sandy, but contains no chert. The halloysite seams and pockets vary from a few inches to several feet in thickness.

The masses of pure, white halloysite rarely exceed 1 foot, as most of the material is stained by the black oxides. Some small seams of kaolin were noted, but the conditions evidently were not favorable for kaolinic alteration.

On account of the small size and irregular distribution of the halloysite masses, mining seems to have been difficult, and it was necessary to move a large amount of worthless material.

Analyses.—The following table includes all available analyses of halloysite from the mine of the North American Chemical Company and other localities in northwestern Georgia. All analyses except the first two were made by Dr. Edgar Everhart for the Geological Survey of Georgia.

Analyses of halloysite from northwestern Georgia

Constituents	1.	2.	3.	4.	5.
SiO_2	42.20	37.10	43.76	40.77	42.24
Al_2O_3	37.30	41.00	28.19	38.50	34.86
Fe_2O_3	tr	....	1.40	.62	.34
FeO	....	....	.20	.10	.06
MgO	....	....	.09	.04	.08
CaO	tr	tr	tr	.09	.02
Na_2O	....	....	.20	tr	.16
K_2O	....	....	.24	.06	.09
Ignition	19.95	20.40	14.17	14.38	13.21
Moisture	....	....	7.85	5.49	9.21
TiO_2	tr	tr	.10	tr	tr
P_2O_5	....	....	....	....	....
NiO	....	....	1.13	.11	....
CoO	.12	1.06	.04	tr	....
MnO	.11	.38	3.13	.14	.06
	99.68	99.94	100.50	100.30	100.33

Cons'ts	6.	7.	8.	9.	10.	11.
SiO_2	34.24	40.60	93.90	40.82	45.05	40.13
Al_2O_3	38.54	37.00	3.68	39.15	34.00	37.26
Fe_2O_3	.74	.32	1.00	.40	3.38	.56
FeO	....	.00	.61	.08	.29	....
MgO	.10	.08	.06	.10	.03	tr
CaO	.00	.02	.00	.00	.00	.00
Na_2O	....	.06	.14	.08	tr	.00
K_2O	....	.06	tr	tr	tr	.00
Ignition ..	16.82	13.88	.65	18.58	13.15	14.07
Moisture ..	5.79	8.51	.38	.40	3.76	8.08
TiO_2	.00	.00	tr	.05	.15	.00
P_2O_5	4.08	....	....	....	....	....
NiO	....	....	tr	.08	.09	....
CoO	....	....	tr	tr	tr	....
MnO	.05	tr	.08	.10	.20	.00
	100.36	100.53	100.50	99.84	100.10	100.10

1. Light halloysite from mine of the North American Chemical Company, Chattooga County. Analyst, D. J. Demorest, Ohio State University.

2. Dark halloysite from mine of the North American Chemical Company, Chattooga County. Analyst, D. J. Demorest, Ohio State University.

3. Halloysite, black. Alexander property (?), Chattooga County. S. W. McCallie, collector, Sept. 3, 1913.

4. Halloysite, brown with some black veins. Alexander property, Chattooga County. S. W. McCallie, collector, June 30, 1913.

5. Halloysite. Alexander property, Chattooga County. S. W. McCallie, collector, June 30, 1913.

6. Gibbsite (?), amorphous or cryptocrystalline substance in halloysite. Alexander property, Chattooga County. S. W. McCallie, collector, Sept. 3, 1913.

7. Halloysite, Chattooga County. S. W. McCallie, collector, July 31, 1913.

8. Chert in halloysite. Chattooga County. S. W. McCallie, collector, July 31, 1913.

9. Halloysite. Chattooga County. S. W. McCallie, collector, July 31, 1913.

10. Halloysite, brown, jasper-like. Catoosa County. From T. E. Grafton, Rome, Ga., May 31, 1913.

11. Halloysite (?). Property of M. W. Cloer, Lot 245, 26th. Dist., 2d. Sec., Murray County. From J. R. Barnett, Chatsworth, Ga., Oct. 20, 1914.

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