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IRON ORES, FUELS, AND FLUXES

OF THE

BIRMINGHAM DISTRICT, ALABAMA

BY

ERNEST F. BURCHARD AND CHARLES BUTTS

WITH CHAPTERS ON THE

ORIGIN OF THE ORES

BY

EDWIN C. ECKEL

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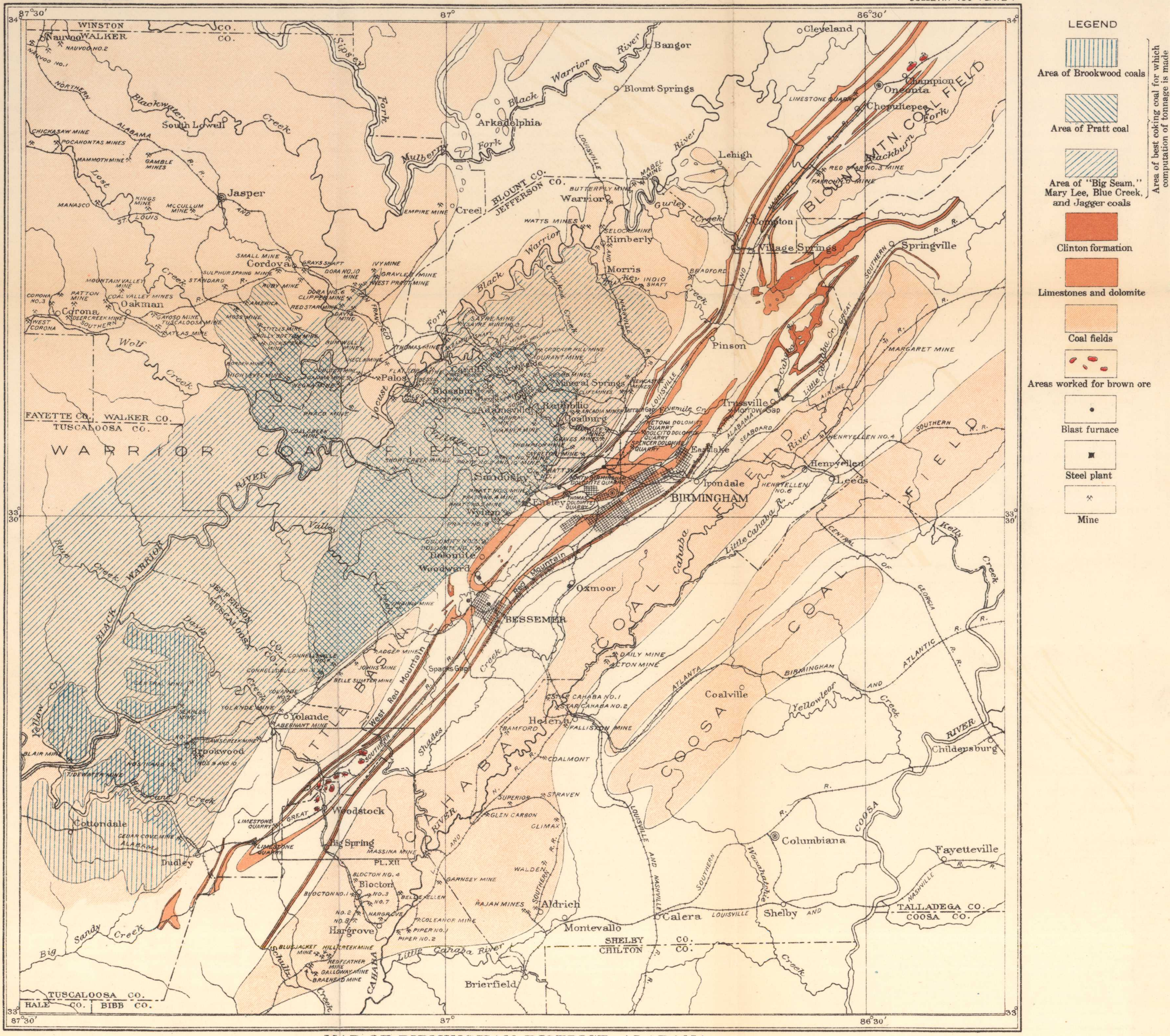

A. Hoen & Co. Lith. Baltimore, Md.

MAP OF BIRMINGHAM DISTRICT, ALABAMA

SHOWING OUTLINES AND RELATIONS OF AREAS OF IRON ORE, COAL, LIMESTONE, AND OTHER ECONOMIC FEATURES

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1908

IRON ORES, FUELS, AND FLUXES OF THE BIRMINGHAM DISTRICT, ALABAMA.

By Ernest F. Burchard, Charles Butts, and Edwin C. Eckel.

INTRODUCTION.

Geologic studies of the iron ores of the Birmingham district, Alabama, were begun by the United States Geological Survey in 1906, in accordance with a plan to prepare special reports on each of the important iron-ore districts of the southern United States.

The report as here presented is a composite work containing contributions from three geologists. Ernest F. Burchard was engaged during June and July, 1906, and January, 1909, in field studies of the iron ores and mapping of the rocks associated with them, and has accordingly prepared the bulk of the report, comprising the chapters describing the red ore, the character and relations of the red-ore beds, the detailed descriptions of the various portions of the district, the estimates of red-ore reserves, the discussion of mining methods, the geologic relations and local descriptions of the brown-ore deposits, and the maps, sections, and other illustrations relating to the iron ores of the district.

Charles Butts conducted, during the seasons of 1904, 1905, 1906, and 1908, an independent investigation of the general geology and coal resources of the Birmingham region, the results of which will be published finally as geologic folios. Mr. Butts has prepared for this report the chapters on general geology and on fuels and fluxes, and the maps and illustrations accompanying those portions of it.

Edwin C. Eckel, who at the beginning of this work was in general charge of the iron-ore investigations of the Survey, but who shortly afterward resigned from the Survey to undertake private work, has contributed the chapters on the origin of the red ores and of the brown ores, based on a broad study of both of these ores in the Appalachian region.

The term "Birmingham district" as here used is based upon commercial rather than geographic features. It includes the region whose mining industries are tributary to those blast furnaces which are grouped about Birmingham as a center, in distinction from the furnaces which are grouped in the Attalla-Gadsden and the Anniston-Talladega districts.

The district thus limited extends as a long, narrow belt, about 75 miles long and 10 miles wide, trending northeast and southwest, from the vicinity of Springville and Village Springs at the northeast to a point about 8 miles below Vance at the southwest. Birmingham is near the middle of this area.

Within the Birmingham district are very extensive deposits of red hematite, large though less extensive deposits of brown ore, and important beds of coking coal and fluxing limestones and dolomite. In the present report these materials will be taken up in the order named, the detailed discussion of the ores being preceded by a brief description of the general topographic and geologic features of the district.

In the course of this investigation, the geologists employed upon it were assisted in every possible way by representatives of the iron and steel companies of the district as well as by many individual property owners. Maps, analyses, and special data were placed freely at their disposal by the various corporations and individuals connected with these industries. In preparing this report, the writers have attempted to utilize the material thus generously placed at their disposal in such a way as to secure the publication of results of general interest and importance, while at the same time avoiding the disclosure of data which might be properly regarded as of a confidential nature.

GENERAL GEOLOGY.

By CHARLES BUTTS.

TOPOGRAPHY.

The city of Birmingham and its suburbs are built in the valley region of Alabama. This valley region lies between the east side of the Coosa coal field on the southeast and the Warrior coal field on the northwest, and its ridge and valley type of topography is in strong contrast with the irregular, roughly dissected topography of the Warrior and Plateau coal fields. (See Pl. I.)

The major topographic features of the area under discussion are the broad anticlinal valley known as Birmingham Valley; Shades Mountain, which bounds the valley on the east; and Sand Mountain, known farther south as Rock Mountain, which bounds it on the west. Birmingham Valley may be regarded as extending from Springville on the northeast to Big Sandy Creek on the southwest. Its general level is 500 to 600 feet above the sea. Along the northwestern part of the valley is a chert ridge increasing in height and width from south to north. This ridge is known in the vicinity of Bessemer as the Salem Hills, north of Bessemer as Flint Ridge, and in Birmingham as Enon or Cemetery Ridge. North of Birmingham the ridge is not named. The chert ridge lies between two minor valleys, that on the east of the ridge being known as Jones Valley and that on the west as Opossum Valley. Jones Valley may be said to extend from Vance to an indefinite northern end in the vicinity of Chalkville. Opossum Valley extends from west of Salem Hills northward and is continuous with Murphrees Valley north of Village Springs. The median chert ridge of Birmingham Valley increases in height and width northward, and in the region north of Foster Mountain the chert is covered by higher rocks until it passes into the plateau known as Blount Mountain, whose general level is 1,300 feet above the sea. Blount Mountain separates the valley of Canoe Creek on the east from Murphrees Valley on the west.

On the east of Jones Valley runs Red Mountain, with altitudes reaching 1,100 feet, while on the west of Opossum Valley is Sand Mountain, varying in altitude from 700 feet at Birmingham to 900 feet west of Mount Pinson. From Mount Pinson this ridge extends northward as the western boundary of Murphrees Valley and becomes 1,150 feet above the sea at Chepultepec. From Pratt City southwestward beyond Bessemer this ridge is hardly noticeable; it increases in altitude southward from Bessemer and reaches 750 feet southwest of McCalla, where it is known as Rock Mountain.

Along the west side of Opossum and Murphrees valleys from Cunningham Creek northward is a ridge known as West Red Mountain, which corresponds geologically and topographically to Red Mountain on the east side of Jones Valley. Between West Red Mountain and Sand Mountain is a deep narrow valley. Likewise on the east side of Red Mountain is a corresponding valley known as Shades Valley. Shades Valley is bounded on the east by Shades Mountain and Blackjack Ridge, which in turn correspond to Sand Mountain on the west side of Opossum and Murphrees valleys. All these minor valleys—Jones, Opossum, Murphrees, and Shades—are included within Birmingham Valley.

It is of interest to note here that while in respect to the immediately adjacent country Birmingham Valley is really a valley, yet in respect to the main drainage of the region, Black Warrior and Cahaba rivers, it is a watershed, which is drained mainly into Black Warrior River through Blackburn Fork and Gurley, Turkey, Fivemile, Village, Valley, and Big Sandy creeks, all of which flow westward to the Black Warrior.

The most important features of these ridges from the standpoint of commercial geography are the gaps through which communication between Birmingham and the outside world is made easy. Red Gap, between Irondale and Gate City, is the most important, since it is the gateway to Birmingham from the northeast. (See Pl. IV, *A*.) Through it pass the tracks of all four of the railroads entering Birmingham from that direction. It will suffice to mention a number of other gaps traversed by railroads, such as Graces Gap, Readers Gap, and Sparks Gap, through Red Mountain; Stinking Creek, Abes Creek, Brock Gap, and Genery Gap through Shades Mountain; and Sayreton Gap and Boyles Gap through Sand Mountain.

STRATIGRAPHY.

GENERAL STATEMENT.

There is given in this place only an outline of the geology of the Birmingham district. For the areal distribution of formations the reader is referred to the geologic map (Pl. II, pocket). The rocks exposed range from middle Cambrian to Pennsylvanian (upper Carboniferous). The following is a generalized section:

Generalized section of rocks in the Birmingham district, Alabama.

	Feet.
Tertiary: ?Lafayette formation. } Present in extreme southwestern part of district.	
Cretaceous: Tuscaloosa formation. }	
Carboniferous:	
Pennsylvanian: Pottsville formation ("Coal Measures")	2,600–7,000[a]
Unconformity.	
Mississippian:	
Parkwood formation	0–2,000
Pennington shale (30–300 feet). Bangor limestone (670 feet); includes Hartselle sandstone member (100+ feet). } Floyd shale	1,000±
Fort Payne chert	200–250
Unconformity.	
Devonian:	
Chattanooga shale. Frog Mountain sandstone. }	1–25
Unconformity.	
Silurian: Clinton (Rockwood) formation	250–500
Unconformity.	
Ordovician: Chickamauga (Pelham) limestone	200–1,000
Unconformity.	
Cambro-Ordovician: Knox dolomite (includes at base Ketona dolomite member, 600 feet)	3,300
Cambrian:	
Conasauga (Coosa) limestone	1,000+
Rome (Montevallo) formation (great thickness).	
	7,351–16,075

CAMBRIAN AND ORDOVICIAN ROCKS.

In these systems there are included the Rome (Montevallo) formation and the Conasauga (Coosa) limestone, both of known Cambrian age; the overlying Knox dolomite, the lower part of which is regarded as Cambrian and the upper part Ordovician, though the plane of division between the Cambrian and Ordovician is unknown; and the Chickamauga (Pelham) limestone, of known Ordovician age.

CONASAUGA (COOSA) LIMESTONE AND ROME (MONTEVALLO) FORMATION.

The lowest Cambrian rocks exposed in this area are limestone and shale, possibly 1,000 to 1,500 feet thick, so far as can be judged from the width of outcrop in Opossum Valley. These rocks have been designated the Conasauga limestone by the United States Geological Survey, and the Flatwoods or Coosa formation by the Alabama Geological Survey. They consist of thin-bedded blue limestone interbedded with shale, which in some sections, as in the vicinity of Bessemer, carries considerable chert in thin layers. This lime-

[a] This maximum in Cahaba coal field.

stone is underlain by a mass of shale of great thickness, which to the east is known as the Rome formation. Locally it has been called the Montevallo shale. In this report it is called the Rome formation.

KNOX DOLOMITE—KETONA DOLOMITE MEMBER (BASE).

The Knox dolomite includes the rocks between the Conasauga and the Chickamauga (Pelham) limestone. The formation is prevailingly a dolomite with chert. In the Birmingham region and other parts of Alabama the lower part of the formation is almost free from chert, and on account of both this lithologic difference and its economic importance it has been separated out as a member from the mass of the Knox and named the Ketona dolomite member. The name Ketona is chosen because of the extensive quarry in this member at Ketona. The Ketona dolomite overlies the Conasauga (Coosa) limestone with apparent conformity, and is 500 to 600 feet thick along Opossum Valley east of Birmingham. It is a nearly pure dolomite, with but little chert. It is thick bedded, crystalline in texture, and of prevailingly light-gray color. From it is drawn most of the fluxing rock used in the Birmingham furnaces, and it is therefore described further under the heading "Fuel and fluxes" (pp. 194–195).

The rest of the Knox dolomite, 2,700 to 2,800 feet thick, overlies the Ketona dolomite member conformably. It is composed of dolomite with chert layers, which in places reach a thickness of 10 feet or more. Possibly one-fourth of the formation is chert.

CHICKAMAUGA (PELHAM) LIMESTONE.

Overlying the Knox dolomite unconformably is the Chickamauga limestone, of Ordovician age. It is the same as the Trenton or Pelham limestone of the Alabama Geological Survey. In Birmingham Valley this is a thin-bedded bluish to dove-colored limestone ranging generally from 200 to 500 feet thick. It has been used for flux to some extent, and will receive fuller description in the section on fluxes.

SILURIAN ROCKS.

CLINTON (ROCKWOOD) FORMATION.

The Chickamauga (Pelham) limestone is succeeded unconformably by the Clinton formation. The Clinton is one of the important formations, since it carries the red ores of the region. It is of Silurian age, and is nearly the equivalent of the Clinton formation of New York. It is 200 to 500 feet thick and is composed of shale and sandstone in greatly varying proportions. There are present everywhere one or more iron-ore beds of greater or less importance. The thickness and position of these beds vary greatly from place to place, and it is doubtful whether the different beds can be identified and correctly correlated through any great distance. Detailed descriptions of the formation at different points, illustrated by sections, will be found under the heading "Geologic relations and development" (pp. 39–54), and to those descriptions the reader is referred for more complete information.

DEVONIAN ROCKS.

CHATTANOOGA SHALE AND FROG MOUNTAIN SANDSTONE.

The whole Devonian system, many thousand feet thick in the northern Appalachians, is in this region represented by a few feet of black shale, the Chattanooga shale, and in places by a bed of sandstone up to 20 feet thick, underlying the horizon of the shale. The sandstone is pretty surely of Oriskany age, since from a thin layer of quartzite at its horizon in Clear Branch Gap, southwest of Bessemer, and from other places Oriskany fossils were obtained. This sandstone is especially well developed north of Trussville, where it carries phosphate nodules. It occurs at the same horizon as the Frog Mountain sandstone of the Rome district, and in all respects corresponds to that sandstone, although not now continuous with it on account of structural breaks. Because of its stratigraphic position and lithologic similarity it will be called Frog Mountain sandstone in this report. The Devonian rocks in the vicinity of Birmingham are well exposed in Lone Pine Gap, Walker Gap, and Graces Gap, where there are complete exposures from the upper part of the Clinton formation to the bottom of the Fort Payne chert.

MISSISSIPPIAN (LOWER CARBONIFEROUS) ROCKS.

GENERAL STATEMENT.

Overlying the Devonian black shale unconformably are rocks of Mississippian or lower Carboniferous age. At the base of the Mississippian rocks, throughout the whole region, is the Fort Payne chert; this is succeeded in Brown and Murphrees valleys by the Bangor limestone, with the included Hartselle sandstone member, and by an overlying shale which is correlated on stratigraphic and lithologic grounds with the Pennington shale to the north. At the southern end and along the east side of Blount Mountain, and along the east side of Shades Valley, the Pennington shale is overlain by shales and sandstones to which the name Parkwood formation is here given (p. 20). South of Boyles Gap in Opossum Valley and south of Oxmoor in Shades Valley the Bangor limestone runs out and is replaced by black and gray shales similar to the Floyd shale to the northeast. Because of its stratigraphic position and lithologic similarity this shale will be called Floyd shale in this report. South of Boyles Gap and Oxmoor, therefore, the Mississippian rocks above the Fort Payne chert consist of the Floyd shale (including the Hartselle sandstone, which persists after the thinning out of the Bangor limestone and thus locally becomes a member of the Floyd shale) and the Parkwood formation above the Floyd. The Floyd shale is thus the equivalent of the Bangor limestone and the Pennington shale (Pl. III). In reports of the Alabama Geological Survey the Floyd shale and the rocks comprising the Parkwood formation have been treated together as the "Oxmoor or shale and sandstone phase" of the upper part of the lower Carboniferous rocks, and the Bangor limestone has been called the "Bangor or limestone phase" of the same rocks, the two phases being regarded as contemporaneous.[a]

As a result of the writer's study of the geology of the region, however, the conclusion has been reached that only the Floyd shale and the rocks included by the Alabama Survey in the "Bangor or limestone phase" are contemporaneous. The Parkwood formation of Shades Valley and Blount Mountain is absent from the section in Murphrees and Brown valleys, having been eroded west of Birmingham Valley before the deposition of the Pottsville or "Coal Measures," so that they rest unconformably on the Pennington shale.

The variations in the stratigraphy of the Mississippian formations above the Fort Payne chert are shown in the sections below:

Section of Mississippian rocks above the Fort Payne chert in Brown and Murphrees valleys.

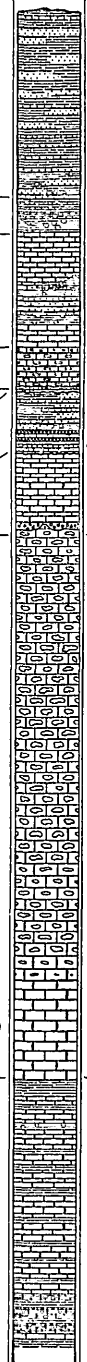
	Feet.
Pottsville formation.	
Pennington shale	100
Bangor limestone:	
Limestone	350
Shale	30
Sandstone (Hartselle member)	100
Shale	50
Limestone	160
Fort Payne chert.	
	790

Section of Mississippian rocks above the Fort Payne chert near Irondale.

	Feet.
Pottsville formation.	
Parkwood formation, shale and sandstone	2, 000
Pennington shale, dark, calcareous (?)	292
Bangor limestone:	
Limestone	317
Shale, soft, dark, calcareous (?)	39
Sandstone (Hartselle member)	117
Shale, dark, calcareous (?)	97
Limestone	88
Fort Payne chert.	
	2, 950

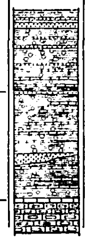
Still farther south, in the vicinity of Readers Gap, borings show only dark shale, probably calcareous, in the 500 feet immediately over

[a] McCalley, Henry, Report on the valley regions, p. 53; and Geological atlas of Alabama.

System.	Formation.	Symbol.	Section.	Thickness (feet).	General Character.
Carboniferous (Mississippian series).	Parkwood formation	Cpw		Knife-edge to 2,000	Prevailingly gray shale and sandstone; no calcareous beds. Fossils very scarce.
	Pennington shale	Cpsh		60 to 300	Gray, green, and red shale, with a little chert and some sandstone and conglomerate. Highly fossiliferous.
	Bangor limestone (Hartselle sandstone member)	Cbl (Chs)		700 (100)	Prevailingly thick-bedded, light-gray crystalline limestone. Hartselle sandstone member and shale in midst. Merges through sparingly cherty limestone into Fort Payne chert below. Highly fossiliferous. (Prevailingly fine-grained firm sandstone, locally coarse and friable.)
	Fort Payne chert	Cfp		200	Mostly thin-bedded chert; locally thick bedded at bottom. Generally fragile. Fossiliferous.
	Unconformity				
Devonian.	Chattanooga shale and Frog Mountain sandstone.	Dc & Do		250 to 500	Black carbonaceous shale, locally sandstone below, with phosphate nodules and fossils.
	Unconformity				
Silurian.	Clinton (Rockwood) formation Iron ore (Big and Irondale seams).	Sc			Gray and yellow shale, green, brown, and red, highly ferruginous sandstone with beds of limy iron ore.
	Unconformity				
Ordovician.	Chickamauga (Pelham) limestone	Oc		300 to 500	Thick to thin-bedded, dove-colored to blue limestone.
	Unconformity				
Cambro-Ordovician.	Knox dolomite	€Ok		3,300	Thick-bedded crystalline dolomite, with chert in nodules and stringers included in the dolomite layers, or in beds between the dolomite layers.
	(Ketona dolomite member—base)	(€Oke)		(600)	(Thick-bedded noncherty gray crystalline dolomite; much used for flux.)
Cambrian.	Conasauga (Coosa) limestone	Cc		1,000+	Prevailingly thin-bedded blue limestone, interbedded with gray or yellow shale.

0 500 1000 Feet

A.

Formation.	Symbol.	Section.	Thickness (feet).	General Character.
Parkwood formation	Cp		1,500 to 2,000	Same description as in *A*.
Floyd shale	Cfsh		1,000	Gray, dark, and black shale, calcareous at horizons. Contains beds of sandstone and lenses of limestone. Highly fossiliferous throughout. Equivalent to the Bangor and Pennington formations. Hartselle sandstone member.
Fort Payne chert	Cfp		200±	

B.

SECTIONS OF ROCKS BELOW THE COAL MEASURES.

A. In Murphrees and northern part of Birmingham valleys. *B.* In southern part of Birmingham and Shades valleys; section below Floyd shale is same as in *A* the Fort Payne chert. The well logs are corroborated in the main by all that can be seen of the formation. South of Boyles Gap and Oxmoor good sections and accurate measurements of the rocks under discussion are not obtainable. A compiled section for the region south of Oxmoor, probably a close approximation, is as follows:

	Feet.
Pottsville formation.	
Parkwood formation, shale and sandstone	2,000
Floyd shale:	
Shale, some calcareous, sandstone, and limestone lenses	700
Sandstone (Hartselle member)	100
Shale, dark, calcareous	200
Fort Payne chert.	
	3,000

FORT PAYNE CHERT.

The Fort Payne chert lies unconformably upon the Chattanooga shale. The name is taken from the town of Fort Payne, in De Kalb County, where the formation is well developed.

The formation is made up of chert layers from a few inches to 2 feet in thickness, generally separated by thin partings of shale. Some of the layers are very even surfaced, especially the thicker ones, but generally the layers are very rough and uneven surfaced. The chert is generally of a yellowish color, though much-weathered pieces are commonly whitish, with small red blotches. It is very brittle and breaks easily. It is so much fractured in places that it can be blasted out to a depth of 100 feet in a condition to be used for road surfacing without further preparation other than a few blows of a sledge for the larger pieces. The thickness of the formation ranges from 125 to 200 feet and possibly a little more in some sections. About 140 feet is exposed in Dale Gap. At Blount Springs the thickness appears to be 250 feet. Well borings in Shades Valley show 125 to 200 feet of chert and limestone in the formation.

BANGOR LIMESTONE.

The Bangor limestone takes its name from the town of Bangor, Ala. As shown in the sections (pp. 189, 191) it is lithologically composite, being made up of limestone, sandstone, and shale, the limestone predominating.

Limestone and shale.—The limestone is thick bedded and mostly crystalline, but oolitic layers occur. It is generally light gray in color. Most of the limestone is of a high degree of purity, as shown by the analyses (pp. 190, 191). Limestone both from above and below the Hartselle sandstone member has been used for flux. Some shale and clay occur within the limestone; a bed of red shale 10 feet thick is near the top, and a bed of gray shale and clay 3 feet thick lies 100 feet below the top in the quarry at Dale. Running through the limestone is a persistent sandstone (Hartselle), next to be described. The sandstone is accompanied both above and below by persistent beds of dark or black fossiliferous shale. These shale beds, as well as the sandstone member, are well displayed in Red Gap at Gate City. The Bangor grades below, through slightly cherty limestone, into the Fort Payne chert. A little chert occurs in places in the limestone above the Hartselle sandstone member.

The limestone of the Bangor is known to extend south along the west side of Birmingham Valley to Boyles Gap, and along Shades Valley to Graces Gap. At Boyles Gap the limestone is 50 to 100 feet thick, but at Sayreton Gap, 2 miles southwest of Boyles Gap, hardly a trace of it can be seen. It is completely replaced by the shale here called Floyd shale, which persists southward to Big Sandy Creek, with the Hartselle sandstone member running through it. At Graces Gap, in Shades Valley, there is known to be a considerable thickness of limestone, but in the vicinity of Readers Gap only shale, possibly with thin limestone layers, occurs in the 500 feet above the Fort Payne chert. The Bangor limestone thus passes laterally completely into the Floyd shale between Graces Gap and, say, Readers Gap. This passage is expressed on the geologic map by the merging, in Shades Valley west of Bessemer, of the patterns by which the areas of the two formations are represented.

Hartselle sandstone member.—About 200 feet above the bottom of the Bangor limestone is the Hartselle sandstone member, 100 feet thick. This sandstone varies from fine grained and hard to coarse grained and friable. The latter phase is well exhibited in Red Gap, where the rock is utilized for sand, being so soft as to pulverize in the hand.

The Hartselle sandstone is one of the most persistent divisions in the region, being present in Blount Valley, Murphrees Valley, and along the west side of Birmingham Valley to Readers Gap, and perhaps farther south. It forms the sharp ridge back of the hotel at Blount Springs, and that making Little Sand Mountain, southwest of Trussville. This name replaces "Oxmoor" sandstone, as used in northeastern Alabama.

PENNINGTON SHALE.

The name Pennington is here applied to the shale which in Brown and Murphrees valleys intervenes between the Bangor limestone and the "Coal Measures," and in Shades Valley between the Bangor limestone and the base of the Parkwood formation. The name is from Pennington Gap in Virginia. This shale has been mapped from the type locality in Virginia to a point west of Knoxville, Tenn., and is known to occur at numerous points between that locality and the Birmingham district. On stratigraphic and lithologic grounds, therefore, this shale in the Birmingham district is correlated with the Pennington shale.

In Brown and Murphrees valleys the Pennington is mainly gray shale 50 to 100 feet thick, but there are layers of red and green shales and a little chert locally. In Shades Valley it contains dark or black and gray shale, a little chert, pink shaly sandstone, and one layer at least of fine conglomerate, in all about 300 feet thick.

In Shades Valley the top of the Pennington is at the base of the heavy sandstone making Little Shades Mountain and Bald Ridge west of Oxmoor and at the base of the ridges bounding the valley on the east from Irondale to Trussville and beyond. The part of the Bangor limestone above the Hartselle sandstone, together with the Pennington shale, thus practically coincides with the flat land of Shades Valley north of Oxmoor, as the Floyd shale does south of that place. The Pennington passes into the Floyd with the Bangor limestone.

FLOYD SHALE.

This name Floyd was introduced by Hayes for a mass of black shale in Floyd County, Ga. This shale corresponds in character, and apparently in stratigraphic position, to the dark and black shale in the southern part of Birmingham Valley, into which the Bangor limestone and Pennington shale pass, as described above. The name Floyd is therefore used for the corresponding shale of this region.

The Floyd shale outcrops along the west side of Birmingham Valley from Sayreton Gap to Big Sandy Creek, with the Hartselle sandstone persisting as a member, with the same characters it possesses in the Bangor limestone, as described above. The Floyd likewise extends along Shades Valley and the west side of the Cahaba coal field from west of Bessemer to Schultze Creek, where all the Paleozoic rocks pass beneath the Cretaceous cover. Only the Floyd occurs in Little Cahaba Valley east of Leeds, no Bangor or Pennington being present there.

The Floyd is composed chiefly of shale. It includes a little fine-grained sandstone, at one horizon a thin fine conglomerate, and at many points and horizons thin limestones. Pink sandy shale, gray shale, and dark to black shale occur. The dark shale is largely calcareous, and the black shale probably somewhat carbonaceous. The shale is highly fossiliferous, and the fossils persist up to the bottom of a hard, siliceous, blocky sandstone that was traced continuously from Bald Ridge south to a point west of Bluff Ridge Church. Above the base of the sandstone the rocks are markedly different, mostly siliceous, entirely noncalcareous, and nearly nonfossiliferous. The top of the Floyd is placed, therefore, at the base of the above-described sandstone. The Hartselle appears to be absent from the Floyd south of Readers Gap.

The thickness of the Floyd is not well determined, but can not be less than 1,000 feet, since its equivalent Bangor and Pennington are nearly 1,000 feet thick at Irondale, as shown by a bore hole.

PARKWOOD FORMATION.

As already mentioned, in Shades Valley and along the south end and east side of Blount Mountain are shales and sandstones, varying in thickness from 200 or 300 feet on the east side of Blount Mountain to 2,000 feet on the east side of Shades Valley, which have been included by the Alabama Geological Survey in "Oxmoor or shale and sandstone phase, contemporaneous, of the upper part of the lower Carboniferous."[a]

The shales and sandstones here considered have no representatives in Birmingham, Murphrees, and Brown valleys above the Bangor, and, in the writer's judgment, should be treated as a distinct formation, and they are so treated here. The reasons for this treatment will be fully stated in the Birmingham folio, soon to appear. To these rocks the name Parkwood formation is here applied, from the town located near the middle of the outcrop of the formation in Shades Valley. The Parkwood formation is defined as including the 1,500 to 2,000 feet of shale and sandstone lying above the bottom of the heavy sandstone making Little Shades Mountain and Bald Ridge one-half mile west of Oxmoor, and beneath the Brock coal bed near the crest of Shades Mountain.

The Parkwood formation is composed entirely of shale and sandstone very similar to the "Coal Measure" rocks. It differs from the Bangor, Pennington, and Floyd in being entirely without calcareous matter and destitute of fossils. Shale predominates in the formation. It is generally gray or greenish, and sandy. Sandstone strata up to 100 feet thick occur and are generally made up of layers that are thin or of medium thickness. Most of the sandstone is fine grained, but some beds of coarse, highly siliceous sandstone occur.

The name "Oxmoor" would be quite suitable for these rocks, since that town is located near the center of their outcrop in Shades Valley, but as the name has been used in two different senses already its adoption would lead to further confusion.

PENNSYLVANIAN ROCKS.

POTTSVILLE FORMATION ("COAL MEASURES").

Unconformably overlying the Parkwood formation are the coal-bearing or Pennsylvanian rocks, of Pottsville age. Along the southeast margin of the Warrior field is a stratum of sandstone 100 to 600 feet thick, making Sand Mountain from Birmingham northward,

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[a] McCalley, Henry, Report on the valley regions of Alabama, pt. 2, 1897, p. 53; and Geological atlas of Alabama.

and Rock Mountain from Valley Creek southward. Along the northwest margin of the Cahaba field a sandstone of similar character, perhaps identical with this, makes the ridge known as Shades Mountain or Black Jack Ridge. This sandstone is the Millstone grit of the Alabama Geological Survey. It is a coarse, siliceous, conglomeratic sandstone below, grading into a fine-grained, more thin-bedded sandstone above.

The remaining Pottsville rocks are shale and sandstone with coal beds. In the Warrior field these rocks are about 2,600 feet thick, while in the Cahaba and Coosa fields they are much thicker. In the Warrior field the position of the important coal beds is as follows:

Six hundred to 800 feet above the basal sandstone described above is the Black Creek coal bed, with the Jefferson bed close above. Three hundred to 400 feet above the Black Creek coal is the Mary Lee coal; 500 to 700 feet above the Mary Lee coal is the Pratt coal; and about 800 feet above the Pratt coal is the Brookwood coal. Close below each of the last three coal beds named are other coal beds, constituting respectively the Mary Lee, Pratt, and Brookwood groups of coal, the relations of which appear in the sections in Plate XV. The important coking-coal beds are elsewhere described in more detail, pages 170–174.

STRUCTURE.

BIRMINGHAM VALLEY.

General relations.—The geologic structure of Birmingham Valley is in general anticlinal, with a comparatively shallow syncline extending along the middle. On the southeast the rocks of Shades Mountain and Blackjack Ridge dip uniformly about 15° SE. into the Cahaba coal field. The rocks of Sand Mountain, on the west side of Murphrees Valley, dip 15° NW. as far south as Village Springs; thence southward the dip increases, becoming vertical at Cunningham Gap; thence to Dolomite the rocks are generally overturned, with a dip of 50° to 70° SE. The overturned rocks are finely exposed in Sayreton and Boyles gaps. Southwest of McCalla the rocks of Rock Mountain dip normally northwest at high angles.

Passing northwest through Birmingham, across Birmingham Valley from Shades Mountain to Sand Mountain, southeast dips prevail to the middle of Jones Valley or a little farther, then the dip is reversed and becomes northwest as Enon Ridge is approached. On the west side of Enon Ridge the dip is again southeast, and southeast dips prevail across Opossum Valley to Sand Mountain. The main structure is thus shown to be anticlinal, with a low syncline along the median line of the anticline, marked by the chert ridges from Salem Hills northward. This median syncline becomes deeper northward and in Blount Mountain carries the whole series of formations up to the Carboniferous.

Faults.—The simple structure outlined above is complicated by faults. One of these extends along the east side of Enon and Flint ridges from Birmingham to Hawkins Spring, about 3½ miles northeast of Bessemer. Along this fault the Cambrian limestone is thrust up to the northwest into contact with the Knox dolomite, cutting out the outcrop of the Ketona dolomite member, as shown on the map (Pl. II). On the west side of Opossum Valley an overthrust fault cutting out the west limb of the anticline extends from Mount Pinson to Vance. Along this fault the Cambrian rocks are thrust up into contact successively with all the higher formations until in the vicinity of Wylam they are in contact with Carboniferous rocks. Along this fault from Thomas southward compound faulting occurs with the formation of small fault blocks containing the Clinton and other formations, as shown in figure 2. About 2 miles southwest of Dolomite this fault divides, one fork running eastward and probably passing into the anticline that in the vicinity of Adger and Johns separates the little basin from the big basin in the Warrior coal field, the other running to the south and continuing to Vance. A minor fault runs along the west base of McAshan Mountain, the Clinton (Rockwood) formation being dropped down into contact with Knox dolomite on the west. Southwest of Vance another fault drops the Fort Payne chert down

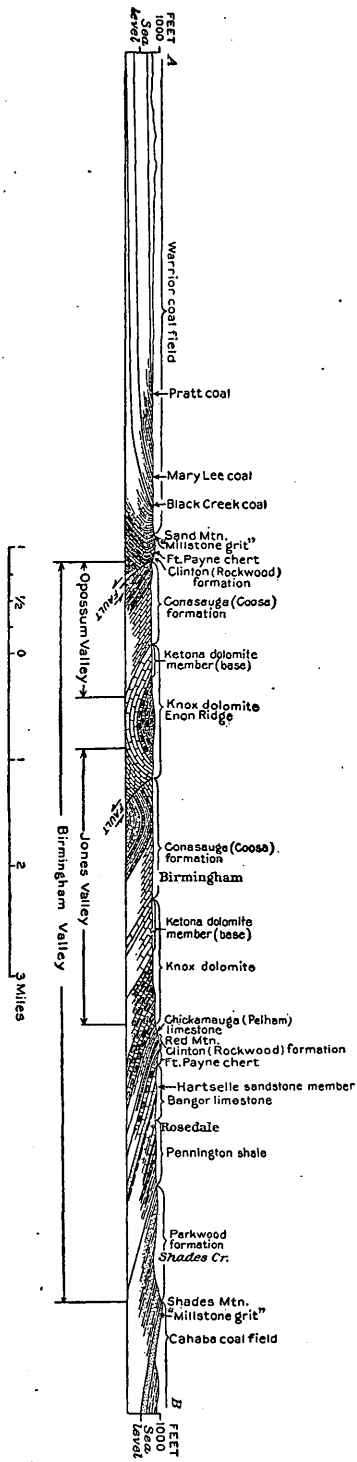


FIGURE 1.—Geologic structure section across valley at Birmingham (on line A-B, Pl. II).

into contact with Chickamauga limestone on the east. (See map, Pl. II, and section, fig. 10.) The structure southwest of this region is very complicated and is rather fully outlined on pages 105–106, so further description will not be given here.

On the east side of Murphrees Valley is another great strike fault which, unlike those just described, brings younger rocks on the east into contact with older rocks on the west.

Besides the strike faults thus described there are a number of minor cross faults which are probably normal and which offset the outcrop of the formations which they cut. Conspicuous examples of these are the faults shown on the geologic map (Pl. II) at the south

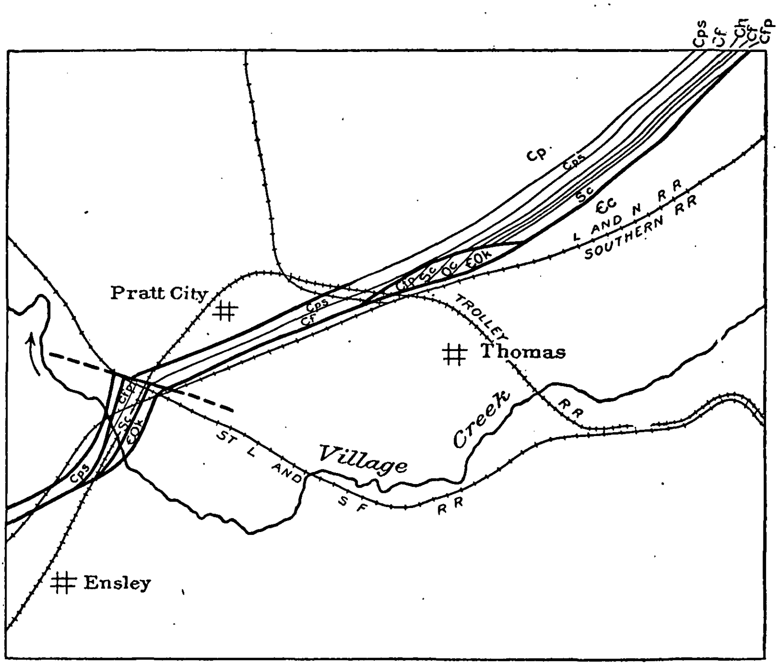


FIGURE 2.—Sketch map showing faulted areas of Clinton and other formations in the vicinity of Pratt City, Ala. Sc, Clinton (Rockwood) formation; Oc, Chickamauga (Pelham) limestone; ƐOk, Knox dolomite; Ɛc, Conasauga limestone; Cp, Pottsville formation ("Coal Measures"); Cps, basal Pottsville sandstone; Cf, Floyd shale; Ch, Hartselle sandstone member; Cfp, Fort Payne chert.

end of Blount Mountain, the one at Mount Pinson, and the one at Red Gap between Gate City and Irondale.

SHADES VALLEY.

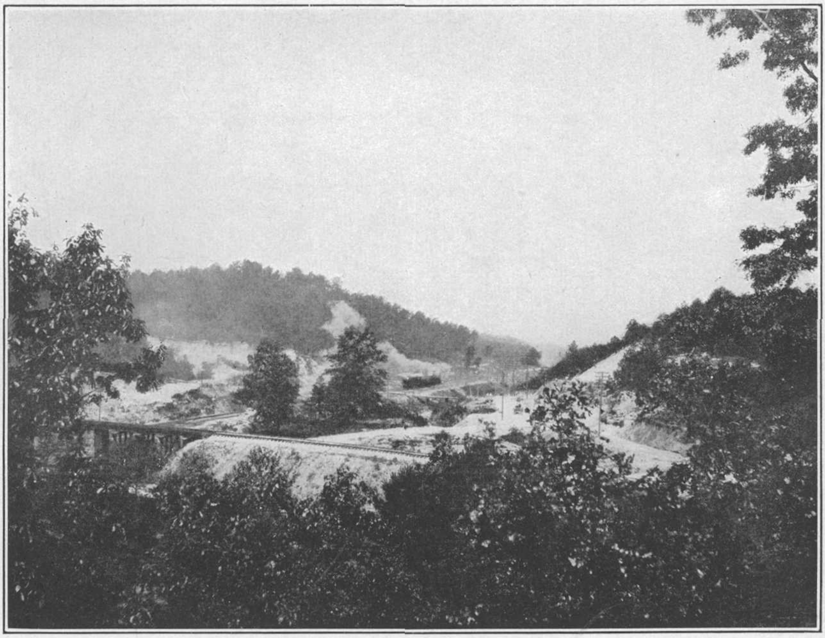
The geologic structure of Shades Valley is a matter of importance on account of its bearing on the depth and condition of the red-ore beds that underlie the valley. In the structure section (fig. 1) the rocks of Red Mountain and Shades Valley are represented as dipping regularly southeast at an angle of 15°. The drawing is warranted by the dip of the rocks on both sides of the valley as well as by the dip at many points in the valley itself. Since, however, a dip of 15°

would give a depth of 1,500 feet to the Clinton formation and a thickness of 1,200 feet for the Bangor limestone and Pennington shale on the east side of Shades Valley, doubt is cast upon the correctness of the assumed average dip. Near the east side of Shades Valley, Clinton ore is reported at 1,200 feet.

Considerable structural irregularity is thus indicated, and this conclusion drawn from the plotting of the section is confirmed by observation in the field, though on account of lack of exposures only a very meager knowledge of the structure has been obtained. On Shades Creek, 8 miles south of Bessemer, dips of 20° to 25° NW. were observed, and showed the presence of two folds at least which interrupt the general southeast dip. One of these anticlines undoubtedly extends up Shades Creek to the Southern Railroad, where a bore hole reached a red-ore bed at less than 200 feet below the surface. A considerable expanse of coarse-grained, light-gray limestone which lies along Shades Creek in this region looks like the limestone between the Fort Payne chert and Hartselle sandstone; if it is such it shows the existence of an anticline by which it is brought to the surface. Fort Payne chert is exposed along the Southern Railroad near Canaan Church. Exposures are fairly good in Shades Valley from the latitude of Readers Gap south, and the rocks can be seen to lie nearly flat over wide areas, a fact that is indicated by the wide area of the Floyd shale in that region. Just north of Readers Gap there are evidences of minute puckerings of the strata. A short distance south of Halls Spring the Hartselle sandstone is folded into a small U-shaped syncline, and near by is a narrow outcrop of vertical rock. On the Louisville and Nashville Railroad, about one-half mile south of Graces Station, a sharp overturned fold is exposed in a cut (Pl. IV, *B*). At a number of points very steep southeast dips were observed.

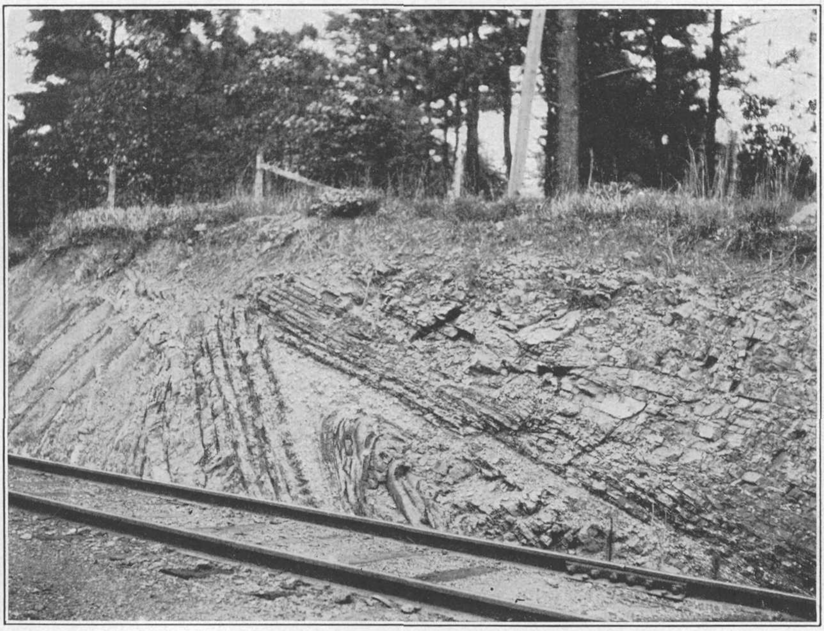
Besides the features mentioned above, a number of faults, of greater or less magnitude, and a good many flexures have been encountered in the various ore mines of the region. The facts cited go to show that the structure of Shades Valley is irregular, though it is impossible, owing to the general concealment of the strata, to give any detailed account of the number and magnitude of the irregularities. There may be many small irregularities or a few great ones, or there may be both, the last being the most probable supposition.

In planning future operations beneath Shades Valley, the importance of taking into consideration the certainty of some structural irregularities, and the possibility of other and perhaps greater ones, and their effect upon the expense of ore mining, will be apparent from the foregoing description.



A. RED GAP AT GATE CITY, ALA.

Looking eastward toward Birmingham.



B. ANTICLINE OVERTURNED TO NORTHWEST.

Louisville and Nashville Railroad, one-half mile south of Graces Gap.

WARRIOR COAL FIELD.

Along the southeast margin of the Warrior coal field the rocks dip steeply to the northwest on their outcrop, but the dip gradually diminishes to the northwest, and about one-half mile from the outcrop the rocks become practically horizontal. The dip on the outcrop varies from 15° to verticality. The rocks in the interior of the field are not absolutely flat, but are slightly folded into broad anticlines and synclines, and in general dip slightly southwest. These slight structural irregularities, however, present no obstacles to coal mining. The rocks of the basin are broken by faults trending northwest and southeast, in a direction nearly perpendicular to the margin of the field. A number of these faults have been encountered in mining west of Birmingham; others are known south of Brookwood, and it is likely that they exist all along the southeast margin of the field. The throw of these faults varies, the greatest being probably less than 200 feet. The fault planes are nearly vertical. Some of these faults scarcely exceed 1 mile in length, others may reach 5 miles or more. In some places mining operations have extended around one or both ends of a fault, and they are thus shown to begin with a slight throw, which increases to a maximum, then diminishes until the fault disappears at the opposite end. Probably they are all of this character. The faults do not damage the coal, which can be mined out right up to the fault plane, though of course they interfere considerably with coal mining and make it more expensive.

CLINTON ORE.

CHARACTER.

By Ernest F. Burchard.

MINERALOGY.

The Clinton iron ore, so named from its typical occurrence in sedimentary rocks at Clinton, N. Y., and in strata of equivalent age in other parts of North America, belongs to the class of iron oxides known as red hematite. (See Pl. V.) It includes the structural varieties known as red fossil and oolitic ore. The mass of the ore is amorphous red hematite mixed with calcium carbonate, silica, alumina, magnesium carbonate, and other minerals in minor quantities.

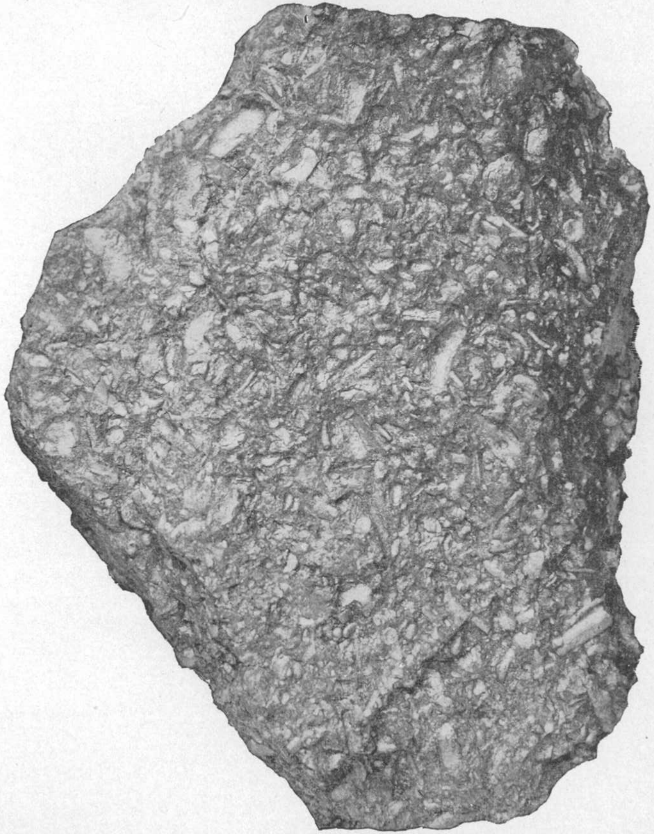
STRUCTURE.

The structure and mineralogy of the Clinton ore are closely related features of the deposits. The ore with its associated minerals occurs in lenticular beds analogous to strata of sandstone, shale, and limestone, and interbedded with such rocks.

The fossil ore consists of aggregates of fossil organic forms such as bryozoans, crinoids, corals, and brachiopods. (See Pls. V, *B*, and VI, *A*.) These forms were evidently at one time principally calcium carbonate, and they have been replaced partly or wholly by ferric oxide. The fossil material, much of which consists of broken and waterworn fragments, evidently was gathered by the action of waves and currents into beds, and subsequently cemented together by calcium carbonate and ferric oxide. More or less clay material has been likewise included in the beds during their formation, and this commonly exists as thin seams of shale.

The oolitic ore consists of aggregates of flat grains with rounded edges, somewhat of the size and shape of flaxseeds. (See Pls. V, *A*, and VI, *B*.) These grains generally lie with their flatter sides parallel to the bedding planes of the rock, and the mass is cemented by ferric oxide and more or less calcium carbonate. The flat grains have a nucleus of quartz, generally very minute, about which successive layers of iron oxide, and, in many instances, very thin layers of silica and aluminous material have been deposited. One of the two varieties of ore generally predominates in a bed, but in certain localities the fossil and oolitic materials are mixed in nearly equal proportions. The fossil ore, where unweathered, as compared with the oolitic ore

A. OOLITIC ORE.



B. FOSSIL ORE.

SAMPLES OF CLINTON ORE FROM CLINTON, N. Y.

in the same condition, is apt to be the more calcareous, while the oolitic ore may carry higher proportions of silica and alumina.

A characteristic of the Clinton ore that is secondary rather than original is that where weathered or acted upon by surface waters the lime carbonate is dissolved out of the beds, thereby increasing the content of iron oxide, silica, and other constituents proportionately. Such altered ore is popularly termed "soft ore," and appropriately, too, for where altered it is usually porous and friable as compared with the unaltered material, which is termed "hard ore." The alteration of the ore beds takes place along the outcrop and to distances of a few feet to 400 feet, depending on the attitude of the beds and on the thickness and permeability of their cover. The quantity of the soft ore is small as compared to that of the hard ore, and owing to its higher content of iron and its greater accessibility much of the soft ore has already been taken in mining, so that in the future the reserves of this variety of ore will steadily decrease in importance.

CHEMICAL COMPOSITION.

Conditions of blast-furnace practice define the grade of material that may be regarded as an ore. For instance, a lower limit of metallic iron and a higher limit of impurities may be allowed in a limy ore than in one that contains but little lime. In localities where brown iron ores are available for mixing with Clinton ores, an ore of the Clinton class can be used as a flux in many instances, although it runs so low in iron and so high in lime that it might not be regarded as acceptable in districts where no brown ore can be used. In general, the hard and semihard ores used to-day in the Birmingham district range in percentages of major constituents as follows: Metallic iron, from 32 to 45 per cent; lime oxide, from 5 to 20 per cent; silica, from 2 to 25 per cent; alumina, from 2 to 5 per cent; magnesia, from 1 to 3 per cent; phosphorus, from 0.25 to 1.5 per cent; sulphur, from a trace up to 0.5 per cent; and water, from 0.5 to 3 per cent. The ore is therefore of non-Bessemer grade. Small quantities of manganese are found in the ore in places. The content of this mineral seldom exceeds 0.25 per cent. In the soft ore the lime generally runs less than 1 per cent, so that the percentages of the other constituents are proportionately higher.

SPECIFIC GRAVITY.

The Clinton ore exhibits rather wide variation in specific gravity due (a) to variations in composition, and (b) to variations in structure. By experiments with 1-inch cubes and lumps of ore the specific gravities of certain southern Appalachian Clinton ores have been found to range from 2.93 to 3.56. The above figures correspond roughly to weights of from 183 to 225 pounds per cubic foot, and to volumes of 12.25 to 10 cubic feet per long ton.

ORIGIN.

By Edwin C. Eckel.

OPPOSING THEORIES.

GENERAL STATEMENT.

For many years the origin of the oolitic and fossil ores which occur in rocks of Clinton age has been much discussed. Disregarding minor points of difference it may be said that the various theories which have been advanced to account for the origin of these ores can be reduced to three. These three opposing theories are, briefly stated, as follows:

1. *Original deposition:* The ores were formed at the same time as the rocks which inclose them, having been deposited in a sea or basin along with the limestones, sandstones, and shales which now accompany them.
2. *Residual enrichment:* The ore beds are merely the weathered outcrops of slightly ferriferous limestones, the lime having been leached out above water level, leaving the insoluble portion of the limestone in a concentrated form.
3. *Replacement:* The ores are of much later origin than their inclosing rocks, having been formed by the replacement of original beds of limestones by iron brought in by percolating waters.

PRACTICAL IMPORTANCE OF THE QUESTION.

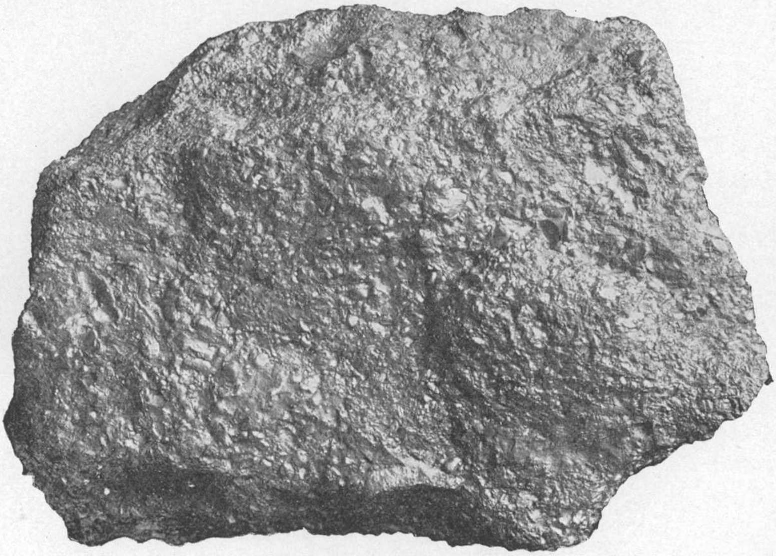
In addition to the questions of purely geologic interest which are connected with the differences of opinion as to the origin of the Clinton ores, the matter has a decidedly practical bearing on the working of the ores. This phase of the subject may be stated as follows:

If the ore deposits are due to the replacement or surface decay of a limestone, they can be expected to decrease rapidly in value with depth, becoming lower in iron and higher in lime, until at no great depth the bed will consist entirely of unaltered limestone.

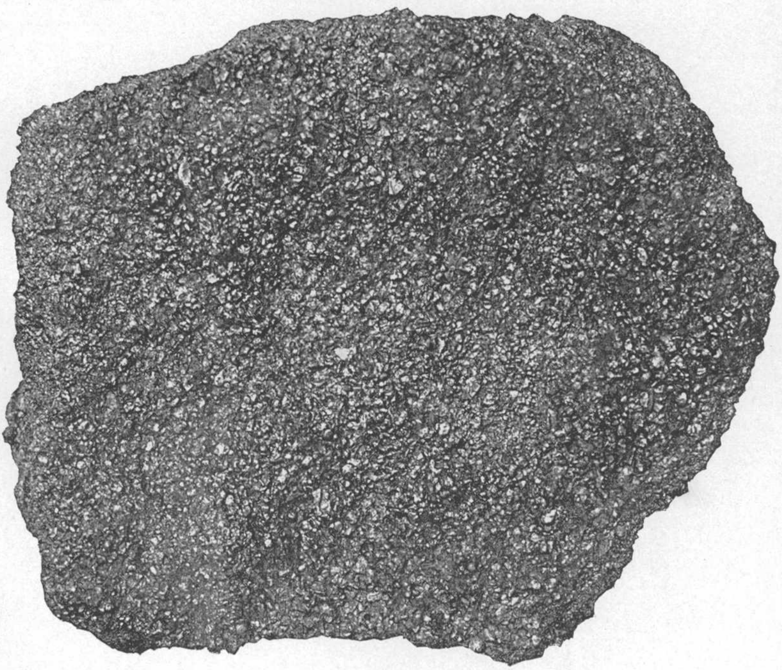
If, on the contrary, the ore deposits are original, no such regular decrease in richness is to be expected as the mines are driven deeper. Patches of low-grade ore may be struck, but these will be due to original differences in the richness of the ore, and a slope might pass downward through such a patch of lean ore into another area of high-grade ore.

ERRONEOUS STATEMENTS REGARDING ALABAMA ORES.

Pumpelly, as well as a few earlier observers, accepted the secondary origin of the Clinton ores on purely theoretical grounds. This left the matter open for discussion, and Smyth's views favoring a depositional origin would probably have gained ready acceptance if two



A. FOSSIL ORE.



B. OOLITIC ORE.

SAMPLES OF CLINTON ORE FROM BIRMINGHAM, ALA.

errors, one of observation and one of interpretation, had not been introduced at this stage into the literature of the subject.

The errors noted were derived from statements in papers by J. B. Porter and I. C. Russell, respectively.

In 1887 Porter made a statement which has often been erroneously adduced in support of the "residual" hypothesis and which may have been the direct cause of Russell's error. The statement[a] is as follows:

An interesting confirmation of the theory that lime increases in the red ore as it is mined downward is given by one of the ore properties of the Sloss Furnace Company, near Birmingham, as shown in the accompanying table. * * * At the time of the analysis the mine was 130 feet deep on the ore, and the following figures give the percentage of carbonate of lime for each 10 feet descent:

Surface	Trace.	70 feet below surface	25.61
10 feet below surface	Trace.	80 feet below surface	29.92
20 feet below surface	Trace.	90 feet below surface	29.89
30 feet below surface	Trace.	100 feet below surface	23.37
40 feet below surface	21.06	110 feet below surface	28.82
50 feet below surface	23.90	120 feet below surface	21.32
60 feet below surface	37.01	130 feet below surface	30.55

With our present knowledge of the Birmingham ores we can readily see that all this table shows is the usual rather abrupt change from soft to hard ore, occurring here at a point 40 feet below the surface—a change to be expected and in no way connected with the theoretical deeper change from iron ore to limestone. It might further be pointed out that analyses which involve such relations as 37.01 per cent of lime carbonate at 60 feet and 21.32 per cent at 120 feet could hardly be looked on as showing any gradual change of iron ore into limestone in depth. But that is just what these analyses are usually quoted for, and usually misquoted so as to read "lime" in place of the "lime carbonate" specified by Porter.

Porter's statement was promptly used in a way he had not intended, and to this misinterpretation was added a very curious error of observation, which at this date is hardly comprehensible. Russell, discussing the general question of rock decay, made the following statement[b] which unfortunately has become classic:

Portions of the Silurian rocks of Alabama, readily recognized as limestones when unweathered, are easily mistaken for sandstone and shales when only their weathered outcrops can be seen. The Clinton ore, or "fossil ore," interbedded with strata of shale and sandstone, forms one of the most characteristic beds in the Upper Silurian rocks of Tennessee and Alabama. In the mines of Gadsden and of Attalla, Ala., where Clinton ore is worked, the strata are highly inclined (a dip of 70° to 80° to the southeast prevailing) and well exposed for study. The outcrops of the beds are of soft, porous, highly fossiliferous ore, which has a deep brownish red color, and is easily worked and easily smelted. The ore at Attalla retains this character to the depth of about 250 feet, measured down the slope, and then changes to a hard, compact, ferru-

[a] Trans. Am. Inst. Min. Eng., vol. 15, p. 189.

[b] Bull. U. S. Geological Survey, No. 52, 1889, pp. 22, 23.

ginous limestone, rich in fossils. (A similar change in fossil ore has been noted by T. H. Dewees, in Pennsylvania; Second Geol. Survey Pennsylvania, Report F, 1878, p. xlvi.) The marked difference in the character of the ore in the upper portions of the mines as compared with that from the lower portions is due entirely to weathering. This is shown by the general appearance of the ore at various horizons and by its chemical composition. Two typical samples of the ore, selected by me—one from near the surface, representing the ordinary character of the soft ore, and the other from a depth of 250 feet, representing the hard ore, but not the most calcareous variety—gave on analysis the following percentages of iron, lime, and carbonic acid, after drying at 105° Centigrade:

Analyses of Clinton iron ore.

[By R. B. Riggs.]

Constituents.	Surface sample.	Sample from 250 feet below surface.
Iron (Fe)	57.52	7.75
Lime (CaO)	1.38	47.64
Carbonic acid (CO_2)	.30	34.90

Russell then quotes the observations of J. B. Porter, above noted, in support of this view, and concludes as follows:

At Attalla the change from "soft ore" to ferruginous limestone, or "hard ore," takes place at about the present level of stream drainage. At this horizon the stratum increases from 2½ to 3 feet in thickness. This increase in thickness below the level of drainage indicates that the removal of the calcareous portion of the ferruginous strata has allowed the bed to be compressed. As the unweathered ore is of doubtful economic value, owing to its high percentage of lime and the difficulty of mining, exaggerated estimates of the importance of the Clinton ore deposits of the South are to be guarded against.

With one important exception Russell's statement of the case is fair enough But the exception is very important and introduces an error which persists to the present day. It is perfectly true that, at a depth of 250 feet (or even less), the ore at Attalla changed from "soft" to "hard." But the hard ore is now known to carry 38 to 42 per cent of iron, instead of the 7¾ per cent credited to it by Russell. It will be seen that this puts an entirely different face on the matter, for it is hardly possible to consider merely as a "ferruginous limestone" a rock consisting of 60 per cent iron oxide, 10 to 12 per cent silica and alumina, and 20 to 30 per cent lime carbonate.

How Russell obtained such a sample of "hard ore" is difficult to understand; but when the analysis once reached the dignity of print it exhibited a surprising persistency. A few quotations may show how it still affects opinion regarding the origin of the Clinton ores.

J. F. Kemp, though recognizing the value of Smyth's work on the subject, still writes:[a]

The ore in many places is really a highly ferruginous limestone, and below the water level in the unaltered portion it often passes into limestone, while along the outcrop it is quite rich.

[a] Ore deposits of the United States and Canada, 5th ed., 1903, p. 114.

And, on a later page:

These hematites have undoubtedly originated in some cases by the weathering of ferruginous limestones above the water level. I. C. Russell has shown that the unaltered limestone at the bottom of a mine in Attalla, Ala., 250 feet from the surface contained but 7.75 per cent Fe, while the outcrop afforded 57.52 per cent. G. B. Porter has recorded the gradual increase of lime also in another Alabama mine from a trace at the outcrop to 30.55 per cent at 135 feet.

In a recently published volume [a] by Heinrich Ries the same point of view is retained:

The origin of these ore bodies has been argued from different standpoints, some holding that they represent altered limestone beds, because of the presence of fossils in them, while the concentric nature of the oolites, with a nucleus of worn quartz grains, has led others, especially Smyth, to ascribe a concretionary nature to them. The former theory is strengthened by finding at many places an increase of the lime contents of the ore with the depth. Thus at Attalla, Ala., the Clinton limestone at 250 feet from the surface carries only 7.75 per cent of iron, while at the outcrop it has 57 per cent of iron.

The error, once allowed to enter the literature of the subject without prompt contradiction, has of course become fixed in the average general text-book on either geology or economic geology. Since such text-books are of necessity largely compilations, the retention of erroneous statements can hardly be charged to the account of the compilers; but in this particular case the error was so obvious that one might have expected its detection at sight. It seems almost impossible, in view of the marvelous development of the Alabama iron industry, that it could still be believed that the Clinton ores did not exist at depths of more than 100 feet or so.

OBJECTIONS TO RESIDUAL ENRICHMENT THEORY.

The theory of residual enrichment is so contrary to our present knowledge of mining conditions in the Clinton ores that objections to it seem almost too obvious to state. Perhaps the two most immediately convincing arguments are those that follow:

1. The theory requires that if a bed of Clinton ore be followed down from its outcrop the iron will gradually decrease and lime carbonate increase, until at some point between the surface and the ground-water level the place of the ore bed will be occupied by a much thicker bed of slightly ferruginous limestone. In answer to the supporters of the theory it is therefore sufficient to state that the Clinton ore has been mined from several hundred fairly deep openings in the eastern and southern United States, and that nowhere has such a change from ore to limestone been observed. An ore bed may split or thin out and terminate in depth, but it will do the same thing when followed laterally along the outcrop; and in neither direction would such termination prove anything more than that the original beds were deposited in essentially limited basins. Where

[a] Economic geology of the United States, New York, 1905, p. 267.

the ore beds terminate, moreover, they do so by gradual thinning, as may be expected of any sedimentary deposit; and not by thickening, as is required by the theory of residual enrichment. Deep mines and drill holes far back from the outcrop also prove that the ore beds are as continuous as any sedimentary deposit can reasonably be expected to be.

2. To confirm or refute the foregoing objection to the "residual enrichment" theory would of course require personal examination of at least one mine. For those who can not make their own observations, a purely theoretical objection may be suggested. On the residual enrichment theory, whatever iron is now in the ore was contained, presumably in the form of carbonate, in the original limestone. If this hypothetical limestone contained 5 per cent metallic iron, which would make it more than a "slightly ferruginous limestone," it would require the disappearance of 8 feet of limestone to give rise to a bed of ore (40 per cent iron) 1 foot thick. The "Big Seam" of the Birmingham district, even allowing for the low grade of much of its total thickness of 30 feet, would under this theory have been derived from the solution of a 200-foot bed of limestone. A shrinkage of this extent would produce structural effects that should be very evident in any deep mine, but which, as a matter of fact, are entirely lacking.

Even more serious difficulties appear when we endeavor to explain how the original iron carbonate changed, during simple weathering, to the anhydrous oxide; or how the resulting oxide took the form of concentric shells inclosing grains of sand.

FACTS SUPPORTING THEORY OF SEDIMENTARY ORIGIN.

The principal facts supporting the theory of sedimentary origin may be briefly summarized as follows:

1. In mining from slopes running down on the dip of the ore bed, when once the limit of surface weathering is passed—and this may be at any point from 1 to 100 feet below the outcrop—no further important change in the ore is found with increasing depth; though a number of mine workings are now close to 2,000 feet from the outcrop.

2. A number of borings in Alabama have struck the ore at points from one-half to 1 mile back from the outcrop, and at depths of 400 to 800 feet below the surface. The ore encountered in these borings was hard ore of the usual quality, and not merely a "ferruginous limestone." Several borings in New York have struck Clinton ore at distances of from 10 to 15 miles back from the outcrop. These borings showed good hard ore at depths of 644 to 995 feet below the surface.

3. The physical character of the oolitic ore can not readily be explained on any replacement theory, while the formation at the present day of original oolitic materials is a matter of common knowledge.

4. The occurrence of fragments of the ore in overlying beds of limestone in the Clinton formation, as described by Smyth,[a] points to the fact that the ore had been formed prior to the deposition of this limestone.

5. If the replacement theory were accepted, one would expect that the ore beds would show a greater vertical range; that is, that they would at places occur in rocks of other than Clinton age. Throughout their entire extent the Clinton beds are closely associated with Silurian and Devonian limestones and shales, some of which offer excellent receptacles for replacement deposits, but the characteristic red ores are confined to the Clinton itself.

DIFFERENCES IN CLINTON ORES.

ORIGINAL DIFFERENCES IN COMPOSITION.

The variations in character shown by different samples of Clinton ore, from either the same or different beds and localities, are in part due to original differences in composition, and in part to changes which have affected the ore since its original deposition.

At the time of their deposition considerable differences in composition could probably have been found in different samples of Clinton ore. These differences were in part physical and in part chemical, and frequently both. In one basin, for example, the ores might be largely of the oolitic type, being composed of concentric layers of iron oxide with a sand grain for nucleus, the oolites being generally cemented by lime carbonate. Contemporaneously at another place the ores might be forming through the replacement, by iron oxide, of the lime carbonate of a mass of shells and shell fragments. The first ore would be distinctly more siliceous than the second.

The most convenient example of such an original difference in composition may be taken from the records of the writer's field work during 1905 on the Clinton ores of New York, at their type locality, near the village of Clinton, in Oneida County.

The ores are well exposed within a few miles of Clinton at many openings. The section there shown, when complete, involves the following beds in descending order:

	Feet.
Shales and thin limestones.	
"Fossil" or "flux" ore	1½–2
Shales and thin limestones	22
"Oolitic" ore	2½–3
Shales and thin limestones.	

The "shales and thin limestones" of this section are of characteristic Clinton type. The shales are bluish gray on a fresh surface, often showing a decided greenish tint on weathering. The limestones are in thin layers, rarely over an inch or two in thickness, and are full of

[a] Op. cit., p. 493.

fossils, but these fossils appear distinctly only on weathered surfaces. In color the limestones are gray or pinkish on a fresh surface, weathering a dull yellowish.

Two ore beds are always present in this district, though they may not be shown in the same mine or pit, while a thin third bed occasionally comes in just below the "fossil ore." The two main beds furnish two entirely distinct types of ore, the fossil ore and the oolitic ore, which are strikingly dissimilar in appearance, composition, and origin.

The difference in appearance is well brought out in the accompanying illustration (Pl. V), which shows specimens collected by the writer at this locality. The oolitic ore is red-brown in color when freshly exposed, rather greasy to the touch, and soils the hands much like an oily paint. On old exposed surfaces it has become partly hydrated, taking on a yellow tint. It is composed of little grains or oolites, somewhat flattened, and ranging from one-sixteenth to one-tenth inch in diameter. Larger grains occur, and occasionally fair-sized pebbles, but fossils are rare, and this type of ore is predominantly oolitic or granular in appearance. Examination of these oolites by either chemical or microscopic means shows that each is made up of a central core of quartz—a little rounded grain—inclosed by successive concentric shells of iron oxide.

Illustrations of the Birmingham ore (see Pl. VI) show the similarity to the New York ore. The fossil ore, on the other hand, contains few or no oolites, being mainly composed of fossils, both entire and fragmentary, which are in part replaced and in part merely surrounded by iron oxide. In color it is less reddish than the oolitic ore, owing to the greater percentage of impurities usually contained in it, and to the appearance of the grayish calcite of the fossils on any fractured surface.

The two types of ore present striking differences in chemical composition, due primarily to the difference in the character of the materials around which and in which the iron oxide was deposited. These differences in composition are well brought out by comparison of the following pair of analyses, made by Dr. E. C. Sullivan in the laboratory of the United States Geological Survey, of specimens collected by the writer near Clinton, N. Y.

Analyses of Clinton ores, Clinton, N. Y.

	Fossil ore.	Oolitic ore.
Silica (SiO_2)	8.71	16.82
Alumina (Al_2O_3)	3.67	3.54
Iron oxide (Fe_2O_3)	30.24	46.04
Lime (CaO)	20.64	9.96
Magnesium (MgO)	7.84	3.41
Carbon dioxide (CO_2)	24.78	13.62
Sulphur trioxide (SO_3)	.15	.20
Phosphorus pentoxide (P_2O_5)	.75	1.29

LATER REPLACEMENTS.

Reasons have been given for disbelieving the theory that the Clinton ores owe their origin primarily to any replacement process. But it would be incorrect to assert that during the ages which have elapsed since the deposition of these ores in the Clinton sea no changes have taken place in their composition. Since deposition the Clinton beds of the Eastern and Southern States have been, several times at least, elevated above sea level and then depressed below it. Such alterations in level, taken in connection with corresponding changes in topography, manifestly offer much opportunity for the removal or rearrangement of the soluble constituents of any rock. It can only be said that so far as known no definite proof has been presented that the Clinton ores owe any important part of their present distribution or present richness to deep alterations of this type. With regard to recent leaching along the outcrop the case is very different, as will now be explained.

HARD AND SOFT ORES.

The terms "hard" and "soft," as applied to the two principal varieties of Clinton ores, hardly express the facts, for the distinction between the two varieties in question is based upon differences in their chemical composition rather than upon differences in hardness.

Most of the red ore of Alabama is, in its typical or "hard" variety, a highly limy ore. The ore beds are usually overlain and underlain by comparatively impervious shales; and in most places dip at rather high angles. These conditions favor the penetration of the ore, near the surface at least, by percolating water. The result is that near the outcrop, and for some distance down the slope, the lime carbonate of the original ore is largely or entirely leached out. This removal of one constituent of course increases the relative percentages of the remaining less soluble ingredients, while it renders the ore more porous and friable. The resulting "soft ore" is therefore very low in lime, and correspondingly high in iron oxide. A secondary effect of the change, shown best where the cover is heavy and the dip low, is that the overlying shales settle down slightly as the bulk of the ore is reduced, so that on the outcrop the ore bed often has less than its normal underground thickness.

CHANGES DURING CONVERSION OF HARD INTO SOFT ORES.

The Clinton ores below water level generally carry large percentages of lime carbonate with lesser amounts of magnesium carbonate. When exposed to the action of percolating waters charged with carbon dioxide, the lime and magnesium carbonates are dissolved, and carried off in solution by the water. The other chief constituents of the ore—iron oxide, silica, and alumina—are practically unaffected by the water. The chemical results of the change are therefore:

(1) The ore loses all or almost all of its lime and magnesium carbonates.

(2) The percentages of iron, silica, and alumina are increased as the carbonates are decreased, but the relative percentages of these three less soluble constituents are unchanged.

An example will make this clear. Assume a hard ore composed (disregarding minor ingredients) as follows:

Not removable by leaching:	
Silica	7.50
Alumina	2.50
Iron oxide	50.00
	60.00
Removable by leaching:	
Lime carbonate	37.00
Magnesium carbonate	3.00
	40.00

If this ore were so thoroughly leached that all of its lime and magnesium carbonates were removed, the residual soft ore would be made up entirely of the relatively insoluble iron oxide, silica, and alumina. The comparative percentages of these three constituents would remain the same, but since 40 per cent of the total bulk of the ore has been removed in solution the percentages of the remaining constituents would be increased in the ratio 100:60. The soft ore would then show on analysis:

Silica	12.50
Alumina	4.17
Iron oxide	83.33

It will be seen that the original hard ore carrying 35 per cent metallic iron has been changed to a soft ore carrying about 58 per cent. But the ratios between the three insoluble constituents are unchanged, being in the two tables, for iron oxide, silica, and alumina, as 20 is to 3 is to 1.

It must be borne in mind that there is no definite relation between the richness of the soft and hard ores from two different openings. That is to say, if mine A yields a very much richer soft ore on the outcrop than mine B, that does not imply that in depth the hard ore from A will be richer than the hard ore from B. As a matter of fact, the contrary is often true. The ore which originally contained the larger percentage of lime carbonate is, other things being equal, the more likely to be thoroughly leached by percolating water; and so we are brought to the somewhat surprising conclusion that the poorer the original (hard) ore, the more likely it is to yield a rich soft ore on its outcrop.

When the hard ore contains very large percentages of silica and alumina the statement does not hold, for these impurities are practically insoluble and their percentage is increased during leaching just as is the precentage of iron oxide. So of two very siliceous ore beds the one showing the lower iron in the hard ore is also apt to show lower iron in the soft ore. But when two ores are leached, one naturally high in lime carbonate, the other higher in silica and alumina, the results may accord with the rule stated. Suppose that the two New York Clinton ores described on page 34 were changed into soft ore by complete leaching of their lime and magnesium carbonates. The result would be as shown in the table below:

Analyses showing effect of leaching in Clinton ores.

	Fossil ore.		Oolitic ore.	
	Original (hard) ore.	Leached (soft) ore.	Original (hard) ore.	Leached (soft) ore.
Silica (SiO_2)	8.71	18.64	16.82	23.04
Alumina (Al_2O_3)	3.67	7.85	3.54	4.85
Iron oxide (Fe_2O_3)	30.24	64.71	46.04	63.07
Lime (CaO)	20.64	....	9.96	....
Magnesia (MgO)	7.84	....	3.41	....
Carbon dioxide (CO_2)	24.78	....	13.62	....

From this it can be seen that the fossil ore, originally much the poorer of the two, would on leaching yield a soft ore slightly richer than that produced by the leaching of the originally richer oolitic ore.

CHARACTER OF THE OOLITIC ORE.

Examination of a typical specimen of hard oolitic ore, with the information furnished by chemical analysis, shows that the ore is made up of four principal ingredients—iron oxide, lime carbonate, free silica, and clay. Very small percentages of other constituents—iron sulphide, lime phosphate, and magnesium carbonate—also occur, but they may be disregarded at present.

The four principal constituents above named are arranged in a very definite and distinct way in the ore. Most of the silica is present as quartz, in rounded grains of various sizes; each of these grains is surrounded by one or more concentric layers of iron oxide, which is usually mixed with more or less fine clayey matter; while the lime carbonate surrounds and incloses the oolites thus formed. It will be noted that this description, taken by itself, points strongly in the direction of one particular theory of origin of the ores, that of original deposition, while it throws great difficulties in the way of accepting the replacement hypothesis. The manner in which the ingredients of the ore are arranged, as above outlined, would seem to admit of but one possible series of events which could give rise to the formation of such an ore. There were, first of all, rounded sand grains and small quartz pebbles; these were next enveloped by a deposit of iron oxide (with some clay); and finally the iron-covered grains were cemented together by a deposit of lime carbonate.

SPECIFIC GRAVITY.

The following series of determinations of the specific gravity of Clinton ores from various portions of the United States is taken from reports of the Kentucky Geological Survey, the Alabama Geological Survey, and the Tenth Census:

Specific gravity of Clinton ores.

Fe.	SiO_2.	Al_2O_3.	CaO.	Sp. gr.	Fe.	SiO_2.	Al_2O_3.	CaO.	Sp. gr.
61.61	11.59	0.07	0.05	4.012	49.49	....	....	....	3.958
58.36	....	....	....	4.330	49.26	....	....	....	3.559
57.18	....	....	....	4.326	48.86	....	....	....	4.037
56.04	....	....	....	4.201	48.78	....	....	....	3.750
55.40	....	....	....	4.013	48.65	....	....	....	3.869
54.76	....	....	....	4.121	47.90	....	....	....	3.880
54.48	....	....	....	4.109	47.09	....	....	....	3.694
54.35	....	....	....	4.170	46.34	....	....	....	3.777
54.17	15.96	3.94	.22	3.942	45.98	....	....	....	3.577
54.15	....	....	....	4.177	44.88	....	....	....	3.742
53.60	10.52	5.58	2.23	4.110	44.02	....	....	....	3.411
53.30	....	....	....	4.138	43.31	37.58	0.26	0.03	3.230
52.75	....	....	....	3.898	41.77	....	....	....	3.740
51.75	11.73	5.78	2.53	3.914	40.04	....	....	....	3.694
51.71	10.88	6.89	2.26	4.007	37.03	....	....	....	3.574
51.63	....	....	....	3.914	36.02	27.74	2.32	10.02	3.168
50.69	....	....	....	4.005	33.58	43.69	2.13	.69	3.190
50.64	....	....	....	3.921	31.77	....	....	....	3.425
50.13	....	....	....	3.941	31.30	....	....	....	3.386
49.89	....	....	....	3.946	*a* 48.53	....	....	....	*a* 3.842

a Average.

The above table shows, of course, the higher specific gravity which accompanies richness in iron. This is perhaps brought out more clearly if the ores are grouped as in the table following:

Specific gravity of soft ores.

Range in metallic iron.	Number of samples.	Average specific gravity.	Range in metallic iron.	Number of samples.	Average specific gravity.
30 to 40 per cent...............	5	3.3486	50 to 55 per cent..............	14	4.0262
40 to 45 per cent...............	5	3.5634	55 per cent and over..........	5	4.1724
45 to 50 per cent...............	10	3.8047			

The commercial value of the data above presented is lessened by the fact that all except 6 of the 39 specific-gravity determinations recorded in the preceding table were made on the powdered ore. When determinations are thus made on powdered materials, the effect of natural porosity is masked, and all such determinations therefore give results too high by an unknown amount. No miner has the slightest interest in knowing the weight of powdered ore;

the thing that he wishes to know is the weight of ore as it occurs in blocks in the mine. Recently there has been determined in the Birmingham district a series of actual specific gravities of lumps of ore by displacement of water. The ore thus treated was afterward analyzed. The results of certain of these tests and analyses are given on page 131.

GEOLOGIC RELATIONS AND DEVELOPMENT.

By Ernest F. Burchard.

THE ORE-BEARING FORMATION.

DISTINGUISHING FEATURES.

The Clinton (Rockwood) formation, in which the red ores occur, consists within the Birmingham district principally of overlapping lenticular beds of sandstone and shale, with four well-marked horizons of iron ore, generally in the middle one-third of the formation. The iron ore consists partly of strata of fine to coarse silica sand, coated and cemented with ferric oxide, and partly of fossil fragments which are wholly or partly ferruginous. The whole mass of the ore contains much calcium carbonate in places, especially where unweathered. The unweathered ore ranges from a calcareous, richly ferruginous sandstone to a ferruginous siliceous limestone, but there appear to be no true limestone strata in the formation within the district here described, although beds of limestone are present in the Clinton in northeast Alabama and in Georgia and Tennessee. The distinguishing feature of the formation is the relatively large quantity of iron oxide, either in the ferric or ferrous state, disseminated throughout all the beds. There are generally sharp lines of demarcation between beds of iron ore, shale, and sandstone, but in places these beds change vertically from one form to another by gentle gradations. Consequently there are in the section beds of ferruginous shaly sandstone and sandy shale, or the material may carry sufficient iron oxide to be styled a sandy ore or a shaly ore. The ferruginous character of the Clinton formation is not peculiar to the southern Appalachians; rocks of equivalent age contain beds of hematite throughout the whole length of the Appalachians, as well as in such widely separated outlying localities as New Brunswick, New York, and Wisconsin.

In the Birmingham district four ore horizons are generally recognized. The ore beds are known as the Hickory Nut, Ida, Big, and Irondale seams, the last named being the lowest. In general they are comprised in a section of the Clinton formation between 70 and 85 feet in thickness. The Hickory Nut seam lies about 80 feet below the top of the formation. The intervals between the ore horizons are variable, but roughly they average respectively 16, 35, and 3 feet. In several of the mines of the Tennessee Company north of Readers Gap, the top of the Big seam lies between 160 and 165 feet below the Fort Payne chert.

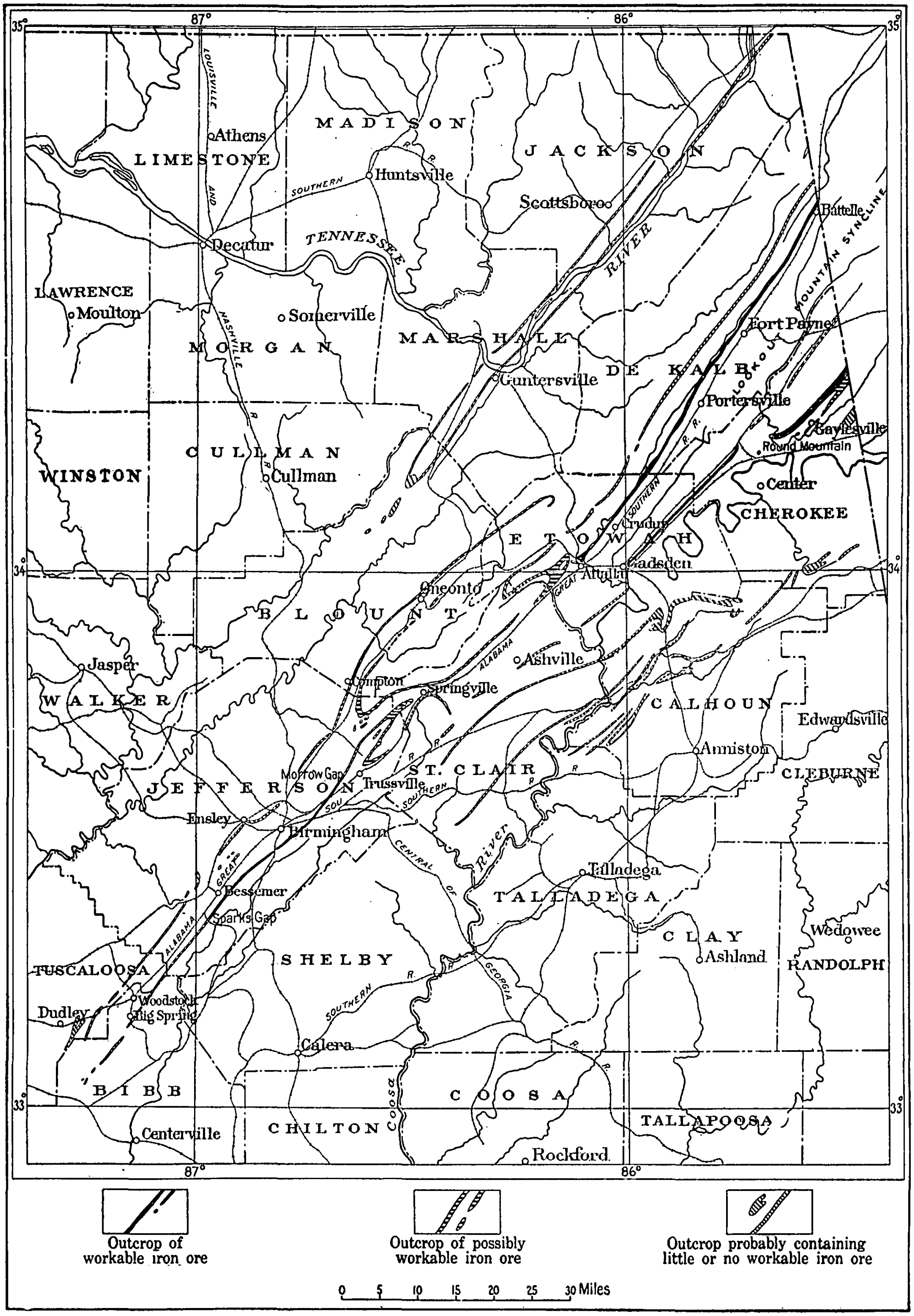
In the Birmingham district the Clinton formation is thickest toward the northeast, measuring more than 500 feet, and at this end of the area the proportion of shale is greatest. With thinning of the formation toward the south and southwest, where it becomes less than 300 feet thick, the proportion of sandstone increases. It is difficult, however, to apply one set of rules to all the areas of the Clinton strata, particularly to strips of the formations that lie on opposite sides of the valley and are separated by structures that are in the main anticlinal. Red Mountain and West Red Mountain, for instance, lie nearly parallel to each other, generally only 6 or 7 miles apart, yet there are greater differences in the composition of the Clinton formation at corresponding points in these ridges than there are between points on the same ridge separated by two or three times that distance. Such abrupt changes at right angles to the strike of the beds are readily accounted for, however, by the thinning and termination of certain lenticular beds in a northwest-southeast direction, and the occurrence of beds of a different composition at corresponding horizons. Sections on West Red Mountain can not be correlated with those made 6 or 7 miles distant on Red Mountain, but there is little difficulty in correlating sections 12 to 15 miles apart on Red Mountain. (See Pl. VII.)

RELATIONS TO ANCIENT SHORE LINES.

These conditions may perhaps be accounted for by considering that the ore beds were deposited in long, narrow bays and lagoons in comparatively shallow water, in which, by means of the sorting action of currents, the sediments were spread along the shore line in such a way that they are homogeneous in character for greater distances parallel to the shore line than normal to it. While the axes of folding may not extend exactly parallel to these ancient shore lines, it is believed that in general these directions coincide fairly closely in the southern Appalachian region. In other words, the axial directions of the folds denote the general directions of the old shore lines.[a]

Reference to the geologic map (Pl. II) makes it evident that the axial direction of the anticline having Red Mountain on its southeast flank is fairly constant, although it shows local deflections from

[a] See Willis, Bailey, Mechanics of Appalachian structure: Thirteenth Annual Rept. U. S. Geol. Survey, 1892, pp. 253–258; also, A theory of continental structure applied to North America: Bull. Geol. Soc. America, vol. 18, 1907, pp. 389–412.



SKETCH MAP OF NORTHEASTERN ALABAMA, SHOWING OUTCROPS OF CLINTON FORMATION.

a straight line. From Bessemer southwest to Sparks Gap this direction swings 20° farther toward the south than the direction of the axis between Birmingham and Bessemer. The character of the ore beds changes more abruptly from Bessemer to Sparks Gap than between Birmingham and Bessemer. If this change be due to the fact that here the outcrop is cutting diagonally across the basin of ore instead of following parallel to it, some very interesting economic as well as scientific relations between character of ore and old shore lines are suggested. The shore line may, however, have been as sinuous as the present structural axis, and the change in character of sediments may have been due to the presence of a promontory or cape beyond which the sediments were swept by currents from the northeast into the area from which Clinton beds now have been eroded, while from the southeast currents bore sediments that modified the ore beds in that direction.

A line of drill holes beginning at Readers Gap in Red Mountain and extending northeastward into Shades Valley parallel with the direction of outcrop of red ore between Woodward Junction and Graces Gap would be of great value in showing whether the ore is fairly constant parallel to the supposed shore line, and would also pay for the sake of the information that would be yielded regarding the ore beds.

SECTIONS SHOWING POSITION OF ORE BEDS.

Along the outcrop of the Clinton from northeast to southwest there are slight variations in composition, as is indicated by the following seven sections on Red Mountain, beginning northeast of Birmingham and continuing at irregular intervals for about 38 miles southwest. In each section the observed thickness has been corrected for the dips, which range between 20° and 50°, so that the computed thickness closely represents the actual thickness of the beds.

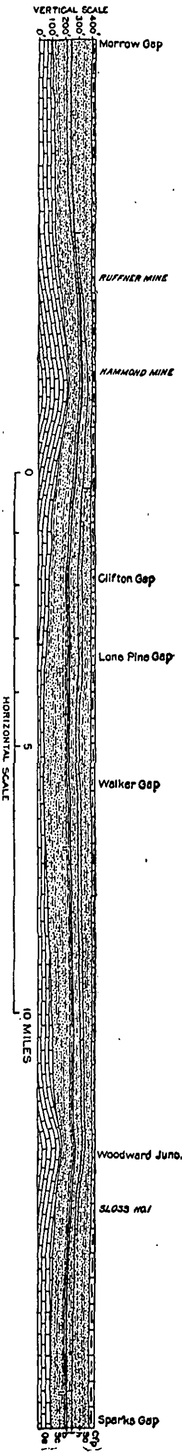


FIGURE 3.—Hypothetical strike section compiled from seven observed sections along outcrop of Clinton (Rockwood) formation on Red Mountain, Alabama. Cfp, Fort Payne chert; Sc, Clinton (Rockwood) formation; h, Hickory Nut seam; i, Ida seam; b, Big seam; Oc, Chickamauga (Pelham) limestone; ir, Irondale seam.

1. Section of Clinton (Rockwood) formation in the NE. ¼ sec. 23, T. 17 S., R. 2 W., near Irondale.

	Ft.	in.
Top of formation not exposed.		
Sandstone, yellowish, heavy bedded	40	
Concealed	11	9
Sandstone	4	7
Concealed (probably in large part shale)	19	10
Sandstone, green, flaggy, with yellow shale partings	25	
Iron ore (Ida seam)	5	
Shale, red		2
Sandstone, ferruginous, laminated	1	8
Iron ore (Big seam):		
Ore, sandy	1	8
Ore, lean, filled with small quartz pebbles	5	
Ore, minable	7	
Ore, fair quality, but not mined at present	6	
Ferruginous sandstone, ore, and shale, in layers 1 foot or less thick	20	
Sandstone, very hard	3	
"Gouge," calcareous		6
Iron ore (Irondale seam)	5	6
Sandstone, brown, thin-bedded, with shale	20	
Concealed (probably shale)	65	
Limestone (Chickamauga).		
	241	8

2. Generalized section of Clinton (Rockwood) formation from drill record in the SW. ¼ sec. 23, T. 17 S., R. 2 W., just south of Red Gap.

	Ft.	in.
Chert (Fort Payne).		
Shale (may include a few inches of Devonian)	11	
Sandstone, coarse, ferruginous	25	
Iron ore, solid (Ida seam)	6	
Sandstone, coarse, ferruginous	25	
Sandstone, coarse, pebbly; partly a low-grade ore	22	
Shale		1
Iron ore (Big seam):		
Upper part, minable	7	
Lower part, not yet mined	10	
Shale	3	
Iron ore (Irondale seam)	4	4
Sandstone, red, soft	30	
Sandstone, brown	35	
	178	5

3. Section of Clinton (Rockwood) formation on road through gap in the NW. ¼ sec. 5, T. 18 S., R. 2 W.

	Ft.	in.
Chert (Fort Payne).		
Sandstone, heavy bedded	8	
Concealed	6	8
Sandstone, medium bedded	6	9
Concealed	6	8
Shale	5	5
Concealed	53	
Iron ore, sandy (Hickory Nut ? seam)	3	9
Concealed	7	6
Sandstone, coarse, very ferruginous, thin bed	2	3
Sandstone, fine-grained, very ferruginous, thin bed	3	9
Sandstone, coarse, ferruginous, with beds of ore (Ida seam)	10	3
Sandstone, medium bedded, coarse	10	6
Concealed	6	9
Shale	7	6
Concealed	3	9
Sandstone, heavy bed	2	5
Iron ore, coarsely siliceous (Big seam); top 10 feet minable	16	10
Sandstone	7	8
Iron ore (Irondale seam):		
Ore	1	
Shale		7
Ore	1	1
Sandstone	1	
Concealed by shaly sandstone débris	50	1
Sandstone, massive, with shaly partings	24	1
Sandstone, thin bed	5	7
Concealed	4	6
Sandstone, thin bed	5	6
Concealed	4	6
Sandstone, thin bed	3	7
Concealed	7	6
Sandstone, thin bed	3	7
Concealed	5	8
Shale, sandy	7	6
Concealed by red shaly sandstone débris	35	10
Limestone (Chickamauga).		
	331	0

4. Section of Clinton (Rockwood) formation in Walker Gap, in the NE ¼ sec. 14, T. 18 S., R. 3 W.

	Ft.	in.
Chert (Fort Payne).		
Shale, clay, and sand (Devonian)	1	6
Sandstone, massive	16	10
Sandstone and shale	13	7
Shale, drab to pink, with thin streaks of sandstone (partly concealed by débris)	85	4
Sandstone and shale, alternating	50	9
Iron ore (Big seam), top 8 to 15 feet minable	24	
Sandstone and shale, with ore seams in upper part	13	7
Débris	50	10
Shale, yellow, red and olive, with heavy sandstone interbedded	41	
Sandstone, heavy bedded	3	5
Shale, yellow and red	37	4
Base not exposed, but probably within 20 feet	20	
	358	2

5. Section of Clinton (Rockwood) formation in Tanyard Gap, in the SE. ¼ sec. 2, T. 19 S., R. 4 W.

	Ft.	in.
Chert (Fort Payne).		
Shale (Chattanooga) (less than 1 foot).		
Sandstone, thin bedded	12	2
Concealed	10	10
Sandstone, dark red, heavy bedded	8	9
Concealed	11	3
Sandstone, red, heavy bedded	4	8
Concealed	7	8
Sandstone, red, medium bedded	3	10
Sandstone, very ferruginous, with casts of *Pentamerus* (Hickory Nut ore seam)	3	
Sandstone, red, ferruginous, thin bedded	2	4
Concealed	16	4
Sandstone, heavy bedded	2	4
Iron ore (Ida seam); soft ore, minable	3	
Sandstone, heavy bedded	3	
Concealed	15	4
Sandstone, medium bedded	20	2
Iron ore (Big seam):		
Ore, lower 9½ feet minable	11	
Shale	2	6
Ore, minable only where soft	4	6
Shale, sandy, with thin ore seams, not minable	3	
Sandstone, thin bedded	2	4
Shale and thin seams of ore (Irondale horizon ?)	11	3
Sandstone	1	6
Shale	2	8
Concealed	3	9
Shale, sandy	56	
Covered by shale débris	12	6
Limestone (Chickamauga).		
	235	8

6. *Section of upper part of Clinton (Rockwood) formation as shown by core from diamond drill, NE. ¼ SW. ¼ sec. 11, T. 19 S., R. 4 W.*

	Ft.	in.
Chert, solidly stratified (Fort Payne).		
Sandstone, red, with coarse grit	5	8
Grit, coarse, soft, with gray sandstone	5	8
Limestone, gray, hard, cherty	6	7
Limestone, ferruginous	31	
Sandstone, ferruginous	2	7
Sandstone, gray, extremely hard in places	23	6
Sandstone, ferruginous	40	7
Grit, very hard, fine, with reddish sandstone	20	2
Iron ore, limy (Hickory Nut ? seam)	2	7
Sandstone, gray	7	11
Limestone "marbleized"	15	
Sandstone, gray, hard	1	11
Limestone, ferruginous (Ida ? seam)	5	8
Sandstone, ferruginous	22	
Iron ore (Big seam); top 11 feet minable:		
Ore	14	1
Sandstone, gray	2	5
Shale, ferruginous		8
Ore, limy	2	5
Sandstone, highly ferruginous (Irondale ? seam)	4	8
Sandstone, mottled, highly ferruginous and fossiliferous (Irondale ? seam)	1	3
Calcareous rock, gray, with sandstone and shale interstratified	30	
Bottom of formation probably within 35 feet.		
	246	4

7. *Section of Clinton (Rockwood) formation as shown by core from diamond drill at Big Spring, in the SE. ¼ SE. ¼ sec. 34, T. 21 S., R. 6 W.*

	Ft.	in.
Limestone, decomposed (Fort Payne).		
Limestone (?), hard	2	1
Sandstone, reddish	35	
Limestone (?), impure, with shale streak	27	9
Ferruginous rock, red, mottled	2	3
Limestone (?), with mottled red streaks, and shale	25	6
Limestone (?), gray, "marbleized"	1	11
Limestone (?), gray, "marbleized," fossiliferous	8	2
Limestone (?), gray, "marbleized," with liver-colored spots	7	6
Limestone (?) and shale alternating	16	
Sandstone, dark brown	2	6
Sandstone, laminated, ferruginous	29	
Shale, gray, sandy	32	10
Ferruginous rock, streaked	26	3
Iron ore (horizon of Big seam):		
Ore, soft, no core	3	9
Sand, highly ferruginous, no core	4	10
Ore, lean with shale streaks	1	11
Ore, fossiliferous	3	7
Limestone (?), gray, impure, streaked with flint	48	8
Sandstone, red streaked	5	
Limestone (?), with hard black flint (Chickamauga).		
	284	6

DESCRIPTIONS OF THE ORE BEDS (SEAMS).[a]

The foregoing sections show, besides the variation in details of the formation, the relation of the several ore beds. The four beds are all shown in sections 3, 5, and 6, but in the other sections one or more of them have not been recognized. A fifth bed, lower than the Irondale, has been noted at Lone Pine Gap and other places near that locality. It is, however, only a sandstone, locally very ferruginous. The following summary shows the salient features of the important ore beds, commencing with the uppermost:

HICKORY NUT SEAM.

This bed comprises 3 to 5 feet of sandy ore or ferruginous sandstone characterized by a great abundance of the brachiopod *Pentamerus oblongus,* fossils which resemble hickory nuts incased in the partly open outer shucks. The ore is of too low grade to be worked at present. The bed reaches its greatest thickness between Birmingham and Bessemer, and where recognized it lies about 12 to 20 feet above the next lower bed.

IDA SEAM.

This bed consists of 2 to 6 feet of rather siliceous ore associated with 14 to 16 feet of ferruginous sandstone. Ore at this horizon is more continuous and extensive than at the horizon of the Hickory Nut seam. It has been recognized at many of the workings from Bald Eagle Gap beyond Clear Branch Gap. Where worked the bed is from 3 to 5 feet thick and soft ore only has been obtained from it in surface workings. Such ore carries 35 to 44 per cent of metallic iron, with a corresponding range in silica of 42 to 32 per cent. The Ida seam usually occurs 20 to 50 feet above the top of the Big seam.

BIG AND IRONDALE SEAMS.

These two ore beds are considered together, since they are generally closely associated in space. The ore, however, is somewhat different in quality, and the beds are so sharply separated by sandstone or shale that they may be mined independently.

The thickness of the Big seam varies from 16 to 30 feet. It extends as a traceable unit on Red Mountain for practically the whole length of the mining district. Notwithstanding the great thickness there are rarely more than 10 to 12 feet of good ore in a single bench, and at most places only 7 to 10 feet are mined. Probably the maximum thickness of the bed, without reference to the thickness of the workable part, occurs between Red Gap (near Irondale) and Bald Eagle, although for a mile southwest of Red Gap the bed remains

[a] The local usage of the word "seam" for a bed of ore makes necessary the use here of the word "seam" in connection with the local names.

nearly as thick. From northeast to southwest the total thickness of the ore-bearing sediments gradually decreases, without, however, altering greatly the thickness of the workable portion. About the middle of the district the bed becomes separated into two benches, either by a well-defined parting along the bedding plane or by a shale bed, thin at first, but thickening gradually to the southwest. The middle of the Big seam is the workable part in the northeast end of the district, but the upper bench is of most importance throughout the rest of the area. In the southwest portion of the district the lower bench, which farther northeast is composed of ore that may eventually be mined, becomes a series of thin strata of lean ore and shale, and is consequently of no possible value; and finally the upper bench itself becomes shaly and carries only a very low-grade ore.

The Irondale seam is of most value along Red Mountain between Pilot Knob on the northeast and Lone Pine Gap on the southwest. Southwest of Lone Pine Gap the bed consists of interbedded low-grade iron ore and shale or else its identity is completely lost. Its soft ore, now nearly all mined out either by surface trenches or drifts, is the best in the district. Its hard ore is also of high grade and hitherto has been for the most part held in reserve, since ore could be produced from the thicker Big seam at a lower cost per unit of iron.

The structure and composition of the Big and Irondale seams is shown in the following series of sections, taken at intervals of 2 to 5 miles apart along Red Mountain, beginning in the northeast portion of the mining district:

Character of Big and Irondale seams 1 mile northeast of Red Gap, near Irondale.

Strata.	Thickness.		Character.
Sandstone.			
Big seam:	*Ft.*	*in.*	
Ore, sandy	1	8	Unweathered ore: Metallic iron, 16–20 per cent; insoluble, 40± per cent; lime, 18± per cent.
Ore, lean, with fine quartz pebbles	5		
Ore, massive, cross bedded, mined	7		Hard ore, averages metallic iron, 36 per cent; insoluble, 26 per cent; lime, 20 per cent.
Ore, similar in appearance to above, but not mined at present.	6		Percentage of iron grades down from 35 at top to less than 20 at bottom; insoluble rises to more than 60 per cent.
Sandstone, ferruginous, lean ore, and shale, in thin strata.	20		
Shale	0–6		
Sandstone, very hard	3		
"Gouge," calcareous		6	
Irondale seam: Ore, mined	5		Semihard ore, averages metallic iron, 37 per cent; insoluble, 29 per cent; lime carbonate, 14.25 per cent.
Shale, hard.			

Character of Big and Irondale seams one-half mile south of Red Gap.

Strata.	Thickness.		Character.
Sandstone, coarse, ferruginous.			
Big seam:	*Ft.*	*in.*	
Ore, containing much silica in coarse grains and fine pebbles.	22		Upper half, soft ore: Metallic iron, 22± per cent; insoluble, 64± per cent; lime, trace. Lower half, soft ore: Metallic iron, 32± per cent; insoluble, 47± per cent; lime, trace.
Shale		1	
Ore, mined	7		Soft ore: Metallic iron, 36± per cent; insoluble, 45± per cent; lime, trace.
Ore, not mined	10		Semihard ore: Metallic iron, 25± per cent; insoluble, 50± per cent; lime carbonate, 8.12 per cent.
Shale, soft	3		
Irondale seam: Ore, mined	4	4	Soft ore: Metallic iron, 50± per cent; insoluble, 15± per cent; lime, trace.

The two following sections, made within the next 5 miles southwest, show that although the total thickness of the iron-bearing strata in this direction grows gradually less yet the thickness of workable material remains fairly constant:

Character of Big and Irondale seams near Lake View, Birmingham.

Strata.	Thickness.		Character.
Sandstone, thin bedded.			
Big seam:	*Ft.*	*in.*	
Ore, mined	10		Soft ore: Metallic iron, 40± per cent; insoluble, 39± per cent; lime, trace. Hard ore: Metallic iron, 34± per cent; insoluble, 26± per cent; lime, 20± per cent.
Shale		8	
Ore, not mined	7		Value decreases regularly downward. Soft ore: Metallic iron, 15 to 25 per cent; insoluble, 50 to 60 per cent.
Shale	2		
Irondale seam:			Hard ore: Metallic iron, 38± per cent; insoluble, 16± per cent; lime carbonate, 24± per cent. Soft ore: Metallic iron, 47± per cent; insoluble, 26± per cent. Only hard ore mined at present.
Ore	2	8	
Shale		9	
Ore	2	2	

Character of Big and Irondale seams near Lone Pine Gap.

Strata.	Thickness.		Character.
Shale.			
Big seam:	*Ft.*	*in.*	
Ore mined	10±		Hard ore: Metallic iron, 36± per cent; insoluble, 25± per cent; lime carbonate, 20± per cent. Soft ore: Metallic iron, 44± per cent; insoluble, 35± per cent. Semihard ore mined at present.
Shale	1±		
Ore, not mined	6	6	Value decreases regularly downward, top ore being poorer than the ore mined above.
Shale	2		
Irondale seam: Ore, not mined	6		Low-grade ore interbedded with shale.

The following section illustrates the complete deterioration of the Irondale seam:

Character of Big and Irondale seams at open cut, Green Spring mine, SW. ¼ sec. 11, T. 18 S., R. 3 W.

Strata.	Thickness.		Character.
Sandstone, coarse, ferruginous.			
Shale, yellow.			
Big seam:	*Ft.*	*in.*	
Ore, massive, cross bedded and jointed; mined.	8		Soft ore: Metallic iron, 42± per cent; insoluble, 31± per cent; lime, 2± per cent. Semihard ore: Metallic iron, 38± per cent; insoluble, 32± per cent; lime, 8± per cent. Mostly semihard ore mined at present.
Parting on bedding plane.			
Ore, rather a ferruginous sandstone or coarse grit; mined in only a few places.	8		
Shale		2	
Sandstone, ferruginous and shaly	1		
Shale, sandy		6	
Sandstone, ferruginous	1	3	
Shale		2	
Sandstone		4	
Shale		2	
Ore, sandy		5	
Shale		5	
Ore, sandy		3	
Shale		2	
Irondale (?) seam:			
Ore, very sandy	1	6	Not minable.
Shale		2	
Sandstone, fine grained, very ferruginous.	1	4	
Shale		2	
Sandstone, fine grained, very ferruginous.		10	
Shale		1	
Sandstone, very ferruginous		5	
Shale		1	
Sandstone, very ferruginous		10	
Shale.			

At Graces Gap the Irondale seam has not been recognized. The Big seam has a thickness of about 22 feet here, and the upper bench, containing 10 to 12 feet of ore, is mined. Four miles southwest of the locality of the foregoing section the ore presents the following phase:

Character of Big and Irondale seams at mouth of slope No. 12, Tennessee Coal, Iron, and Railroad Company, SE. ¼ sec. 20, T. 18 S., R. 3 W.

Strata.	Thickness.		Character.
Shale and sandstone in thin beds.			
Big seam:	*Ft.*	*in.*	
Ore mined	8–10		Hard ore: Metallic iron, 35± per cent; insoluble, 18± per cent; lime, 16± per cent. Only hard ore mined now.
Shale, thin parting.			
Ore, lean and siliceous, with a few local shale partings.	9		Not minable under present conditions.
Ore, oolitic and fossiliferous, in thin bands alternating with streaks of calcite and shale.	2	1	
Ore, shaly	1	3	
Ore		4	
Shale		8	
Irondale (?) seam:			
Ore, siliceous		6	Not minable.
Shale		1	
Ore, siliceous		8	
Shale		3	
Ore, very sandy	1	3	
Shale		1	
Sandstone, ferruginous		7	
Shale, sandy.			

Character of ore seams at Songo mine, NW. ¼ sec. 29, T. 18 S., R. 3 W.

Strata.	Thickness.	Character.
	Ft. in.	
Hickory Nut (?) seam: Ore, lean, sandy.	3+	Carries in places 20 per cent iron.
Shale and sandstone	26	
Big seam:		
Ore, minable, average	8	Hard ore: Metallic iron, 37± per cent; ainsoluble, 17± per cent; lime carbonate, 25± per cent.
Shale	9±	
Ore, lean, not mined	3-4 6	
Shale	0-12	
Irondale seam (?)		
Ore, very sandy, not minable	10	Grows leaner in iron and lime and higher in silica with depth.
Shale.		

Three and one-half to 5 miles southwest of the Songo mine is that part of Red Mountain opposite Bessemer. Here the parting between the upper and lower benches of the Big seam reaches a thickness of 3 feet in places. The upper bench continues with its usual quality and thickness, 8 to 10 feet of ore being mined. Thin streaks and lenses of shale begin to appear near the top and bottom of this bench. The lower bench of the Big seam has thinned down to between 4 and 7 feet in thickness, and is generally composed in its upper portion of ore too poor to mine and of alternating thin strata of ore and shale below The horizon of the Irondale seam carries thin beds of ore between shaly layers. At the Woodward mine No. 1, in Tanyard Gap, the beds have somewhat the following character and relations:

Character of ore seams at Woodward mine No. 1, SE. ¼ sec. 2, T. 19 S., R. 4 W.

Strata.	Thickness.	Character.
Sandstone, heavy bedded.	*Ft. in.*	
Ida seam: Ore formerly mined	3	Soft ore: Metallic iron, 40± per cent.
Sandstone, heavy bedded	3	
Probably shale and shaly sandstone	15 4	
Sandstone, medium bedded	20 2	
Big seam:		
Ore, lower 9½ feet mined	11	Soft ore: Metallic iron, 50± per cent; silica, 18± per cent. Hard ore: Metallic iron, 37± per cent; silica, 11± per cent; lime, 12± per cent.
Shale	2 6	
Ore, mined on outcrop	4 6	Soft ore: Metallic iron, 49± per cent; silica, 23± per cent.
Shale, sandy, with thin ore seams, not minable.	3	
Sandstone, thin bedded	2 4	
Horizon of Irondale (?) seam: Shale, with thin seams of ore.	11 3	
Sandstone.		

At the lower Sloss-Sheffield workings, Sloss No. 1, a mile southwest of Woodward No. 1, the character and relations of the important ore beds are about as follows:

Character of ore seams at Sloss mine No. 1, SW. ¼ sec. 11, T. 19 S., R. 4 W.

Strata.	Thickness.	Character.
Sandstone and ferruginous shale.	*Ft. in.*	
Ida seam: Ore, minable on outcrop....	5?	Soft ore: Metallic iron, 38± per cent; silica, 40± per cent.
Sandstone, ferruginous, with shale partings.	20±	
Big seam:		
Ore, 8½ to 10 feet, mined............	10-12	Soft ore: Metallic iron, 48± per cent; silica, 23± per cent. Hard ore: Metallic iron, 36± per cent; silica 11± per cent; alumina, 3.75± per cent; lime, 16± per cent.
Shale, sandy........................	2 5	
Shale, ferruginous..................	8	
Ore..................................	2 5	Soft ore, outcrop: Metallic iron, 47± per cent; silica, 23± per cent.
Irondale seam: Sandstone, ferruginous.	5 11	
Sandstone.		

Two and three-fourths miles southwest of Sloss No. 1 is the Raimund No. 3 slope of the Republic Iron and Steel Company, and at this point, which is near the southwestern limit of present active mining on Red Mountain, the ore-bearing strata show the following section:

Character of Big and Irondale (?) seams at Raimund No. 3 slope, SE. ¼ sec. 21, T. 19 S., R. 4 W.

Strata.	Thickness.	Character.
Shale.		
Big seam:	*Ft. in.*	
Ore, solid, mined....................	8	Soft ore: Metallic iron, 47± per cent; insoluble, 24± per cent; lime, 0.80± per cent. Soft ore mined at present.
Shale................................	1 6	
Sandstone, shaly, ferruginous.......	9	
Ore..................................	3	Lower bench.
Shale................................	1	
Sandstone with shaly partings......	1 6	
Shale................................	3	
Horizon of Irondale (?) seam: Ore, sandy, lean, with shale partings.	1	

JOINTS IN THE ORE BEDS.

An interesting structural feature of the ore beds, best illustrated in the Big seam, is the jointing of the beds. Two systems of prominent joints persist through many miles along Red Mountain, and minor joints are associated with them. The general strike of the rocks on Red Mountain varies from N. 25° E. to N. 45° E., and the direction of the dip varies from S. 65° E. to S. 45° E. One of the systems of joints strikes N. 60° to 80° W., with steep dips (80° or more) to the southwest or northeast. The joints of the other prominent system extend N. 27° to 40° E., the planes being nearly vertical or dipping steeply to the northwest and southeast. There is another set of joints, not so prominent as the above, extending N. 20° W., with almost vertical planes. The joints first mentioned range generally from 10 to 30 feet apart. In places joints of the second set are much more closely spaced. The first two sets of joints therefore are nearly, but not quite, parallel, respectively, to the directions of dip and strike of the rocks. The joints facilitate the removal of the ore in the mines and in the open cuts, and several of the older mine slopes are driven in the direction of the joint planes instead of directly down the dip of the beds.

The relation between the directions of some of the joints and the minor faults along Red Mountain appears to be significant. Faults at the Ishkooda mines, at Woodward, Raimund, and Potter all range in direction between N. 35° E. and N. 40° E., which correspond closely with the direction of the northeast-southwest system of joints, and slipping of the strata along joint planes has been observed in other places.

ORE BEDS ON WEST RED MOUNTAIN.

On West Red Mountain the rocks dip at high angles and appear not to carry valuable beds of iron ore throughout the middle of the district. At the extreme ends of the district, however, the dips are more gentle, and workable beds have been discovered; for instance, at Compton, Vance, and Dudley. The two following sections of the Clinton formation, measured by Charles Butts, show the general character of the beds in the northeast half of West Red Mountain. Comparison of these sections with those made on Red Mountain (pp. 42–45) indicates that the formation thickens to the northwest. The measured thicknesses have been corrected for dip, and the figures represent the computed actual thickness of the beds.

Section of Clinton (Rockwood) formation on West Red Mountain, at Cunningham Gap, in the SW. ¼ sec. 10, T. 16 S., R. 2 W.

	Ft.	in.
Chert débris (Fort Payne).		
Sandstone, highly ferruginous, exposed in prospect pit	5	
Concealed	39	
Sandstone	7	10
Concealed	31	6
Sandstone	2	
Concealed	15	8
Sandstone, in massive beds	31	6
Concealed	15	
Sandstone	4	
Concealed	23	9
Sandstone	5	
Concealed	7	10
Sandstone	1	
Concealed	15	7
Sandstone	2	
Concealed	7	9
Sandstone, ferruginous (shown by prospect pit)	2	
Concealed	15	8
Sandstone	1	
Concealed	7	
Sandstone, thick bedded	23	8
Concealed	31	6
Sandstone, thick bedded	27	8
Shale	2	
Sandstone, thin to very thick beds, with shale partings	102	
Sandstone, thin bedded	23	8
Concealed	47	5
Sandstone	4	
Concealed	5	
Limestone, impure and ferruginous (probably top of Chickamauga).		
	507	

Section of upper part of Clinton (Rockwood) formation in gap of West Red Mountain near Dale, Ala.

	Ft.	in.
Shale, black (Devonian).		
Sandstone, greenish predominating, grayish and reddish, evenly bedded, with shale partings, most numerous at top	110	
Shale, yellowish green	5	6
Sandstone, gray, thin bedded	10	6
Iron ore	2	
Concealed	6	
Sandstone, ferruginous, with decomposed ore	6	
Iron ore, lean, limy, fossiliferous	10	
Concealed by very red soil and red sandstone débris	210	
Limestone (Chickamauga).		
	360	

Workable ore at Compton occurs in but one bed, which shows the following sections:

Section of ore seam at Compton mine.

1.		2.		3.	
Shale.	*Inches.*	Shale.	*Inches.*	Shale, ferruginous.	*Inches.*
Ore	13	Ore	17	Ore	7
Shale	1-2	Shale	1-3	Shale	1½
Ore	16	Ore	18	Ore	29
Shale.		Shale.			

1. First right entry, near main slope.
2. First left entry, 300 feet from main slope.
3. Outcrop, near top of mountain.

The bed at Compton ranges generally from 30 to 36 inches in thickness, with a thin parting of shale, irregular in position, as shown in the sections. Locally the entire bed is pinched down to a very few inches or entirely cut out by downward bulging of the overlying shale, which at these places has a concretionary or concentric structure. Such pinches, which result in the local absence of the ore bed, are termed "faults" by the miners, but there is no dislocation of the beds and the ore is usually picked up again if the workings are driven on far enough in the same plane.

The extreme southwestern part of Birmingham Valley is partly covered by the clay and sand of the Tuscaloosa formation and the loam of the Lafayette formation, but in places rock ridges have been revealed by stream erosion. Extensive prospecting by drill, test pits, and slopes has been carried on within the last two years in the region between Dudley and Big Sandy Creek, and the Clinton (Rockwood) formation has been shown to contain workable beds of ore. All the evidence heretofore obtained regarding the somewhat obscure geologic relations of this district indicates that the workable beds of ore are in a strip of Clinton formation, offset in a manner somewhat similar to McAshan Mountain, 17 miles to the northeast. In other words, the outcrop of the formation here has been repeated by folds and faults. In the region south of Dudley the beds are completely overturned, so that the dips are to the southeast. This locality is in the Brookwood quadrangle, at the extreme southwest end of the district, and is more fully discussed on pages 105–106.

LOCAL DESCRIPTIONS.

DIVISIONS OF THE DISTRICT.

Owing to the considerable extent of Birmingham Valley, to the distribution of the ore beds along the margins and at the ends of the valley, and to the variation in the character of the ore from place to place, the district is divided for convenience of description in this paper into seven parts. The order of the divisions from A to G represent in a general way the commercial importance of the divisions, based on (*a*) quality of ore, (*b*) quantity of ore, (*c*) structure of ore beds, (*d*) accessibility, and (*e*) distance from furnaces. It should be understood, however, that this outline of divisions is not intended as a definite estimation or appraisal of relative values. Such facts as were obtained in a brief study of the district are presented herewith in order that interested persons may draw their own conclusions therefrom.

DIVISION A.

GENERAL DESCRIPTION.

Division A includes that part of Red Mountain extending from Morrow Gap in sec. 32, T. 16 S., R. 1 W., southwest to Sparks Gap in sec. 32, T. 19 S., R. 4 W., a distance of about 26 miles.

All but two of the productive mines of the district are in this strip of Red Mountain. About thirty-five workings, including slopes, open cuts, and combination mines, were in active operation between 1906 and 1909 in this part of the district.

The mines within Division A are served by the Birmingham mineral division of the Louisville and Nashville Railroad, which is built along the slope of Red Mountain 100 to 350 feet below the summit of the ridge. As may be seen on the map, the road runs, first on one side of the mountain, then on the other, threading its way back and forth through several natural passageways, such as Sadlers Gap, Lone Pine Gap, Walker Gap, and Readers Gap. From Readers Gap the road leads to Bessemer, with a spur extending southwest along the ridge to the Raimund and Potter slopes. In addition, the Woodward Iron Company's private railroad connects Red Mountain at Woodward Junction with the blast furnaces at Woodward and with the Warrior coal field farther west. Certain mines, particularly those where the road passes along the west side of the mountain, are so situated that their tipples can be built directly on a siding of the railroad. Others, facing the east, have built spurs reaching back into lateral ravines. Through Red Gap, between Irondale and Gate City, five railroads enter Birmingham from the east and north. At Graces Gap the Louisville and Nashville main line passes southward across the Cahaba coal field to the Gulf; at Readers Gap the Atlanta, Birmingham and Atlantic Railroad enters the city from the east, and at Sparks Gap the Southern Railway finds an outlet souteastward. Therefore this portion of the district is well supplied with transportation lines and consequently its rapid development has been facilitated.

Data concerning the ores and mines within Division A will be presented in the order of locations from Morrow Gap southwestward.

TOWNSHIP 16 S., R. 1 W.

MORROW GAP.

The Clinton formation at Morrow Gap, in the northeast corner of sec. 32, strikes nearly east-west, and its attitude affords a striking illustration of the abrupt bending or buckling to which the formations have been subjected, in places without definite faulting. The thinner formations in general exhibit this structure most clearly, and the resultant weakness of the rocks at such points of flexure has made favorable places for erosional gaps in the ridge. Facing northward in the gap are several abandoned tunnels and open trenches, where many years ago soft ore was obtained. No accurate measurements of the ore bed could be obtained at these workings, as shale and débris covered every vestige of the face of the bed, but from all available indications and information the ore bed, which McCalley regarded as the Big seam, is more probably the Irondale seam. Its workable portion is about 4 feet thick. Fragments of the soft ore picked up along the old tramway appeared to be of good grade. The abnormal structure here has probably shattered the ore seam considerably, besides producing irregular dips and possibly minor faults, so that deeper mining can not be carried on advantageously at present. There are reserves of ore here which will be exploited in time. A section by McCalley, evidently made at these mines when they were open, is given as ore section 1 (fig. 5). Analyses, also from McCalley, which show the ore to be of good grade, are given on page 79. An old railroad spur extends into Morrow Gap from the Louisville and Nashville to the east, and evidently the old mine was formerly an important producer of soft ore.

ALFRETTA MINES.

The Alfretta group of slopes are part of the properties of the Republic Iron and Steel Company. No. 1 is in the SE. ¼ NE. ¼ sec. 32, about one-half mile south of Morrow Gap, on the east slope of Red Mountain. The mine is reached by a spur from the Louisville and Nashville track, and the workings are in a ravine well down toward the foot of the ridge. The rocks at this place strike about N. 25° E., and dip 10° to 17° in the mine slope. The Irondale seam is mined here and shows a thickness of 4½ to 6 feet. A section made at the mouth of the first left entry is shown in ore section 2 (fig. 5). The mine has not yet reached a completely hard ore, the iron content in the soft ore running from 44 to 52 per cent, and in the semihard ore about 43 per cent. (See analyses, p. 79.) Alfretta No. 1 slope had been driven about 500 feet January 1, 1909, and from it were turned 8 right and 10 left headings. The mine is equipped with air drills. Indications were found of a thin ore-bearing bed 50 feet or more above the Irondale seam, but the material was too lean to be mined.

TOWNSHIP 17 S., R. 1 W.

ALFRETTA NO. 2.

Alfretta slope No. 2 is in the NE. ¼ NW. ¼ sec. 5, half a mile southwest of Alfretta No. 1. This mine has topographic relations similar to those at Alfretta No. 1. The rocks strike nearly N. 45° E., and in the first 150 feet of the slope the dip is about 15°. At 150 feet from the mouth of the slope occurs a slight fault by which the ore is dropped the thickness of the bed, and beyond this point the dip becomes 33° and continues to about 225 feet, beyond which point the ore flattens, and then begins to rise. This attitude of the strata is due to a synclinal axis at right angles to the axis of Red Mountain. In order to maintain the requisite dip the slope must be turned toward the south. Work has not been carried on here since November, 1907. At that time the slope was 423 feet long. There were 7 headings on the left and 3 on the right in this mine, and the workings were all reported to be in soft ore. An unusual though not excessive quantity of water had to be pumped from this slope. The Irondale seam, which was mined here, ranges from 4 to 5½ feet in thickness, and its section at the mouth of the slope is given in ore section 3 (fig. 5). The quality of ore is about the same as that at No. 1.

ALFRETTA NO. 3.

Alfretta slope No. 3 has been recently started in the NW. ¼ NW. ¼ sec. 5. On January 1, 1909, its length was about 110 feet, with three headings, all in soft ore. The slope is driven on the Irondale seam, which averages about 5½ feet thick.

ALFRETTA NO. 4.

In the same quarter section and about 400 feet southwest of No. 3 is slope 4, formerly called the Wahnetah mine. These workings face the east and consist of two open cuts, one drift, and one slope, 330 feet long, with 5 left and 4 right headings. The rocks here strike only slightly north of east, and dip about 30° S. The Irondale seam is mined here, and runs 3½ to 6 feet thick, with an average thickness of about 5 feet. A section of the ore bed at the breast of the drift heading is given in ore section 4 (fig. 5), and analyses of the soft ore, which runs from 45 to 52 per cent metallic iron, are given on page 79.

The next exposure of ore to the southwest is in the railroad cut about 450 feet west of the road crossing in Sadlers Gap. (Analyses, p. 79.)

OLIVIA MINE.

About one-half mile southwest of Sadlers Gap is the Olivia mine, operated in 1906 by the Birmingham Ore and Mining Company. The Olivia is in the SE. ¼ sec. 6, T. 17 S., R. 1 W., and is on the west side of the crest of Red Mountain. The rocks strike about N. 55° E., and dip 15° SE. The workings consist of trenchings on a small scale, shallow mining on the outcrop, and two short slopes. The ore is evidently the Irondale seam, and there is but one bed known here. The ore runs from 3 feet 9 inches to 4 feet 7 inches thick, with usually 12 inches of gouge in addition at the top. In places an inch of shale is present in streaks at 8 inches to 2 feet from the floor of the ore bed. The ore is soft, and carries from 42 to 50 per cent metallic iron. See ore section 5 (fig. 5), and analyses, page 79. The Olivia workings were not in active operation during 1908.

About 1,000 feet southwest of the Olivia mine the Louisville and Nashville track passes to the east side of the ridge through a low gap eroded mainly in the Fort Payne chert, and between this point and Bald Eagle, a distance of more than a quarter of a mile, the Clinton strata are obscured by a fault, or possibly may not have been deposited at this point. The Knox dolomite to the west appears to be overlapped by Fort Payne chert from eastward. The absence of the ridge-making sandstone, characteristic of the lower half of the Clinton in this vicinity, accounts for the fact that here Red Mountain itself is really missing, being replaced by a gently rounded low hill of Fort Payne chert with a still lower gap at each end.

BALD EAGLE GAP.

On the south side of the wagon road through Bald Eagle Gap the Clinton formation is again noticeable and its soft ore has been worked as late as September, 1903, in trenches and drifts now abandoned. The Clinton is not in its normal position at this point, since the beds strike S. 65° E., and their dip is 20° to 25° N. 25° E. Soft ore from this point carries 46 to 52 per cent metallic iron. Representative analyses are given on page 79.

TOWNSHIP 17 S., R. 2 W.

HIAWATHA.

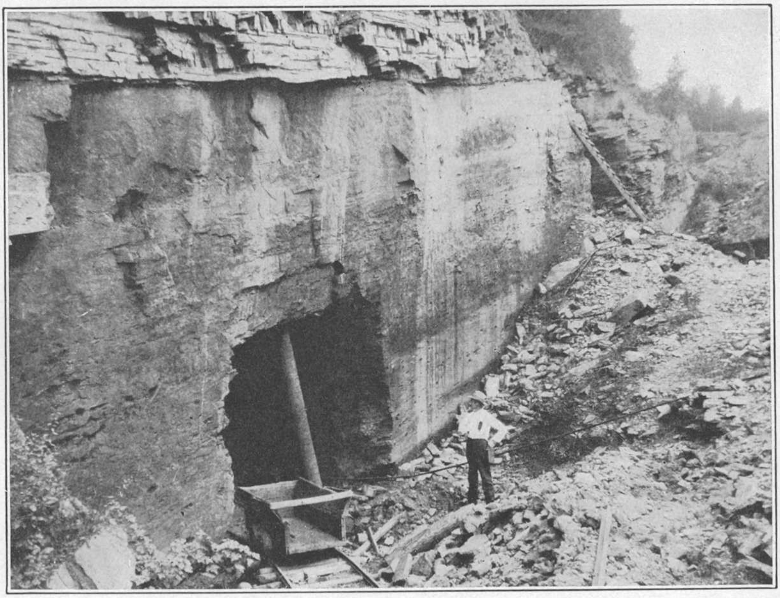
In sections 12 and 13, southwest of Bald Eagle Gap, for more than a mile there are old workings in several westward-facing ravines. Here the rocks dip 15° to 18° southeast, and the Irondale seam and the Big seam above it have been robbed of soft ore by trenching along the flanks of the ravines, also on the crest of the ridge, and drifting on the strike of the beds at right angles to the ravines. This locality seems to be the farthest northeast at which workable soft ore has been obtained from what can be definitely recognized as the Big seam. The old workings, known as the Hiawatha and Ruffner No. 2, were equipped with inclined tramways leading from the Louisville and Nashville Railroad nearly to the summit of the ridge, and were operated as late as the end of 1904, when the soft ore began to grow rather lean. At first the Irondale seam here yielded 48 to 51 per cent metallic iron, but at the last its yield of iron dropped to 37 per cent, while the silica showed no appreciable diminution. Analyses are given on page 79. The hard-ore reserves in this locality are too lean to be worked just at present, and they appear to be practically untouched between Bald Eagle on the northeast and Ruffner No. 1 on the southwest, a distance of about 1¼ miles. The Irondale seam will probably be found to contain the greater part of the available hard ore in this strip of the ore-bearing formation, since the Big seam as an important soft-ore producer only begins here, and consequently its hard ore must be decidedly lean judged by present standards.

RUFFNER.

In the NW. ¼ and SW. ¼ sec. 13 are the Ruffner workings of the Sloss-Sheffield Steel and Iron Company. The east slope of Red Mountain in this locality is cut by steep, narrow, V-shaped ravines, at places one-fourth to one-half mile apart, and these ravines cut deeply into the Clinton formation, which is exposed from the crest of the mountain about two-thirds of the way down the east slope. The dip of the rocks here is about 17° SE., and it is only slightly steeper than the slope of the hill. The upper ore beds crop out at the crest of the ridge and are covered by only 20 to 40 feet of shale and sandstone for the greater part of the distance down the slope until the Clinton passes beneath the Fort Payne chert. As a consequence of these relations between topography, rock structure, and position of the ore beds, which are in the upper half of the Clinton formation, the ore beds are exposed in many of the ravines from the crest nearly to the foot of the ridge.

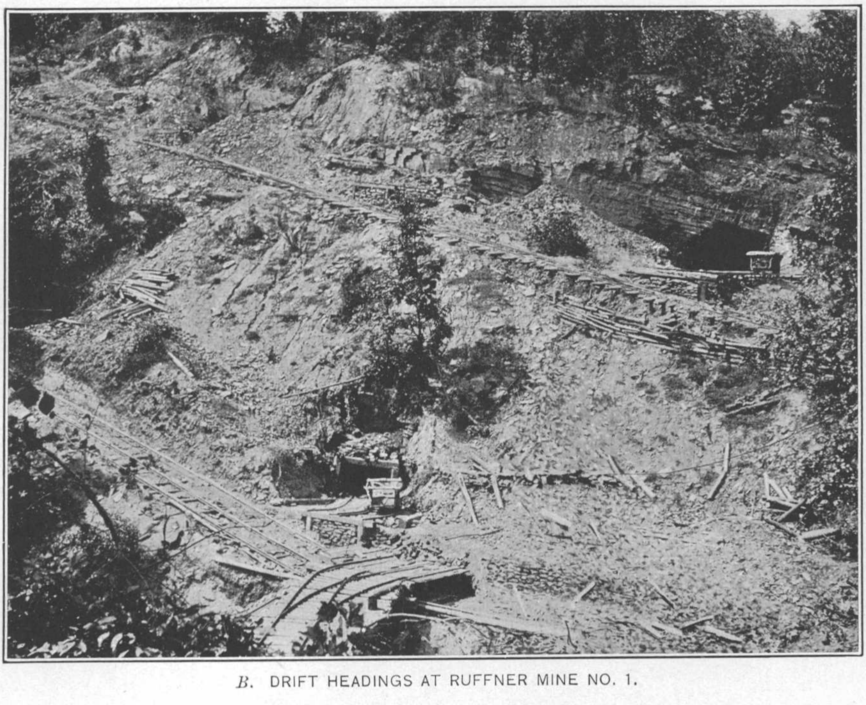
A generalized section of the Clinton formation in this locality is given on page 42. The Irondale seam, soft and hard ore, 5 feet 6 inches thick, and part of the Big seam, soft ore, 7 to 9 feet thick, are workable under present conditions. Ore sections 6, 7, and 8 (fig. 5) represent sections, respectively, of the Ida seam, Big seam (best portion), and Irondale seam. The Ida seam is not worked at present. It is reported to carry 30 to 33 per cent metallic iron, 40 to 50 per cent insoluble, and 10 per cent lime carbonate. The exploited part of the Big seam carries in the soft ore about 40 per cent metallic iron and 40 per cent insoluble; the hard ore 35 to 40 per cent iron, 20 to 30 per cent insoluble, and 15 to 25 per cent lime carbonate. The Irondale seam carries in the soft ore 40 to 50 per cent iron and 35 to 45 per cent insoluble, and the hard ore 28 to 36 per cent iron, 28 to 36 per cent insoluble, and 15 to 20 per cent lime carbonate. (See working analyses, pp. 79–80.)

Advantage has been taken of the favorable physical conditions at many workings in this locality, but those at Ruffner No. 1, in the SW. ¼ NE. ¼ sec. 13, probably have been most extensively developed and best illustrate the possibilities of what is here termed the "second stage" of mine development in this district. The Louisville and Nashville Railroad is on the east side of the mountain here and a spur extends back into the ravine as far as grade will allow. Some filling has been done in the bottom of the ravine, utilizing the strippings from above the outcrop of the ore bed. A tipple and crusher stand on a bridge across the hollow at the end of the spur. An inclined tramway extends up each flank of the ravine, and entries or drifts are driven in on the workable portion of the Big seam, 50 feet apart, at right angles to the tramways and along the strike of the beds. Seven to 9 feet of soft to semihard ore in the



A. UPPER TWO-THIRDS OF BIG SEAM, RUFFNER MINE NO. 1.

Showing drift in workable part.



B. DRIFT HEADINGS AT RUFFNER MINE NO. 1.

Lower drift is on Irondale seam; upper is on Big seam.

upper half of the Big seam have been mined from these entries and from "upsets" or rooms driven upward on the beds. (See Pl. VIII, *A*.) Two loaded mine cars are carried at one time down the incline on a carriage built with a horizontal deck, the weight of the whole being sufficient to pull up the balance car, which in turn hauls up the carriage loaded with two empties. Movements of the cars are controlled by brakes on the sheave operated by a starter in a tower at the top of the incline. All the ore above the tipple is thus handled economically by gravity. In addition to the openings on the Big seam, the Irondale seam (28 to 30 feet lower) is also being worked in one place on a similar plan, the relations of the parallel system of entries on the north side of the ravine being shown in Plate VIII, *B*. At this place the Irondale seam is also mined from a slope the mouth of which is near the tipple. This slope in January, 1909, was about 480 feet deep, with 10 right and 9 left headings. Soft ore was found to extend down to water level, a distance of 75 feet from the mouth of the slope, beyond which point the hard ore set in rather abruptly. In January, 1909, the drift entries and the slope on the Irondale seam were the only active workings at Ruffner No. 1. Mining on the Big seam was discontinued in October, 1907, owing, it is reported, to the fact that the available soft ore was nearly exhausted. In the NE. ¼ SW. ¼ sec. 13 a slope known as Ruffner No. 3 was started in December, 1908. This opening is on the north side of a ravine about one-third mile southwest of Ruffner No. 1. It is about 60 feet above the Louisville and Nashville track, with which it is connected by a spur track. This opening is apparently to be driven in the direction of a set of vertical joints in the ore, S. 80° E. The beds here dip about 18° S. 65° E. The Irondale seam, which is to be mined in this slope, is similar in character and thickness to that bed at Ruffner No. 1. The Big seam here is composed of coarse-grained, cross-bedded, ferruginous sandstone, or sandy ore, of dark-brown color on the outcrop.

IRONDALE.

Between Ruffner and Red Gap, in sec. 23, opposite Irondale, lies a strip of Red Mountain about 1 mile long where the Irondale seam has been worked extensively for its soft ore. The bed is 4½ to 5 feet thick here, but there are shaly partings in it. The ore exposed at the mouth of an old drift in the NE. ¼ NE. ¼ sec. 23, about one-half mile north of Red Gap, showed the section given in ore section 9 (p. 76). The beds here dip 22° S. 50° E. The Big seam at this locality appears to be rather high in silica and contains irregular sandy pockets. No ore is being mined here at present.

RED GAP.

At Red Gap, the east gateway to Birmingham, the Clinton formation has been offset to the west by a fault, the total offset amounting to about the outcrop width of the formation. For a mile south of the gap the dip is gentle, 15° to 16°, and consequently the Clinton presents a slightly wider outcrop area than just to the north of the gap. Soft ore mined from the Irondale seam at the Howard workings, now idle, just north of Red Gap, contained 45 to 49 per cent iron. (See p. 80.)

In this vicinity there is an exceptional thickness of ferruginous beds together in the section. From the top of the Ida through the Big seam to the bottom of the Irondale there are fully 70 feet of beds that for the most part are "near ore." These beds are persistent in character for a mile and a quarter from the outcrop, as shown by a drill hole near Shades Creek.

About one-half of a mile south of Red Gap, in the SW. ¼ SW. ¼ sec. 23, the SE. ¼ SE. ¼ sec. 22, and the NW. ¼ sec. 26, is the Hammond mine of the Alabama Consolidated Coal and Iron Company, opened in January, 1906. This mine is on the east slope of Red Mountain. It consists of a slope driven about 1,350 feet measured from the outcrop down the dip of the beds, which is 15° to 16° S. 53° E. The slope is reached by a tunnel 275 feet long driven from a ravine in the southeast side of Red Mountain. The tunnel strikes the ore about 550 feet below the outcrop, and the working slope extends about 800 feet below the tunnel. Headings are turned off 50 feet apart each side of the slope. Only the Irondale seam is worked in this mine. It ranges from 26 inches on the outcrop to 5 feet thick at 1,300 feet from the outcrop. The bed carries 3½ to 4 feet of good ore.

The Hammond mine was last operated late in 1907. While in operation 5 to 5½ feet of ore were taken, including 1 foot to 1½ feet of shaly "gouge," which reduced the grade of the ore. By mining a less thickness of ore or by washing and picking the shaly material out before the ore is sent to the furnace the mine can probably be operated advantageously again. The ore has been shown by drill hole near Shades Creek to extend with unchanged dip for more than a mile, and to increase in thickness to nearly 7 feet, thus proving a large ore reserve for the Irondale seam in this locality. Ore from here was formerly shipped to the blast furnaces of the Alabama Consolidated Coal and Iron Company at Gadsden and Ironaton, Ala.

A generalized section of the Clinton formation for this locality is given on page 42, and a graphic section of the best part of the Big seam is given in ore section 10 (fig. 5). The best ore in the Big seam runs when soft about 36 per cent iron, with about 45 per cent insoluble and a trace of lime. None of it is worked at present, but it will doubtless be considered valuable within the next decade. The Irondale seam, soft, carries about 50 per cent iron, 15 per cent insoluble, and a trace of lime, and the hard ore 34 to 38 per cent iron, with 7 to 9 per cent lime. A hole was drilled on this property penetrating all the ore beds, and analyses of portions of the core, representing the Ida seam, four sections of 10 feet each of the Big seam, and the Irondale seam, are given on page 80.

Further sections of the Irondale seam measured by McCalley in a test drift about one-half of a mile southwest of the Hammond mine show the bed to contain 4 to 5 feet of soft ore of good quality. (See ore sections 11 and 12, fig. 5, and analyses on page 80.)

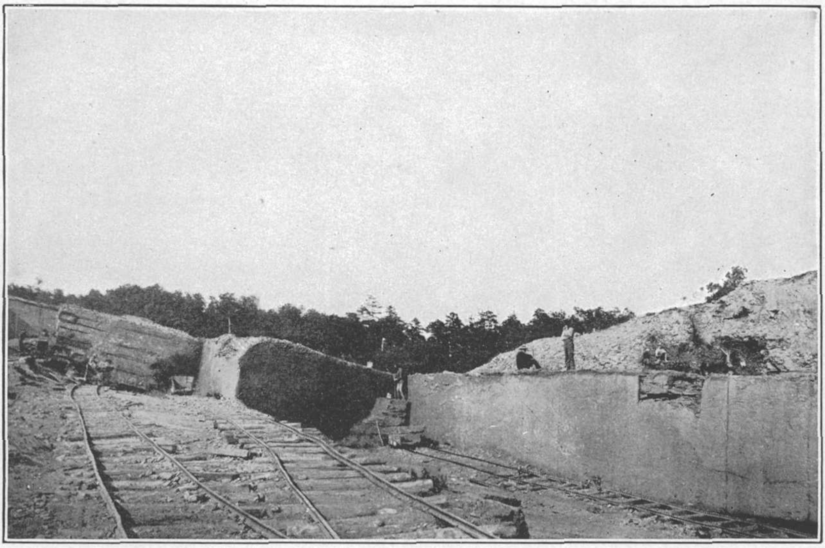
DAGO.

In the southwest corner of sec. 27 and the southeast corner of sec. 28 and the NW. ¼ sec. 34 and the E. ½ sec. 33 are the abandoned mines on the properties known as "Dago." The properties are now owned by the Republic Iron and Steel Company. The rocks dip about 16° here. The grade of an old incline extends up the slope of the mountain and the openings face southeast. The Irondale seam was formerly mined here, but it is thinner than at most places in this vicinity, being but 2 feet 6 inches in thickness on the outcrop. A section measured at the mouth of an old drift near the foot of the hill is as follows:

Section at old Dago mine.

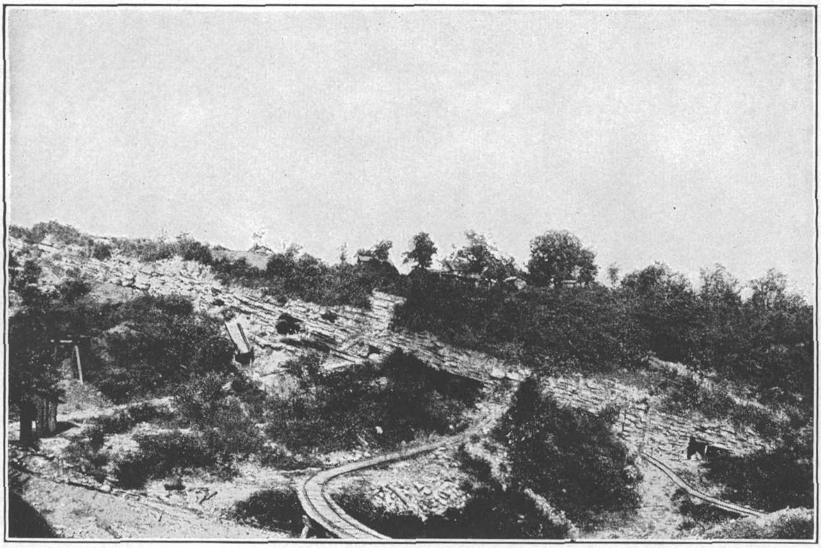
	Ft.	in.
Sandstone, yellowish.		
Sandstone, ferruginous, probably including horizon of Ida seam.	15	
Débris	5	
Iron ore (Big seam), lean, massive, coarse, pebbly	14	
Shale, yellow	3	6
Iron ore (Irondale seam)	2	6
Sandstone, yellow.		

Average samples of the three seams were analyzed by the Alabama Geological Survey with results given on page 80. The Irondale appears to be the only ore here of commercial grade. It carries (soft) about 50 per cent iron and 22 per cent silica.



A. UPPER WORKABLE PART OF BIG SEAM, IN OPEN CUT AT HELEN-BESS MINE.

Shows jointing of ore bed.



B. NORTH INCLINE AT VALLEY VIEW MINE.

Showing drift headings.

HELEN-BESS.

In the SE. ¼ sec. 32 is the Helen-Bess mine of the Birmingham Ore and Mining Company. The workings are along the crest and down the southeast slope of Red Mountain on both sides of a ravine. A spur is turned into the hollow from the Louisville and Nashville track, and the general plan of mining resembles somewhat that of Ruffner No. 1 mine, outlined on page 58, except that much more open-cut work is in progress at the Helen-Bess. The rocks here dip about 17° S. 40° E., and along the crest and for a few hundred feet down the slope the soft ore of Big seam, part of which is of good quality, is overlain by so thin a cover that for a few years prior to the fall of 1907 it was profitably stripped. A face of ore 10 to 11 feet thick at the top of the Big seam is thus obtained which has been quarried rather than mined, and the jointing greatly facilitates its removal. There are two sets of joints here (a) and (b). (See Pl. IX, *A*.) Joints (a) strike N. 40° E. and dip about 80° NW. These joints are 10 to 15 feet apart. Joints (b) strike N. 70° W., dip about 80° NE., and are from 1 to 10 feet apart. (See illustration, Pl. IX, *A*. The ore face illustrated is nearly 12 feet thick, including 1 foot of gouge at the top.) The Irondale seam, carrying 4 feet 10 inches of ore parted near the middle by 6 to 12 inches of shale, is mined by drifts and a slope. This slope, in January, 1909, was about 500 feet long, with 7 headings on each side, 60 feet apart. The Irondale lies close below the Big seam, being separated from the lower, siliceous part of the latter by 1 to 2 feet of shale.

A little ore has been mined from the top 6 or 7 feet of the Ida seam at this mine where that bed is under heavy cover toward the lower part of the hill. The ore is reported to carry (soft) about 40 per cent iron and about 37 per cent insoluble. It is doubtful whether any large quantity of ore of sufficiently high grade to satisfy furnace men can be obtained from this bed, especially where the ore becomes hard and iron content is correspondingly lowered. (See analysis, p. 80.) The Big and Irondale seams here, as shown in the general data on page 48, also in ore sections 13 and 14 (fig. 5), and in the analyses (pp. 80–81), are of sufficient thickness and of fairly satisfactory quality. The content of iron ranges from 32 to 35 per cent, silica from 30 to 32 per cent, and lime from 6 to 8.5 per cent in the semihard ore.

KEWANEE.

Southwest of Helen-Bess about one-fourth mile, in the SW. ¼ SE. ¼ sec. 32, are the workings of the Kewanee mine. These workings consist of inclines cut along the flanks of an eastward-facing ravine, with a tipple on the Louisville and Nashville track. Along the inclines the upper part of the Big seam is plainly exposed. The best ore is about 10 feet thick, rather siliceous, and carries 32 to 34 per cent iron, 34 to 40 per cent insoluble, and 5 to 8 per cent lime in the semihard variety. The Irondale seam has also been worked here. Its iron content is about the same as that of the Big seam, but the hard ore carries 15 to 20 per cent of lime. This mine has been worked from time to time for several years, the latest developments having been suspended in the fall of 1907, when ore was being shipped to the Williamson furnace in Birmingham.

TOWNSHIP 18 S., R. 2 W.

Southwest of the Kewanee mine there are at present no active mines within 2 miles. This strip of Red Mountain crosses parts of sections 33 and 32, T. 17 S., R. 2 W., and parts of sections 5, 6, and 1, T. 18 S., R. 2 W. Within five or six years, however, considerable soft ore has been removed from the outcrop of the Big seam just northwest of the crest of the mountain here. This locality is about opposite the center of the city of Birmingham, and overlooks the residence portion known as South Highlands, which is built on the Knox foothills of Red Mountain. Part of the Big seam has been trenched a good part of the distance, and the Irondale seam has been worked on the surface of its outcrop and by drifts on the flanks of five or six ravines that cut the southeast slope of the mountain.

The rocks dip generally 20° to 24° SE. in this locality, and a generalized section of the Clinton formation derived from the outcrops along the wagon road in the gap across Red Mountain in the NE. ¼ sec. 5 is given on page 43. Analyses by W. B. Phillips of soft ore from this outcrop indicate a range in iron from 29 to 42 per cent and of silica from 34 to 53 per cent. (See p. 81.) About 10 feet of the bed will probably be considered minable in the near future, although the ore is all rather coarsely siliceous.

At the old Hedona workings in the NE. ¼ sec. 6 ore from the Big seam ranged in December, 1903, from 38 to 44 per cent iron and about 35 per cent insoluble, and the Irondale seam, soft, 46 to 50 per cent iron and 25 per cent insoluble. (See p. 81.) The Big seam in this locality is known to be rather more siliceous and less rich in iron than it is in neighboring localities. The Irondale seam is apparently of good grade here, though it is known to fall rapidly in grade southwestward from Lone Pine Gap. There is evidently a large quantity of medium-grade hard ore still untouched here.

In the Louisville and Nashville Railroad cut at the east end of Lone Pine Gap may be seen a fairly good section of the upper part of the Clinton formation and the Devonian deposits between the top sandstone of the Clinton and the Fort Payne chert. The rocks dip here 24° S. 40° E. At the west end of the wagon bridge over the railroad in the gap the Big seam outcrops, the upper 9 feet of which is good ore. At the old Lone Pine No. 3, operated in 1904, the soft ore of the Big seam yielded 39 to 44 per cent iron and 32 to 35 per cent insoluble. In the summer of 1907 hard ore was shipped from here carrying 35 per cent iron, 29 per cent silica plus alumina, and 8 to 10 per cent lime. (See analyses, p. 81.)

TOWNSHIP 18 S., R. 3 W.

VALLEY VIEW.

The next mine in active operation is the Valley View, in the NE. ¼ sec. 12. This mine is situated on the crest and east slope of Red Mountain on both sides of an east-facing ravine, in which is an inclined tramway. (See Pl. IX, *B*.) The top 10 to 14 feet of the Big seam are worked here. The ore has been surfaced so far as the topography would permit, on the top of the ridge and down the flanks of the ravine; then drifts were driven in on the strike of the bed and underground mining carried on. An underground slope, about 700 feet long January 1, 1909, has been driven west of the ravine, with 3 left and 8 right headings turned off. Cars of ore from drifts opening on the east side of the ravine are run across the ravine through left-hand entries into the slope and are then hauled up the slope by cable. Since the ore-carrying railroad is here on the west side of the mountain, the cars can not be operated by gravity, so the ore is hauled up to the tipple, where it is crushed and loaded directly on cars on a siding. The rocks dip about 20° at this place. The general character of the ore seams is shown in the table on page 48. At present a semihard ore is mined from the Big seam. (See analysis, p. 82.) If only 10 feet of ore are taken the iron content in the semihard ore can be kept up above 40 per cent, with about 10 per cent silica, but when 12 to 14 feet of ore are taken, by mining more bottom, the ore will run about 35 per cent iron with 25 to 30 per cent silica. Neither the Irondale seam nor the Ida seam is mined here at present, although both are recognized in the section. The Ida, 7 feet thick, lies about 40 feet above the Big seam, and is reported to carry 40 per cent of iron where soft. The Irondale, separated from the lower siliceous part of the Big seam by 2 feet of shale, is itself a low-grade ore interbedded with shale. (See ore sections 15 and 16, fig. 5.)

The Valley View property is owned by the Central Iron and Coal Company and the ore is mined on contract by the Birmingham Ore and Mining Company.

GREEN SPRING.

One mile farther southwest, in the SE. ¼ sec. 11, is the Green Spring mine, belonging to the "Red Mountain group" of the Tennessee Coal, Iron and Railroad Company. The topography at this place is similar to that along the greater part of Red Mountain. The crest of the ridge is formed by sandstone lying above the Big seam, and there are three ravines cutting back up the east slope and forming notches or incipient gaps in the top of the ridge. The dip of the beds is moderate, about 18° S. 40° E., and to an unusual extent, along both the strike and dip, the formation has been so eroded as to leave a cover over the ore bed thin enough to be stripped profitably. The mine is therefore at present worked as an open cut, which extends for nearly half a mile along the ridge. Some trenching down the flanks of the ravines was formerly carried on here for soft ore. The ore in the cut is gathered up in trams and drawn by mules to a central track where it is hauled to a tipple and crusher built over the Louisville and Nashville siding. The character of the ore beds at this place is shown in the table, page 49. The Big seam shows a total thickness of 16 feet above the first shale parting. The top 8 feet are of better grade than the next lower 8 feet, and are easily separated from the lower portion along a bedding plane. Below the shale parting, which is thin, there are about 10 feet of lean, shaly ore, which may represent the lower bench of the Big seam and the Irondale also. The Irondale seam is not workable. Eight or more feet of ore are taken from the top of the Big seam. Most of it is of a semihard grade, carrying about 38 per cent iron, 32 per cent insoluble, and 8 per cent lime. A harder ore, or one carrying more lime, can probably be obtained here also. The soft ore carries about 42 per cent iron and is of a peculiar blue-black tint. Further analyses are given on page 82, and ore section 17 (fig. 5) shows the average thickness of the ore here.

WALKER GAP.

Walker Gap cuts entirely through Red Mountain in the NW. ¼ sec. 14. The character of the Clinton formation along the Louisville and Nashville Railroad cut is shown on page 44. Only the Big seam can be identified here, although ferruginous beds below and above it may represent the horizons of the Irondale and Ida seams, respectively.

For a mile along the ridge southwest of Walker Gap there are no active workings, but here and there are test pits and trenches from which soft ore has been obtained.

GRACES GAP.

Northeast of Graces Gap there are evidences of extensive open-cut workings on the outcrop of the Big seam where soft ore was formerly obtained. Topographic conditions are favorable here for mining and transportation of the ore, since the Louisville and Nashville Railroad passes through the gap. The rock structure shows some disturbance of the strata. An anticlinal fold is noticeable in the shale near the base of the Clinton on the east side of the railroad cut. Near the outcrop just northwest of the present workings a fault has been encountered in which the ore has been displaced from 14 to 60 feet. The beds are steeply tilted, and the fault may be an extension of the one noticed at the Ishkooda mines. (See p. 65.) The gap has evidently been eroded at a point of weakness in the strata.

The present workings at Graces Gap are those of the Spaulding mine of the Republic Iron and Steel Company on the northeast side of the gap in the SW. ¼ sec. 15. A main haulway tunnel is driven northeast on the strike of the bed beginning at the outcrop in the gap. This tunnel enters the rock at a height above the railroad sufficient to bring the ore out on a trestle which supports the tipple and crusher over the railroad track. The main drift runs northeast about 750 feet on a level and from it descends the main slope to the southeast. This slope, January 1, 1909, was reported to be about 1,000 feet long and to have 13 right and 15 left entries below the haulway tunnel, turned from it every 60 feet. A hoisting engine is stationed opposite the junction of the haulway and the slope, and the tram cars are hauled up the slope by cable. They are then switched back into the haulway and drawn by mules to the tipple. The upper bench of the Big seam is mined here. The bed has a total thickness of about 22 feet, but only 10 feet to 12 feet 9 inches at the top is mined at present. (See ore sections 18 and 19, fig. 5.) While the upper part of the seam shows no systematic stratification, there is usually a limy zone in the upper 3 feet or upper one-fourth of the portion that is worked. The two middle fourths carry nearly an equal quantity of lime and the lower one-fourth carries the least lime and the highest silica of all. The iron runs highest in the third one-fourth of the bed, and lowest in the top one-fourth.

These relations are shown in the following analyses, which were made in 1908 from a sample taken from a 12-foot face of ore in one of the headings about 800 feet below the outcrop.

Analyses of hard ore from upper bench of Big seam, Spaulding mine.

Description.	Fe.	SiO_2.	Al_2O_3.	CaO.
Top 3 feet	30.52	12.30	1.89	22.67
Third 3 feet	37.92	23.80	2.72	9.43
Second 3 feet	34.87	25.42	2.84	11.36
Bottom 3 feet	35.92	27.28	3.05	9.38
Computed average	34.81	22.20	2.63	13.21

At another point in the mine about 1,000 feet below the outcrop, 18 feet of the Big seam, including 6 feet of the lower bench, showed the following analyses, in sections of 2 feet each:

Analyses of 18 feet of Big seam, Spaulding mine.

Description.	Fe.	SiO_2.	Al_2O_3.	CaO.
Upper bench:				
Top 2 feet	31.15	9.74	2.17	22.80
Second 2 feet	37.29	13.70	2.84	15.87
Third 2 feet	39.65	19.90	3.18	9.57
Fourth 2 feet	36.81	22.60	3.80	10.03
Fifth 2 feet	37.17	25.40	3.21	8.48
Sixth 2 feet	35.99	26.00	3.18	9.28
Lower bench:				
Seventh 2 feet	38.35	23.80	3.64	8.42
Eighth 2 feet	33.98	27.62	3.08	10.31
Ninth 2 feet	34.10	26.64	2.65	10.14
Computed average	36.05	21.71	3.08	11.54

These results show that the lower bench compares very favorably with the rest of the bed below the top 4 feet. Another face that was sampled at about the same distance from the outcrop showed less lime, as follows (compare ore section 19, fig. 5):

Analyses of 8 feet of lower bench of Big seam, Spaulding mine.

Depth from top of Big seam.	Fe.	SiO_2.	Al_2O_3.	CaO.
12 to 14 feet	37.05	24.56	3.39	7.22
14 to 16 feet	34.69	26.16	3.18	7.33
16 to 18 feet	37.70	27.16	3.80	5.04
18 to 20 feet	35.52	25.68	2.84	9.51
Computed average	36.24	25.89	3.30	7.28

Below the worked portion the material is evidently slightly more siliceous with depth and, in places, shale partings, one-half to 2 inches thick, appear. Two sets of joints are present in the workings, one striking N. 60° W., the other N. 35° E., with steep inclinations, respectively, southwest and northwest. Below the Big seam is a ferruginous sandstone, but there is no definite evidence of the Irondale seam here. An average sample of the soft ore from the outcrop at Graces Gap gave on analysis 44.28 per cent iron and 29.32 per cent silica.[a] The mine run of hard ore carries 34 to 37 per cent iron, 18 to 20 per cent silica, and 13.5 per cent lime. (See p. 82.)

ISHKOODA.

Southwest of Graces Gap, in the SW. ¼ SW. ¼ sec. 15, the NW. ¼ NW. ¼ sec. 22, and diagonally across sec. 21, are the old Ishkooda mines now reopened by the Tennessee Coal, Iron and Railroad Company. The first slope southwest of the gap, now abandoned, was known as the Spaulding. It was only about 200 feet long. Eighteen hundred feet southwest was the old No. 1, and 1,200 feet beyond was the old McElwain, now No. 15. A fault was encountered in old No. 1 and in No. 15. In the latter it is about 1,280 feet from the outcrop.

It would be preferable to describe together all the slopes of the Tennessee Company which constitute the Red Mountain group, since there is considerable uniformity in their general plan and in the system under which each is operated. To describe them as a unit would, however, be a departure from the plan of noting successively all properties from northeast to southwest through this division of the district, since the Tennessee Company's mines are in several instances separated by mines of other companies. Three of the Ishkooda workings correspond to Nos. 15, 14, and 13 of the Tennessee Company's groups of mines. The old open cuts are southeast of the crest of the mountain. The rocks dip 19° to 22° and the Big seam has been mined by open cuts on an extensive scale, almost to the limit of the stripping, 25 to 30 feet. In description of the Ishkooda fault McCalley says:[b]

"No. 1, in the NW. ¼ NW. ¼ sec. 22 * * * is in the upper 10 feet of the Big seam. Its slope has reached a depth of about 400 feet. Two parallel northeast and southwest faults, about 30 yards apart, have been struck in it. The upper or northwest fault has a displacement of only a few feet; the other one must have a displacement of nearly 100 feet, though it has not been cut through."

According to later reports, the Fort Payne chert is dropped so as to form the hanging wall of the fault. The fault is apparently a normal one. Measurements subsequent to McCalley's report indicate that the downthrow is between 125 and 140 feet in a vertical direction.

McCalley[c] mentions the presence of the Irondale, Big, Ida, and Hickory Nut seams in the general section here, although only the upper 6 to 12 feet of the Big seam were worked at the date of his report. In January, 1909, all the slopes in the Ishkooda group were in operation except No. 15, which was nearly ready for mining. In slopes 14 and 13 about 11 feet 6 inches of ore at the top of the Big seam is taken. In No. 14, in the sixteenth right heading, which in January, 1909, was near the bottom of the slope, the bed shows at the top 3 inches of sandstone and 3 inches of shale, which are shot down with the ore in order to leave a safe roof (see ore section 20, fig. 5). In places the total thickness of this material reaches 2 feet. Below this material the ore bed is locally sandy and lean, and locally it is highly calcareous, with coarse, kidney-shaped lumps of calcite, or pebbles of argillaceous material. Twelve feet is the usual depth below the permanent roof to which the bed is cut. Below this depth there is a parting on a bedding plane, and there are 4 to 6 feet of leaner ore between this bedding plane and the first shale parting below.

[a] McCalley, Henry. Report on the valley regions of Alabama, pt. 2, 1897, p. 384.
[b] Op. cit., p. 387.
[c] Op. cit., pp. 388, 391, and 394.

The hard ore from this locality carries 34 to 35 per cent iron, 13 to 15 per cent silica, and 15 to 18 per cent lime. As compared with ore from the Muscoda and Fossil slopes it is slightly less rich in lime.

Slopes 14 and 13 are not driven directly down the dip of the ore, but each is driven along a distinct system of joint planes in the ore. No. 14 follows the direction approximately S. 71° E., and No. 13 is driven S. 20° E. As the slopes become deeper it is found that this plan has certain disadvantages. As the slopes diverge the distance to the intermediate driving line becomes continuously greater, and as the slopes are driven downward they themselves approach the driving lines of the other adjacent workings.

The Tennessee Coal, Iron and Railroad Company slope No. 13 starts in the NE. ¼ SW. ¼ sec. 21. Hard ore is obtained here below a cover 75 to 100 feet thick. In 1896 this slope had reached a length of 1,700 feet, had 17 right and 16 left entries, and was then the deepest slope on Red Mountain. No work was done here between 1902 and 1908, when the slope was reopened and the haulage system changed so that the ore is hoisted by skip to the northwest face of the mountain. According to McCalley the old Eureka No. 1, now the Tennessee Company No. 14, was the first mine to furnish red ore to establish the coke-iron industry in Alabama. This first coke iron was made at the Eureka Company's furnaces at Oxmoor in 1872. A section of the Big and Irondale (?) seams near Eureka No. 1 (No. 14), measured by Mr. L. S. Goodrich,[a] is as follows:

Section of Big and Irondale (?) seams opposite Oxmoor.

	Ft.	in.
Big seam, upper bench:		
13. Ore	7	3
12. Shale and pebbles	Trace.	
11. Ore	8	
10. Shale		3
Big seam, lower bench:		
9. Ore	2	3½
8. Shale		3¼
7. Ore	8	2
6. Shale		1¼
5. Ore		2½
4. Shale		2
3. Ore		11
2. Shale	7	0
Irondale (?) seam:		
1. Ore	1	3

Analyses of soft-ore samples from the strata numbered 1, 3, 5, 7, 9, 11, and 13 were made by Dr. Otto Wuth, of Pittsburg, Pa., and the results are given on page 82. Analyses of ore from all the Ishkooda workings are given on pages 82–83.

Slopes 12 and 11 are in the northern part of section 29. Here, as elsewhere, the soft ore has been stripped and dug from the northwest face of the mountain until the cover became too heavy. The slopes follow the upper part of the Big seam, 7 feet 4 inches to 7 feet 10 inches of which is mined. Ore section 21 (fig. 5) shows the character of this ore in the twenty-eighth heading of slope 12 and ore section 22 (fig. 5) shows the ore of the lower bench in the slope near the twenty-eighth heading. The character of the whole bed here is shown on page 49. It is possible that the Irondale seam is represented in the horizon of ferruginous sediments about 4½ feet below the bottom of the Big seam. The dip of the bed at the mouth of No. 12 is 16½°, but it decreases to 10° or 12° below. No. 12 was 2,121 feet long December 11, 1908, and No. 11 was 2,100 feet long, with entries turned off about 60 feet apart.

[a] McCalley, Henry, op. cit., p. 389.

These slopes are not projected directly down the dip of the beds, but follow the direction of one of the system's vertical joints in the ore, because these joints facilitate the removal of the ore. By following joints, which in No. 12 run about S. 70° E. and in No. 11 about S. 63° E., instead of following the dip, which is about S. 40° E., the slopes lose in steepness about 7 feet in 100 feet. This may or may not be an advantage, depending upon the actual dip of the ore.

A general description of slope-mining plans and methods will be found on pages 135–142.

All the mines from No. 15 southwest to Sparks Gap are slope mines, and all the slopes, with one exception, that of the Tennessee No. 3, open on the northwest side of the mountain and deliver ore to the Louisville and Nashville Railroad, which is built on that side.

SONGO.

The Songo mine, in the SW. ¼ NW. ¼ sec. 29, is worked by the Birmingham Coal and Iron Company. It consists of two slopes. No. 1 was about 1,300 feet long driven directly down the dip, in a direction S. 52½° E., with about 19 headings on each side, in January, 1909. Songo slope 2 is about 950 feet northeast of No. 1. Its length was about 425 feet on the above date. The upper bench of the Big seam carries in this locality 7½ feet to 9 feet of ore, including 6 inches to 1 foot of shaly, siliceous roof ore that is shot down in mining. The lower bench of the bed, separated by about 9 inches of shale, has been worked to a depth of 4 to 6 feet below the parting. The ore is lean and locally streaked with shale in the lower bench, and very little of this ore was being shipped at the beginning of 1909. The upper 7½ to 9 feet of the Big seam (see ore section 23, fig. 5) carries in the hard ore 37 to 39 per cent iron and about 14 per cent lime oxide. (See analyses, p. 83.) The general structure of the ore beds in this locality is shown on page 50.

TENNESSEE COMPANY'S FOSSIL DIVISION.

Slopes 10, 9½, 9, 8, 7, and 6½ constitute the Tennessee company's fossil division. They lie one-quarter to one-half mile apart. (See Pl. X, *A*.) No. 10 and No. 9½ are in the SE. ¼ sec. 30, and No. 9 is in the SW. ¼ sec. 30. No. 8 is in the NW. ¼ sec. 31, and Nos. 7 and 6½ are in the SE. ¼ sec. 36. In all these slopes the upper part of the Big seam is mined. The ore taken ranges from 8 feet 10 inches to 9 feet 4 inches in thickness. Ore section 24 (fig. 5) is typical of the bed mined in slope 10. The content of metallic iron for this part of the bed ranges from 34.5 to 37.5 per cent; the silica from 10 to 14 per cent; and the lime from 14 to 18 per cent.

Interest has been shown for many years in the possibility of mining ore from the upper part of the lower bench of the Big seam. In the Ishkooda group of slopes there is at places no shale parting at all between the upper and lower benches of the bed, and elsewhere it consists of less than 6 inches of shale. In the Fossil group the parting ranges from 5 inches to 1 foot 8½ inches in thickness. The total thickness of the lower bench is generally nearly if not quite equal to that of the upper bench along this part of Red Mountain. The lower part of the lower bench is generally shaly, so that only 5 or 6 feet just below the upper bench can be seriously considered.

Analyses by W. B. Phillips prior to 1896[a] of the soft and hard ore in the upper half of the lower bench of the Big seam indicate that this ore is of fair grade, since the metallic iron ranges in the soft ore from 37 to 46 per cent, with 29 to 43 per cent insoluble matter; and the hard ore carries 29 to 40 per cent iron, 19 to 29 per cent insoluble matter, and 4 to 14 per cent lime. Recent systematic sampling of the lower bench by the Tennessee Coal, Iron and Railroad Company has shown conclusively that the ore in the upper 5 to 9 feet of the lower bench of the Big seam carries hard ore just about as high in metallic iron as the upper bench. The silica, however, runs 7 to 14

[a] McCalley, Henry, op. cit., pp. 396–397.

per cent higher and the lime 6 or 7 per cent lower. Analytic data regarding these interesting relations are given on pages 83–84, and questions concerning the mining and utilization of this ore are discussed on pages 124–125.

As was stated in the notes on the Songo property, some of the lower ore has been used at that mine. However, this lower bench will probably never be available for use unless taken at the time the upper bench is mined, because the present system of final robbing and caving of the workings on the upper bench of ore will prevent working the lower bench.

The total length of slope 10 was about 1,406 feet in December, 1908. The dip of the ore bed varies from 24° to 30°. Slope 9½ had been driven 500 feet in December, 1908. The soft ore extended down about 400 feet, with gradual transition to hard ore.

Slope 9 was reported to be down nearly 1,948 feet in December, 1908. The average thickness is considered to be 9 feet 3 inches of ore, as represented by ore section 25. In this locality a well-defined shale parting 6 to 12 inches thick is present between the upper and lower parts of the Big seam, and it makes a good floor or foot wall from which to remove the ore of the upper ledge. The dip in slope 9 varies from 19° to 25°.

Slope 8 was reported to be 2,301 feet in length in December, 1908, which is the greatest slope length in the district. There is an average of 9 feet 4 inches of ore here, and the general dip is 20° to 22°, but there are locally slight rolls in the strata, which do not interfere with mining. The upper bench of the Big seam, has a shale parting in places. A section of the bed measured in the fifty-first heading, or near the bottom of the slope, is given in ore section 26 (fig. 5). The top 4½ feet of the ore, as mined, appears to carry less iron than the lower 4½ feet. According to analyses by Phillips[a] there was formerly found to be a difference of 10 to 15 per cent in the content of metallic iron between the average run of the upper and lower halves of the worked portion of the seam at this place.

Slope 7, formerly known as the Alice mine, was reported in December, 1908, to extend about 2,103 feet. A view of the tipple and power house at this mine is shown in Plate X, *B*. The rocks at this place show evidence of having been somewhat disturbed in addition to the general tilting suffered by the strata. At the outcrop there are dips varying from 20° to nearly 90°. Within the slope the dip flattens from about 30° to 11°, then gradually increases to 28° near the end of the slope. Several small "rock faults" in the ore, ranging from 2 to 12 or more feet across, are reported to be cut through in the slope. These are simply barren places in the rock. The workings are in the upper bench of the Big seam. The soft ore has been mined out on the outcrop, and the workable ore underground ranges from 8 to 10 feet thick, with a general average of 9 feet 4 inches. The average thickness of the bed is shown in ore section 27 (fig. 5).

At this locality there is in the formation about 15 to 20 feet above the top of the Big seam, a siliceous, grayish ore of very irregular thickness whose soft ore has been worked to some extent and is reported to have reached a thickness of 15 feet in places. Analyses by W. B. Phillips[b] show that this soft ore carried 44 per cent iron and 32 per cent silica. The upper portion of the Big seam is separated from the lower here by 18 to 20 inches of shale, but the lower bench appears not to have been worked. Fifty feet below the bottom of the Big seam is another bed, supposed by the miners to be the Irondale. Its soft ore showed a good composition, and McCalley[c] reports that it was formerly worked on the outcrop.

Average analyses of the hard ores recently mined from all these slopes are given on pages 83–84.

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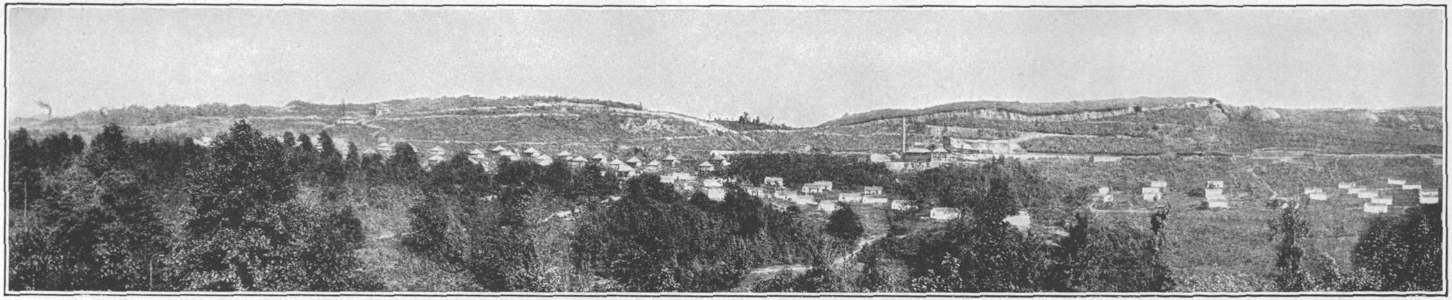
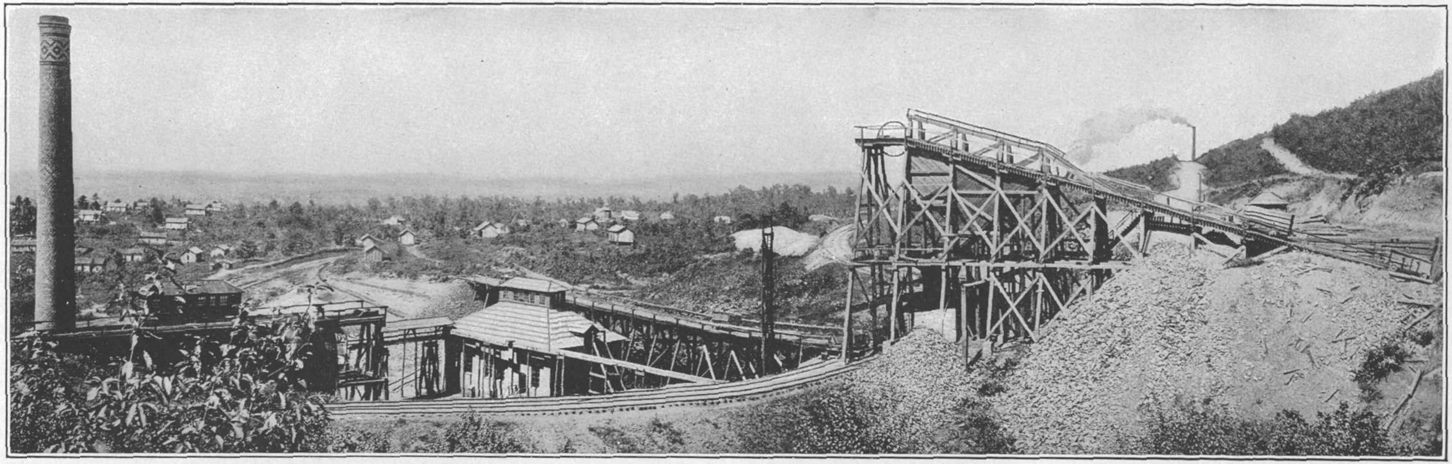
[a] McCalley, Henry, op. cit., p. 399.
[b] Idem, p. 402.
[c] Idem, p. 401.



A. RED MOUNTAIN; SEEN FROM CHERT RIDGE EAST OF GRASSELLI, ALA.

Showing four slope mines of Fossil group, continuous open-cut workings or strippings, and location of ore-carrying railroad near Chickamauga-Clinton contact.



B. TIPPLE AND MOUTH OF SLOPE OF ALICE MINE (SLOPE NO. 7, TENNESSEE COAL, IRON AND RAILROAD COMPANY).

Plateau of the Warrior coal field in distance, beyond Jones Valley.

TOWNSHIP 19 S., R. 4 W.

WOODWARD.

The Woodward Iron Company's slopes 2, 3, and 1 are located in the SW. ¼ sec. 36, T. 18 S., R. 4 W., and the SE. ¼ sec. 2, T. 19 S., R. 4 W. Besides these slopes there was in 1906 in the NW. ¼ NW. ¼ sec. 1, T. 19 S., R. 4 W., a temporary slope or scram said to be mining 5 feet of siliceous soft ore from the lower bench of the Big seam. Slope 3 has been laid out a little farther southwest, or about 600 feet from No. 2. This slope is reached by a drift beginning in the upper portion of the Chickamauga limestone. At Woodward mine No. 2 the present mining is on the upper bench of the Big seam, which is about 10½ feet thick here. In places 1½ to 2 feet of the bed are left at the top as roof, since this portion of the bed is rather siliceous and makes a better roof than the sandstone above the bed. (See ore section 28, fig. 6.) Between the upper and lower benches of the Big seam is 18 to 24 inches of shale. This slope was down about 830 feet in January, 1909, nearly all the distance in hard ore. The normal dip is 28° to 30°, but at about 185 feet from the entrance to the slope the strata flatten out for a short distance and again resume their normal dip. The rocks are folded and fractured noticeably in the vicinity of the main entrance, and a small fault is reported to occur in one of the right-hand entries, now robbed. The ore at this place is reported to average slightly leaner in iron and lime than at the No. 1 slope, three-fourths of a mile farther southwest.

Woodward mine No. 1 is located near the northwest foot of Red Mountain at Tanyard Gap. A general section of the Clinton formation at this point is given on page 44. The Hickory Nut and Ida seams and the Big seam, with its upper and lower benches, are present here, and also a shaly, ferruginous horizon which may represent the Irondale seam. The Hickory Nut seam never was mined, but the Ida seam yielded a thickness of 3 feet of soft ore, carrying about 40 per cent iron. This was stripped for some distance along its outcrop, and its ore is said to have constituted nearly one-eighth of the ore charge at the Woodward furnace in 1895. In the slope the upper bench of the Big seam is about 12 feet thick. Nine and one-half to 10½ feet of ore are obtained. Occasionally a thin parting of shale is found 15 to 18 inches from the bottom or top. The top 18 inches of the bed are generally left for a roof, as at slope 2. The thickness of the seam bed at the mouth of the twentieth right heading is shown in ore section 29 (fig. 6). The dip of the rocks is variable here also. On the outcrop it is 34°, but within the slope it flattens out and ranges between 20° and 28°, until at the lower end, a distance of about 1,500 feet from the outcrop, the beds abruptly bend downward at an angle of 40°, and the ore is faulted downward a distance reported to be about 15 feet. The direction of this fault is N. 35° E., as observed in the slope, and its hade is 80° to the downthrow. This fault was struck in 1908, and the slope was driven about 57 feet in the sandstone hanging wall. Later a hole was drilled in the bottom of the rock slope, locating the ore, according to the statement of the mine boss, and in January, 1909, the slope was being driven toward the ore and being lowered at the bottom so as to smooth out the "knuckle." Considerable water comes down into the slope through this fault plane. A northeast-southwest fault is also reported by McCalley to have been struck elsewhere in the workings of this mine.[a]

"Water channels" passing along fractured beds are reported to have been encountered in several places, for instance in the eleventh right entry, and adjacent to these the ore was soft but surrounded by hard ore.

The bottom ledge of the Big seam is here about 4¼ feet thick and carries where soft 45 to 47 per cent iron, but less than 35 per cent of iron where hard. Under present conditions it is not considered worth mining, since it is poor in lime. The ore

[a] McCalley, op. cit., p. 404.

from the upper bench at these mines contains enough, or in places a trifle more than enough, lime to be self-fluxing. Systematic chemical analyses are reported to have been made of samples of ore taken every few feet from the outcrop to the bottom of the slope and from each entry to the right and left of the slope. The composition of the ore has been found to vary considerably from place to place, and the degree of variation has been found to be as great within a few yards as it is between remote parts of the mine, but the average run of the mine has been remarkably regular since the hard ore was reached. The hard ore "slacks" when left standing several years in pillars, making it necessary to rob promptly to obtain the pillars. Analyses of the ores are shown on page 84.

The output of these mines is carried by the company's railroad to Woodward, Ala., about 3 miles northwestward, where the Woodward Iron Company, one of the pioneers of the district, carries on its iron industry midway between its coal and its iron-ore properties. The blast-furnace plant comprised, in January, 1909, three stacks, two of which are rated at 400 tons and one at 200 tons per day of twenty-four hours. There are about 500 coke ovens.

SLOSS.

Southwest from Woodward slope 1 about one-half mile is another gap, or notch, in Red Mountain, and at that point, in the NE. ¼ NW. ¼ sec. 11, is located the mouth of the slope of Sloss mine No. 2. The Sloss workings here comprise two slopes, the lower or No. 1 being about 2,400 feet southwest of No. 2, mostly in the NW. ¼ SW. ¼ sec. 11. It is also located below a notch in the mountain. These mines are in that part of Red Mountain directly opposite Bessemer. As a result of the erosion of southeast-dipping beds, the outcrop of Clinton strata in the gaps occurs farther southeast and at a lower altitude than on the unbroken face of the mountain. The Sloss slopes and Woodward No. 1 therefore enter the ore measures nearly at the level of the valley.

Slope 2 is driven S. 58° E., practically in the direction of dip of the beds. This dip is 22° to 25°. Here the upper and lower benches of the Big seam are parted by 3 feet of shale and are so distinct that the upper bench is known as the "upper seam." This upper bench runs about 12 feet thick. Two feet are left for roof at the top, above a thin shale parting. There are local rolls in the roof that make the bed thinner, but as a rule the foot wall is even. A thickness of 10 to 11 feet of ore is obtained here, and a representative section is shown in ore section 30 (fig. 6). The length of this slope November 14, 1908, was reported to be 1,330 feet. Soft ore extended down the dip for about 60 feet. The passage from soft ore to hard ore is rather abrupt. The lower bench of the Big seam shows near the mouth of the slope about 5 feet of low-grade ore interbedded with shale bands. There is more shale than ore and the ore itself would probably average only 15 to 25 per cent iron.

At Sloss slope 1, from the outcrop 480 feet down, the rocks dip about 24°, then for about 200 feet the rocks flatten to 16°, and then steepen to 26° down to 1,300 feet, where the dip becomes 17°. Several such waves in the strata have been noted, and the general trend of their axes is northeast-southwest, or parallel to the strike. This slope was first begun at an angle to the dip or in the direction of the vertical jointing, S. 40° E., so that its grade represented a slope of about 24°, but the slope has since been relocated in a direction S. 67° E., or at right angles to the strike of the beds. The character of the Clinton formation was determined by a drill hole sunk 1,200 feet ahead of the slope at this mine in September, 1896. The section is given on page 45. The slope now extends beyond this drill hole, as it was encountered in one of the side entries. The upper ledge of the Big seam is 10 to 12½ feet thick. In mining, 18 inches to 2 feet is left at the top for roof, but this is reported to be taken down when the pillars are robbed and the roof allowed to settle. (See ore section 31, fig. 6, representing the ore in the fourteenth left heading.) Localities are reported to have been encountered in the workings where the ore horizon was occupied for a width of

50 feet by barren shale, but such pockets, or "horses," have been found to give place to good ore when cut through, and rarely have they been found to extend from one heading to the next. These barren lenses of rock are termed "rock faults" by the miners, but they are not accompanied by dislocation of the strata such as a true fault requires. Irregular masses of "limestone" have also been reported to extend down from the roof into the ore bed. Hard ore sets in at 60 to 80 feet down the dip. The parting between the two benches of the Big seam appears from the drill record to be 8 inches of shale and 2 feet 6 inches of gray sandstone, which is more probably a sandy shale. A thin bed at the top of the lower bench is reported by McCalley[a] to be of good grade, but it is not of workable thickness. In former years soft ores were obtained also from the Ida seam, which lies about 20 feet above the Big seam, and from the so-called "gray seam" still farther above the Ida.

Working analyses of the Sloss ores, also analyses of ore from the core cut from the Big seam in the deep drill hole, are given on page 84.

In November, 1908, this slope extended about 1,710 feet from the outcrop. At the face of the slope a fault has been struck. The throw of this fault had not been determined January 1, 1909, but the conditions resemble those at the fault in Woodward slope 1. (See p. 69.)

The fault shows a clean, sharp break. There is no marked change of dip of the beds, and no fracturing of the strata. At the fault plane there is only a thin, soft, ferruginous "gouge," one-fourth to one-half inch thick, between the sheared ore bed and the barren sandstone that has been faulted into juxtaposition with the ore. This sandstone appears to be the material lying normally 10 to 20 feet above the Big seam. The fault strikes N. 10° E., making at the left of the slope an angle of about 77° with the slope, so that it cuts at a slight angle the twenty-sixth left heading, a short distance from the slope. At the face of the slope the fault hades 85° SE., but where observed in the twenty-sixth left heading the hade appeared to be reversed. In general the fault hades very nearly vertical. At the bottom the slope inclines about 32°, and at time of visit had not been driven beyond the fault. Unlike the conditions at Woodward No. 1, the fault in these workings was comparatively dry. The strike of the fault in Sloss No. 1, N. 10° E., does not closely correspond with that in Woodward No. 1, N. 35° E., and if it be continuous between these slopes, which are about 1 mile apart, it must change in direction. No fault is reported to have been encountered in Sloss No. 2, which lies midway between the two points where faults have been noted, but the workings at No. 2 have not been driven so far as the two slopes on either side. There is also the possibility that these faults, having apparently so small a throw, die out within a few hundred feet in either direction, and that they are but local breaks which should be expected along the axis of the fold in which the strata are upturned from Shades Valley northwestward to form Red Mountain.

TENNESSEE COMPANY, MUSCODA DIVISION.

The Muscoda mines, consisting of slopes 6, 5, 4, 3 (abandoned), 2, and 1, are in the strip of Red Mountain extending a little more than a mile northeast of Readers Gap and one-half mile southwest of that point. No. 6 is in the SW. ¼ sec. 10 and No. 5 and No. 4 are in the NE. ¼ sec 15, all northeast of Readers.

Slope 6 enters the ore bed well up on the northwest side of the mountain. The rock dip near the mouth of the slope is about 31°, but farther down it ranges from 21° to 27°. The upper bench of the Big seam is mined here, and it measures 9 to 13 feet thick. In places the whole thickness may be mined, but in others it is necessary to leave 1 foot or more for roof. The average thickness of ore mined is 11 feet 6 inches. "Horses" of barren rock have been struck in certain of the headings, but none in the slope. Soft ore is reported to have extended 275 feet down the slope and to greater distances from

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[a] Op. cit., pp. 405-407.

the outcrop in certain of the headings. This unusual depth of soft ore is due to a ravine on the southeast side of the mountain which has reduced the cover over the ore bed and also concentrated the surface waters into the thin overlying measures. Under these conditions there is usually a gradual rather than an abrupt transition from soft to hard ore. Ore section 32 (fig. 6) represents the ore as measured in the fifty-eighth heading, or about 1,675 feet from the outcrop. The parting between the two benches of the Big seam is reported to be about 2 feet thick here, with ore of no value below. This slope was reported to be about 1,850 feet long in December, 1908, and to have more than 60 entries turned from the main slope.

Slope 5 is situated similarly to No. 6. Near the mouth of the slope the dip of the beds is 26°, but it is as low as 22° in places and as great as 33° in others. The upper bench of the Big seam is here 12 or more feet thick. The average thickness of ore mined is 11 feet 6 inches. The bed is parted at 15 to 18 inches from the top by a thin seam of shale. The ore above this parting is of inferior quality, so it is left as roof, and this top ore makes such a good roof that few timbers are required. Soft ore extended down only 100 feet from the outcrop. The structure of the ore is reported to be fairly uniform. A section of the working face of the ore bed in heading 58, about 1,700 feet from the outcrop, is given in ore section 33 (fig. 6). This slope, in January, 1909, was in the neighborhood of 1,875 feet long.

Slope 4 also begins high on the northwest side of Red Mountain. The dip of the rocks ranges between 17° and 28°. The upper bench of the Big seam measures 11 to 12 feet in thickness, and yields an average of 11 feet 6 inches of ore. A section of the ore in the sixty-fourth heading, about 1,780 feet from the outcrop, is given in ore section 34 (fig. 6). At the right of the slope, in entries 22, 24, 26, and 28, the ore is reported to have disappeared in "broken ground," due to a local synclinal fold whose axis is approximately at right angles to the strike. The effects of the fold disappear at greater depths, as is shown by the normal relations of the strata in headings Nos. 34 and up. On account of this structure, entries 22 to 28 were not driven beyond the disturbed zone. Entries 30 and 32 were driven into barren rock, but No. 34 and the following headings entered ore. The flow of water at this point is larger than at any other slope on Red Mountain. The continuous work of a pump with a 14-inch suction and 13-inch discharge is required to handle the water from slopes 4 and 5.

In December, 1908, this slope was reported to have 62 entries, and to measure about 1,830 feet in length. The development of slopes 6, 5, and 4, since the report of McCalley, printed in 1897, has been probably the most rapid of any in the district, owing to the fact that the maximum thickness of the best workable ore on Red Mountain is found here. At the time of McCalley's visits in 1896, the length of Nos. 6, 5, and 4 were, respectively, 350, 600, and 350 feet, as compared with 1,850, 1,875, and 1,830 feet at the close of 1908.

Slopes 3, 2, and 1 are within one-half mile southwest of Readers Gap. Their workings are for the most part in the SW. ¼ sec. 15.

Old slope 3 or "No. 3 scram" is not now being worked. It is about 410 feet in length. The entrance to this slope was through a drift that faces north in Readers Gap. The upper bench of the Big seam contains the workable ore here, its thickness being 8 to 10 feet. (See ore section 35, fig. 6, which represents the ore near the outcrop.)

Slope 2 was in operation in December, 1908, and was reported to be about 1,300 feet long, with 22 right and 22 left entries. The dip of the ore bed is rather irregular, varying from about 10° at the outcrop through a steeper place where it is 26° to 30°, then flattening again to 15°, increasing gradually to 44°, and finally decreasing to 27°. The upper bench of the Big seam as mined runs from 8 to 10 feet of ore, the top 18 inches of which are very calcareous. Ore section 36 (fig. 6) shows the face as measured in the twenty-eighth heading. Soft ore is reported to have extended nearly 400 feet on the dip, and some is being found at much greater distance in several of the left-hand headings which are not under heavy cover.

Slope 1 at the close of 1908 had been driven 1,330 feet on the dip, which ranges from 9° to 41° 15′. The beds at the bottom of the slope in January, 1909, dip at about 30°. The ore here runs 8½ to 9½ feet thick, averaging 9 feet. An illustration of its character in the thirty-fifth heading is given in ore section 37 (fig. 6). Apparently the beds have not been disturbed to any extent by faulting in these workings, but locally "horses" of barren rock and sandy ore have been encountered. The active workings December, 1908, comprised the tenth to the thirty-sixth headings. Analyses showing the quality of the ores from this locality are given on pages 84–85.

RAIMUND.

The Raimund workings of the Republic Iron and Steel Company consist of slope 1, a short abandoned slope, old No. 2, a new slope 2, and slope 3 (formerly Potter No. 1). They are in the NW. ¼ sec. 22 and the SE. ¼ sec. 21, well toward the crest on the northwest side of Red Mountain. In No. 1 the dip of the strata is about 34°, and the average thickness of the ore mined is about 8¼ feet, with, in places, a thin streak of shale near the top. An illustration of the bed as measured at the entrance to the ninth right heading is given in ore section 38 (fig. 6). No faults have been found in Raimund No. 1 mine, but "bars" or "horses" 10 to 12 feet wide are said to have been struck. Soft ore with gradual passage into hard ore extended down the dip 300 to 400 feet. This wide extent of soft ore is due to thin cover on the southeast side of the mountain. No. 1 slope was reported December, 1908, to be about 1,257 feet long with 21 headings turned off on each side. Headings 10 to 21 were producing ore at that time. At this locality the parting between the upper and lower benches of the Big seam becomes comparatively thick, about 15 feet of measures being reported here, below which are 3½ to 4½ feet of ore too lean to mine. There are also 3 to 4 feet of poor ore 20 feet or more above the workable bed. Analyses of ore from this slope are given on page 85. Between slopes 2 and 3 is a short slope, the right "scram," with headings in the soft ore. The beds dip here 35°, and the Hickory Nut seam, according to measurements of the company's engineers, lies 48.5 feet above the top of the Big seam.

Raimund No. 3 is in the SE. ¼ sec. 21. At this slope 7½ to 8½ feet of ore, with an average of 8 feet, is being mined from the upper bench of the Big seam. Ore section 39 (fig. 6) gives an illustration of the workable ore at the mouth of the slope. A more complete section, showing the relations of the workable portion to the underlying strata, is given on page 51. The rock dips 38° S. 50° E. on the outcrop, but increases to 45° at the point reached by the slope in January, 1909. This slope had been extended nearly 575 feet at that date. The soft ore is nearly all robbed from this slope. (See analyses, p. 85.)

POTTER.

The portion of the Potter property owned by the Tennessee Company has at present one slope, No. 1, in the NE. ¼ sec. 28. It is driven on the upper bench of the Big seam on its outcrop on the northwest side, just below a small notch in Red Mountain, about 1,000 feet southwest of Raimund No. 3. The rock dip is 38°, more or less, and the length of slope was 400 feet from the outcrop in June, 1907, with 5 headings on each side. At that time work was temporarily discontinued, owing to the fact that the ore was cut off by a fault. The ore has since been relocated by drilling in two places beyond the fault. The throw of the fault is about 300 feet, measured vertically, and the ore lies more nearly horizontal beyond the fault. The ore averages 7 feet thick, with a shale roof, and with a shale parting between the workable ore and 3½ feet of poor ore that lies below. The average thickness of the workable ore is shown in ore section 40 (fig. 6.) About 30 feet above the Big seam is a seam called by the miners the "Steel" or "Hickory Nut" seam. It dips 37° SE., shows on the outcrop 36 inches of fair-looking ore with two shale streaks, and is overlain and underlain by sandstone. All the ore raised from this slope to June, 1907, was reported to be soft. (See p. 85 for analyses.)

SPARKS GAP.

The remainder of Division A of the district is comprised in the strip of Red Mountain between Potter No. 1 and Sparks Gap, about 1 mile in length. Two prospect slopes have been sunk about 700 feet apart near the middle of this strip of the mountain, one in the NW. ¼, the other in the SW. ¼ sec. 28. These prospects were made by the Tennessee Coal, Iron, and Railroad Company. Both these prospects had been abandoned some months prior to June, 1906, and at No. 1, the northernmost, no measurement of the ore could be made owing to the condition of the slope, but it is reported to be between 5 and 6 feet thick. The dip at prospect slope 1 is about 30° for the first 100 feet down the slope, then it flattens to 23° for about 70 feet, where the ore abruptly disappears in a fault. No. 2 is driven on an ore bed that outcrops about 35 feet below the crest of the ridge. At the mouth the dip is 40° S. 50° E., but about 70 feet down the slope it becomes very much steeper, and a few feet farther down the ore is cut off by what appears to be the same fault encountered in prospect 1 and in Potter No. 1. The beds exposed at the mouth of this prospect are shown graphically in ore section 41 (fig. 6). The ore was all in a very soft and decomposed condition. The upper 1 foot was sandy, especially at the top, while the main body, 4 feet 10 inches in thickness, besides being parted by several streaks of shale, appeared to be of very questionable quality.

Formerly there has been some doubt whether the ore bed in these prospects is the Big seam or a higher bed. According to present information, it appears probable that southwestward from the Potter slope the upper bench of the Big seam begins to deteriorate, becoming thinner and shaly, and that the ore found near Sparks Gap represents the horizon of the upper bench of the Big seam.

On the northeast side of Sparks Gap an old drift about 1,100 feet long was driven by the Tennessee Company on the strike of this ore bed, which here dips 40° to 43° SE. The ore exposed here is illustrated in ore section 42 (fig. 6). The ore, where soft, is probably of workable grade, as indicated by the analyses on page 85, but the total thickness of 4½ feet indicates an abrupt thinning of the Big seam between Potter and Sparks Gap.

RÉSUMÉ—SECTIONS AND ANALYSES.

A discussion of the economic geology of the productive ore field in Division A will be found under the heading "Applied geology," pages 116–144. In review of the preceding data, the important characteristics of the productive ore beds in Division A are given in the following table:

Tabular résumé of ore seams in Division A.

Ore seam and locality.	Length of outcrop.	Average thickness of minable ore at outcrop.	Dip in Red Mountain.	Average composition (hard ores).		
				Fe.	SiO_2.	CaO.
Irondale seam:	*Feet.*	*Feet.*	°			
1. Morrow Gap to Bald Eagle	11,000	4.25	15–18	35.14	31.23	4.55
2. Bald Eagle to Red Gap	15,000	4.5	15–18	33.67	22.54	12.89
3. Red Gap to Helen-Bess	18,200	4	15–20	35.81	25.57	8.48
4. Helen-Bess to Hedona	6,800	3.5	17–22	36.12	*a* 19.60	14.29
Big seam:						
5. Bald Eagle to Red Gap	15,000	7	15–18	35.87	*a* 26.54	10.92
6. Red Gap to Helen-Bess	18,200	8	15–20	34.77	30.91	7.73
7. Helen-Bess to Hedona	6,800	10	17–22	32.01	32.81	8.51
8. Hedona to Walker Gap	14,500	10	20–25	35.40	25.90	9.50
9. Walker Gap to Graces Gap	5,000	12	20–25	36.26	19.02	13.50
10. Graces Gap to Spring Gap	11,700	9.5	18–25	34.90	14.86	16.98
11. Spring Gap to Woodward No. 2	14,200	9	18–32	36.97	12.58	16.12
12. Woodward No. 2 to Readers Gap	15,500	10.75	20–30	35.10	10.64	19.31
13. Readers Gap to Potter	10,000	8.5	18–40	35.44	11.20	18.25
14. Potter to Sparks Gap	5,200	5.5	30–45	33.28	12.18	19.41

a Insoluble matter.

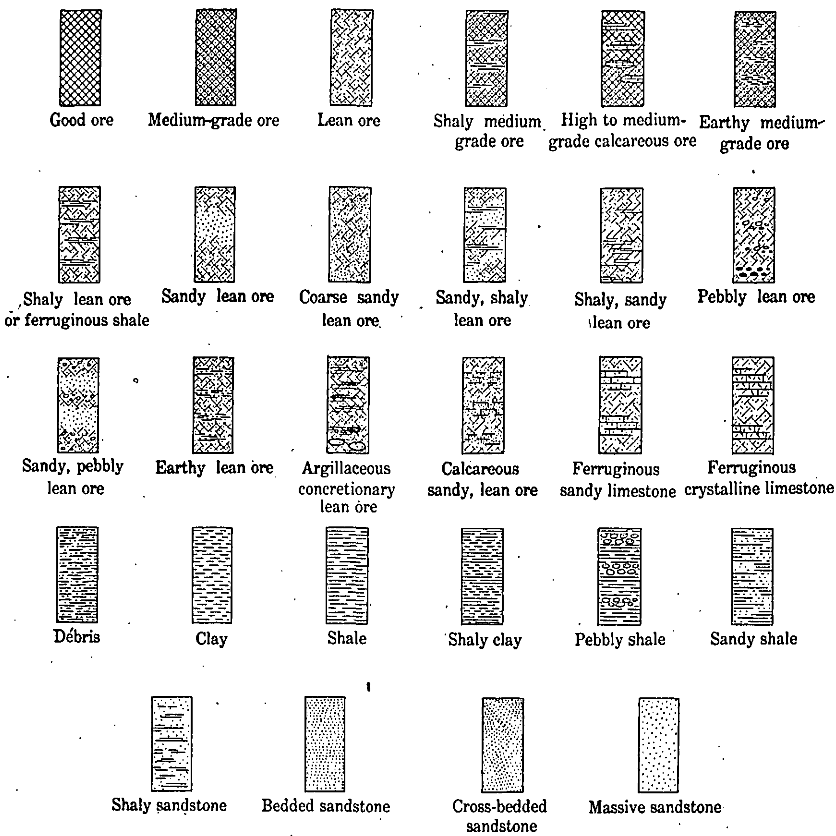

FIGURE 4.—Explanatory key to ore sections.

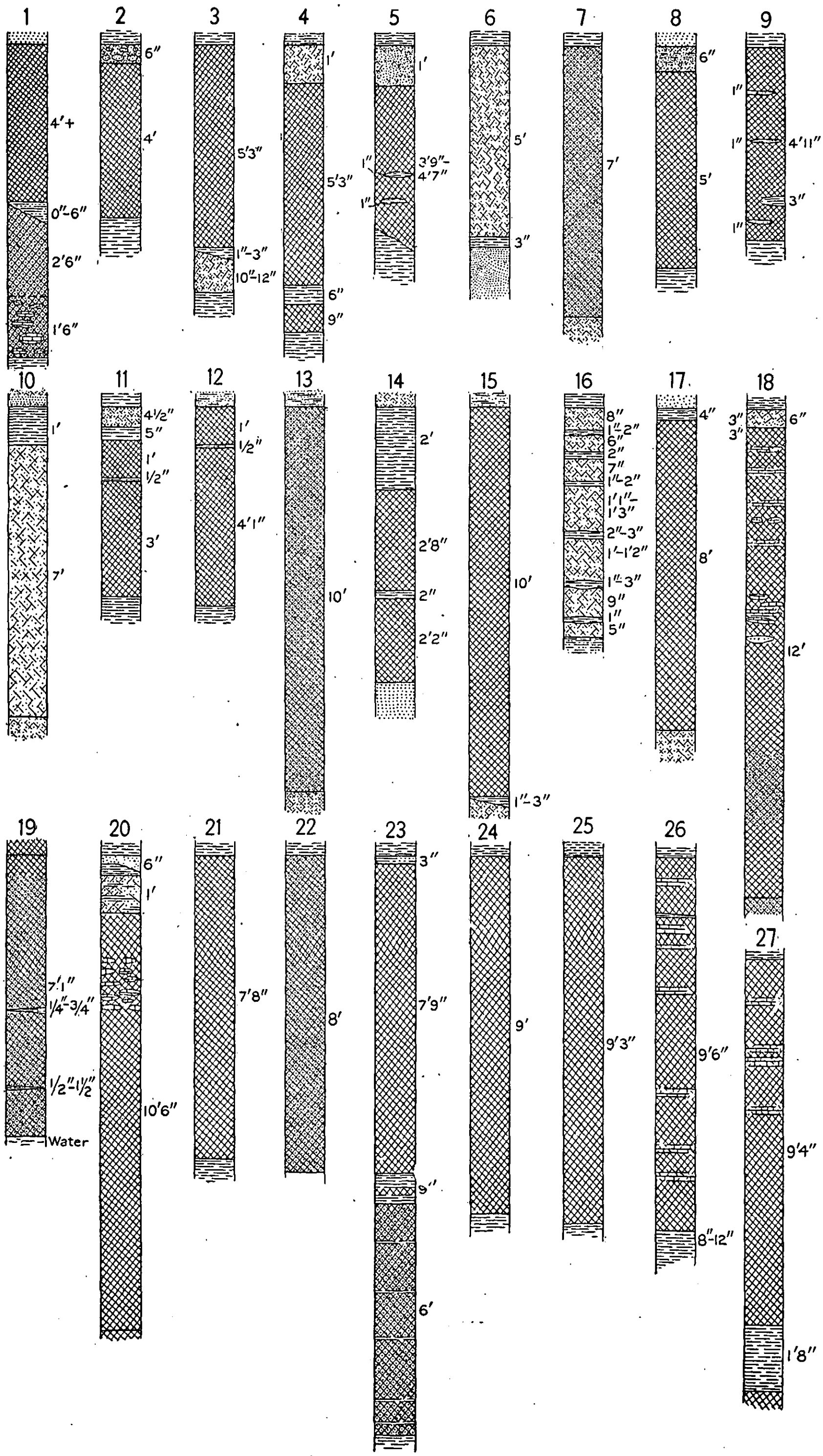

FIGURE 5.—Sections of ore beds, Division A, Birmingham district. (See p. 77.)

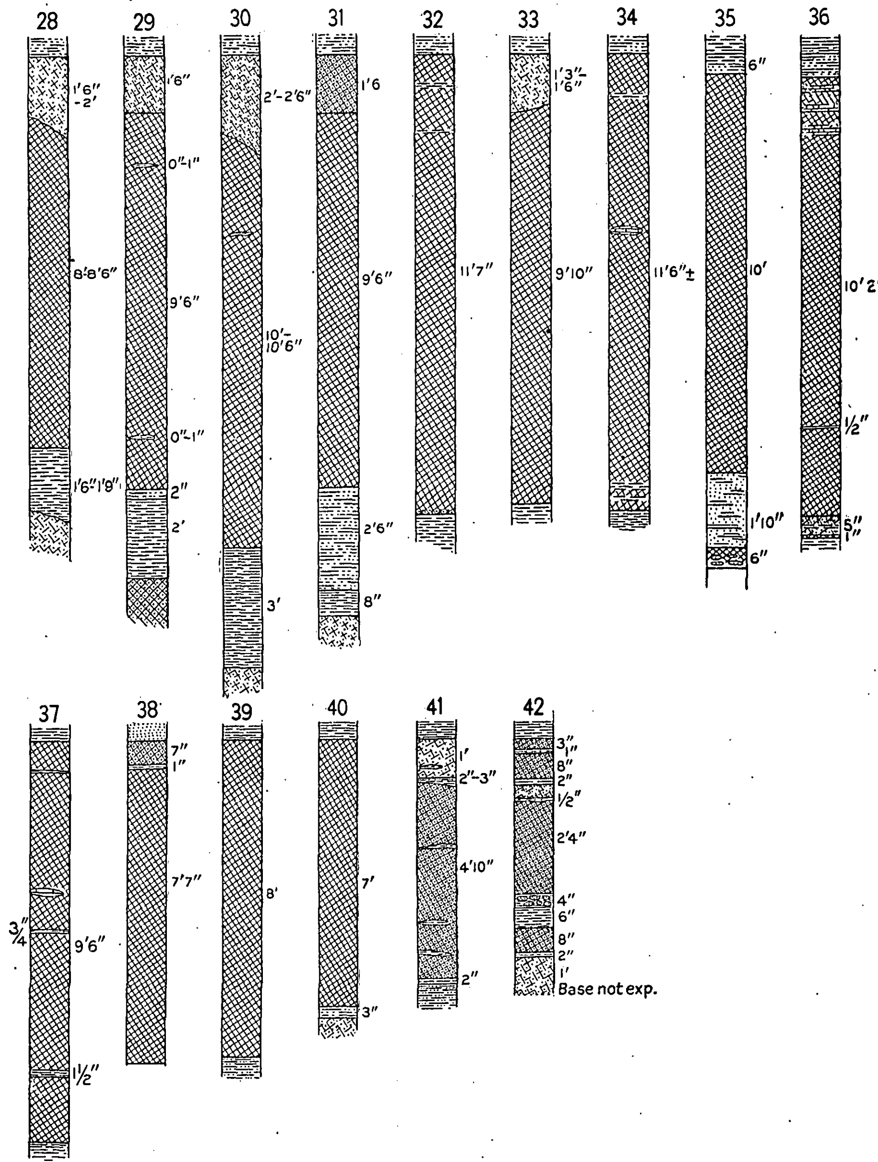

FIGURE 6.—Sections of ore beds, Division A, Birmingham district.

1. Irondale seam, old mine, Morrow Gap section at mouth of first left; SW. ¼ NE. ¼ sec. 32, T. 16 S., R. 1 W.
2. Irondale seam, Alfretta No. 1; NE. ¼ sec. 32, T. 16 S., R. 1 W.
3. Irondale seam, Alfretta No. 2; NW. ¼ sec. 5, T. 17 S., R. 1 W.
4. Irondale seam, Alfretta No. 4; NW. ¼ sec. 5, T. 17 S., R. 1 W.
5. Irondale seam, Olivia No. 4; SE. ¼ sec. 6, T. 17 S., R. 1 W.
6. Ida seam
7. Big seam (best part) } Ruffner No. 1 mine; NW. ¼ sec. 13, T. 17 S., R. 2 W.
8. Irondale seam
9. Irondale, old drift; NE. ¼ sec. 23, T. 17 S., R. 2 W.
10. Big seam, Gate City mine; SW. ¼ sec. 23, T. 17 S., R. 2 W.
11. Irondale seam; SE. ¼ NW. ¼ sec. 27, T. 17 S., R. 2 W.
12. Irondale seam; SE. ¼ NW. ¼ sec. 27, T. 17 S., R. 2 W.

13. Big (workable part)} Helen-Bess mine; NW. ¼ sec. 33, T. 17 S., R. 2 W.
14. Irondale
15. Big (workable part)} Valley View mine; NE. ¼ sec. 12, T. 18 S., R. 3 W.
16. Irondale
17. Big seam, Green Spring mine; SE. ¼ sec 11, T. 18 S., R. 3 W.
18. Big seam, upper bench, Spaulding mine at bottom of slope.
19. Big seam, lower bench, Spaulding mine in sump at eleventh right heading.
20. Big seam, upper bench, Tennessee Company No. 14, sixteenth right heading.
21. Big seam, upper bench, Tennessee Company No. 12 slope, twenty-eighth heading; NE. ¼ sec. 29, T. 18 S., R. 3 W.
22. Big seam, lower bench, Tennessee Company No. 12 slope, twenty-eighth heading.
23. Section, upper and lower benches, Big seam, Songo slope, tenth right heading; SW. ¼ NW. ¼ sec. 29, T. 18 S., R. 3 W.
24. Type section in Tennessee Company No. 10 slope; SE. ¼ sec. 30, T. 18 S., R. 3 W.
25. Type section in Tennessee Company No. 9 slope; SW. ¼ sec. 30, T. 18 S., R. 3 W.
26. Section in fifty-first heading Tennessee Company No. 6 slope; NW. ¼ sec. 31, T. 18 S., R. 3 W.
27. Type section, Big seam, upper bench, Tennessee Company No. 7 slope; NE. ¼ sec. 36, T. 18 S., R. 4 W.
28. Type section, Woodward No. 2 slope; SW. ¼ sec. 36, T. 18 S., R. 4 W.
29. Type section, Woodward No. 1 slope, twentieth right heading; NE. ¼ sec. 2, T. 19 S., R. 4 W.
30. Type section, upper bench, Big seam, Sloss No. 2 slope; NW. ¼ sec. 11, T. 19 S., R. 4 W.
31. Section upper bench, Big seam, Sloss No. 1 slope, fourteenth left heading; NW. ¼ sec. 11, T. 19 S., R. 4 W.
32. Upper bench, Big seam, 1,670 feet from mouth, Tennessee Company No. 6 slope; SE. ¼ sec. 10, T. 19 S., R. 4 W.
33. Upper part Big seam, Tennessee Company No. 5 slope, fifty-eighth left heading; SE. ¼ sec. 10, T. 19 S., R. 4 W.
34. Upper part Big seam, Tennessee Company No. 4 slope, 1,780 feet from outcrop; NE. ¼ sec. 15, T. 19 S., R. 4 W.
35. Upper bench, Big seam, Tennessee Company No. 3 slope, near mouth; SE. ¼ sec. 15, T. 19 S., R. 4 W.
36. Upper bench, Big seam, twenty-eighth right heading, Tennessee Company No. 2 slope; SW. ¼ sec. 15, T. 19 S., R. 4 W.
37. Upper bench, Big seam, section, Tennessee Company No. 1 slope, thirty-fifth left heading; SW. ¼ sec. 15, T. 19 S., R. 4 W.
38. Upper part Big seam, Raimund slope No. 1; NE. ¼ sec. 22, T. 19 S., R. 4 W.
39. Upper part Big seam, Raimund slope No. 3; SE. ¼ sec. 21, T. 19 S., R. 4 W.
40. Upper part Big seam, Potter slope No. 1; NE. ¼ sec. 28, T. 19 S., R. 4 W.
41. Upper part Big seam, Tennessee Company abandoned prospect No. 2; SW. ¼ sec. 28 T. 19 S., R. 4 W.
42. Upper part Big seam, Sparks Gap drift; NE. ¼ sec. 32. T. 19 S., R. 4 W.

Analyses of Clinton ores, Division A, Birmingham district, Alabama.

Locality and character of sample.	Authority.[a]	Fe.	SiO_2.	Al_2O_3.	CaO.	Mn.	P.	S.	H_2O.
Irondale (?) seam.									
Morrow Gap:									
Sample, outcrop, upper bench	M,364	47.31	24.57	......	......	......	0.312	......	......
Sample, under cover, upper bench	M,364	44.81	14.98	......	0.83	......	.419	......	......
Sample, outcrop, lower bench	M,364	29.55	40.68	......	5.76	......	.273	......	......
Sample, under cover, lower bench	M,364	35.14	31.23	......	4.55	......	.395	......	......
Irondale seam.									
Alfretta average soft ore:									
Car lots	S	46.35	[b]22.12		......	......	......	......	......
Do	S	48.90	[c]20.68		......	......	......	......	......
One week, July, 1906	T	46.99	22.52	5.20	.70	......	.14	......	1.34
Alfretta No. 4 (Wahanetta):									
Average 4 cars	S	49.30	[c]26.00		......	......	......	......	......
Average 2 cars	S	51.30	[c]23.36		......	......	......	......	......
Average 1 week, June, 1906	T	44.26	26.67	5.10	.55	......	.67	......	1.16
Alfretta No. 1, semihard ore, average 6 months, 1907	R	43.30	21.30	4.32	3.56	0.24	.26	......	......
Alfretta No. 2, soft ore, average August, 1907	R	44.37	27.40	3.26	.76	......	.014	......	......
Alfretta No. 4, soft ore, average November, 1907	R	45.38	21.30	4.01	.056	......	.19	......	......
Sadlers Gap:									
Average 1 car	S	48.80	[c]25.36		......	......	......	......	......
Average 2 cars	S	50.95	[c]22.28		......	......	......	......	......
Olivia:									
Average 4 cars	S	46.00	[c]27.08		......	......	......	......	......
Average 2 cars	S	50.60	[c]21.48		......	......	......	......	......
Average 1 car	S	47.60	[c]25.48		......	......	......	......	......
Do	S	49.00	[c]24.56		......	......	......	......	......
Average 3 weeks, May, 1906	T	42.77	24.88	7.07	.93	......	.14	......	4.13
Average 12 cars, August, 1906	T	47.83	18.80	5.10	.75	......	.145	......	6.17
Bald Eagle	S	47.25	[c]28.04		......	......	......	......	......
Do	S	51.20	[c]22.68		......	......	......	......	......
Hiawatha:									
Average 1 car	S	50.00	[c]22.60		......	......	......	......	......
Do	S	49.90	[c]24.56		......	......	......	......	......
Do	S	45.20	[c]23.92		......	......	......	......	......
Do	S	41.25	[c]25.36		......	......	......	......	......
Ruffner No. 1:									
Prospect sample, top 6-inch gouge	S	8.35	[c]24.84		32.51	......	......	......	......
Prospect sample, first foot below gouge	S	23.65	[c]49.28		7.31	......	......	......	......
Prospect sample, second foot below gouge	S	27.75	[c]34.60		13.05	......	......	......	......
Prospect sample, third foot below gouge	S	40.30	[c]23.56		8.88	......	......	......	......
Prospect sample, fourth foot below gouge	S	48.10	[c]17.88		5.54	......	......	......	......
Prospect sample, fifth foot below gouge	S	46.65	[c]19.52		5.67	......	......	......	......
Average prospect samples of 5 feet of ore	S	37.29	[c]28.97		8.09	......	......	......	......
Sample, soft ore	M,373	52.21	19.19	......	......	......	.225	......	......
Sample, semihard ore	M,373	40.94	23.14	......	4.96	......	.630	......	......
Semihard ore—									
Average, second 3 months, 1906	S	32.88	[c]31.13		10.07	......	......	......	......
Average, 13 cars, July, 1906	S	33.22	[c]32.22		9.80	......	......	......	......
Average, 94 cars, February, 1907	S	33.41	27.79	4.62	11.02	......	......	......	......
Average, 90 cars, March, 1907	S	32.80	27.28	4.52	11.67	......	......	......	......
Average, 104 cars, April, 1907	S	31.35	29.98	4.46	11.13	......	......	......	......
Average, 158 cars, May, 1907	S	34.50	24.03	4.78	12.13	......	......	......	......
Average, 108 cars, June, 1907	S	33.90	23.26	4.79	13.13	......	......	......	......
Hard ore, average October-November, 1907, about 720 cars	S	33.67	22.54	5.00	12.89	......	......	......	......

[a] Authorities: A, Alabama Consolidated Coal and Iron Company; B, Birmingham Ore and Mining Company; Bc., Birmingham Coal and Iron Company; C, Central Iron and Coal Company; M (followed by page number), McCalley, Henry. Report on valley regions of Alabama, pt. 2: Alabama Geological Survey, 1897; R, Republic Iron and Steel Company; S, Sloss-Sheffield Steel and Iron Company; T, Tennessee Coal, Iron, and Railroad Company; W, Woodward Iron Company; Wm, Williamson Iron Company.

[b] Insoluble matter.

[c] SiO_2 plus Al_2O_3.

Analyses of Clinton ores, Division A, Birmingham district, Alabama—Continued.

Locality and character of sample.	Authority.	Fe.	SiO_2.	Al_2O_3.	CaO.	Mn.	P.	S.	H_2O.
Big seam (workable part).									
Ruffner No. 1:									
Soft ore—									
Average, 6 cars, June, 1906	S	34.80	[a]43.44						
Average, 2 cars, July, 1906	S	35.50	[b]35.88						
Average, 88 cars, January, 1907	S	34.50	44.60	4.95					
Average, 35 cars, March 1907	S	36.41	41.82	4.50					
Hard ore, prospect samples—									
Top 1 foot	S	30.00	[b]30.80		13.12				
Second 1 foot	S	36.15	[b]31.28		7.87				
Third 1 foot	S	39.90	[b]28.80		6.23				
Fourth 1 foot	S	41.70	[b]20.72		8.97				
Fifth 1 foot	S	27.00	[b]28.64		16.83				
Sixth 1 foot	S	38.30	[b]23.00		10.85				
Seventh 1 foot	S	36.10	[b]22.64		12.57				
Average of 7 feet	S	35.87	[b]26.54		10.92				
Soft ore, outcrop sample	M, 373	41.68	34.11				0.157		
Ida (?) seam.									
Ruffner:									
Outcrop sample	M, 373	33.64	48.19				.203		
Sample 300 feet in drift	M, 373	31.46	39.28		5.78		.081		
Gate City, Howard mine:									
Soft ore sample	S	48.20	[b]27.12						
Do	S	45.20	[b]32.20						
Near Gate City: Sample from drill hole, A. C. C. & I. Co	A	43.90	31.60	3.18	Trace.		.17		
Big seam.									
Near Gate City:									
Sample from drill hole, top 10 feet	A	24.20	62.00	1.92	None.		.11		
Sample from drill hole, second 10 feet	A	33.40	44.80	3.01	Trace.		.11		
Sample from drill hole, third 10 feet (7 feet workable)	A	36.40	42.30	3.12	Trace.		.11		
Sample from drill hole, fourth 10 feet	A	28.60	46.70	2.76	4.55		.20		
Irondale seam.									
Near Gate City:									
Sample from drill hole	A	51.20	10.90	3.84	Trace.		.17		
Drift, SE. ¼ NW. ¼ sec. 27, T. 17 S., R. 2 W	M, 375	42.34	29.81				.107		
Howard mine: Soft ore, February, 1907	A	46.60	23.20	5.20	1.10		.18		
Hammond mine:									
Soft ore—									
7 cars, April, 1907	T	45.78	22.88	4.13	1.52		.17	1.51	
10 cars, April, 1907	T	40.49	28.96	4.14	1.32		.16	2.85	
2 cars, March, 1907	A	47.60	23.06	4.76	Trace.		.24		
Do	A	42.40	29.80	5.44			.19		
Semihard ore—									
2 cars, May, 1907	A	35.80	26.08	3.39	9.74		.32		
1 car, October, 1907	A	34.27	27.90	4.35	7.30		.32		
3 cars, April, 1907	T	38.18	23.80	4.19	7.32		.31	1.30	
16 cars, April, 1907	T	34.84	26.45	4.23	8.20		.30	1.53	
Dago mine	M, 376	50.46	21.50				.021		
Ida seam.									
Helen-Bess locality	M, 377	16.27	75.17				.236		
Irondale seam.									
Helen-Bess mine:									
Soft ore, average 1 car	S	50.80	[b]23.20						
Do	S	40.00	[b]26.52						
Do	S	48.90	[b]25.40						
Hard ore, average 5 cars, December, 1908	B	37.92	[b]20.10		12.38				

[a] Insoluble matter.

[b] SiO_2 plus Al_2O_3.

Analyses of Clinton ores, Division A, Birmingham district, Alabama—Continued.

Locality and character of sample.	Authority.	Fe.	SiO_2.	Al_2O_3.	CaO.	Mn.	P.	S.	H_2O.
Big seam.									
Helen-Bess locality, soft ore	M, 377	33.59	47.67				0.474		
Helen-Bess mine:									
Soft ore—									
Average 2 cars, 1906	S	39.20	[a] 40.80						
Average 5 cars, 1906	S	41.10	[a] 36.04						
Average 2 cars, 1906	S	35.15	[a] 45.48						
Average 1 car, 1906	S	38.10	[a] 40.76						
Sample, June, 1906	B	40.86	33.50	4.50	Trace.				
Semihard ore, average June, 1906	T	39.95	33.34	4.02	1.02		.29		1.59
Soft ore, average 5 cars, July, 1907	T	39.81	35.73	3.60	1.65		.33		
Semihard ore, average 20 cars, June, 1907	T	34.77	30.91	3.35	7.73		.33		
Hard ore, average 2 cars, June, 1907	T	32.01	32.81	3.35	8.51		.32		
Irondale seam.									
Kewanee mine:									
Soft ore, 2 cars, 1906	S	45.35	[b] 30.04						
Soft ore, 1 car, 1906	S	48.00	[b] 26.72						
Hard ore, 1907	Wm	36.12	[b] 19.60		8				
Do	Wm	31.42	[b] 14.53		11.20				
Big seam.									
Kewanee mine:									
Soft ore, 1 car, 1906	S	37.05	[b] 42.56						
Do	S	39.95	[b] 39.64						
Soft ore, No. 2, 1907	Wm	37.85	[b] 42.03		.36				
Semihard ore, top 10 feet	Wm	32.76	[b] 34.40		4.54				
Semihard ore, top 14 feet	Wm	32.78	[b] 39.52		2.94				
Outcrop gap, NW. ¼ sec. 5, T. 18 S., R. 2 W.:									
Sample	M, 379	38.53	38.90				.405		
Sample, upper 5 feet	M, 380	42.16	34.30				.26		1.82
Sample, middle 5 feet	M, 380	32.51	34.00		5.15		.30		.87
Sample, lower 5 feet	M, 380	28.95	52.80				.22		2.05
Big seam, upper bench.									
Hedona mine: Soft ore, average 3 cars, December, 1903	S	41.85	[a] 34.40						
Do	S	39.25	[a] 36.00						
Irondale seam.									
Hedona mine, soft ore:									
Average 1 car, October, 1903	S	47.55	[a] 27.32						
Average 2 cars, November, 1903	S	49.20	[a] 24.92						
Irondale (?) seam.									
Lone Pine No. 3, soft ore	S	42.40	[a] 34.76						
Do	S	44.20	[a] 31.48						
Big seam, upper bench.									
Lone Pine:									
Sample 9-inch top gouge	M, 380	41.30	36.50						1.00
Sample first 2 feet below gouge	M, 380	45.00	34.60						.50
Sample second 2 feet below gouge	M, 380	44.70	31.80						.40
Sample third 2 feet below gouge	M, 380	44.00	33.80						.60
Sample fourth 2 feet below gouge	M, 380	46.50	29.80						.60
Soft ore—									
Average 3 cars, June, 1904	S	42.95	[a] 31.84						
Average 3 cars, June, 1904	S	40.80	[a] 34.36						
Average 2 cars, January, 1906	S	38.90	[a] 30.28						
Average 2 cars, January, 1906	S	36.90	[a] 31.24						
Average 6 cars, April, 1907	T	43.71	25.98	5.42	1.38		.23		
Semihard ore—									
Average 5 cars, April, 1907	T	42.12	25.17	4.08	4.45		.33		
Average 6 cars, April 1907	T	39.25	27.71	3.48	5.38		.31		
Average 2 cars, May, 1907	T	37.02	26.36	4.30	6.01		.30		
Average 4 cars, June, 1907	T	36.91	28.47	3.52	7.42		.30		
Hard ore, average 5 cars, August, 1907	T	36.37	25.00	3.53	8.86		.35		
Average 1 car, July, 1907	T	35.40	25.90	3.26	9.50		.36		

[a] SiO_2 plus Al_2O_3.

[b] Insoluble matter.

Analyses of Clinton ores, Division A, Birmingham district, Alabama—Continued.

Locality and character of sample.	Authority.	Fe.	SiO_2.	Al_2O_3.	CaO.	Mn.	P.	S.	H_2O.
Big seam.									
Valley View mine:									
Soft ore, average, 1905	B	44.00	28.00	4.50	Trace.				
Semihard ore, 1906	C	45.13	13.54	3.51	7.14	0.20	0.38		2.00
Do	C	44.60	14.08	4.80	7.13				.72
Hard ore—									
Average, 1905	B	36.00	20.00	3.50	11.20				
2 cars, May, 1907	T	37.22	25.59	3.26	8.16		.30		
10 cars, June, 1907	T	35.98	32.00	3.30	6.13		.34		
12 cars, July, 1907	T	37.28	26.64	3.78	8.10		.34		
Big seam, upper bench.									
Green Spring mine:									
Nearly soft ore, average, May, 1906	T	42.65	27.49	3.81	1.98		.33		1.19
Semihard ore—									
Average, June, 1906	T	38.40	28.45	3.45	7.21		.35		.62
Average, December, 1906	T	36.52	31.03	3.43	6.56		.33		.57
Average, year, 1906	T	38.77	29.01	3.57	5.02		.35		1.00
Average, year, 1907	T	36.77	30.10	3.35	6.43		.34		.84
Graces Gap, near Spaulding mine: Soft ore	M, 384	44.28	29.32				.179		
Spaulding mine:									
Hard ore—									
Average from 70 samples from all headings, January, 1908	R	34.66	18.65	2.91	20.01				
Average March, 1908	R	35.10	19.70	3.09	13.33				
Average, September, 1908	R	36.26	19.02	3.54	13.50	.30	.34		
Average, October, 1908	R	36.90	18.22	3.15	13.14	.26	.34		
Big seam, lower bench.									
Spaulding mine:									
Average top 6 feet, eleventh left heading	R	35.48	26.09	3.12	9.62				
Average top 8 feet, eleventh right heading	R	36.24	25.89	3.30	7.28				
Irondale (?) seam.									
Eureka No. 1 (stratum 1 in section, p. 66)	M, 390	46.79	16.73	2.01			.166		
Big seam.									
Eureka No. 1:									
Sample (stratum 3 in sec. p. 66)	M, 390	42.22	31.91	4.05			.196		
Sample (stratum 5 in sec. p. 66)	M, 390	41.91	31.16	4.64			.187		
Sample (stratum 7 in sec. p. 66)	M, 390	42.36	31.83	4.46			.196		
Sample (stratum 9 in sec. p. 66)	M, 390	41.98	32.04	5.13			.196		
Sample (stratum 11 in sec. p. 66)	M, 390	43.71	31.62	4.16	1.03		.183		
Sample (stratum 13 in sec. p. 66)	M, 390	54.98	16.31	3.76	.68		.213		
Eureka No. 2:									
Sample averaged from whole thickness	M, 393	49.51	22.25				.259		
Sample hard ore from drift in upper 12 feet	M, 393	35.75	14.18		12.34		.404		
Sample, 3 feet of soft ore overlying hard ore	M, 393	49.09	13.21		.20		.60		5.94
Sample hard ore from first right heading	M, 393	41.54	10.12		11.31		.43		.65
Sample hard ore from first and third right and lefts	M, 393	43.72	11.74		9.18		.44		.60
Sample hard ore from bottom heading, August, 1893	M, 393	39.68	12.40		12.32		.62		1.75
Irondale (?) seam.									
Eureka No. 2:									
Sample semihard ore 2½ feet thick	M, 393	40.68	14.91		7.48		.239		
Big seam, upper bench.									
Tennessee Co. No. 15: Average, August 1, 1901	T	36.92	12.04	2.65	15.85	.24	.338	0.079	
Tennessee Co. No. 14: Average, August 1, 1901	T	37.42	13.69	2.77	15.61	.255	.359	.087	

Analyses of Clinton ores, Division A, Birmingham district, Alabama—Continued.

Locality and character of sample.	Authority.	Fe.	SiO_2.	Al_2O_3.	CaO.	Mn.	P.	S.	H_2O.
Big seam, upper bench—Continued.									
Tennessee Co. No. 13:									
Average, August 1, 1901	T	37.04	13.64	3.01	15.95	0.289	0.341	0.116	......
Average, December, 1908	T	34.58	14.57	2.93	17.44	......	.32	......	0.52
Average, year, 1908	T	35.99	15.91	2.99	15.53	......	.33	......	.64
Tennessee Co. No. 12:									
Average, August 1, 1901	T	34.96	11.29	2.79	18.02	.195	.319	.061	......
Average June, 1906	T	35.80	14.14	3.39	16.20	......	.31	......	46
Average, year, 1906	T	33.76	13.49	3.04	18.32	......	.32	......	.44
Average, December, 1907	T	34.81	12.60	4.13	18.06	......	.31	......	.58
Average, year, 1907	T	36.24	13.59	3.09	16.28	......	.32	......	.59
Average, December, 1908	T	36.07	13.89	2.84	16.51	......	.33	......	.50
Average, year, 1908	T	34.25	13.53	2.95	18.19	......	.31	......	.57
Tennessee Co. No. 11:									
Average, June, 1906	T	36.19	14.15	3.33	15.71	......	.33	......	.55
Average, August 1, 1901	T	36.45	10.72	2.79	17.98	.21	.327	.097	......
Average, year, 1906	T	34.68	12.44	3.01	18.05	......	.35	......	.32
Average, December, 1907	T	35.69	13.76	3.02	17.09	......	.33	......	.54
Average, year, 1907	T	35.71	14.48	3.27	16.28	......	.33	......	.58
Average, December, 1908	T	34.05	14.52	2.80	17.92	......	.31	......	.60
Average, year, 1908	T	34.47	15.15	2.95	17.21	......	.32	......	.54
Songo mine:									
Average, working analyses, 1906	C	38.55	9.58	3.35	13.80	......	......	......	.40
Do	C	39.17	10.26	3.38	14.05	.11	.27	......	1.50
Average 6 cars, December 8, 1908	Bc	38.60	a 15.40		12.60	......	......	......	......
Tennessee Co. No. 10:									
Average, March, 1906	T	36.59	11.55	3.04	16.77	......	.31	......	.59
Average, year, 1906	T	35.29	13.35	3.23	15.94	......	.33	......	.36
Average, December, 1907	T	35.44	11.70	2.80	17.95	......	.32	......	.59
Average, year, 1907	T	36.11	12.64	3.06	16.94	......	.32	......	.58
Average, December, 1908	T	35.57	13.02	2.90	17.32	......	.33	......	.60
Average, year, 1908	T	36.42	12.58	2.80	17.17	......	.32	......	.54
Tennessee Co. No. 9:									
Average, soft ore, August 1, 1901	T	50.39	13.26	4.06	3.04	.26	.414	.089	......
Average, August 1, 1901	T	34.60	10.04	2.59	19.61	.26	.293	.089	......
Average, May, 1906	T	37.08	13.83	3.40	13.71	......	.33	......	.59
Average, year, 1906	T	36.14	12.59	3.21	16.63	......	.32	......	.36
Average, December, 1907	T	35.36	11.85	3.95	17.90	......	.32	......	.48
Average, year, 1907	T	36.65	12.95	3.09	16.54	......	.32	......	.60
Average, December, 1908	T	37.13	12.79	2.87	15.77	......	.33	......	.60
Average, year, 1908	T	36.65	13.07	2.94	16.95	......	.32	......	.60
Tennessee Co. No. 8:									
Average, August 1, 1901	T	37.48	9.73	2.68	17.54	.21	.319	.096	......
Average, June, 1906	T	37.37	12.49	3.17	15.86	......	......	......	......
Average, year, 1906	T	36.54	13.39	3.14	16.11	......	.35	......	.67
Average, December, 1907	T	36.29	11.36	3.24	17.82	......	.33	......	.61
Average, year, 1907	T	36.61	12.99	3.09	16.37	......	.33	......	62
Average, December, 1908	T	38.56	12.08	2.85	15.46	......	.34	......	.45
Average, year, 1908	T	36.86	12.75	2.91	16.65	......	.32	......	.58
Tennessee Co. No. 7:									
Average, August 1, 1901	T	34.53	10.91	2.86	18.79	.22	.298	.084	......
Average, June, 1906	T	37.62	12.94	3.41	15.47	.35	......	......	.41
Average, year, 1906	T	36.07	12.61	3.14	16.43	......	.34	......	.52
Average, December, 1907	T	37.16	12.63	3.01	16.33	......	.32	......	.58
Average, year, 1907	T	37.79	13.26	3.07	15.31	......	.33	......	.68
Average, December, 1908	T	39.59	12.60	2.83	14.58	......	.34	......	.44
Average, year, 1908	T	36.34	12.51	2.83	17.21	......	.33	......	.50
Big seam, lower bench—hard ore.									
Tennessee Co. No. 14:									
Top 4 feet, 650 feet from outcrop	T	35.90	26.76	3.10	9.03	.20	.36	.009	......
Top 5 feet, 800 feet from outcrop	T	35.34	24.96	3.01	9.89	.20	.34	.044	......
Tennessee Co. No. 13:									
Top 2½ feet, 660 feet from outcrop	T	35.14	25.36	3.24	9.80	.18	.35	.012	......
Top 5 feet, 1,090 feet from outcrop	T	31.72	28.40	2.90	11.02	.21	.28	.014	......
Tennessee Co. No. 12:									
Top 9 feet 5 inches, 1,430 feet from outcrop	T	37.13	21.16	2.85	11.73	.19	.34	.019	......
Top 7 feet, 1,760 feet from outcrop	T	38.81	20.48	3.35	9.38	.18	.38	.018	....
Tennessee Co. No. 11:									
Top 9½ feet, 1,310 feet from outcrop	T	37.08	20.44	3.28	10.20	.17	.36	.018	......
Top 9⅓ feet, 1,820 feet from outcrop	T	38.56	20.06	3.26	9.18	.15	.33	.020	......
Tennessee Co. No. 10:									
Top 6 feet, 740 feet from outcrop	T	38.71	19.34	3.39	10.51	.22	.35	.040	......
Top 9 feet, 1,060 feet from outcrop	T	39.17	18.96	2.93	8.82	.17	.37	.027	......

a Insoluble matter.

Analyses of Clinton ores, Division A, Birmingham district, Alabama—Continued.

Locality and character of sample.	Authority.	Fe.	SiO_2.	Al_2O_3.	CaO.	Mn.	P.	S.	H_2O.
Big seam, lower bench—hard ore—Con.									
Tennessee Co. No. 9:									
Top 9 feet, 1,330 feet from outcrop.	T	37.08	23	3.35	10.15	0.19	0.34	0.016	......
Top 9 feet, 1,530 feet from outcrop.	T	36.31	23.02	3.18	10	.15	.35	.041	......
Tennessee Co. No. 8:									
Top 5 feet, 1,410 feet from outcrop.	T	38.45	17.80	3.43	11.58	.17	.34	.057	......
Top 9 feet, 1,800 feet from outcrop.	T	34.17	20	3.14	13.87	.19	.31	.014	......
Tennessee Co. No. 7:									
Top 5 feet, 1,350 feet from outcrop.	T	38.45	18.44	3.77	11.58	.16	.36	.023	......
Top 8 feet, 1,700 feet from outcrop.	T	35.80	20.32	3.31	12.24	.20	.32	.018	......
Woodward mines: Average sample..	M, 404	49.12	23.06	......	......	......	.208	......	......
Big seam, upper bench.									
Woodward mines: Average sample, soft ore	M, 404	51.63	17.26	......	......	......	.181	......	......
Woodward mines: Average sample, hard ore	M, 404	37.50	17.69	......	9.03	......	.294	......	......
Woodward Nos. 2 and 3, mixed soft ores, 1906	W	40.54	24.24	8.62	......	......	......	......	......
Do	W	40.20	31.70	8.19	......	......	......	......	......
Do	W	50.23	16.58	5.92	......	......	......	......	......
Woodward Nos. 1 and 2, mixed hard ores, 1906	W	33.76	9.74	2.52	21.58	......	......	......	......
Do	W	38.70	11.60	3.17	15.43	......	......	......	......
Do	W	41.00	10.78	3.56	14.14	......	......	......	......
Do	W	37.54	12.80	2.97	10.82	......	......	......	......
Do	W	39.50	10.46	2.68	14.60	......	......	......	......
Woodward No. 1: January, 1908	W	36.69	10	3.60	17.35	......	.32	......	......
Woodward No. 2: January, 1908	W	37.00	10.38	3.30	17.10	......	.33	......	......
"Gray ore" (probably Hickory Nut) seam.									
Woodward mines: Average sample..	M, 404	39.18	38.29	......	......	......	.100	......	......
Big seam, upper bench.									
Sloss No. 2:									
Average 5 cars, 1906	S	38.40	10.86	3.70	16.56	......	......	......	......
Average 5 cars	S	38.55	9.04	3.64	18.94	......	......	......	......
Average September-November, 1908	S	35.22	11.51	3.92	18.61	......	......	......	......
Sloss No. 1:									
Average sample, soft ore	M, 407	48.23	12.75	......	.47	......	.609	......	......
Core from drill hole, 1896, top 4 feet	S	37.14	9.32	......	20.23	......	.35	......	......
Core from drill hole, second 4 feet.	S	37.29	11.26	......	20.88	......	.33	......	......
Core from drill hole, third 4 feet..	S	25.96	13.82	......	14.54	......	.27	......	......
Core from drill hole, average whole core	S	36.89	11.18	......	20.66	......	.32	......	......
Average 5 cars	S	34.60	11.48	3.76	19.15	......	......	......	......
Do	S	38.15	10.32	3.76	15.76	......	......	......	......
Average September-November, 1908	S	34.63	11.38	3.82	18.91	......	......	......	......
Big seam, lower bench.									
Sloss No. 1: Average sample, outcrop.	M, 407	47.47	23.14	......	......	......	.238	......	......
"Gray ore" (probably Hickory Nut) seam.									
Sloss No. 1: Average sample, outcrop.	M, 407	35.30	46.27	......	......	......	.007	......	......
Ida seam.									
Sloss No. 1: Average sample, outcrop.	M, 407	38.09	40.80	......	......	......	.047	......	......
Big seam, upper bench.									
Tennessee Co. No. 6:									
Average, May, 1906	T	35.46	11.55	3.20	17.92	......	.32	......	0.59
Average, year, 1906	T	35.13	11.31	3.27	18.37	......	.32	......	.52
Average, December, 1907	T	34.53	10.40	3.06	18.93	......	.31	......	.35
Average, year, 1907	T	36.54	10.92	3.14	18.34	......	.31	......	.58
Average, December, 1908	T	33.38	9.80	2.68	20.98	......	.30	......	.36
Average, year, 1908	T	35.64	10.68	2.94	19.02	......	.31	......	.48
Tennessee Co. No. 5:									
Average, August 1, 1901	T	35.25	8.06	2.95	20.52	0.25	0.302	0.089	......
Average, June, 1906	T	35.29	11.46	3.54	18.41	......	.31	......	0.42
Average, year, 1906	T	36.14	10.58	3.31	18.03	......	.32	......	.55

Analyses of Clinton ores, Division A, Birmingham district, Alabama—Continued.

Locality and character of sample.	Authority.	Fe.	SiO_2.	Al_2O_3.	CaO.	Mn.	P.	S.	H_2O.
Big seam, upper bench—Continued.									
Tennessee Co. No. 5—Continued.									
Average, December, 1907	T	37.28	10.15	3.18	17.59	......	.31	......	.42
Average, year, 1907	T	36.57	10.79	3.18	17.67	......	.31	......	.66
Average, December, 1908	T	35.39	11.09	3.16	18.48	......	.32	......	.40
Average, year, 1908	T	36.12	10.23	3.09	18.64	......	.32	......	.56
Tennessee Co. No. 4:									
Average, August 1, 1901	T	36.94	8.45	3.13	19.12	.25	.306	.087	......
Average, June, 1906	T	35.55	10.94	3.36	18.25	......	.31	......	.52
Average, year, 1906	T	35.77	10.41	3.27	18.44	......	.32	......	.56
Average, December, 1907	T	35.47	10.36	3.19	18.93	......	.31	......	.53
Average, year, 1907	T	35.84	10.55	3.17	18.36	......	.31	......	.56
Average, December, 1908	T	34.49	10.19	3.08	19.23	......	.31	......	.30
Average, year 1908	T	35.25	10.32	3.09	19.12	......	.32	......	.59
Tennessee Co. No. 2:									
Average, August 1, 1901	T	39.86	9.24	3.86	15.84	.21	.32	.080	......
Average, June, 1906	T	35.88	10.45	3.44	18.36	......	.30	......	.46
Average, year, 1906	T	35.91	10.45	3.37	18.28	......	.31	......	.59
Average, December, 1907	T	35.99	10.10	3.18	18.46	......	.31	......	.52
Average, year, 1907	T	35.98	10.57	3.27	18.22	......	.31	......	.56
Average, December, 1908	T	35.01	10.63	3.10	19.93	......	.30	......	.46
Average, year, 1908	T	35.01	10.20	3.13	19.40	......	.30	......	.52
Tennessee Co. No. 1:									
Average, August 1, 1901	T	39.70	10.06	3.93	15.27	.23	.315	.090	......
Average, June, 1906	T	35.04	11.81	3.86	17.91	......	.31	......	.52
Average, year, 1906	T	35.62	10.64	3.52	18.29	......	.31	......	.57
Average, December, 1907	T	35.53	10.74	3.27	18.39	......	.32	......	.46
Average, year, 1907	T	35.61	11.07	3.44	18.11	......	.32	......	.60
Average, December, 1908	T	35.57	10.12	3.08	19.49	......	.30	......	.49
Average, year, 1908	T	34.81	10.72	3.21	19.16	......	.31	......	.51
Tennessee Co. No. 5: Soft ore, average, August 1, 1901	T	52.34	11.25	4.29	3.92	.27	.455	.093	......
Tennessee Co. No. 4: Soft ore, average, August 1, 1901	T	51.99	13.49	4.21	2.79	.24	.314	.088	......
Tennessee Co. No. 3: Soft ore, average, February, 1906	T	49.40	17.07	5.05	.95	......	.19	......	2.37
Tennessee Co. No. 2:									
Soft ore, average, August 1, 1901	T	53.43	13.08	5.37	1.49	.24	.30	.077	......
Soft ore, average, May, 1906	T	46.34	18.52	4.96	2.29	......	.40	......	2.57
Tennessee Co. No. 1:									
Soft ore, average, August 1, 1901	T	53.42	14.29	5.02	1.16	.21	.223	.081	......
Soft ore, average, March, 1906	T	44.70	19.34	5.16	2.94	......	.43	......	2.01
Raimund No. 1: Soft ore, average, September, 1908	R	35.81	11.70	3.95	17.53	.27	.28	......	......
Raimund No. 2: Soft ore, average, September, 1908	R	36.31	11.89	4.02	16.93	.28	.25	......	......
Raimund No. 3:									
Soft ore, average, June, 1906	T	47.82	18.46	5.47	.81	......	.34	......	2.20
Soft ore, average, year, 1906	T	48.61	17.38	5.16	1.06	......	.31	......	2.59
Soft ore, average, year, 1907	T	49.51	16.43	4.89	1.19	......	.35	......	2.79
Hard ore, average, September, 1908	R	35.26	11.50	3.74	18.24	.24	.27	......	......
Tennessee Co., Potter No. 1:									
Average, June, 1906	T	49.40	17.05	4.96	1.03	......	.33	......	1.82
Average, year, 1906	T	48.23	18.31	5.42	.96	......	.29	......	2.38
Average, year, 1907	T	46.85	20.07	5.56	1.15	......	.32	......	2.79
Sparks Gap:									
Sample, top 3 inches, soft ore	M, 414	48.00	[a]26.70		......	......	.15	......	......
Sample, next lower 8 inches, soft ore	M, 414	47.60	[a]27.91		......	......	.11	......	......
Sample, next lower 24 inches, soft ore	M, 414	52.20	[a]21.21		......	......	.11	......	......
Sample, next lower 8 inches, soft ore	M, 414	47.80	[a]28.25		......	......	.06	......	......
Sample, lowest 12 inches, soft ore	M, 414	34.04	[a]42.50		......	......	.014	......	......

[a] Insoluble matter.

DIVISION B.

GENERAL DESCRIPTION.

Division B of the Birmingham red-ore district comprises the strip of Red Mountain from Sparks Gap southwest to Big Spring, a distance of 17 miles. Although the division is of considerable extent the only actual mining of ore has been a little stripping on the outcrop near Sparks Gap and the opening of some short slopes south of McCalla. At Big Spring considerable surface prospecting has been done. There is ore in the Clinton formation throughout this whole stretch of the mountain, but more thorough prospecting is necessary to demonstrate whether or not it is of workable grade and quantity. Discouraging results have been obtained in places, to be sure, but these have been widely separated and can not be regarded as conclusive evidence as to the character of the ore, especially since in most places the prospecting was done only on the weathered outcrop of the beds. The most promising field for exploration in this division lies on the east slope of Red Mountain and in the valley farther east, southwest of a line drawn at right angles to Red Mountain through McCalla station and northeast of a line drawn similarly through Green Pond.

Thorough prospecting by means of a core drill will be necessary, and the results should demonstrate whether there is an ore field in this vicinity that can be opened up by shaft mining. Such a field would be fairly accessible to existing transportation lines and not at all remote from furnaces.

TOWNSHIPS 19 AND 20 S., R. 4 W.

SPARKS GAP TO CLEAR BRANCH GAP.

As stated above, a little trenching has been done on the outcrop of an ore bed along the northwest face of Red Mountain just south of Sparks Gap, but these workings had been long abandoned when visited in June, 1906. An old, caved-in slope was also connected with these strip pits. Shale débris completely covered the ore bed, which is evidently the same as that shown in ore section 42 (fig. 6). About 50 feet higher, along the summit of the ridge, just northwest of the crest, outcrops a bed of coarse, dark, siliceous ore. Its dip ranges from 30° to 35° SE. This bed has been cut into at four or five places within half a mile south of the gap, but not more than 20 inches of ore is present, principally a 15-inch layer. This bed probably represents the so-called "gray" ore seam, which may occupy the horizon of the Hickory Nut seam, recognized farther northeast in the district by its fossiliferous character, or it may occupy the horizon of the Ida seam. About one-half mile south of Sparks Gap, in the NE. ¼ sec. 32, T. 19 S., R. 4 W., there are also three or four abandoned prospect slopes on the northwest face of the ridge, 40 to 50 feet below the summit, that evidently were started on the outcrop of the main ore bed or with the object of intersecting the "gray" ore seam. The main bed is evidently overlain by a thick bed of fissile shale which breaks down easily, completely covering the outcrop of the ore, and quickly filling up the abandoned slopes.

From this locality southwestward for 1½ miles, or to a point one-half mile southwest of Clear Branch Gap, the Clinton strata are in places so highly inclined that they present but a narrow outcrop, and they are probably also partially engulfed in a fault. On the small knob one-fourth mile northeast of Cow Gap the strata appear to be largely of sandstone, and the coarse, dark, siliceous ore seam outcrops just northwest of the summit, overlain by massive ferruginous sandstone. Only about 12 inches of this bed is visible.

In Cow Gap there is no exposure of Clinton strata, but there is considerable sandstone débris. The axis of the ridge northeast of this gap is formed by Fort Payne chert in large brecciated masses dipping steeply.

In Owens Gap the outcrop of Clinton strata is about 270 feet across. The rocks dip 70° S. 60° E. and are overlain by Fort Payne chert, but appear to be in contact below with Knox dolomite to the west. The actual thickness of the exposed Clinton strata would be about 255 feet, which may or may not represent the full thickness of the formation. A portion of the Clinton may therefore be faulted down at this point, and there is no evidence of the presence of the Chickamauga limestone in Cow Gap, Owens Gap, or Clear Branch Gap. The Chickamauga beds have been noted, however, within a half mile southwest in their normal relations. From Owens Gap southwest to about 700 feet beyond Clear Branch Gap there is little or no evidence of the presence of Clinton or Chickamauga strata.

Instead of explaining the absence of both Clinton and Chickamauga beds at the surface of this locality by assuming the presence of a fault, it is here suggested that there may have been an island of Knox dolomite here, over the top of which no Clinton strata, at least, were ever deposited. There appears to have been at any rate in this locality and extending eastward some kind of barrier just below sea level or low shore line that formed a southern limit to the basin in which the Big seam of Clinton ore was deposited. Southward from Potter the ore begins to thin out and its character resembles near-shore deposits of coarse-grained material. Finally as Clear Branch Gap is approached the ore disappears entirely, and at the gap the Clinton formation itself is absent. Drill holes about 2 miles southeast of Sparks and Cow gap indicate very thin, poor-quality ore at shallow depths.

PLEASANT HILL.

South of Pleasant Hill the Clinton strata again appear in their normal relations in the SE. ¼ sec. 6, T. 20 S., R. 4 W., and prospecting for ore has been undertaken here. In the NE. ¼ SE. ¼ sec. 6 an old prospect slope has been driven into the northwest side of Red Mountain about 40 feet below the summit. Only shale was observed to be on the dump, and the prospect was evidently abandoned without reaching ore. In the NW. ¼ SE. ¼ sec. 6 two old prospect pits on an ore bed (Ida?), just northwest of the crest of the mountain, showed 25 to 26 inches of ore. (See ore section 43, fig. 7.) The dip is about 40° S. 40° E. An average sample of this soft ore was found to contain about 40 per cent iron and 33 per cent silica. (See analyses, p. 90.) A slope below these pits, or about 20 feet below the summit on the northwest side, goes down at an angle of about 45° in shale and ferruginous sandstone. No ore showed on the outcrop. The slope was abandoned and partly full of water. Several other caved-in cuts have been made on the northwest slope of the ridge at 20 to 40 feet below the crest, but none shows any ore. Search has evidently been made for the bed that lies below the top bed near Sparks Gap, but these prospects may be too high in the formation. In the SW. ¼ SE. ¼ sec. 6, about 85 feet below the crest of the ridge on the east side of the mountain, a horizontal drift was driven in June, 1906, N. 55° E., and at about 200 feet from the entrance it cuts the top or Ida (?) seam, which outcrops near the crest of the ridge. Twenty-five inches of ore is found in this bed, as shown in ore section 44. This bed grades into hard shale at the bottom, but is fairly distinct from the overlying sandstone. (See analysis, p. 90.) The dip of the rocks is 31° to 35°. For 40 to 50 feet, loose surface material was encountered in the drift, but beyond it passes through hard firm rock. This drift was continued in the hope of getting a good section of the next bed below the Ida, but the rocks inclosing it were found to be faulted out of their normal position.

In the NW. ¼ NW. ¼ sec. 7 the Ida seam lies near the crest of the ridge, and a bed which will be called, for convenience, the Big seam, lies about 42 feet below it. The Ida carries 2 feet 6 inches of coarse siliceous ore, which is shaly near the base. The Big seam showed in a prospect pit here 5 feet of ferruginous material, consisting of 13 inches of "kidney" ore and about 4 feet of highly siliceous fine-grained ore, or ferruginous sandstone, parted by 5 or 6 thin shale seams. (See ore section 45, fig. 7.) The "kidneys" consist of flat pebbles one-fourth to one-half inch thick and 1 to 2 inches long, with smooth glistening surfaces coated with iron oxide. When broken open, they appear to be in part concretionary, but also contain grains of silica cemented by argillaceous material mixed with iron oxide. The beds here dip about 45° S. 50° E.

In another large prospect pit farther southwest in sec. 7 there has been disclosed an unusual thickness of good soft ore, ranging from 6 to 7½ feet thick. At the top of the ridge the Ida seam dips about 45°, and about 30 feet lower on the northwest face of the ridge the trench discloses a bed of ore which has evidently been faulted in two places, within 50 feet measured horizontally. The upper fault appears to be of the overthrust type, and the bed on the hanging wall has been overturned and folded in the dragging, so as to be almost doubled in thickness. The throw of this fault displaces the beds more than their thickness, but the lower fault, which also hades toward the upthrow, has a throw of not more than 5 feet. The relations of the beds are rather puzzling here and have given rise to the belief that a lower thicker bed of ore has thus been faulted to the surface. This view is further strengthened by the fact that the quality of the ore thus exposed is much higher than that found in the Big seam in trenches within 100 feet of this point. No ore quite resembling it in character or thickness is found except in a trench about 2 miles southwest. If there is another good bed of ore below the Big seam, it would probably have been discovered before this time, considering the amount of prospecting that has been done in this locality, but to make certain the area should be prospected with a core drill, and by further trenching along the outcrop.

TOWNSHIP 20 S., R. 5 W.

For several miles southwestward along Red Mountain, in township 20 S., R. 5 W., the Ida seam outcrops and the Big seam may be traced by prospect pits. The coarse-grained quartzose character of the Ida seam and the layer of kidney-shaped concretions at the top of the Big seam are persistent.

In the NE. ¼ SE. ¼ sec. 12 a prospect slope has been sunk. When noted in January, 1909, the slope was nearly filled with caved-in shale and water. The slope is driven on an ore bed dipping 35° S. 55° E., consisting of 2 feet of coarse-grained ore at the top, with kidney concretions, and 3 feet of fine-grained siliceous ore at the bottom. On the dump was considerable calcareous fossiliferous ore, evidently lean in iron, from the "kidney" horizon. It is reported that this slope followed the ore for about 100 feet to a place where the bed abruptly thickened and then was lost in a fault. The slope was driven 30 or 40 feet farther, reaching a thin bed of ore, and was then abandoned. The texture of this hard ore somewhat resembles the much-faulted blocks of ore in sec. 7, T. 20 S., R. 4 W. A drill hole sunk 1,000 feet beyond the mouth of the slope cut the Ida seam at 317 feet and failed to reach the Big seam 100 feet lower.

In the SW. ¼ NW. ¼ sec. 13 a prospect pit disclosed a bed more than 6½ feet thick altogether consisting of ore and shale. The ore is coarse grained at the top and contains concretions about 3 feet from the top. (See ore section 46, fig. 7.) The beds dip 47° S. 55° E.

In the SE. ¼ sec. 14 a prospect trench shows nearly 8 feet of ore and shale. The ore carries kidney-shaped concretions at the top and is fossiliferous and granular below. The beds dip 45° or steeper. A ferruginous bed, possibly the Ida seam, appears 20 to 30 feet southeast, across the strata.

Outcroppings of ore have also been observed by McCalley[a] in the SW. ¼ SE. ¼ sec. 12, which probably represent both the Ida and Big seams. About three-fourths mile farther southwest, in the NW. ¼ SW. ¼ sec. 13, there was uncovered in prospecting a bed 8 feet thick, containing 3 feet of ore of fair quality at the top and 5 feet of interbedded ore and shale below.

[a] McCalley, Henry, Report on the valley regions of Alabama, pt. 2, 1897, p. 415.

TOWNSHIP 21 S., R. 6 W.

The Clinton formation continues in apparently normal relations in Red Mountain southwest into Bibb County. Through T. 21 S., R. 5 W., the strata are mostly concealed by Cretaceous and Tertiary sediments, although still farther southwest, in R. 6 W., there are exposures of the formation. Two beds of ore have been noted about 60 feet apart. The character of these two beds, observed by McCalley,[a] in the NW. ¼ SW. ¼ sec. 24, are given in ore sections 47 and 48 (fig. 7) and analyses on page 90. These beds can not confidently be correlated with any of the well-known ore beds that are being worked farther north. It is thought, however, that they may correspond in general to the horizons occupied by the Ida and Big seams.

Farther southwestward Red Mountain becomes only a low ridge, partly buried by Lafayette sands and gravels, with much sandy brown-ore débris. Some scattered prospecting has been done where the Clinton strata are exposed by ravines and creeks, and a section of ore and other strata observed in an old prospect in the NW. ¼ sec. 35 is given in ore section 49 (fig. 7). If there are only 22 inches of coarse-grained siliceous ore in the principal layer, neither the quantity nor the quality of the ore can be said to be satisfactory here. These beds dip 35° SE.

About one-half mile southwest of the last-mentioned locality are the prospects of the Crowe Coal and Iron Company, near Big Spring. Ore section 50 (fig. 7) represents a section of the lower ore bed as measured in June, 1906, at the mouth of the abandoned main slope, and ore section 51 represents the ore as indicated by the drill record. This drill record, itself a complete section of the Clinton formation at this place, in the NE. ¼ SE. ¼ sec. 34, is given on page 45. The main prospect slope here was given about 250 feet. For about 100 feet the dip of the beds was 45°; but it had increased to more than 50° at the bottom. The ore was soft down nearly to the bottom of the slope, where lime began to appear. The hard ore carried 25 per cent or less of iron, 30 to 40 per cent insoluble, and about 25 per cent of lime carbonate. (See analyses, p. 90.)

A higher slope probably was intended to intersect the top bed of ore, which has been observed at other points on the ridge; but it evidently was started too high, for it goes into chert and clay above the Clinton beds.

Southeast of the gap at Big Spring there are several old prospects on the northwest slope of the ridge formed by the Clinton strata. Although the prospects are badly obliterated by débris, they show that there are two ore beds present, one near the top of the ridge, the other about 40 feet lower.

Nothing further is known regarding the ore southwest of the vicinity of Big Spring. The Clinton strata are for the most part so completely buried by post-Paleozoic sediments that their exact location is for the most part doubtful except where they are revealed by the erosion of the larger creeks. Below Hills Creek, in the southwest corner of sec. 20, T. 22 S., R. 6 W., a low ridge of sandstone is exposed, and farther southwest, in the southwest corner of sec. 12, T. 24 N., R. 9 E., in the valley of Schultz Creek, are sandstones that are believed to be the extreme southwestern exposure of Clinton beds on the line of Red Mountain.

RÉSUMÉ—SECTIONS AND ANALYSES.

So little is known concerning the quality and extent of the ore in the area of Division B that it would be useless to attempt an estimate of its ore reserves. Whatever ore there may be here would probably not be regarded as available just at present. The best service that can be rendered by this report is to show collectively what facts have been disclosed by prospecting, to represent on the map (Pl. II) the outcrop and relations of the Clinton formation, and

[a] Op. cit., p. 502.

to express an opinion (stated on p. 86) as to the location of the most promising field for exploration. Red Mountain, throughout Division B, is a direct continuation of the ridge of richest ore-bearing strata in the State. For part of the distance, in the area between McCalla and Big Spring, the structure is apparently in its general features similar to that between Potter and Sparks Gap on Red Mountain; that is, the rock dips are, so far as could be ascertained, mainly rather steep to the southeast, with numerous faults trending with the strike of the beds. This feature is in itself a discouraging consideration in relation to future prospecting, besides leaving the questions of quantity and quality of the ore yet to be more fully determined.

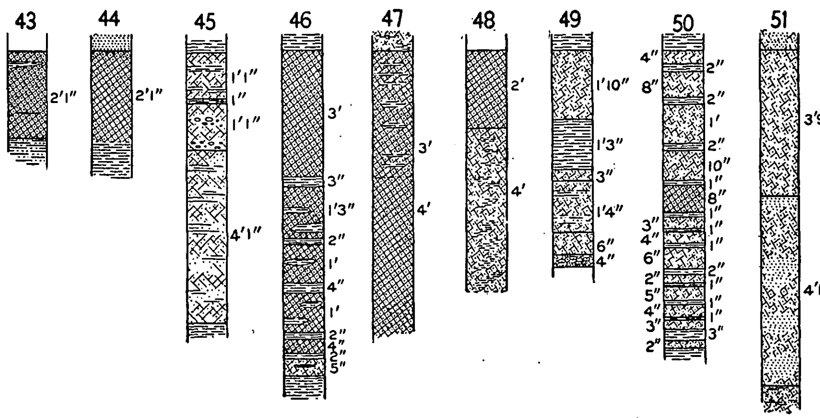

FIGURE 7.—Sections of ore beds, Division B, Birmingham district.

43. Ida seam, prospect pit; SE. ¼ sec. 6, T. 20 S., R. 4 W.
44. Ida seam, prospect tunnel; SW. ¼ sec. 6, T. 20 S., R. 4 W.
45. Big seam, prospect pit; NW. ¼ NW. ¼ sec. 7, T. 20 S., R. 4 W.
46. Big seam, prospect pit; SW. ¼ NW. ¼ sec. 13, T. 20 S., R. 5 W.
47. Ida (?) seam; NW. ¼ SW. ¼ sec. 24, T. 21 S., R. 6 W.
48. Big (?) seam; NW. ¼ SW. ¼ sec. 24, T. 21 S., R. 6 W.
49. Prospect pit, one-half mile northeast of Big Spring; NW. ¼ sec. 35, T. 21 S., R. 6 W.
50. Big seam, prospect, mouth of slope of Big Spring; NE. ¼ SE. ¼ sec. 34, T. 21 S., R. 6 W.
51. Big seam, drill hole, Big Spring; NE. ¼ SE. ¼ sec. 34, T. 21 S., R. 6 W.

Analyses of Clinton ores, Division B, Birmingham district, Alabama.

Locality of sample.	Authority.[a]	Fe.	SiO_2.	Al_2O_3.	CaO.	P.
Ida (?) seam.						
Outcrop NW. ¼ sec. 6, T. 20 S., R. 4 W.	M,415	40.23	33.28	....	....	0.069
Prospect, SW. ¼ SE. ¼ sec. 6, T. 20 S., R. 4 W.	O	39.98	25.47	3.49	5.78	.22
Big seam.						
Prospect, SW. ¼ SE. ¼ sec. 6, T. 20 S., R. 4 W., upper part	O	31	....	....	....	....
Prospect, SW. ¼ SE. ¼ sec. 6, T. 20 S., R. 4 W., lower part	O	26	....	....	....	....
Ida seam.						
Prospect, NW. ¼ SW. ¼ sec. 24, T. 21 S., R. 6 W.	M,502	60.96	4.28	....	....	Trace.
Prospect, NW. ¼ SW. ¼ sec. 24, T. 21 S., R. 6 W.	M,502	61.87	5.16	....	....	.122
Big (?) seam.						
Slope, NE. ¼ SE. ¼ sec. 34, T. 21 S., R. 6 W.	C	30±	[b] 20±		40±	....
Slope, NE. ¼ SE. ¼ sec. 34, T. 21 S., R. 6 W.	C	25±	[b] 30–40		25±	....

[a] Authorities: M (followed by page number), McCalley, Henry, Report on valley regions of Alabama, pt. 2, 1897; O, owners of property; C Crowe Coal and Iron Company.
[b] Insoluble matter.

DIVISION C.

GENERAL DESCRIPTION.

Division C includes that portion of Red Mountain that extends from Morrow Gap northeastward about 6 miles; the area underlain by Clinton strata around the margins of the two synclinal basins through which the headwaters of Cahaba River flow, from St. Clair County to a point 3 miles north of Trussville; and the strip of Clinton that is exposed along the Alabama Great Southern Railroad beginning 2 miles northeast of Trussville and extending, with breaks, to Springville. Altogether there is in this division a linear outcrop of Clinton strata approximating 28 miles, varying in width from 150 feet, where the measures are vertical and partly engulfed in a fault, to more than a mile, as in the shallow syncline in the southwest corner of T. 15 S., R. 1 E.

No underground mines have been opened in this area. Some soft ore has been obtained from surface workings, especially in the vicinity of Red Gap, in sec. 15, T. 16 S., R. 1 W. Prospecting has been done on the outcrop of the beds, in many places, but especially within the first 6 miles northeast of Morrow Gap, and it is probable that surface mining of soft ore will soon be systematically developed in this locality. The Louisville and Nashville Railroad extends in the valley between Red Mountain and Little Sand Mountain, about 4½ miles northeast of Red Gap, and could readily build spurs 2 or 3 miles farther north if developments demanded such extension. Farther northeast, however, the synclinal area between Big Cahaba Creek and Little Canoe Creek, and that in the vicinity of Cahaba Mountain, are not so well situated as regards present transportation facilities, although there are no points which could not be reached by railway if sufficient ore were found.

The following notes on the ore are given in order from southwest to northeast:

TOWNSHIP 16 S., R. 1 W.

From Morrow Gap northeast through sec. 28 there is much coarse-grained sandstone in the Clinton formation. The dip of the beds is in general about 15° SE., only a little steeper than the slope of the mountain. An ore bed, possibly the Irondale, is in the upper half of the formation, and an outcrop in a gully in the southwest corner of the NE. ¼ sec. 28 showed 4 feet 2 inches of siliceous looking, cross-bedded ore.

On the side of a high knob in the SE. ¼ sec. 21 there is an outcrop of what is probably the same ore bed, judging from its character, thickness, and position in the formation. The thickness of the ore measured by McCalley[a] is given in ore section 52 (fig. 8). This ore outcrops also farther down the mountain side, where it is about 4 feet thick. The ore is granular and compact, but appears to vary considerably in quality, as shown by the analyses on page 95, as it carries from 31 to 45 per cent iron in the soft ore.

[a] Op. cit., p. 363.

On the Trussville-Birmingham wagon road, where it descends the west slope of Red Mountain in the SW. ¼ sec. 15, a lean-looking ore bed is partly exposed. The dip of the beds is here about 13° SE. On the knob north of this road crossing, and down the slope to the southeast, there is evidence of a thin bed of soft ore at the surface or but a few feet below it, dipping at about the same angle as the hill slope (12°±). There is thus a large area of readily available soft ore here, since it can for the most part be obtained by means of wheel scrapers, and can probably be worked even if only 20 to 24 inches thick. At Red Gap, in the middle part of sec. 15, the relation between rock dip and hill slope is plainly shown. The dip is gentle and so nearly corresponds with the slope up the road from the southeast that an ore bed is exposed practically at the surface for a width of 600 feet. Many old strip pits and trenches west of the wagon road have been opened on the soft ore within a few years. The soft ore carried about 44 per cent iron, according to an analysis given by McCalley. (See p. 95.) Ore débris is very much in evidence also along the ridge northward from Red Gap, and on the second high knob north of the gap a prospect shows a 20-inch ledge of firm ore. The same ore bed is traceable through the eastern part of sec. 10, where it outcrops just east of the crest of the ridge.

The outcrop area of the Clinton strata in secs. 10, 11, and 2 is noticeably even in width (nearly half a mile) for a distance of more than 2 miles, and the rocks form a natural, gentle dip slope on the east side of Red Mountain. In accordance with this condition the bed of ore that outcrops near the crest of the ridge is exposed also in the ravines near the east foot of the ridge. In the W. ½ SW. ¼ sec. 11, on the north side of a long hollow, there are extensive prospect strippings, which expose a bed of ore 23 to 25 inches thick. The relations of this ore are given in ore section 53 (fig. 8). The dip here is about 10° SE. This ore lies about 40 feet below a massive bed of coarse, ferruginous sandstone, and these relations suggest that this thinner bed may be the Irondale seam, while the ferruginous sandstone bed represents the horizon of the Big seam. In several other hollows to the northeast the thin bed of ore lies close to the stream bed, and the massive ferruginous sandstone forms a ledge 40 to 50 feet above, on the flanks of the ravines.

Near the southwest corner of sec. 2, along the wagon road across the mountain, there are two ore colorations on the southeast slope, probably caused by the outcropping of the Irondale (?) seam in two places, since here the road ascends nearly a dip slope and crosses the outcrop of the ore at two levels. The beds dip 15° to 20°. Above these outcrops and about 50 feet below the top of the hill the bed of ferruginous sandstone of Big (?) seam makes a prominent ridge or shelf across the road. Conditions are somewhat similar to those in Red Gap, but the Irondale (?) seam does not appear to be as good here. Several other prospects in the SE. ¼ sec. 2, well down in the ravines toward the foot of the slope, show that the Irondale (?) seam maintains a thickness of 16 to 21 inches of rather siliceous looking ore, grading below and above into sandstone, as shown in ore section 54 (fig. 8). In the NE. ¼ sec. 2 the ferruginous sandstone ledge has been prospected and in ore section 55 (fig. 8) is given an illustration of the lower part of this bed. Above the sandy shale at the top of the section given there is about 30 inches of thin-bedded, cross-bedded, sandy ore, overlain by 4 feet of coarse ferruginous sandstone or conglomerate. This portion of the bed contains much iron for a sandstone, yet it is not an ore.

In the northwest corner of sec. 1 the sandy Big seam is exposed in a ravine and is about 5 feet 6 inches thick. It dips about 15° SE. The ore, however, is very low in grade, carrying only about 22 per cent iron and over 63 per cent silica.[a]

By reference to the map it will be seen that Clinton strata are exposed by the creek that cuts southeastward diagonally across sec. 1. Only the top of the formation is thus cut into and no ore beds are exposed.

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[a] McCalley, Henry, op. cit., p. 361.

TOWNSHIP 15 S., R. 1 W.

In the SE. ¼ SE. ¼ sec. 35, T. 15 S., R. 1 W., the Big (?) seam has been prospected by blasting a fresh face in the ledge that it forms at the head of an east-facing hollow. The rocks dip here 7° N. 35° E., this unusual dip indicating the beginning of the canoe-shaped basin that lies to the northeast. The thickness of the ore exposed here is shown in ore section 56 (fig. 8). The ore, even in the lower bench, is not much more than a highly ferruginous sandstone.

In the strip of Clinton that crosses the western part of sec. 36 and the southeast part of sec. 25 there is no showing of ore. It is probable that in sec. 36 beds would be found resembling those shown in ore section 56, but to the northward the formation is highly tilted, and the narrow outcrop of the Clinton in connection with the probable absence of Chickamauga limestone suggest that the Clinton is here partly faulted out. Therefore the indications for workable ore are not favorable in sec. 25 and in the NW. ¼ sec. 30, T. 15 S., R. 1 E., where these conditions prevail.

TOWNSHIP 16 S., R. 1 E.

Two and one-half miles northeast of Trussville, in the NW. ¼ sec. 18 and extending into sec. 7, is an area of Clinton strata, the nose of a sharp anticline. Along the northwest-southeast wagon road in the SE. ¼ NW. ¼ sec. 18 several prospect pits have been dug on the Big seam, and others on a thin bed below it. The Big seam here dips 40° S. 60° E., and is composed of 12 to 15 feet of thin-bedded, very sandy ore overlain by hard shale. This ore is a bright red when freshly broken, but weathers to dark red or almost black color. The ore is firm and compact and shows slickensided surfaces. This ore is apparently very siliceous and probably too low in iron to be of value under present conditions. Prospecting at this place was done so long ago that the lower bed could not be measured accurately, but it appears not to exceed 2 feet in thickness. Along Big Cahaba Creek the Clinton is well exposed, and in the SE. ¼ NW. ¼ sec. 6, near Self's old mill site, some prospects have been made, showing less than 3 feet of siliceous, pebbly, ferruginous rock. (See ore section 57.) About one-fourth mile northeast of Self's old mill site, in the bank of a small branch, a prospect freshly blasted shows 4 feet of fine to medium-grained, dark-red, ferruginous sandstone, overlain by 12 inches of coarse, pebbly sandstone (ore section 58). This same bed, of what may be regarded as poor ore, outcrops in the creek about 200 yards below the prospect.

TOWNSHIP 15 S., R. 1 E.

Although the Clinton formation underlies about half of the area of secs. 31 and 32, T. 15 S., R. 1 E., but little prospecting has been done there, since the rocks lie so nearly flat that the ore beds do not outcrop conspicuously. Judging from the quality of the ore seen in sec. 6 of the township next south, it would hardly pay to prospect secs. 31 and 32 to the extent of drilling, which would be the only thorough way to prospect them, owing to the flatness of the strata. On the southeast slope of the mountain, in the SW. ¼ SW. ¼ sec. 32, there are outcrops of two beds about 15 feet apart. The upper bed has about 14 inches of good ore; the lower is 4 to 5 feet thick, but too lean to work. The rocks dip here 25° to 30° WNW.

In the SE. ¼ sec. 20 a seam 26 inches thick of alternating thin streaks of ore, shale, sand, and clay is exposed in a fresh prospect (ore section 59, fig. 8). This is of interest only as it shows the character of what is probably the Irondale seam in this locality. McCalley[a] gives analyses (see p. 95) of samples of both beds in this locality, though he states that the beds are but 12 to 22 inches thick. It is probable also that the analyses represent picked samples.

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[a] Op. cit., p. 430.

In the NW. ¼ sec. 20, on the opposite limb of the syncline from the locality last mentioned, prospecting on the northwest side of Red Mountain has disclosed a bed of apparently good soft ore 20 to 24 inches thick. The dip of the beds is normally into the mountain, or southeast, but on the northwest edge of the strip, near the northwest corner of sec. 20, the beds dip 60° to 80° NW., and a bed of ore 2 feet thick has been opened in several prospects. Chickamauga limestone is not known to outcrop in this vicinity between the Clinton and the Knox formations. The structure suggested by these conditions is that the Clinton strata on the northwest side of Red Mountain here forms a narrow anticline that is faulted against Knox chert on its northwest limb. The ore bed thus outcrops on each side of the Clinton anticline.

The crest of the ridge here is formed by a hard ledge of coarse sandstone or fine conglomerate, probably of Chattanooga (Devonian) age, since it lies at the top of the Clinton formation. Stratigraphically above this, but bordering it on the southeast, are typical Fort Payne chert beds. Strewn along the top of the ridge and following the Clinton-Chattanooga-Fort Payne contact through secs. 20 and 17, and nearly to the middle of sec. 16, are fragments of a peculiar cherty brown ore, which breaks into rhombohedrons similar to calcite and also splits like shale along certain planes. It grades from a slightly ferruginous chert to material that is practically solid iron hydroxide. In the NW. ¼ NE. ¼ sec. 20 a steep gully on the southeast slope of the ridge, cutting more steeply than the dip of the underlying beds, has removed the Fort Payne cover and exposed the top of the Clinton formation about 100 feet below the crest of the ridge. The top of the Clinton here is a peculiar type of chert, easily distinguished from the Fort Payne chert by its faint banded structure, its more sandy texture, and its tendency to break into almost rectangular pieces about the size of half a brick. It usually presents a leached appearance. Inclosed in beds of this chert, close to the sandstone of Chattanooga age, is a trough-shaped deposit of the cherty brown ore in place. The material was freshly exposed in a prospect. In cross section it measured 7 feet in width and 4 feet in depth, and is of unknown length. Its strike follows that of the inclosing beds, N. 50° E., and it pitches slightly to the southwest. The ore material is banded concentrically or in troughlike layers, and appears in section like the end of a tree trunk cut away from the medial line so that the rings of growth half encircle a center which just appears at the edge of the cut. This vein, or shoot, if it may be so styled, or a similar one, is probably the source of the fragments of peculiar ore strewn along the ridge. The material rests in this exposure on clay at the bottom and decomposed chert along the sides. At the top the ore is mainly a brown limonite, but on the east side the deposit is red. The ore is of good grade, but the type of deposit does not suggest that the vein is anywhere of greater depth than is shown at this place, and moreover it is in such a comparatively inaccessible position that haulage by wagon would be difficult and expensive.

In the northern part of sec. 16 the Clinton formation forms a structural, but not a topographical, saddle between the synclinal basin to the south and the one to the north of this place. Around the south and west margins of the north synclinal basin the Clinton has been prospected, but without very encouraging results. The section of a test pit near the top of the high knob in the NW. ¼ NW. ¼ sec. 16 (ore section 60, fig. 8) was measured by McCalley.[a] McCalley notes also the outcrop of a sandy ore 5 to 7 feet thick in the SW. ¼ NE. ¼ sec. 9 and of three seams in the SE. ¼ SW. ¼ sec. 3.[b] The rocks at this place dip 40° to 50° SE. Both these exposures are probably on outcrops of the Big seam, which apparently is not of workable quality here.

As to the character of the ore in the remaining portion of Division C, viz, the strip of Clinton strata along the Alabama Great Southern Railroad north and south of Argo, there are few available data. The beds dip at high angles and are for some distance

[a] Op. cit., p. 358. [b] Op. cit., p. 283.

either partly or wholly buried by a fault along their strike, so that mining conditions would be unfavorable at all events. As to the character of the bed, it was reported by good authority that in places between Argo and Springville it carries 15 inches of good ore, where soft, and this would appear to be a very reasonable statement as compared with the visible thickness of the bed in the same strip of outcrop beyond Springville.

RÉSUMÉ—SECTIONS AND ANALYSES.

In conclusion it may be said that the most promising locality in Division C is that part of Red Mountain between Morrow Gap and sec. 36, T. 15 S., R. 1 W. The workable ore bed is here correlated with the Irondale seam. Its thickness ranges from 20 to 24 inches where it can be considered as of workable thickness at all, and there the workings will of necessity be confined to trenches on the outcrop and to open cuts where the requisite stripping is not too heavy. As to quality, the ore is, where soft, of good grade; as to position,

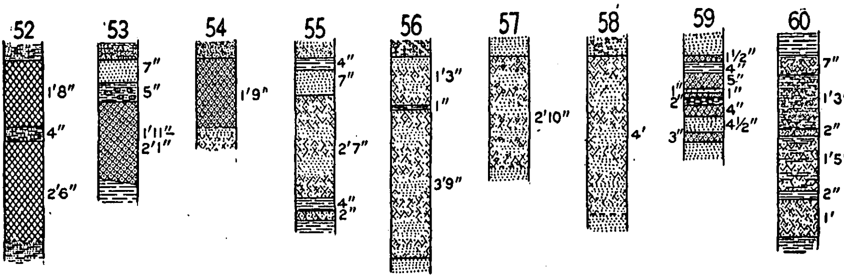

FIGURE 8.—Sections of ore beds, Division C, Birmingham district.

52. Outcrop Irondale (?) seam; SE. ¼ sec. 21, T. 16 S., R. 1 W.
53. Prospects, Irondale (?) seam, 2 miles east of Chalkville; W. ½ SW. ¼ sec. 11, T. 16 S., R. 1 W.
54. Prospect, Irondale (?) seam; NE. ¼ sec. 2, T. 16 S., R. 1 W.
55. Prospect, Big (?) seam; NE. ¼ sec. 2, T. 16 S., R. 1 W.
56. Prospect, Big (?) seam; SE. ¼ SE. ¼ sec. 35, T. 15 S., R. 1 W.
57. Prospect, Big (?) seam; SE. ¼ NW. ¼ sec. 6, T. 16 S., R. 1 E.
58. Prospect, Big (?) seam; NE. ¼ sec. 6, T. 16 S., R. 1 E.
59. Prospect, Irondale (?) seam; SE. ¼ sec. 20, T. 15 S., R. 1 E.
60. Prospect, Big (?) seam; NW. ¼ NW. ¼ sec. 16, T. 15 S., R. 1 E.

the bed in this locality is for the most part well situated with regard to the topography and to transportation facilities, and its cover and dip are favorable to economical stripping and open-cut mining. Therefore it is probable that a large tonnage of soft ore is still available here.

Analyses of Clinton ores, Division C, Birmingham district, Alabama.

Locality.	Authority.[a]	Fe.	SiO_2.	P.
Outcrop, SE. ¼ sec. 21, T. 16 S., R. 1 W	M, 363	45.02	28.37	0.188
Outcrop, SE. ¼ sec. 21, T. 16 S., R. 1 W	M, 363	31.35	49.90	.394
Outcrop, middle sec. 15, T. 16 S., R. 1 W	M, 362	43.94	30.08	.153
Outcrop, "upper seam," SE. ¼ sec. 20, T. 15 S., R. 1 E	M, 430	54.31	15.44	.191
Outcrop, "lower seam," SE. ¼ sec. 20, T. 15 S., R. 1 E	M, 430	45.43	26.80	.177

[a] Authority: M (followed by page number), McCalley, Henry, Report on valley regions of Alabama, pt. 2, 1897.

DIVISION D.

GENERAL DESCRIPTION.

Division D includes West Red Mountain from Compton, a small mining town 2 miles north-northeast of Village Springs, to near Tarrant Gap. It comprises a single strip of Clinton formation about 15 miles long. Through the whole distance the Louisville and Nashville Railroad traverses the valley southeast of the ridge at a distance of one-half to 1 mile. The only active ore mine in this division is at Compton. Most of the rocks are highly inclined everywhere on West Red Mountain, and for 8 or 9 miles are bordered on the southeast by an overthrust fault. The Clinton formation in West Red Mountain is probably slightly thicker than in Red Mountain, and there are differences in the composition of the rocks and in the character of the ore beds that are difficult to account for in the short distance of 5 or 6 miles that separates the two limbs of the anticline, especially since along the strike the rocks are fairly constant in character for two or three times that distance. As stated on page 40, these conditions perhaps may be due to more abrupt differences in sedimentation from place to place in a direction at right angles to the shore line of the body of water in which the rock sediments were deposited than parallel to this shore line; or else the sediments that constitute these two ridges may have been deposited in separate basins, and therefore may never have been continuously connected strata as has heretofore been supposed. Such conditions might be accounted for in part by the presence of strips of land or barriers between the places where certain areas of Silurian rocks were deposited.

TOWNSHIP 14 S., R. 1 W.

COMPTON.

Recently the Birmingham Ore and Mining Company operated a mine at Compton. The Clinton formation forms the crest of West Red Mountain here, and dips from 25° to 35° N. 65° W., passing below the Fort Payne chert high on the ridge. The mine is situated on the west slope of the ridge, and the ore bed, which outcrops near the summit, is reached by a crosscut tunnel with relations similar to those shown in the profile (fig. 17). The present workings consist of the main drift, connecting with the slope which follows the dip of the ore, and three right and three left entries turned from the slope; also a drift that enters the beds on the outcrop in a ravine about halfway up the mountain side and extends along the strike. There are also some abandoned drift workings of a similar sort and some trenches on the outcrop of the bed where soft ore has been obtained.

There is only one important bed of ore in the formation here, and this ranges from 30 to 36 inches in thickness, with a thin parting of shale, irregular in position.

Illustrations of the working face of the ore bed, made within short distances of each other, showing slight local variations in the bed, are given in ore sections 61, 62, 63, and 64 (fig. 9). In the second left entry, and extending diagonally across the third left, across the main slope, and to the third right, is a place where the beds are pinched down to a very few inches or entirely cut out by a downward bulging of the overlying shale, which there has a concretionary or concentric structure. When last operated, in the summer of 1906, the face of the slope was just reaching a thin edge of ore beyond the barren rock. Such structures have been explained on page 54. Hard ore was last mined at Compton. Analyses made in August, 1904, showed about 40 per cent iron, 25 to 30 per cent lime carbonate, and only 9 to 11 per cent insoluble. An ore with so much lime and so little insoluble matter is suitable for fluxing with the addition of soft ore or brown ore. (See analyses, p. 100.)

Northeastward on this ridge, which is in that direction called Red Mountain, the ore is reported to be from 16 inches to 3 feet thick. Near Blackburn Fork, in the NE. ¼ SW. ¼ sec. 30, T. 13 S., R. 1 E., a prospect has been made exposing ore beds 3½ feet thick. In the vicinity of Chepultepec the seam is reported to be about 16 inches thick.

DALE.

A section of the upper part of the Clinton formation is exposed in the gap through West Red Mountain near Dale, along the railroad cut, where the beds dip 23° to 25° NW. This section, given on page 53, shows that the ore horizon is above the middle of the formation, and that there are probably two horizons of ore-bearing material. The upper (2-foot) seam is probably the one worked at Compton.

TOWNSHIP 15 S., R. 1 W.

In the NW. ¼ NW. ¼ sec. 9, T. 15 S., R. 1 W., prospecting was done on the outcrop of the ore beds along the southeast slope of the ridge, three-fourths of a mile north of the gap through which Self Creek flows. The crest of the ridge is formed by the base of the Fort Payne chert and the topmost sandstone beds of the Clinton formation. The beds on the east slope of the ridge dip 33° to 35° N. 70° W., but the dip increases southward. There is 2 feet or less of fair-grade ore here in the upper ledge, which corresponds to the one worked at Compton. A thicker bed of lean ore, high in lime where hard and very sandy where the lime has been leached from it, is also present but is probably not of workable grade. There are no data on which to correlate these ore beds with those on Red Mountain except their general position and relative thickness. For the sake of convenience in description these beds will here be styled the "upper" and the "lower" beds.

In the gap cut by Self Creek, in the SE. ¼ SE. ¼ sec. 8, the dip of the beds is 70°. Only the top of the Clinton is exposed here, the ore-bearing portion being heavily covered by débris, but the trace of what is probably the "lower" bed is noticeable across the wagon road in the north side of the gap.

From Self Creek southward to the next gap, about 3 miles distant, the beds dip at steep angles to the northwest, with Fort Payne chert forming the crest of the ridge. The top 100 feet of Clinton strata are mostly sandstone, massive in places. The "upper" bed has been cut into in several old prospects in sec. 17. It appears to carry 2 to 2½ feet of rather siliceous ore.

Prospecting, as noted by McCalley,[a] has disclosed the "upper" and "lower" beds in the NW. ¼ sec. 20. They are apparently about 17½ feet apart, the upper one containing 5 feet of coarse sandy ore, and the lower one 9 feet or more of lean, sandy, shaly material, dipping 45° NW. Analyses of ore from the upper bed in this locality, given by McCalley, show that the soft ore ranges from 39 to 44 per cent iron and from 32 to 37 per cent silica, but it is doubtful whether these analyses represent an average of the entire bed. (See p. 100.) It is more than probable that they are analyses of fragments of the ore, excluding the shale, which would not only greatly reduce the percentage of iron in the bed, but would increase the cost of mining. Ore section 65 (fig. 9) shows the relations of the "upper" and "lower" beds. About three-fourths of a mile southwest, in the southwest corner of sec. 20, two beds 35 to 40

[a] Op. cit., pp. 344, 345.

feet apart are exposed. The "upper" ore here is thin, 1 foot 4 inches in thickness, with decomposed shale containing streaks of ore above. The lower bed contains about 6 feet of soft, black, friable, sandy, ferruginous material, overlain by shale carrying streaks of ore. The beds dip about 30° NW. (See ore section 66, fig. 9.)

In the NE. ¼ SE. ¼ sec. 30, at the old Blackburn mill, the "lower" bed has been cut by the mill race. There are two benches of very sandy ore, 2 feet 6 inches and 3 feet 6 inches thick, separated by 3 feet of shale, with about 1 foot 3 inches of fair ore above 10 inches more of shale (ore section 67, fig. 9). McCalley[a] reports this bed as showing in addition 9 feet of ore behind the mill wheel, but although this was looked for in the present survey no such thickness could be found. An average sample of ore from this bed is reported by McCalley to carry 27.5 per cent iron, 48.6 per cent silica, and 0.72 per cent phosphoric acid. (See p. 100.) The strata at this place are overturned until they dip back 85° SE. About 200 yards northwest of the old mill are three or four old test pits at the nose of a small ridge of Clinton strata. A bed apparently higher and thinner than the one at the mill is disclosed here, but owing to the conditions of the prospects the thickness and dip of the beds are not determinable. The ore on the dumps was of the soft, or noncalcareous, variety, with coarse to fine grains of silica cemented by ferric oxide, and showed slickensided planes. The structure along Turkey Creek just south of these prospects is somewhat complicated. A northeast-southwest fault has here offset about 1,000 feet west the rocks composing West Red Mountain, besides overturning, dragging, and crushing the strata inclosing the ore beds. For this reason, conditions affecting mining would doubtless prove rather unfavorable immediately north of Turkey Creek, in sec. 30.

As shown on the map, the ore-bearing formation resumes its normal course in the SW. ¼ sec. 30, but the beds are much overturned. In the NW. ¼ SW. ¼ sec. 30 a test pit was dug some twelve years ago, exposing ore in one bench about 11 feet thick, with a dip of 60° SE. (See ore section 68, fig. 9.) This ore is soft and rather lean and siliceous, carrying 32 to 33.9 per cent iron and 48 to 49.7 per cent silica[b] (p. 100).

In the SW. ¼ SE. ¼ sec. 25 an old test pit shows a bed of siliceous ore nearly 10 feet thick, dipping 42° S. 30° E. The ore is coarse to fine grained, with round and flattened silica grains. It is a soft ore of good specific gravity and probably averages slightly higher in iron than the samples last mentioned.

TOWNSHIP 16 S., R. 2 W.

Two miles and a half southwest, in the SE. ¼ sec. 3, is an outcrop of ore showing about 5 feet of ore in one bench (ore section 69). The ore here dips about 45° W. In the NW. ¼ NE. ¼ sec. 10 the outcrop of a smaller bed has been observed[c] having lean, loamy, soft ore in an upper bench averaging 21 inches in thickness and a firm lower bench, 6 to 8 inches thick, the two being separated by 2½ feet of decomposed ferruginous material (ore section 70, fig. 9).

McCalley also gives the analysis of a soft ore from a test pit near the above exposure, which carried 29.6 per cent iron and 53 per cent silica. Analysis of what is probably the same, or "upper," bed in Cunningham Gap is given by McCalley,[d] showing the ore to contain nearly 30 per cent iron and 55 per cent silica (p. 100). The general character and thickness of the Clinton strata in Cunningham Gap is shown on page 53. The concealed intervals probably represent shale beds for the most part. Both beds of the ore show also in places in the SE. ¼ sec. 16.

TERMINATION OF THE OUTCROP.

In the NW. ¼ sec. 28 the outcrop of the Clinton formation in West Red Mountain is terminated by an overthrust fault, which for about 25 miles either completely or partly buries the strata and renders the ore beds inaccessible or so badly breaks

[a] Op. cit., pp. 346, 347.
[b] McCalley, Henry, op. cit., p. 348.
[c] McCalley, Henry, op. cit., p. 349.
[d] Op. cit., p. 350.

them up that they are valueless. Notes on fragments of ore beds in this area along the fault line southwest of Tarrant Gap are given by McCalley.[a]

Among the localities in T. 17 S., R. 3 W., thus noted, are Boyles Gap in sec. 6, the SE. ¼ sec. 15, the NE. ¼ sec. 29, the SE. ¼ sec. 30; and in T. 18 S., R. 4 W., a locality is noted in the NW. ¼ sec. 11.

Since the structure in such areas is so unfavorable and their extent so limited, space is not devoted to them here, for the ores can not be regarded even as future reserves.

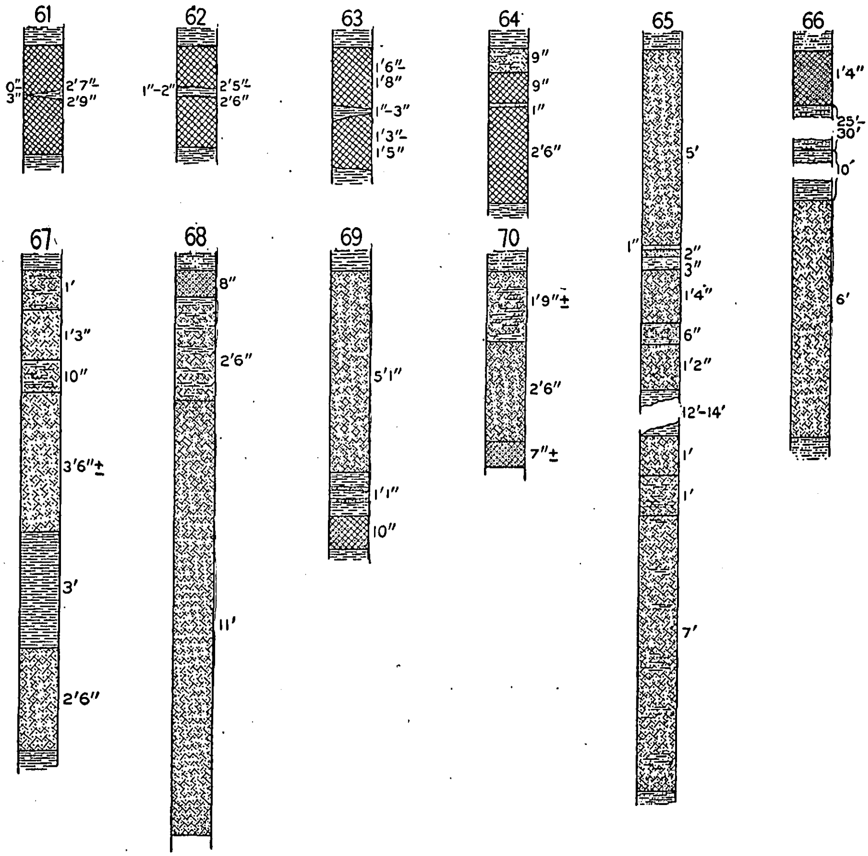

FIGURE 9.—Sections of ore beds, Division D, Birmingham district.

61. At outcrop, Compton mine.
62. At entrance, first right, Compton mine.
63. At entrance, second left, Compton mine.
64. At breast, first left, 300 feet from main slope, Compton mine.
65. Test pit on "upper" and "lower" beds ; SE. ¼ NW. ¼ sec. 20, T. 15 S., R. 1 W.
66. Outcrop, "lower" bed; SW. cor. sec. 20, T. 15 S., R. 1 W.
67. Partial section at old Blackburn mill; NE. ¼ SE. ¼ sec. 30, T. 15 S., R. 1 W.
68. Test pit; SW. ¼ SW. ¼ sec. 30, T. 15 S., R. 1 W.
69. Outcrop; SE. ¼ sec. 3, T. 16 S., R. 2 W.
70. Outcrop; NW. ¼ NE. ¼ sec. 10, T. 16 S., R. 2 W.

[a] Op. cit., pp. 350–353.

RÉSUMÉ—SECTIONS AND ANALYSES.

From the notes presented on this division of the district it is seen that in the strip from above Compton to Tarrant Gap there are two beds of ore. The upper bed is thin, 1½ to 2 feet thick, but carries good hard ore in the upper end of the area, while the lower bed is thicker, running 5 to 11 feet in thickness, but is nearly everywhere comparatively lean in iron and high in silica, so that it would be of value only locally, and then only as soft ore. Conditions for underground mining are favorable only in the upper end of the area, and owing to the steep dip and heavy cover open-cut work and trenching can be done only to a limited extent on the outcrop. On the other hand, the ore is everywhere within a short haul to a railroad, so that if conditions should demand it work might be done on a small scale in several places that will yield soft ore.

Analyses of Clinton ores, Division D, Birmingham district, Alabama.

Locality.	Authority.[a]	Fe.	P.	SiO_2.	CaO.
Compton mine	S	40.20	....	[b] 9.60	16.53
Do	S	40.70	....	[b] 11.16	14.19
Prospect, "upper seam," SE. ¼ NW. ¼ sec. 20, T. 15 S., R. 1 W	M, 345	39.60	0.230	37.08	....
Prospect, "upper seam," SE. ¼ NW. ¼ sec. 20, T. 15 S., R. 1 W	M, 345	44.33	.231	31.61	....
Prospect at Blackburn's mill	M, 347	27.53	.316	48.64	....
Outcrop, NW. ¼ SW. ¼ sec. 30, T. 15 S., R. 1 W	M, 348	32.22	.310	49.67	....
Outcrop, NW. ¼ SW. ¼ sec. 30, T. 15 S., R. 1 W	M, 348	33.92	.162	47.96	....
Outcrop, NW. ¼ NE. ¼ sec. 10, T. 16 S., R. 2 W	M, 349	29.61	.145	52.95	....
Cunningham Creek Gap	M, 350	29.96	.270	54.82	....

[a] Authorities: M (followed by page number), McCalley, Henry, Report on the valley regions of Alabama, pt. 2, 1897; S, Sloss-Sheffield Steel and Iron Company.
[b] Insoluble matter.

DIVISION E.

GENERAL DESCRIPTION.

Division E comprises the Clinton strata in West Red Mountain, with the fragmentary areas of the same strata within Birmingham Valley, southwest of Birmingham. These fragmentary areas include outliers within the chert area of the valley and strips like that of McAshan Mountain and those in the extreme southwestern end of the valley at Vance and southwest of Dudley. For the most part these strips lie in the Brookwood quadrangle. A rough estimate of the length of outcrop of all the fragments placed end to end, including portions which are covered by Cretaceous and Tertiary sediments, but whose location is known, would be 45 miles. The structure of the West Red Mountain strip is similar to that in the same ridge above Birmingham—that is, the strata stand nearly vertical or overturned, or rarely dip normally northwest. Some of these relations are shown in figure 2. In places the strata are buried and also offset greatly by faults. A structural feature not exhibited in any other of the divisions of the district is the duplication of Clinton areas by faulting and by folding with faulting. An area duplicated by faulting is McAshan Mountain, and the partly buried ridges extending from Vance and Dudley southwestward have been formed by folding and faulting, forming nonsymmetrical synclinal strips partly bounded by faults. Possibly of a similar type are the small patches of Clinton strata that lie on the chert ridges north-northeast of Bessemer.

In July, 1906, only one mine was producing ore in this division, that of W. P. Pinckard & Co. (in 1909 owned by the Big Sandy Iron and Steel Company), 1½ miles south of Dudley. A little mining has been done near the northern end of McAshan Mountain; also in West Red Mountain north of Woodstock, and at Vance, but work at these three places has long since been abandoned.

South of Bessemer the Alabama Great Southern Railroad passes southwest through the valley 1½ to 2½ miles from West Red Mountain as far as Dudley, where it leaves the ore-bearing area and turns westward across the deeply buried coal field. At Chamblee the Louisville and Nashville Railroad follows a gap west through West Red Mountain, crossing again to the east side of it in the gap eroded by Valley Creek. Northeast of Bessemer the Louisville and Nashville Railroad is again near West Red Mountain. Therefore, this division is well supplied with transportation facilities, so that wherever the ore can be profitably mined it can be reached by a spur from an ore-carrying road.

The following notes are given in order of location from northeast to southwest. Much of the information was obtained by McCalley eleven or twelve years ago, and although nearly all the localities were visited during the present survey, not all the data quoted could be verified. Some errors in location were printed in McCalley's report, and these have been corrected so far as possible in this report.

TOWNSHIP 18 S., R. 4 W.

In the southeastern part of sec. 14 and the western part of sec. 23 are patches of bedded sandstone containing red ore. The areas are surrounded by Knox chert, and possibly are underlain in part by a few feet of Chickamauga limestone. Chert débris containing Fort Payne fossils is found in places on the surface. Considerable red-ore débris of good quality, fossiliferous and containing quartz pebbles, is in evidence in the gullies in this vicinity. The ore consists mostly of rounded waterworn pebbles and small bowlders, all well leached. An average sample of 30 to 40 of these ore pebbles carried nearly 60 per cent iron. (See p. 111.) On top of a small round hill in the SW. ¼ SE. ¼ sec. 14 are some abandoned open cuts. The thickness of the ore could not be measured, but it may be as thick as that noted by McCalley.[a] There is plenty of ore débris here, and several hundred tons of soft ore may have been removed and hauled by wagon to the dummy road that once ran where the trolley line now runs. The ore dips 15° S. 80° E. The ore as noted by McCalley is somewhat in excess of 5 feet thick, exposed in a test pit in the northern part of sec. 23. (See ore section 7, fig. 11.) Owing to the limited area of this patch of Clinton formation it is of slight importance, especially since part of the soft ore has already been removed from it.

[a] Op. cit., p. 420.

TOWNSHIP 19 S., R. 5 W.

Near the center of the SW. ¼ sec. 12 McCalley has observed an ore bed 14 inches to 2 feet thick, which appears to be very high in grade, since it contained, according to the analysis, over 60 per cent iron and less than 10 per cent silica. (See analysis, p. 111.) The ore is overturned, dipping southeast, and is probably bordered by a fault. In the SE. ¼ NE. ¼ sec. 23, a ledge of ore 1 foot 7 inches thick was observed by McCalley. The dip of the outcrop is about 85° NW. The soft ore carries about 36 per cent iron and 44 per cent silica, which composition stamps it as of rather low grade. In the southwest quarter of the same section a bed apparently higher in the formation has been prospected on the northwest side of West Red Mountain. Six to 7 feet of leached granular ore exposed here gave as an average analysis 37.82 per cent iron and 43.2 per cent silica (p. 111). The beds dip 60° NW.

In the SW. ¼ sec. 26 four ferruginous seams are exposed in a test trench cut in the top of West Red Mountain. The bottom bed only is of good soft ore, and it is thin. This bed is thought to outcrop in the SE. ¼ SE. ¼ sec. 34, where there is 1 foot 6 inches of good ore with 4 feet 4 inches of poor ore above it. (Ore section 72, fig. 11.) The dip here is about 40° NW. The ore is soft and granular and carries 55 per cent iron. (See p. 111.)

In the SE. ¼ SE. ¼ sec. 35 an outcrop of two beds of ore shows near the crest of McAshan Mountain. The upper one is the more important. It carries more than 4 feet of ore,[a] as in ore section 73 (fig. 11). The beds dip 45° NW. McCalley has provisionally correlated the beds in West Red Mountain with beds in Red Mountain, but no attempt will be made to do so here. The deposits differ so greatly through short distances that the beds here apparently had no connection with those of Red Mountain, perhaps owing to a structural barrier which may have affected the deposition of sediments. That there are also differences within short distances along the strike of the beds is illustrated by comparison of the last section with that of the ore about 200 yards farther southwest. (Ore section 74, fig. 11.) At this place, while the total thickness is nearly the same, only the bottom 10 inches of good ore appear to be shared alike by the two sections. Analyses of average samples of this upper bed, dried at 100° C., gave over 50 per cent iron and 21.6 per cent silica. (See p. 111.)

TOWNSHIP 20 S., R. 5 W.

On the southeast crest of McAshan Mountain in the NW. ¼ sec. 2, T. 20 S., R. 5 W., is an old abandoned slope driven into beds that dip at the entrance about 40° N. 55° W. At the top of the ore bed is a seam of fine-grained, sandy ore 5 to 6 inches thick; next below are 2 to 3 inches of shale with about 31 inches of coarse quartzose ore at the bottom, parted by 10 inches of shale. (Ore section 75.) The top 5 to 6 inches of ore was not worked. It carries about 25.8 per cent iron and 60 per cent silica. The worked soft ore below carried 54 per cent iron and 17 per cent silica. (See p. 111.) This slope is reported to have gone down 200 or more feet, where the ore became too thin for profitable mining. A railroad spur was built from the Alabama Great Southern Railroad to this point, houses were erected, and mining was for the time conducted on a substantial scale. This instance illustrates well the importance of thorough drili prospecting before beginning the real development of a mine in this district.

In the SE. ¼ sec. 3 an outcrop of the upper bed dipping 25° to 30° NW. shows a little thicker than in the previous section. The ledge 2 feet 6 inches thick in the upper part of the bed carries 27 per cent iron and about 62 per cent silica, while the rest of the bed below averages 51 per cent iron and 21.4 per cent silica in the soft ore. (See ore section 76, fig. 11, and analyses, p. 111.) About 150 yards southwest of the last-mentioned exposure, in a gap of McAshan Mountain, the same bed is

[a] McCalley, Henry, op. cit., p. 424.

exposed, showing about 2 feet of ore in two benches, parted by 6 inches of weathered shale. (Ore section 77; fig. 11.)

In the NW. ¼ NE. ¼ sec. 10 the upper bed outcrops on the top of McAshan Mountain and shows about 4 feet 6 inches of ore, principally in two benches, with laminations of ore and sandstone between. (Ore section 78, fig. 11.) These beds dip about 35° NW. At the lower end of this portion of the mountain, in the SE. ¼ NW. ¼ sec. 16, a bed containing about 10 inches of good ore has been noted, dipping 20° NW.[a] Farther southwest McAshan Mountain is represented only by a low, worn-down line of hills, but its strata are continuous some distance southwest of Bucksville, as in the SE. ¼ SE. ¼ of sec. 19, where prospecting has disclosed an ore seam on the southeast slope of the hill. Several test pits and one trench a rod or more long have been dug not long since. The trench showed beds dipping 58° S. 30° E., and consequently overturned. The ore bed is of good quality, fossiliferous, soft ore, in places dark and shiny. The bed is about 26 inches thick. The strata are somewhat fractured, and there is a small fault in the ore bed in the trench, by which the ore is displaced slightly more than the width of the bed. (Ore section 79, fig. 11.)

On West Red Mountain, in the NE. ¼ NE. ¼ sec. 9, the upper of the two ore beds shows in an outcrop that is overturned, dipping 75° SE. The ore is in two benches, each about 20 inches thick, separated by 2 feet 4 inches of shaly ore. (Ore section 80, fig. 11.) An average sample, dried at 100° C. gave on analysis 56 per cent iron and 13.8 per cent silica. (See p. 111.) Southwest of here for 2 miles, more or less, fragments of loose ore are scattered along the top of the mountain, the débris from the outcrop of this ore bed. Near Cooley Creek, in the NE. ¼ NE. ¼ sec. 19, is an outcrop exposing about 71 feet of Clinton strata, in which are three beds of ore about 30 feet apart. The upper bed is reported to carry 3 feet 1 inch of good soft ore separated from a 1 foot 6 inch bench of ore by 8 to 10 inches of loam.[b] This is evidently the most important bed. The one next below appears to have only 8 to 10 inches of fair ore, while the lower one consists of two benches each about 1½ feet thick, separated by 1 foot of shale. The beds here are overturned and dip about 75° SE.

TOWNSHIP 20 S., R. 6 W.

West Red Mountain is continuous southwestward into Tuscaloosa County to about 4 miles northeast of Vance. In the NW. ¼ sec. 35, about 1 mile northeast of Chamblee, some prospecting has been done within the last three years on the ore beds in West Red Mountain. Two trenches each expose more than 100 feet of the measures, and an intermediate trench cuts a portion of the same section. There are in these sections three beds of ore, the top one being about 15 inches thick, separated from the next below, which is 20 inches thick, by 55 feet of ferruginous sandstone and shale. The bottom bed is separated from the next above by 25 to 40 feet of shale and shaly sandstone. It consists of two benches of ore separated by 3½ to 5 feet of sandy shale. The upper bench is 22 to 25 inches thick, fossiliferous and oolitic, and is a soft ore of fair quality. The lower bench ranges from 2 feet 5 inches to 2 feet 10 inches thick and from a lean to a good quality of soft ore. (Ore sections 81 and 82, fig. 11.) The beds dip at angles varying from 15° to 55° S. 30° to 60° E. They are overturned so that the upper bed outcrops at a lower level than the lowest one.

TOWNSHIP 21 S., R. 6 W.

In the gap made by Davis Creek in the SW. ¼ NE. ¼ sec. 3, the Clinton beds exposed by the Louisville and Nashville Railroad cut are nearly vertical. Three thin beds of ore are exposed here which in a general way correspond to those just described, and in the interval of 30 feet between the middle one and the lowest are about 8 feet of very ferruginous sandstone with shaly partings. The lowest bed, 1 foot 2 inches

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[a] McCalley, Henry, op. cit., p. 429. [b] McCalley, Henry, op. cit., p. 357.

thick, showed on analysis 50 per cent iron and 20 per cent silica, and the middle one, 1 foot 5 inches thick, carried 37 per cent iron and 27 per cent silica, both of them being soft ore. (See analyses, p. 111.) On the southwest side of this same gap is an old drift where a little mining was once done. Two beds of clayey, sandy ore are exposed here, each about 5 feet thick. The lower one was worked once, but is reported to have thinned down to only 1 foot thick in a short distance down the dip. The beds dip about 75° NW. and are consequently rather steep for cheap mining. About three-fourths of a mile farther southwest, in the SE. ¼ sec. 4, some old test pits show the presence of two beds of ore separated by about 20 feet of concealed strata. The lower bed, about 5 feet thick, is principally shale. The upper one carries about 34 inches of low-grade ore with four shale or clay partings. McCalley[a] gives a section of these beds and reports that the lower one carried 28 per cent iron, 39 per cent silica, and nearly 0.8 per cent phosphorus in the soft ore. (See analysis, p. 111.)

Southwest from this locality Cretaceous and Tertiary clays and sands appear, and in places obscure the strata of West Red Mountain, which becomes in reality a buried ridge, revealed only by stream erosion. Near Gallants Creek, in the SW. ¼ sec. 9 and the SE. ¼ sec. 8, the Clinton strata appear, and McCalley[b] has measured the following three sections:

1. Section in NW. ¼ SW. ¼ sec. 9, T. 21 S., R. 6 W.

	Ft.	in.
Shale, yellowish.		
Ferruginous sandstone, pebbly at top, with streaks of shale	15	
Concealed by deep red loam	4	
Shale, grayish	12–14	
Ore, very sandy		2–12
Shale, yellowish		4–12
Ore, dark brown, sandy and shaly, about	6	
Shale, yellowish	1½–2	
Ore, of brown color and very sandy		5
Ore and loam		5
Shale, yellow, and red loam	15	

2. Section in NE. ¼ SE. ¼ sec. 8, T. 21 S., R. 6 W.

	Ft.	in.
Loam, deep red.		
Ore, glistening, unctuous, streaks in other material		5
Sandstone, dark, ferruginous	10–12	
Shale and ore in alternate streaks		9
Sandstone, dark, ferruginous	4	
Sandstone, yellowish		11
Sandstone, dark, ferruginous	6–8	
Shale, streak.		
Ore, very sandy, of no value	8–10	
Sandstone, yellowish.		

3. Section in SE. ¼ SE. ¼ sec. 8, T. 21 S., R. 6 W.

	Ft.	in.
Shale, yellowish, with thin seams of ore.		
Ore, very sandy, of no value	10–12	
Shale and ore in alternate streaks	9–10	
Ore, very sandy, of no value	8–9	
Shale and ore, in alternate streaks, exposed	1	6

The rocks shown in sections 1 and 2 are just northwest of a fault and are badly fractured. In the yellowish shale at the top of section 3 there are thin seams of very firm ore, but these are of no value.

[a] Op. cit., p. 469.

[b] Op. cit., pp. 470, 471.

TOWNSHIP 21 S., R. 7 W.

From the western part of sec. 17, T. 21 S., R. 6 W. the Clinton formation is faulted out as far as the NE. ¼ sec. 25, T. 21 S., R. 7 W. At this latter locality begins a strip of the formation that is a duplication of West Red Mountain, with synclinal structure. Several deep test pits have been sunk here revealing ore of good quality, but thin, and containing a large proportion of shale and clay. The strata here are also badly fractured, overturned, and faulted, so that mining them would be impossible.

At Vance in the NE. ¼ sec. 35 the ore outcrops apparently in two beds. One outcropping is almost in strike with beds that pass below the railroad station; the other is 75 to 100 yards northwest. The northwest outcrop shows, it is reported, an ore-bearing bed about 17 feet thick, badly interseamed with shale and clay. The dip of these beds is steep, and the rocks are bordered by a fault and are badly shattered. A limestone wall borders the ore on the south, and the limestone is thrust over the ore from the south. An attempt was made here to mine the ore several years ago, and about 10 feet of the ore bed was exploited in a slope that descended 170 feet with the strike of the bed, until the overthrust fault made farther advance impossible. The top 4 feet of ore was found to carry 37 to 41 per cent of iron in the soft ore, and the bottom 6 feet from 31 to 36 per cent iron. The silica ranged from 27 to 43 per cent, and alumina was high, probably from the large proportion of clay associated with the ore, since it averaged above 9 per cent. (See analysis, p. 111.)

The distribution of the beds southwest of Vance can best be understood by reference to the general geologic map (Pl. II). The syncline itself is folded on the southeast margin, and perhaps is faulted about 4 miles southwest of Vance, so that the Clinton beds are not present at the surface on the southeast limb and the Fort Payne chert is in contact with the Chickamauga limestone. On the northwest the syncline appears to be partly bounded by a fault beginning north of the Alabama Great Southern Railroad and extending southwest about 2½ miles.

The rocks of the West Red Mountain strip lie three-fourths to 1½ miles farther west of the faulted syncline, although the strata are so deeply buried by clay and sand that they do not form even the faintest ridge. It is only at rather widely separated points that there are any exposures, and it is from such incomplete evidence that the beds have been mapped. The Clinton and adjacent strata, comprising the Chickamauga limestone, Fort Payne chert, and Hartselle sandstone, appear in their normal sequence at a few places, everywhere dipping steeply southeast, indicating an overturn, or standing vertical. This strip of the Clinton is consequently very close to the southeast boundary of the Warrior coal field. In the valley of Big Sandy Creek there is evidence of still another strip of Clinton strata duplicated by folding, and there are fragments of these beds exposed in tributary creeks to the southeast, which show a northwest-southeast strike, a direction at right angles to the normal strike. The structure in this region is not only complicated in itself, but the rocks are so nearly everywhere concealed by thick coastal plain deposits that their relations must necessarily always remain very obscure. A cross section of the probable structure, about 2 miles south of Dudley, is shown in figure 10.

Southwest of Vance the Clinton is exposed in the SE. ¼ sec. 34 and the SW. ¼ sec. 35, these beds being on the southeast limb of the syncline. The northwest limb of the anticline appears in the NE. ¼ sec. 33 and the NW. ¼ sec. 34, and there are outcrops of a bed which is reported to be about 8 feet thick in an old test pit near the center of the NE. ¼ sec. 33.[a] These strata are bounded on the northwest by a fault, and are badly broken up. Near the center of the SE. ¼ sec. 33 there is an outcrop of soft, oolitic ore in thin beds interstratified with shaly seams. Ore was also found in test pits on the southeast limb of the syncline, in the NW. ¼ SE. ¼ sec. 34.

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[a] McCalley, Henry, op. cit., p. 473.

TOWNSHIP 22 S., R. 7 W.

Clinton strata are nearly everywhere thickly covered by Cretaceous and Tertiary sands and gravels where they occur in this township, but near the southwest corner of sec. 4 they have been observed, and in the NW. ¼ SE. ¼ sec. 8 a slope has been opened on the northwest limb of the syncline. This development is being carried on by the Big Sandy Iron and Steel Company, and represents the most southwestern locality to be developed in the district. A railroad spur has been built from the Alabama Great Southern Railroad south-southeast 1.8 miles to the tipple at slope No. 1. The Clinton beds here are in the northwest limb of the syncline, and they outcrop at the base of a low ridge covered by gravel and loam. The beds dip S. 65° E. at angles varying from 12° to 14° on the outcrop, through a place where the dip is about 10°, beyond which they dip 17° to 18°. In January, 1909, this slope had been driven about 1,050 feet, with about 12 headings at the left and right. Ore had recently been mined from a bed yielding about 6½ feet of ore from a total thickness of 10 to 12 feet of ore-bearing beds (ore sections 83 and 84, fig. 11). The workings are penetrated by an air shaft in one of the upper levels. Drilling was done by compressed air, and the equipment of the mine is capable of handling a large output of ore. Hard ore from this slope carries 30 to 36 per cent iron, 19 to 28 per cent silica, 6 to 10 per cent alumina, and 8 to 20 per cent lime. Several thousand tons of ore were shipped from here to the furnaces of the Tennessee Company in the summer of 1907. (See analyses, p. 111.)

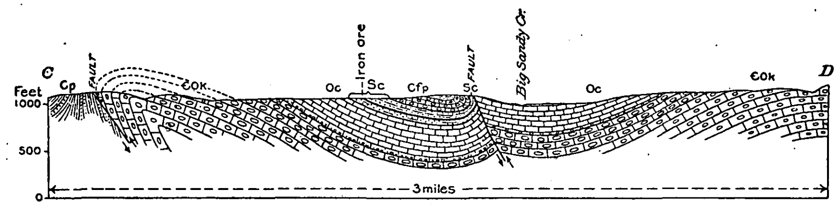

FIGURE 10.—Hypothetical structure section across valley of Big Sandy Creek, 2 miles south of Dudley, Ala. (on line C–D, Pl. II). Cp, Pottsville formation ("Coal Measures"); €Ok, Knox dolomite; Oc, Chickamauga (Pelham) limestone; Sc, Clinton (Rockwood) formation.

The unusually high percentage of alumina in this ore is accounted for by the presence of numerous fine shale seams or shale nodules that occur in places in the ore bed. This shaly material does not occur regularly in the bed. In places there may be none at all within several feet of ore, and in other places there may be from 1 to 8 partings within 6 inches of ore. Generally in the ore bed there are found 5 to 8 layers of clean ore, 3 to 6 inches in thickness. The ore is crushed as it is dumped from the tram cars at the tipple, and it is planned to install here a picking belt and some system of washing the ore. Such a method of treatment promises to greatly improve the grade of the ores and to solve in general the problem of utilizing shaly ores. A few rods west of the mouth of the slope limestone, probably the Chickamauga, was struck in a well that was being sunk to supply the boilers.

The last outcrop of Clinton strata on the east limb of the syncline occurs in the SE. ¼ NE. ¼ sec. 17, near what is known as the "Lewis place." Here, in the road, is a narrow outcrop of thin-bedded sandstone dipping steeply southeast. West of these sandstones are Fort Payne chert beds, and to the east the Chickamauga limestone has a wide outcrop area. The structure thus suggested is that the Clinton beds on the east limb of the syncline have been overturned and partly buried in a fault that a little farther southwest drops them completely below the surface. (See fig. 10.)

In the SW. ¼ sec. 17 the Clinton strata on the northwest limb of the syncline are exposed by the erosion of Big Sandy Creek, and in the NW. ¼ SW. ¼ sec. 17 the Big Sandy Iron and Steel Company has started slope No. 2. In January, 1909, this slope extended about 450 feet. A thickness of ore-bearing beds ranging from 15 to 20 feet is reported here, but the beds appear to contain a great deal of ferruginous shale and clay shale. Material 6 to 8 feet thick is removed in driving the slope. A section, the base of which was concealed, at the mouth of the slope is given as ore section 85, and a section in an upraise at the bottom of the slope in January, 1909, is ore section 86.

The slope starts with an inclination of about 33°, nearly due east. The ore was found to flatten within a short distance to nearly horizontal, and the slope was driven into shale and rock below the ore at just enough grade to lower tram cars. At 450 feet down the slope the ore had not been struck, and an upraise was driven about 10 feet above the slope to the bottom of the ore. Here the ore was found to dip about 9° E., and the face showed 8 feet 6 inches of ore containing shale seams and partings. The face of the ore here lies about 50 feet lower than the mouth of the slope, measured vertically by aneroid barometer.

One-fourth mile or more down Big Sandy Creek below slope 2 are two abandoned prospects, apparently on the same ore bed. The prospect pit on the west side of the creek shows about 6 feet of weathered ore. The roof of the drift on the east side of the creek had slumped so as to entirely cover the ore. The dip here is low, about 6° E. Chickamauga limestone outcrops in the creek a short distance below here.

Seven-eighths of a mile south-southwest of No. 2 a third slope has been started, the location of which, as near as could be ascertained, is in the SE. ¼ NE. ¼ sec. 19. This slope, No. 3, was reported to be in 1906 about 200 feet long. The ore-bearing beds at the outcrop are opened to a thickness of about 10 feet, but the whole of the ore-bearing material is not taken. The ore beds are interstratified with weathered shale seams or "mud slips," which range from 1 to 15 inches thick. The dip at the slope mouth is only 3° to 4° S. 73° E., and as it was expected that the dip would increase within a short distance the slope was driven at a steeper angle than the dip of the beds at the outcrop. It was found that the dip changed to 20°, but the latest reports indicated that the dip was flattening again as the slope was driven farther. Where the slope was driven at a steeper angle than the dip of the beds the whole ore-bearing bed was cut through, and it is reported that its total thickness was nearly 15 feet. About 1,220 feet S. 73° E. from slope 3, or directly in line with this slope, a deep drill hole was being drilled in the summer of 1906. The depth of the drill hole on July 12 was reported by the drillers to be 935 feet, and the material passed through was mainly siliceous. In order to pass below the bottom of this drill hole the dip of the ore beds must increase to 45° or more within a few feet of the point to which the slope had been driven in 1906, or else a fault must pass between slope 3 and the deep drill hole. Beds of Chickamauga limestone dipping 18° N. 5° E. are exposed in Big Sandy Creek at the ford southwest of No. 3. There are no outcrops of Clinton strata in this anticlinal strip southwest of this road crossing, which is in the southern part of sec. 19. The supposition is that the syncline becomes shallower to the southwest, and that the inclosing basin of Knox dolomite, which itself forms an anticline to the west, surrounds the southwest end. One exposure of bedded chert, carrying fossil cryptozoans, characteristic of the Knox, in Big Sandy Creek near the east line of sec. 25, between the areas of Chickamauga limestone in the creek both above and below this point, adds probability to this supposition.

There are no data showing whether or not ore is present in the strip of Clinton corresponding to West Red Mountain. As has been noted, the beds are vertical or slightly overturned, and are believed to be faulted out in part in the area between the Alabama Great Southern Railroad and Big Sandy Creek.

TOWNSHIP 22 S., R. 8 W.

The Clinton strata have been recognized near the line between sec. 13, T. 22 S., R. 8 W., and sec. 18, T. 22 S., R. 7 W. Test pits have been dug into a red, very ferruginous sandstone, decomposed on the outcrop, but hard and firm below. In the southern part of sec. 13, T. 22 S., R. 8 W., about in strike with the last-mentioned test pits, the Clinton strata have been exposed in a gulch and test pit at the left side of the wagon road to Coaling. Chert and very black shale closely overlie these strata in this vicinity. The strata are also known to outcrop in Hendricks Branch in the SW. ¼ sec. 24 and along Big Sandy Creek in the eastern part of sec. 26, but no ore has been found in this strip of the formation.

TOWNSHIP 24 N., R. 7 W.

On Wolf Creek, in the northern part of sec. 1, T. 24 N., R. 7 W., there is a patch of Clinton strata that strikes about N. 45° W. and dips 30° SW. The Big Sandy Iron and Steel Company has a prospect slope (No. 4) here. At the time when visited the creek was high and had flooded the slope so that entrance to it was impossible. Only the top of an ore bed was visible above the water, and it comprised only a few inches of very much-weathered ore, in thin streaks alternating with shale streaks, the whole being overlain by thin-bedded sandstone. The ferruginous material on the dump was fossiliferous and had weathered to the consistency of clay, and was composed of fine grains and small flattened disks of iron oxide, with sand and decomposed shale. It was reported that the dip of these beds increases within the slope, and that the total thickness of the iron-bearing beds is 7 feet. This strip of the formation has been cut away by erosion and is seen no farther to the northwest. Southeast it is covered by unconsolidated Coastal Plain deposits, and its relations are therefore unknown. It may be a portion of the northeastern end of a buried synclinal area of rocks lying in a basin of Knox dolomite similar to the neighboring syncline to the northeast. The probability of such structure is further suggested by the presence of an area of Fort Payne chert lying farther northwest, just south of Big Sandy Creek, and having southwesterly dips. A northwest limb to this syncline is found in the strip of Clinton strata below the Marlowe place, exposed along Big Sandy Creek, in the western half of sec. 2. Here the beds dip steeply southeast and are underlain by Chickamauga limestone, which forms the axis of the narrow anticline between this last unsymmetrical syncline and the vertical strip at the border of the coal field.

A prospect, No. 5, on the property of the same company, has been cut in the steeply dipping Clinton beds on this northwest limb of the anticline on the south side of Big Sandy Creek near the site of an old mill. Ferruginous sandstone, not of workable grade, was exposed at this point.

In the southwestern part of sec. 2 is an outcropping of sandy red ore, and this is believed to be the southernmost point at which the ore-bearing formation is visible in Birmingham Valley.

RÉSUMÉ—SECTIONS AND ANALYSES.

It has been shown that in Division E of the Birmingham red-ore district there are about 45 miles of outcropping ore-bearing strata. In reviewing the data presented it appears doubtful whether more than a few miles of this area contains ore beds that can be depended upon to yield a profitable tonnage of good ore. The beds have been prospected at scores of places and worked at four places, but at only one of these, the one in the area south of Dudley, has mining recently been active. According to the ore sections, beds mostly of lean to fair ore, ranging in thickness from 2 to 6½ feet, have been shown to be present throughout West Red Mountain, McAshan Mountain, and in the syncline southwest of the Dudley area. According to the analyses the ores, mostly soft, carry percentages of iron ranging from 26 to 60 per cent, of silica from 60 to 10 per cent, and of phosphorus no higher than the average Red Mountain ore. Therefore the lack of development in Division E must be due largely to the unfavorable structure of the beds, which not only renders mining difficult or impossible, but also makes very uncertain the extent of the ore beyond the outcrop. West Red Mountain, with its highly tilted or overturned strata, nowhere offers good opportunities for slope mining on the dip, and there are few places where slopes or drifts can be driven on the strike of the seam. McAshan Mountain has the same disadvantages, with the added one of limited extent. The small areas north of Bessemer have been mostly stripped of their available soft ore.

It still remains for the locality southwest of Dudley to be thoroughly prospected before the scale of developments can be determined. If the ore in the vicinity of the new slope No. 1 proves to be of workable grade, carrying 32 to 36 per cent metallic iron, for 3 to 4 miles along the strike, and to maintain this quality and a minable thickness of 6½ feet from the outcrop for 2,600 feet on the dip it will be a simple matter to calculate the ore reserve here. It should be understood, however, that the true conditions of this field have not been fully demonstrated yet. Encouraging results, so far as thickness of ore are concerned, have been obtained at slope 1, and the structural conditions indicate that the dips are not excessive, ranging between 10° and 25° down the northwest limb of the syncline for at least one-half mile. Beyond this distance there may be a sudden backward and upward bending of the strata, possibly accompanied by faulting, and certainly accompanied by such fracturing of the ore beds as to render them difficult to mine. This hypothetical condition is indicated in the structure section (fig. 10).

The development of a productive ore field in this locality would be particularly fortunate for the district, since here the ore is within 3½ miles of a coal mine at Cedar Cove, in the Warrior coal field. Both the coal and the ore are connected with the Alabama Great Southern Railroad by short north and south spurs from Dudley station, and there is a broad outcrop of undeveloped fairly pure Chickamauga limestone, some beds of which may prove suitable for fluxing material, along the headwaters of Big Sandy Creek in secs. 9 and 16, T. 22 S., R. 7 W., within a mile of the ore mine and within 3 miles of Dudley. An analysis of this limestone furnished by W. P. Pinckard, of Birmingham, is given below. Water supplies can be provided by building storage reservoirs on Big Sandy Creek and South Fork of Hurricane Creek. The establishment of an iron industry in the vicinity of Dudley would therefore be a natural result of this grouping of raw materials, providing the iron ore proves to realize expectations. Geologic conditions warrant at least thorough prospecting here.

Analysis of Chickamauga limestone from NW. ¼ sec. 9, T. 22 S., R. 7 W.

Calcium carbonate ($CaCO_3$)	94.87
Magnesium carbonate ($MgCO_3$)	1.20
Silica (SiO_2)	3.46
Phosphorus (P)	.011
Sulphur (S)	.042

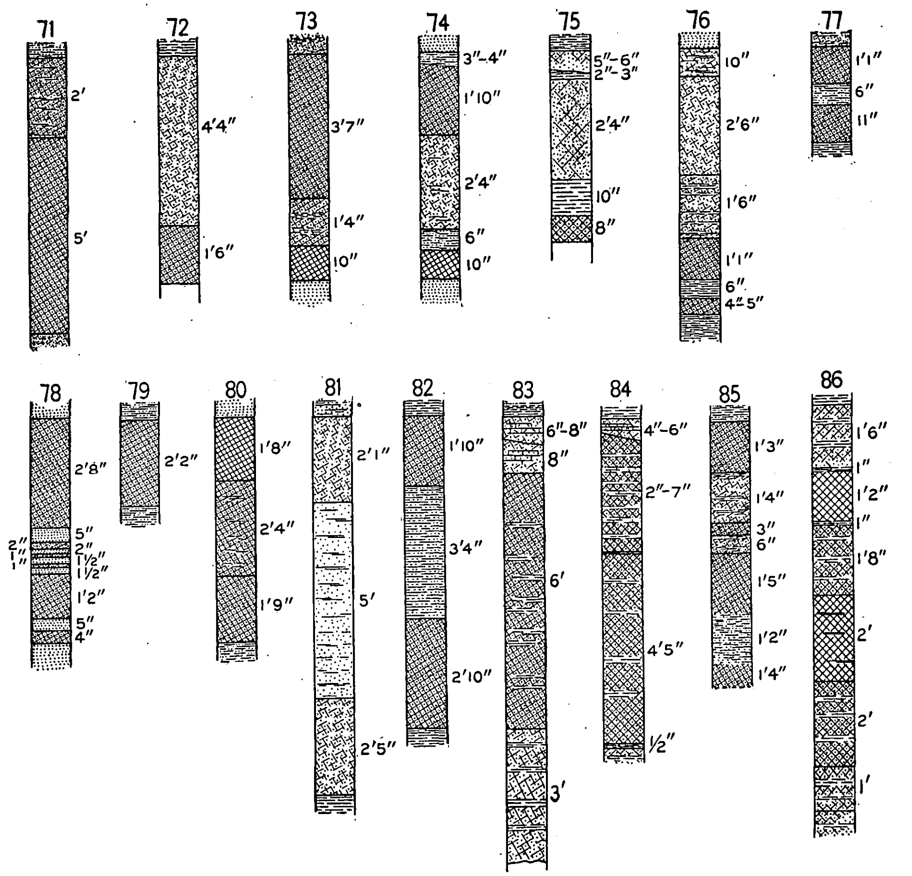

FIGURE 11.—Sections of ore beds, Division E, Birmingham district.

71. Open cut (fragmentary area in valley); NE. ¼ NE. ¼ sec. 23, T. 18 S., R. 4 W.
72. Outcrop; SE. ¼ SE. ¼ sec. 34, T. 19 S., R. 5 W.
73. Outcrop; SE. ¼ SE. ¼ sec. 35, T. 19 S., R. 5 W.
74. Prospect; SE. ¼ SE. ¼ sec. 35, T. 19 S., R. 5 W.
75. Old slope; NW. ¼ NW. ¼ sec. 2, T. 20 S., R. 5 W.
76. Outcrop, McAshan Mountain; SE. ¼ sec. 3, T. 20 S., R. 5 W.
77. Outcrop, McAshan Mountain; NW. ¼ SE. ¼ sec. 3, T. 20 S., R. 5 W.
78. Outcrop, McAshan Mountain; NW. ¼ NE. ¼ sec. 10, T. 20 S., R. 5 W.
79. Prospect, McAshan Mountain; SW. ¼ sec. 19 (probably), T. 20 S., R. 5 W.
80. Outcrop, West Red Mountain; NE. ¼ NE. ¼ sec. 9, T. 20 S., R. 5 W.
81. Prospect, West Red Mountain (about 1 mile northeast of Chamblee); NW. ¼ sec. 35 (probably), T. 20 S., R. 6 W.
82. Prospect, West Red Mountain (about 1 mile northeast of Chamblee); NW. ¼ sec. 35, T. 20 S., R. 6 W.
83. Big Sandy slope No. 1, seventh left heading.
84. Big Sandy slope No. 1, near bottom.
85. Big Sandy slope No. 2, on outcrop.
86. Big Sandy slope No. 2, near bottom.

Analyses of Clinton ores, Division E, Birmingham district, Alabama.

Locality.	Authority.[a]	Fe.	SiO_2.	Al_2O_3.	CaO.	P.	H_2O.
Pebble ore, SE. ¼ sec. 13, T. 18 S., R. 4 W.	M, 422	59.39	9.78	....	....	Trace.	....
Prospect, SW. ¼ sec. 12, T. 19 S., R. 5 W.	M, 353	60.72	9.61	....	....	0.158	....
Outcrop, SE. ¼ NE. ¼ sec. 23, T. 19 S., R. 5 W.	M, 354	36.40	43.78	....	....	.068	....
Prospect, SW. ¼ sec. 23, T. 19 S., R. 5 W.	M, 354	37.82	43.21	....	....	.082	....
Outcrop, SE. ¼ SE. ¼ sec. 34, T. 19, S., R. 5 W.	M, 356	55.05	14.86	....	....	.047	....
Outcrop, "upper seam," SE. ¼ SE. ¼ sec. 35, T. 19 S., R. 5 W.	M, 423	50.04	21.60	....	....	.078	....
Outcrop, "lower seam," SE. ¼ SE. ¼ sec. 35, T. 19 S., R. 5 W.	M, 423	47.32	20.41	....	....	.511	....
Top ledge, slope, NW. ¼ NW. ¼ sec. 2, T. 20 S., R. 5 W.	M, 426	25.78	60.37	....	....	.059	....
Worked ore, slope, NW. ¼ NW. ¼ sec. 2, T. 20 S., R. 5 W.	M, 426	54.39	16.99	....	....	.056	....
Outcrop, top ledge, SE. ¼ sec. 3, T. 20 S., R. 5 W.	M, 427	27.04	61.81	....	....	.084	....
Outcrop, lower bed, SE. ¼ sec. 3, T. 20 S., R. 5 W.	M, 427	51.16	21.38	....	....	.119	....
Outcrop, NE. ¼ NE. ¼ sec. 9, T. 20 S., R. 5 W.	M, 357	56.36	13.85	....	....	.098	....
Lowest bed, railroad cut, NE. ¼ sec. 3, T. 21 S., R. 6 W.	M, 468	50.49	19.95	....	....	.109	....
Higher bed, railroad cut, NE. ¼ sec. 3, T. 21 S., R. 6 W.	M, 468	37.17	27.16	....	....	.072	....
Prospect, "upper seam," SE. ¼ sec. 4, T. 21 S., R. 6 W.	M, 469	28.15	38.99	....	....	.792	....
Slope at Vance, top 5 feet	S	37.45	33.40	9.95	....	.10	....
Slope at Vance, lower 6 feet	S	31.05	42.80	9.49	....	.10	....
Prospect near trestle at Vance, top 4 feet.	S	41.55	27.60	8.82	....	.13	....
Prospect near trestle at Vance, lower 5½ feet	S	36.05	35.60	9.75	....	.10	....
Big Sandy Iron and Steel Co., slope No. 1:							
Sample, soft ore	S	39.20	27.40	11.36	....	.10	....
Sample, soft ore	S	37.10	28.90	12.13	....	.11	....
Sample, soft ore	S	32.40	33.96	13.67	....	.14	....
Sample, soft ore	S	26.10	40.88	15.37	....	.35	....
Sample, soft ore	U. S. G. S.	40.26	[b]32.40		1.11	.42	....
Sample, semihard ore	U. S. G. S.	38.82	[b]21.95		7.48	.30	....
Samples taken April, 1905, from face of slope No. 1, 450 feet from outcrop:							
Top 1 foot	O	37.55	[b]17.32		13.75	....	....
Third 1 foot	O	37.45	[b]17.85		13.54	....	....
Fourth 1 foot	O	38.25	[b]15.61		14.17	....	....
Fifth 1 foot	O	31.80	[b]32.98		10.22	....	....
Slope No. 1:							
Sample, No. 2 heading	R	34.08	22.30	8.07	8.60	....	....
Sample, No. 3 heading	R	30.93	25.60	8.49	8.00	....	....
Sample, No. 4 heading	R	30.13	19.70	7.02	14.28	....	....
Sample, No. 5 heading	R	34.58	19.44	6.61	10.87	....	....
Sample, No. 6 heading	R	31.22	20.20	7.32	12.55	....	....
Sample, No. 11 heading	R	36.95	19.60	6.83	8.69	....	....
Sample, No. 12 heading	R	36.26	18.80	7.36	9.04	....	....
Sample, face of slope 700 feet from outcrop	R	38.33	13.14	5.35	12.45	....	....
Average 10 cars, June, 1907	T	34.34	19.64	6.95	10.40	.30	1.39
Average 18 cars, July, 1907	T	33.62	28.13	8.20	9.49	.28	1.15
Average 5 cars, July, 1907	T	35.29	21.34	7.45	8.98	.26	1.30
Average 9 cars, August, 1907	T	31.52	24.60	7.70	9.30	.27	1.30
Average 5 cars, September, 1907	T	30.30	25.70	9.12	8.96	.80	1.30
Average 50 cars, September, 1907	T	32.93	23.52	8.68	9.36	.28	1.13
Average 9 cars, November, 1907	T	31.25	25.60	8.98	7.91	.28	1.85

[a] Authorities: M (followed by page number), McCalley, Henry, Report on valley regions of Alabama, pt. 2, 1897; S, Sloss-Sheffield Steel and Iron Company; U. S. G. S., George Steiger, chemist, U. S. Geol. Survey; R, Republic Iron and Steel Company; T, Tennessee Coal, Iron and Railroad Company; O, Owners of property.
[b] Insoluble matter.

DIVISION F.

GENERAL DESCRIPTION.

Division F comprises the areas of Clinton formation exposed around the southern margin of the Blount Mountain syncline and on the outlying knobs, such as Miles Mountain, Hayes Mountain, and Meridian Mountain. Altogether, this division occupies an area extending less than 5 miles from east to west and 3 miles from north to south. The general dips of the beds are gentle toward the northeast, north, and northwest, but the southwest rim of the syncline has been faulted in at least three places by the warping of the strata, and the wedge-shaped block of strata in which Miles Mountain stands has been literally squeezed out and dropped beyond the rim of the syncline, while an adjacent block containing parts of Butler, Hayes, and Meridian mountains has been uplifted. This singular distribution of the formations can best be appreciated by reference to the general geologic map (Pl. II).

There is no railroad nearer to this area than the Louisville and Nashville Railroad, which is at the nearest point about a mile from Miles Mountain, and 5 or 6 miles by wagon road from more distant prospects.

No mining has been done in this locality, but prospecting has shown that there are two and possibly three distinct beds of ore in the formation in this locality. The top one is only 6 to 8 inches thick, the one next below is 2½ to 3 feet thick, while the lowest is, where recognized, thicker, but very siliceous.

TOWNSHIP 15 S., R. 1 W.

In the eastern part of sec. 3, T. 15 S., R. 1 W., the middle or main ore bed has been noted by McCalley as having a thickness of 20 to 33 inches.[a] In the SE. ¼ NE. ¼ sec. 10 the upper two beds are exposed on their outcrops. The upper bed, about 6 inches thick, is 20 feet below the top of Village Mountain. The main bed is about 12 feet below it and consists of 3 feet 6 inches of ore with shale streaks near the middle, and is overlain by shale with streaks of ore in it. The dip is 15° to 18° N. 80° E., and there is an outcrop area of Clinton strata nearly one-fourth mile wide here. The upper of the two beds outcrops also on the east slope of the mountain in a ravine in the SW. ¼ NW. ¼ sec. 11, where it shows as a ledge 12 inches thick, according to McCalley.

Across the southern parts of secs. 10 and 11 is a fault extending N. 87° E. This is one of the faults by which the Clinton formation is offset in a wedge-shaped area 2,000 feet west of its normal line of strike. In the Clinton area forming Miles Mountain and vicinity two ore beds have been recognized. A prospect pit in one of these beds on the northeast side of "Black Hollow" in the NW. ¼ NE. ¼ sec. 15 showed about 24 inches of ore in three benches, the best of which is 15 inches thick (ore section 87, fig. 12). The ore contains rather coarse quartz grains and is dark and well leached. Picked samples of the soft ore are reported to have carried about 45 per cent iron. The dip of the rocks here is 8° to 10° N. 50° E., and the same bed outcrops also across this hollow near the top of Miles Mountain.

The Miles Mountain area is bounded on the south by another fault which extends N. 45° E. Southeast of this fault the Clinton area forms Hall Mountain in the NE. ¼ sec. 14. At the west end of Hall Mountain a prospect is cut into a thin ore bed aggregating 21 inches of ore, with two shale partings (ore section 88, fig. 12). The ore is lean looking, medium grained with some fine-grained streaks, and is rather firm. The dip is 12° N. 25° E.

In the SE. ¼ sec. 11 near the foot of Hayes Mountain, there are outcrops of ore on both sides of a ravine. On the north side of the ravine a bed measures 12 inches thick

[a] McCalley, Henry, op. cit., p. 419.

and dips 60° SE. On the opposite side of the ravine, according to McCalley, a thicker bed outcrops, showing 42 inches of ore with a few shale streaks near the bottom. This bed dips 80° SE. It is a soft ore, and an average sample contained 50.97 per cent iron and 14.6 per cent silica.[a]

In the SW. ¼ sec. 13 and the NW. ¼ sec. 24 there is a high knob capped with Clinton beds, which terminate in a fault at the north. The rocks here dip 14° N. 65° W., and consequently form a dip slope to the northwest. A prospect about 150 feet below the top of this slope shows 40 inches of ore with a shale parting near the top (ore section 89, fig. 12). The ore is all very soft and decomposed, and is rather pebbly at the top. This area of Clinton is a scarcely accessible remnant, not more than 400 feet wide and 1,250 feet long, and consequently has no commercial importance.

In the NE. ¼ sec. 13, high on the east side of one of the knobs on Meridian Mountain, a fresh prospect was observed in beds dipping 10° N. 25° W. At this place two ledges of ore are exposed, which are termed by the residents of Claytons Cove the "Ida seam" and the "Big seam." The "Ida" is only 5 to 7 inches thick. The "Big seam" has a total thickness of 5 feet 8 inches of ore with several partings of shale in the lower part. The two beds are separated by 3 feet 2 inches of shale and sandstone (ore section 90, fig. 12). Analyses of these ores, given on page 114, show that the "Ida" soft ore carries 35 to 37 per cent iron and 22 to 41 per cent silica, and that the "Big seam" soft ore carries 32.5 per cent iron with 45.2 per cent silica.

In the hollow that extends northward between Meridian and Hayes mountains the main bed has been exposed by prospecting. On the west side of the hollow, in the NW. ¼ NE. ¼ sec. 13, is a prospect section that shows 3 feet 2 inches of ore, consisting of 18 inches of hard, calcareous, fossiliferous ore, overlain by 20 inches of well-leached, pebbly, fossiliferous ore (ore section 91, fig. 12). The dip of the beds is 20° N. 35° W. This seam is termed locally the "hard seam," but probably it may be correlated with the "Big seam" of the last-mentioned locality.

Farther north in this hollow, in the SW. ¼ SE. ¼ sec. 12 the same bed is exposed in a prospect which shows 20 inches of very fossiliferous ore with some flat concretionary pebbles at the bottom, overlain by 21 inches of material that grades downward from hard sandstone into calcareous ore that is almost a limestone at the bottom. These two benches are separated by 2 inches of shale (ore section 92, fig. 12). A sample analyzed in March, 1907, by R. S. Hodges, of the Alabama Geological Survey, gave only 17.57 per cent iron. This exposure is near the floor of the ravine, and the beds dip 15° N. 35° W.

Near the mouth of this hollow, in the NW. ¼ NE. ¼ sec. 12 a prospect at the nose of the hill, near its base, shows 3 feet of hard, calcitic, pebbly ore (ore section 93, fig. 12).

TOWNSHIP 15 S., R. 1 E.

In the SW. ¼ NE. ¼ sec. 7 there is a knob just southwest of the wagon road which has been prospected near the summit, and a heavy ledge of sandy ore, over 5 feet thick, has been exposed. The beds dip gently N. 5° W. at this place.

RÉSUMÉ—SECTIONS AND ANALYSES.

By reference to the map (Pl. II) it will be seen that the topographic conditions affecting the accessibility of the ore are less favorable here than in other divisions of the district heretofore discussed. The grade of the ore is doubtful, since in many of the prospects the hard ore is lean in iron and high in lime. There is, of course, a possibility that some of the soft ore will eventually be utilized, since the beds are to a large extent above water level and can perhaps be mined on a

[a] McCalley, Henry, op. cit., p. 416.

small scale a short distance down the dip of the beds without requiring much initial expenditure. The beds are, for the most part, under cover too thick for stripping far from the outcrop, and this fact will discourage developments. In any case there would be a long, and, in places, difficult wagon haul to the railroad, and it does not seem that conditions warrant the building of a spur into the locality, although it would be entirely possible to construct one if the quantity and quality of the ores to be reached were satisfactory.

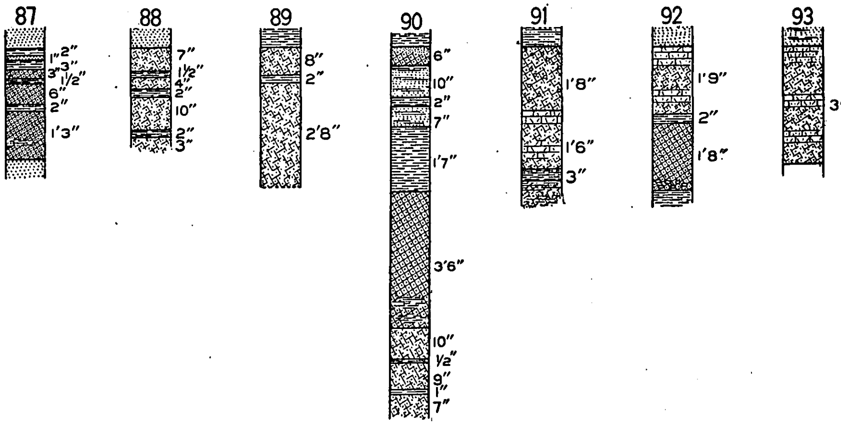

FIGURE 12.—Sections of ore beds, Division F, Birmingham district.

87. Prospect, Miles Mountain; W. ½ NE. ¼ sec. 15, T. 15 S., R. 1 W.
88. Prospect, Hall Mountain; N. part sec. 14, T. 15 S., R. 1 W.
89. Prospect on knob east of Butler Mountain; SW. ¼ sec. 13, T. 15 S., R. 1 W.
90. Prospect, Meridian Mountain; NE. ¼ sec. 13, T 15 S., R. 1 W.
91. Prospect between Hayes and Meridian mountains; NE. ¼ NW. ¼ sec. 13, T. 15 S., R. 1 W.
92. Prospect between Hayes and Meridian mountains; SW. ¼ SE. ¼ sec. 12, T. 15 S., R. 1 W.
93. Prospect between Hayes and Meridian mountains; NW. ¼ NE ¼ sec. 12, T. 15 S., R. 1 W.

Analyses of Clinton ores, Division F, Birmingham district, Alabama.

Locality.	Authority.[a]	Fe.	S.	SiO_2.	Al_2O_3.	CaO.	P.
Outcrop, SE. ¼ sec. 11, T. 15 S., R. 1 W	M, 416.	50.97		14.60			0.084
Prospect, "Ida seam," NE. ¼ NE. ¼ sec. 13, T. 15 S., R. 1 W	A. G. S.	37.42		21.74			
Do	A. G. S.	35.27	0.04	40.88			.32
Prospect, "Big seam," NW. ¼ SE. ¼ sec. 12, T. 15 S., R. 1 W	A. G. S.	32.53		45.21			
Do	D	28.10		38.90	2.94	8.07	
Prospect, "Big seam," NE. ¼ SE. ¼ sec. 12, T. 15 S., R. 1 W	D	34.90		42.05	3.15		
Prospect, "Big seam," NW. ¼ NW. ¼ sec. 18, T. 15 S., R. 1 E	D	35.10		41.55	2.63		

[a] Authorities: A. G. S., R. S. Hodges, chemist, Alabama Geol. Survey; D, Dimmick Pipe Company, Birmingham, Ala.; M (followed by page number), McCalley, Henry, Report on the valley regions of Alabama, pt. 2, 1897.

DIVISION G.

GENERAL DESCRIPTION.

Division G, of the Birmingham district, includes the ore-bearing areas in the vicinity of Springville, St. Clair County, on the flanks of the upper part of Canoe Creek Valley. There are two strips of

Clinton strata, one about $2\frac{1}{2}$ miles northwest of Springville, which is a northeastward continuation of the southeast limb of the Blount Mountain syncline, the lower end of which is described in Division F. The other strip of Clinton strata is just southeast of, and parallel to, the Alabama Great Southern Railroad as far northeast as Springville, where it bends at right angles toward the southeast and extends on the northeast side of the valley of Right Hand Prong of Little Canoe Creek nearly to Truss Mill. This is an extension of a portion of Division C, and is about 9 miles long. The strip northwest of Springville extends northeastward more than 15 miles, but only the portion as far northeast as Goodwin's Mill, a strip about 8 miles long, is considered here. Both these strips are in the Springville quadrangle, which adjoins the Birmingham quadrangle on the east. No detailed geologic survey has been made of the Springville quadrangle, therefore this area is not included on the geologic map (Pl. II). A reconnaissance topographic map of the quadrangle on 1:125000 scale, with contour interval of 100 feet is, however, available, copies of which may be purchased at 5 cents each by addressing the Director of the United States Geological Survey. The general distribution of the formations along Canoe Creek Valley are shown on the geologic map of Alabama, published by the Alabama Geological Survey, and notes on the ore beds are given by McCalley.[a]

DETAILED DESCRIPTION.

In the gap through which the main wagon road passes, $2\frac{1}{2}$ miles northwest of Springville, an ore bed has been prospected and some soft ore obtained from trenches on the outcrop. Two beds of ore, about 50 feet apart, are reported as present here, but only the lower or main bed appears to be important. About 150 tons of ore are reported to have been shipped from here to furnaces at South Pittsburg, Tenn., nineteen or twenty years ago. One pit, blasted out at the roadside, was in good condition and showed 54 inches of ore, of which the top 36 inches was of good quality, composed of siliceous grains thickly coated with iron oxide, and of high specific gravity, but the lower 18 inches was rather sandy and leaner. The ore is soft, and it was reported, probably truthfully, that the upper 3 feet carried 45 per cent iron. The rocks dip 25° N. 15° W. A section of the ore at this place is given in ore section 94 (fig. 13).

In the 5 miles farther northeast on the ridge or series of knobs that represent the ridge, there has been a little prospecting and surface mining, the workable part of the bed ranging from $2\frac{1}{2}$ to 3 feet thick. The dip is not everywhere entirely regular. Where it is 20° or less the beds usually outcrop on both the southeast and northwest sides of the ridge. The strata seem to be folded into gentle rolls or waves whose axes are parallel with the crest of the ridge, and in places the dip becomes abruptly steeper or even overturned.

At a point $1\frac{1}{2}$ miles north of St. Clair switch mining was carried on for about two years, eighteen to twenty years ago. The outcrop on the southeast side of the ridge was worked in open cuts until the cover reached a thickness of 15 to 20 feet, and then underground drifts and shallow slopes were driven, ranging from 50 to 200 feet long. The ore is overlain first by a thin bed of ferruginous, pebbly sandstone, which grades into yellowish shale above. The rocks of the formation here, particularly the over-

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[a] Op. cit., pp. 272-291.

lying shale, more nearly resemble the beds in the Clinton formation farther northeast in Lookout and Chickamauga valleys than those of the Birmingham section. A surface section measured at these workings showed 54 inches of ore, the top 21 inches of which were gray, ferruginous, crystalline limestone with silica pebbles scattered through it, while the lower 33 inches were composed of very soft, dark, decomposed ore, rather coarse-grained (ore section 95, fig. 13). The beds dip 18° N. 70° W. where this section was measured. The ore as mined ranged from 3 to 4 feet thick, and 12,000 to 15,000 tons of soft ore are reported to have been produced. Analyses made of these ores by the Alabama Geological Survey[a] show a range in iron of 48 to 50 per cent with about 20 per cent of silica.

In the strip of Clinton strata south of the Alabama Great Southern Railroad only one bed of ore was seen. This was exposed in prospects near the gap southwest of St. Clair Springs. It measured about 15 inches thick and appeared to be of good soft ore, but is overlain by heavy cover. The rocks dip 35° to 40° SW., but near Springville, at and southwest of the abrupt bend in outcrop, the beds are overturned and have a steep northwest dip.

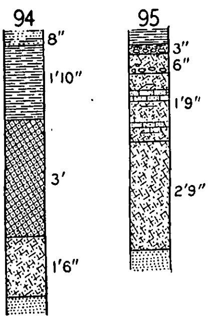

FIGURE 13.—Sections of ore beds, Division G, Birmingham district.

94. Prospect, 2½ miles northwest of Springville.

95. Open cut, 3½ miles northeast of Springville.

RÉSUMÉ—SECTIONS AND ANALYSES.

Judging from the results of a hasty examination the Clinton area on the northwest side of Canoe Creek Valley northeast of Springville can still be regarded as a possible source of future ore supply, since the main bed appears to carry some ore of workable thickness, quality, and extent, besides being favorably situated with regard to topography and transportation facilities. Structural complications may be encountered, chiefly in the form of sharp folds, and at one place, about 1 mile southwest of Steele station, the Clinton formation is faulted below the surface for a short distance.

Analyses of Clinton ore, Division G, Birmingham district, Alabama.[a]

Locality.	Fe.	SiO_2.	P.
"Soft" ore:			
Drift, 4¾ miles northeast of Springville	50.02	19.75	0.167
Outcrop, 5 miles northeast of Springville	48.31	20.55	.120

[a] Authority: McCalley, Henry, Report on the valley regions of Alabama, pt. 2, 1897, p. 277.

APPLIED GEOLOGY.

STRUCTURE OF THE PRODUCTIVE FIELD IN DIVISION A.

GENERAL ATTITUDE AND FAULTING.

It has been shown in the local descriptions of Division A that the ore beds in Red Mountain between the outcrop and the greatest depths reached by slopes (about 2,305 feet on the dip, and about 750 feet vertically, or a few feet below sea level) dip at angles varying

[a] McCalley, Henry, op. cit., p. 277.

generally from 15° to 45°, but averaging less than 30°. It has also been shown that in the field between Walker Gap and Sparks Gap there is a zone of faults along the southeast foot of Red Mountain. These faults trend, in general, north-northeast, or parallel to the direction of Red Mountain, although there are exceptions, for instance, at Ishkooda, where the faults cross the mountain diagonally nearly in a north-south direction. The throw of such faults as have been encountered in mine workings has been found to range from 15 to 300 feet, and the greatest displacement has been found at the southwest end of the field. The hades of the faults have been found to be nearly vertical, or with a very steep hade generally to the downthrow side. Observations of the dip of the rocks at the surface and in drill cores taken from the strata in Shades Valley near the southeast foot of Red Mountain indicate that the strata of Red Mountain flatten as they pass under Shades Valley. The fault zone therefore follows in general the synclinal axis of flexure along which the Shades Valley rocks are bent more steeply into the Red Mountain Ridge to the northwest. Along the ridge itself there are minor synclinal folds at right angles to the main axis of folding, accompanied by fracturing of the beds and by some faults of small throw. At the gaps in the ridge this kind of structure has been revealed by erosion. The faults along the southeast foot of Red Mountain are, however, very difficult to detect or to trace on the surface. The strip along which they occur slopes slightly to the southeast or is nearly level, and the surface is thickly covered by residual soil or clay and by débris of Fort Payne chert and sandstone of the Clinton formation. The faults are evidently for the most part shallow, short breaks, which overlap, longitudinally, en échelon. Two or more may be encountered in passing down the dip of the beds, as in the Graces Gap locality, and it may be proved that along some lines there are no breaks at all in the strata. At certain mines—for instance, Raimund No. 3—the fault zone has been located by drilling in advance of the slope. Several holes have been drilled on the lines of the centers of the slopes at both Raimund No. 3 and Potter in order to determine the throw of the fault, the attitude of the beds beyond the fault, and the character of the ore. From the data obtained by such drilling it is possible to decide whether the ore is worth following beyond the fault, and whether it can be reached by changing the grade of the slope or whether it will be necessary to sink a new rock slope to reach the ore.

LIMITS INDICATED BY DRILLING.

The questions concerning the structure of the ore beds and the thickness and quality of the ore in Shades Valley have become of the greatest economic importance to the district, since it has been recognized that the ore content of Red Mountain proper is limited. The work of the United States Geological Survey in constructing the geologic map brings out certain broad features of the geologic structure of the valley. Several mining companies have done some careful deep drilling recently in Shades Valley. Some of the data thus obtained have been shown to members of the Survey; some have not been so divulged. While certain data have been furnished without restriction as to use or publication, other data have been furnished with the request that they be held confidential. In all fairness, therefore, to those companies and individuals whose money has been spent in proving ore lands in Shades Valley, and who have nevertheless placed information at the disposal of the Survey, such data can not be published here. It may be stated, however, that the deep drilling referred to has fully substantiated the broader features of the structure noted in a geologic reconnaissance of the field, and also supports the deductions regarding the thickness and character of the ore beds discussed below.

STRUCTURE, MORROW GAP TO READERS.

At the upper end of Division A of the district, from Birmingham to Morrow Gap, the general dip of the strata of Red Mountain is 15° to 18°. This dip does not become much less as the rocks pass southeast below Shades Valley. Projected at a dip of 15° to 16° the iron-ore beds would reach a depth below Shades Creek of about 1,200 feet. The actual depth of the bottom of the Irondale seam below Shades Creek, about 1 mile south of Irondale, is 1,233 feet. Southeastward from Shades Creek the ore becomes still deeper before it flattens out under ridges of sandstone bordering Shades Mountain. From such data as are available it appears probable that the ore in the upper part of Shades Valley extends without decrease in thickness to a point beyond Shades Creek. Beyond this creek it may continue eastward below Shades Mountain and the Cahaba basin, although its depth would be prohibitive to mining at present. Clinton ore, reported on good authority to indicate a thickness of 6 feet or more, is faulted to the surface in a narrow strip southwest of Henryellen. It may be considered, however, that the sandstone ridge just beyond Shades Creek (known as Pine Ridge opposite Bald Eagle) forms approximately the southeast limit of available red ore from the vicinity of Shades Gap southwest to a point due east of Clifton Gap opposite the center of Birmingham. The average width of this area from the outcrop of the ore on Red Mountain is 6,400 feet. This limitation is based upon the probable position of the ore at a depth of 1,500 feet. Not all the ore at that depth can be reached by slopes, but it is here considered that before it becomes necessary to mine ore from depths greater than 1,000 feet shaft mining for ore will probably be in successful operation in the Birmingham district.

Southwestward from a point opposite the center of Birmingham to a point opposite Readers, Shades Creek skirts the base of Shades Mountain and lies at distances ranging from 11,000 to 23,000 feet from the red-ore outcrop. Between Shades Creek and Little Shades Creek lies Little Shades Mountain and its northeast continuation, Bald Ridge. The red ore dips southeastward in Red Mountain at angles ranging from 20° to 30°, but the dip becomes less as the rocks pass below Shades Valley and its included ridges. In this valley there is a broad expanse of shale and sandstone, having dips ranging between 8° and 15°, below which the Clinton strata must lie in corresponding positions or, perhaps, with still more gentle dips. According to the thickness of the formations above the Clinton ore, the ore should lie at depths between 1,000 and 1,500 feet below the northwest foot of Little Shades Mountain and Bald Ridge. It is probable, though not demonstrated by drillings, that beyond these ridges, along Shades Creek, the ore will be found at depths between 1,500 and 2,000 feet. For the sake of conservatism, the southeast limit of ore available under present conditions should be considered to lie not farther southeast than the foot of Little Shades Mountain and Bald Ridge. The mean distance of this line from the ore outcrop between Clifton Gap and Readers is about 6,500 feet. Beyond Little Shades Mountain the ore possibly continues to beneath Shades Creek without going much more than 1,500 feet below the surface, but in the strip bounded by Shades Creek and the northwest foot of Little Shades Mountain and Bald Ridge the ore can probably be regarded as available only in the distant future.

The principal faults known to occur in the field between Birmingham and Readers lie along the southeast slope of Red Mountain, or in Shades Valley within one-half mile of the foot of Red Mountain. Many of these faults have been described in connection with the mines in which they occur. As shown on the geologic map (Pl. II), there is a fault near Graces station. This fault brings Clinton ore to the surface in an area too small to be shown on the map. Outcrops of vertical beds of rock in this vicinity and near Halls Spring and elsewhere indicate sharp folds and possible faults.

STRUCTURE SOUTH OF READERS.

Southwestward from the wagon road between Readers and Parkwood, as far as the Southern Railway, there is between Red Mountain and Bluff Ridge an area of nearly 10 square miles below which the Clinton ore lies at depths varying from 150 to nearly 1,100 feet below the surface. The topography of this area is comparatively flat, and the surface rocks are shale and sandstone with a little limestone. The northeast corner of this area lies in a "cove," or reentrant angle, sheltered by the escarpments of Bee Mountain and Bluff Ridge on the north and southeast, respectively. This "cove" topography is very characteristic of the region bordering Lookout Mountain in northwest Georgia. It is due primarily to the structure of the underlying rocks. Both the Lookout Mountain area and the Shades Mountain area are broad synclinal basins, having minor anticlinal folds diagonal to the synclinal axes. The cove known as Johnson Crook at Rising Fawn, Ga., and McLamore Cove near Estelle, Ga., are developed on minor anticlines whose axes plunge toward Lookout Mountain. The relation of topography to rock structure at these places is clearly brought out by the geologic map of the Ringgold quadrangle.[a] The Shades Valley cove between Bee Mountain and Bluff Ridge is analogous to the cove at Rising Fawn, Ga., although the topographic-geologic relations are not so strikingly shown as in the latter place, because in the Shades Valley cove the Clinton rocks are entirely below the surface. There is, however, an anticlinal axis extending about N. 48° to 50° E., passing through Dickeys Spring, and the territory between Canaan Church and Morgan, and finally passing below the sandstone escarpment near the corner of secs. 19, 20, 29, and 30, T. 19 S., R. 3 W. The presence of this axis is not only affirmed by the aspect of the topography and the character and dips of the surface rocks, but by records of drill holes made near the Southern Railway and Rice and Shades creeks farther southwest. As shown on the geologic map, the Fort Payne chert rises to the surface in this vicinity. This anticlinal axis is the locus of a fault between Dickeys Spring and the Southern Railway.

According to the main structural features, the ore between Readers and Sparks Gap, dipping into Red Mountain at angles ranging generally from 15° to 45°, either flattens out without break into Shades Valley or else is faulted in places, as noted in the descriptions. This basin of ore attains a depth of more than 1,000 feet beneath Shades Creek northeast and southwest of Hopewell Church, but gradually rises with dips of 6° to 8° NW. toward the axis of the anticline discussed above, along which it lies comparatively flat at depths ranging from 140 to 220 feet below the surface. This shallow depth of the ore near the Southern Railway, south of Canaan Church, is indicated by the fact that limestone of Fort Payne age, which normally lies about 200 feet above the ore, is exposed here in a surface quarry. It is probable that the anticlinal axis plunges to the northeast, so that at Shades Creek in sec. 30, T. 19 S., R. 3 W., the ore will be found to be several hundred feet deeper. Southeast of this anticlinal axis the rock dips more steeply, 15° to 25°, toward Bluff Ridge. Along the road from Readers to Parkwood the rocks dip 10° to 12° SE. near Shades Creek, but near Rocky Brook the dips are about 3° NW., and at Bee Mountain the rocks lie nearly flat, showing that there is perhaps an intermediate anticlinal axis in the vicinity

[a] Hayes, C. W., Ringgold folio (No. 2), Geol. Atlas U. S., U. S. Geol. Survey, 1894.

of Bee Mountain, or possibly that the rocks dip northwest in a low monocline from the main anticlinal axis in secs. 19 and 30, T. 19 S., R. 3 W., northwestward to Bee Mountain, where they locally flatten, and then dip northwest again at a low angle to the vicinity of Little Shades Creek, beneath which probably lies the synclinal axis of the basin.

Judged simply by the structure and probable depth of the ore in this portion of the field, there should be available to present slopes ore extending from the crest of Red Mountain to a point beneath Little Shades Creek opposite Readers and to Shades Creek opposite the Potter property. The distance from the outcrop to this line ranges from 1 mile to 6,000 feet, measured horizontally. Beyond this line, the ore, if it continues to be of workable thickness, will probably have to be reached by vertical shafts or by rock slopes. The area between the line just defined and a line 1,000 feet beyond the main anticlinal axis should, so far as the structure and depth of the ore are concerned, contain a vast reserve of ore that will not be available until long after present conditions are passed.

THICKNESS AND CHARACTER OF ORE BEDS.

The quantity of the ore reserves depends principally, however, upon the thickness and character of the ore beds. The only beds that need be considered in this connection are the Irondale and Big seams.

IRONDALE SEAM.

The workable portion of the Irondale seam extends on the outcrop from Morrow Gap to Hedona, with breaks at Bald Eagle and Red Gap. The total length of outcrop is about 51,000 feet, or nearly 10 miles. The range in thickness of the workable ore in the bed is between 3½ and 4½ feet. The hard ore carries 33 to 36 per cent iron, 16 to 25 per cent silica, and 8 to 14 per cent lime. The ore is not self-fluxing. The thickness of the bed, so far as is known, does not diminish in the direction of the dip within the distance that it would be practicable to mine the ore from present slopes.

BIG SEAM AS DEVELOPED.

The workable part of the Big seam, viz, its middle part in the northeast end of the district and its upper bench farther southwest, extends from Bald Eagle to Sparks Gap, a distance of a trifle more than 20 miles along Red Mountain, deducting for a break at Red Gap. The Big seam and the Irondale seam overlap between Bald Eagle and Hedona, so that the total length of iron-ore bearing area along Red Mountain is approximately 24 miles. In this connection ore will be considered of workable quality where the soft ore has proved acceptable, although the hard ore may not at present be mined. Such is the case with the Big seam at present between Bald Eagle and Helen-Bess, a distance of some 33,000 feet. The best part of the ore is here 7 to 10 feet thick. The soft ore carries 36 to 40 per cent iron and 26 to 42 per cent silica, while the hard ore carries 32 to 35 per cent iron, 25 to 30 per cent silica, and 8 to 11 per cent lime. The hard ore is thus highly siliceous and low in lime. It has been worked from time to time, but is at present being left in the ground to await the exhaustion of the ores richer in lime and lower in silica, which abound farther southwest on the mountain.

It is not known how far the ore here maintains its thickness down the dip. According to the belief expressed elsewhere in this paper that the ore beds are lens shaped, it is to be expected that at some distance southeast the beds become thinner.

At the Helen-Bess and Kewanee mines hard ore from the Big seam is of such quality that during prosperous times, when there is a strong demand for ore, it will pay to work it. Here the best ore is 10 feet or more thick, and it so continues practically all the way to Readers. In places 11 feet 6 inches of ore are obtained. The ore, however, continues high in silica beyond Walker Gap. Opposite the middle of Birmingham but little more than the soft ore at the outcrop has been utilized. At Valley View the ore has become sufficiently high in grade to warrant continuous mining. Southwestward the ore becomes gradually more desirable in respect to lime and silica, the former rising and the latter falling in percentage, although the iron content remains almost stationary. The Ishkooda ore is slightly better than the ore north of Graces Gap; the ore of the Fossil group (Tennessee Company's Nos. 7 to 10) is better than the Ishkooda; while the Woodward, Sloss, and Readers ores are, considering both thickness and quality, the best of all. In places they contain more than enough lime to make them self-fluxing. Southwest of Readers as far as Potter the good quality is still maintained, but the thickness diminishes. These relations are shown in the table, page 74. Southwestward from Potter to Sparks Gap the ore falls off in quality and diminishes in thickness from 7 feet down to 4½ feet.

It has been shown that in the slopes all the way from Woodward to Spaulding, a distance of more than 4½ miles, the lower bench of the Big seam contains 5 to 10 feet of hard ore, carrying 34 to 39 per cent iron, 17 to 28 per cent silica, and 9 to 13 per cent lime. In other words, it is an ore that is superior to the hard ore of the upper bench near Birmingham. There has been much discussion for and against the use of this ore, and it has been mined to some extent from certain slopes. To the casual observer it would appear that a flagrant waste of good ore was being permitted here, but to one familiar with local conditions it is evident that the question has been carefully considered with regard to practical mining and iron making.

UNDEVELOPED DEPTHS OF BIG SEAM.

As to the vital question of the thickness of the workable ore in the Big seam below Shades Valley, there has been much speculation, and until the year 1907 but little practical investigation. The only means of practical investigation is the core drill, yielding a core 1⅛ inches or more in diameter. In earlier years mining companies have been content with what appeared to be an inexhaustible supply of ore in Red Mountain. With the increase in production of ore and the extension of slopes toward Shades Valley it has become evident that the permanence of the district as an iron producer depends upon ore supplies from beyond Red Mountain; and on the assumption that the ore supply does extend below Shades Valley, much land and many mineral rights have been acquired in that locality by the present ore producers, and some land has been obtained for speculative purposes by persons not connected with the iron trade. Very little of this land was originally prospected. All the interested parties appeared at first to be waiting for some one to begin, hoping to benefit from the experience and expense of the pioneer. Now that "stock taking" has become popular some of the larger companies have begun drilling, and others, as well as individual holders, deterred by the expense of drilling, are waiting to learn what they can from these results. It is this situation which very naturally prompts the owners of drill records to maintain strict secrecy in regard to them until they themselves have secured or disposed of, as the case may be, all the lands in which they are interested.

According to general information the ore between Graces Gap and Sparks Gap continues in practically its outcrop thickness southeastward for 2,500 to 4,000 feet from the outcrop, and in places farther. Beyond this distance, however, the ore appears to thin gradually toward the southeast. Near Sparks Gap it thins abruptly to the southwest and southeast.

According to the evidence furnished by the deeper slopes, there has thus far been no falling off with depth in either quality or thickness of the hard ore. At two of the larger mines, centrally located, about 6 miles apart, systematic analyses have been made of the ore of the upper bench of the Big seam taken from each entry at the right and left of the slopes, and from the face of the slope. In each set of analyses the composition of the ore in the bed has been found to show constant variation vertically across the bed, and to show irregular variations from place to place along the bed. Laterally the degree of variation is often found to be as great within a few yards as it is within 1,000 feet, but the average run of the hard ore at both mines is remarkably regular. The same testimony is afforded by the large number of working analyses from the several slopes of the Tennessee Company, averaged by months and by years. (See pp. 82–85.) These facts tend to show very conclusively that the ore bed does not merge into a ferruginous limestone with depth. It is here suggested that if any change is found eventually in the direction of the dip it will probably be a change to a more siliceous and shaly condition of the ore, such as can be observed along the outcrop of the beds from northeast to southwest. Studies by both the Alabama and the United States geological surveys show that the Clinton formation thins and becomes more siliceous toward the southeast. This change should logically be shared by the inclosed ore beds, and the evidence afforded by drill records in Shades Valley indicates that a change actually occurs.

CONSERVATION OF ORE.

Where the ore mined at present from the upper bench is self-fluxing it is obvious that the introduction of ore from the lower bench of the Big seam, which carries more silica and less lime, will necessitate the addition of fluxing stone to the furnace burdens, thereby increasing the cost of the pig iron. On the other hand, the use of this ore would prolong the productive period of the mine and convert into an asset a large quantity of ore that if passed over and neglected at present will be lost beyond recovery. Probably the only way that this ore can be won is by mining it in connection with the upper bench. When it is left, and the workings are finally robbed of their pillars of ore from the upper bench and the roof has caved, the lower ore is no longer available.

To recover the lower ore at present would, however, introduce serious complications in mining. At the Tennessee Company's mines the slopes are cut in the lower bench of the seam about 8 feet below the working level of the headings, so that tram cars of ore may be dumped over a tipple into the skip in the slope. If the lower bench of ore were mined also the slopes would have to be depressed 8 feet below the bottom of this bench in order to acommodate skip haulage. This would necessitate maintaining for some distance a slope height of 25 to 28 feet, which would be excessive, and would involve deepening and retimbering the present slopes. Beyond the present faces the slopes might be driven below the parting, leaving the upper bench above the slope. The matter of setting props to support the roof in the workings where 18 to 20 feet of ore are taken would also prove inconvenient.

In slopes where tram haulage is employed the problem is simpler, since it is not necessary to depress the slope below the bottom of the ore that is being mined. Part of the ore from the lower bench can be obtained in either case by cutting the floors of the rooms lower. By this method, however, the floors become too flat to permit the ore to be shot down to the cars, and the expense of moving it is thereby increased.

Evidently the problem is discouraging in view of present costs and conditions, but if for every ton of ore mined from the lower bench nearly a ton of ore in the upper bench might be saved for future use, it would seem worth while to carry the investigation as far as possible, even to the extent of equipping one slope to mine the whole seam on a scale that would enable the relative costs to be compared on a working basis.

PRACTICAL SIGNIFICANCE OF ORIGIN.

The question how the ores were formed has a very practical bearing on the extent and quantity of unexploited ore.

It has been observed that the ore, where soft at or near the outcrop, merges more or less gradually into hard ore with depth. This fact indicates clearly that the soft ore has been derived by a secondary process from the hard ore, but it does not furnish any suggestion concerning the genesis of the hard ore itself. The mode of occurrence and the constitution of the hard ore do not indicate that it has resulted from the alteration of a rock originally very different in composition, or that it is directly residual from disintegration of rocks containing minor quantities of iron minerals. The hard ore must therefore be regarded as having been formed in essentially its present condition contemporaneously with the inclosing sandstone and shale of the Clinton formation. Acceptance of this view leads to the conclusion that no regular decrease in iron content is to be expected as the ore beds are explored to greater depths than those already attained.

As to the extent of the beds, observations in mines and along the outcrops, as well as general studies of the stratigraphy, show that the ore beds, in common with the other strata in the Clinton formation, are built up of overlapping thin lenses or layers of sedimentary material. As a whole the Clinton formation exhibits this lenticular structure, and therefore the ore beds also probably were originally lenticular in shape, and the ore lenses were comparable in length and width with sandstone and shale lenses in the formation. The largest of the ore lenses has been observed to extend northeast-southwest 25 to 30 miles along the strike. The lenses are of course very flat and thin in proportion to their other dimensions, and they appear to thin to a feather-edge in some directions, while in others they split into thin seams and dovetail with lenses of shale and sandstone near their extremities. The lenses of sandstone, ore, and shale composing the Clinton formation probably were deposited in a nearly horizontal attitude, or at least with a low initial dip. Folds, faults, and erosion have so tilted, broken apart, and worn away portions of the rocks that it is difficult to recognize in the present outcropping beds portions of what probably were at one time well-defined, lens-like bodies of ore.

The processes of sedimentation by which the beds of sandstone, shale, and iron ore were formed probably were similar to those now operating along the south Atlantic coast of the United States, except that the water bodies were probably narrow bays and lagoons rather than an open ocean. The sediments composing the present shore deposits are carried by many short rivers from the highlands of crystalline rock across a narrow, low, coastal plain, and deposited a short distance offshore in comparatively shallow water. Through the sorting action of currents, and to a less extent that of waves, the sediments are spread along the shore line in such a way that they are homogeneous in character for much greater distances parallel to the shore line than at right angles to it.

Considered in this light it may be possible that the Big seam, the Irondale, and other minor seams exposed along Red Mountain in the heart of the Birmingham district represent portions of thin, narrow, elongated lenses of highly ferruginous rock. These beds are known to change in character only gradually along the northeast-southwest line of exposures, which is in general parallel to the shore line of the Clinton sea or embayment. At right angles to this line, however, the changes are more abrupt, especially toward the northwest, as is shown by comparison of the sections on Red Mountain and on West Red Mountain. Since the beds have not been found to become thicker southeastward, as they dip under the Mississippian rocks, it is fair to assume that at a certain distance from the outcrop the ore beds begin to thin out, just as they apparently do when projected northwestward across the anticline to West Red Mountain. The beds would thus form long, thin, wedge-shaped bodies, the thicker portion of the wedge lying along the outcrop on Red Mountain, with the thin edge, somewhat less regular in outline, lying far southeast. Even the approximate position of this line, which represents what may be termed the thin edge of the ore, is very uncertain. An ore bed a few feet thick is brought to the surface by a fault east of Cahaba River, near Henryellen, and thin ore is reported to occur in the bed of Cahaba River near Blocton. Structural conditions discussed on pages 116–121, and drill records in Shades Valley, however, indicate that for practical purposes the ore bed can hardly be considered available farther southeast than Shades Mountain, the border of the heavy cover of "Coal Measures" rocks, and it is doubtful whether it will prove workable that far southeast. Since there are several beds of ore in the formation, the maximum distance from the outcrop to the limit of workability would probably apply to the thickest and most persistent bed of the series—the Big seam. The other and smaller beds, such as the Irondale and the Ida, would not be expected to continue so far, to judge from their extent and the relations exhibited along the strike, although the possibility of their overlapping the Big seam and thus continuing beyond it in the direction of the dip must not be overlooked. Southeast from Red Mountain near Irondale the Irondale seam maintains its full thickness as far as Shades Creek.

If it is desired to estimate the tonnage of possible recoverable ore in one of these lens fragments it is necessary to calculate the cubical contents of the ore body as if it were projected in a plane. (See fig. 14.) The effect of gentle folding should not seriously alter the calculations; but sharp folds and extensive faults may necessitate throwing out of consideration practically all the ore involved. The limit to which it will pay to drive workings will be determined by the minimum thickness of ore that can be mined with profit at a given depth or distance down the slope or shaft (assuming always that structural conditions are favorable, and that there is a fairly regular decrease in thickness of the ore seams from their outcrop toward the thin edge of the lens). Keeping all these possibilities in

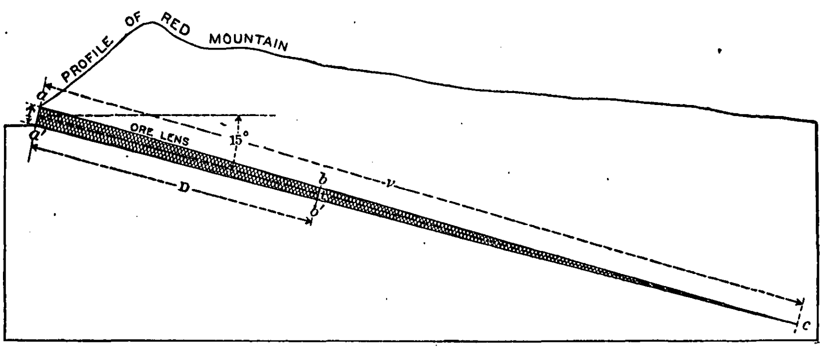

FIGURE 14.—Diagram illustrating thinning out of an ore bed. Vertical scale greatly exaggerated.

mind and using certain additional data suggested below, the engineer or geologist should be able to make a fairly close estimate of the tonnage of the Clinton ore reserves in a district or in any portion of it. The smaller the area involved in the estimate, and the more data available, the smaller the error will be.

ESTIMATES OF ORE RESERVES.

METHOD OF ESTIMATING TONNAGE.

As the first step in estimating tonnage, an area should be divided into units, somewhat after the manner in which the Birmingham district was divided, as outlined on page 55. Then each division should be subdivided again and again until areal units are obtained in which the dimensions can be accurately measured. (See fig. 15.) Every possible item of information concerning thickness of beds in outcrops, mines, drill holes, etc., should be considered, especially in relation to actual locations, in order that errors introduced by too general averages may be avoided. The percentage of ore recoverable under anticipated conditions of structure should enter into the calculation, as well as the specific gravity of the hard ore based on the average percentages of metallic iron, silica, and lime.

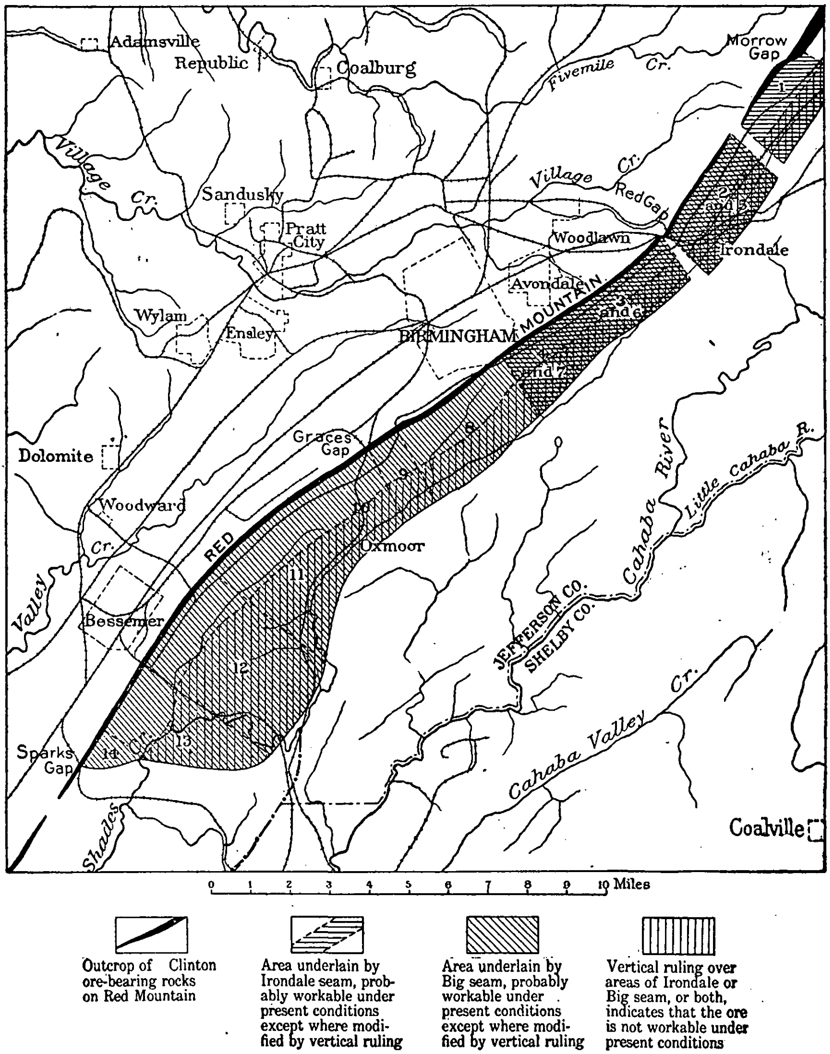

FIGURE 15.—Map showing subdivisions of main portion of Division A, Birmingham district, on which estimates of ore tonnage are based.

If it be assumed, then, that the ore in a certain bed within a given area forms a fairly regular prism, the base and altitude of which may be measured, and that the minable ore of this seam constitutes a truncated portion of this prism (see fig. 14), the cubic contents of this truncated prism of minable ore may be calculated conveniently by substituting in a formula the values of the average thickness, length, and width of the truncated prism of ore. From this result (in cubic feet) may be deduced in the same operation the tonnage of ore of a definite grade, by first using as factors the percentage of recoverable ore and the specific gravity of the same, based on the average percentage of metallic iron, etc., in the hard ore, then multiplying by 62.4, approximately the weight in pounds of a cubic foot of water, which will give the pounds of ore, and then reducing to long tons by dividing by 2,240.

Therefore, to establish a general formula for calculating the ore content for a certain ore bed in a given area, let—

L = length of outcrop;
T = average thickness of ore seam at outcrop;
t = minimum thickness to which ore may be worked;
D = distance from outcrop at which thickness of ore seam becomes t, or maximum distance from the outcrop practicable to mine the ore;
R = percentage of recoverable ore;
Fe = average percentage of metallic iron in hard ore;
G = specific gravity of ore based on value of Fe;
N = cubic feet per long ton of ore, based on value of G.

The total tonnage in long tons, therefore, is $\frac{\frac{1}{2}(T+t) \times L \times D \times R}{N}$.

DATA AND RESULTS.

Estimates of the ore reserves in Division A and in part of Division E of the Birmingham district have been made in preparing this paper, but it is here emphasized that while many more details have been considered than there is space to enumerate here the estimates may be regarded as only tentative ones. For Division A there was computed the tonnage of ore that should be contained under the assumed conditions, first, in the Irondale seam from Morrow Gap to Hedona, and, second, in the upper bench of the Big seam from Bald Eagle to Sparks Gap. From the sum of these estimated quantities was subtracted the total tonnage of red ore that has been produced in the Birmingham district from 1880 to 1908, inclusive. In making this estimate Division A is subdivided into fourteen parts, in four of which the Irondale seam is considered of sufficient importance to be regarded as a source of future ore supplies. These fourteen units of area (see fig. 15) whose ore-bearing strata outcrop along Red Mountain are as follows: Irondale seam—(1) From Morrow Gap to and including the Olivia mine; (2) Bald Eagle to Red Gap; (3) Red Gap to Helen-Bess; and (4) Helen-Bess to Hedona. Big seam, upper bench—(5) Bald Eagle to Red Gap; (6) Red Gap to Helen-Bess; (7) Helen-Bess to

Lone Pine; (8) Lone Pine to Walker Gap; (9) Walker Gap to Graces Gap; (10) Graces Gap to Spring Gap; (11) Spring Gap to Woodward No. 2; (12) Woodward No. 2 to Readers; (13) Readers to Potter; and (14) Potter to Sparks Gap. The estimate is considered to be conservative for the following reasons: (1) No account has been taken of any possible available ore except that in Red Mountain and Shades Valley; in other words, the ore in West Red Mountain has not been considered; (2) no ore seams besides the upper bench of the Big seam and the Irondale seam have been considered; (3) only such portions of the outcrop of these seams have been considered as are known to be workable, and wherever the seams are faulted out or badly broken such portions are not included in the area upon which estimates are based; (4) the percentage of recoverable ore has apparently been placed low enough to be on the safe side; (5) conservative figures have been used as representing the average workable thicknesses at the outcrop, and the probable minimum workable thickness. If in places the former is greater and the latter is less, the value of D will be greater; (6) the percentages of metallic iron used as factors in determining the specific gravities of the hard ore in the various subdivisions have been taken with a view to the possible reduction rather than increase of iron content with distance from outcrop; (7) in deducting the tonnage of red ore already produced the total red ore for the district has been taken, which is greater than that produced by the main portion of the Birmingham district. In regard to this last factor it should be stated that the excess is not great, however, for Red Mountain, between Morrow Gap and Sparks Gap, has produced between 98 and 99 per cent of the red ore of the district.

In obtaining the specific gravity of the hard ore in relation to its content of metallic iron use has been made of the laboratory determinations of Mr. R. T. Pittman, chief chemist of the Sloss-Sheffield Steel and Iron Company, at Birmingham, and those of Dr. J. R. Harris, chief chemist of the Tennessee Coal, Iron, and Railroad Company, at Ensley, Ala. Mr. Pittman's experiments consisted of grinding lumps of typical Birmingham hard red ore down to cubes 1 inch on an edge, determining the specific gravity of each by displacement of water, and afterwards analyzing the ore thus treated. In his experiments Doctor Harris employed the Stanton specific gravity basket and a modified form of the Hogarth flask.

The results of certain of these tests and analyses are as follows:

Specific gravity tests and analyses of Clinton hard ore, Birmingham district.

(By R. T. Pittman, 1906.)

	Weight in air of 1 cubic foot of ore (pounds).	Specific gravity.	Analyses.		
			Fe.	Insoluble.	CaO.
A	213.47	3.42	36.25	13.80	17.98
B	215.97	3.46	37.05	12.40	18.14
C	219.23	3.50	37.60	11.42	17.43
D	220.71	3.53	38.05	10.60	17.52
Average	217.35	3.48	37.24	12.05	17.78

(By J. R. Harris, January, 1909).

	Computed weight in air of 1 cubic foot of ore (pounds).	Specific gravity.	Analyses.						
			Fe.	SiO_2.	Al_2O_3.	CaO.	Mn.	P.	H_2O.
1	219.65	3.52	35.19	10.16	2.86	19.39	0.18	0.28	0.54
2	222.14	3.56	35.70	9.88	2.93	19.24	.17	.29	.48
3	219.65	3.52	36.23	16.18	3.18	15.06	.19	.32	.58
Computed average	220.48	3.53	35.71	12.07	2.99	17.89	.18	.296	.53

1. Average sample from 6 railroad cars of ore from Tennessee Coal, Iron and Railroad Company. Style No. 1.
2. Average sample from 4 railroad cars of ore from Tennessee Coal, Iron and Railroad Company. Style No. 4.
3. Average sample from 5 railroad cars of ore from Tennessee Coal, Iron and Railroad Company. Style No. 13.

According to the last set of results there appears to be no very definite relation between the iron content and the specific gravity within the small variation in composition shown, nor is the bearing of the proportions of lime and silica upon the end result at all clear.

While the two sets of results do not agree very closely, they furnish a basis for roughly computing the number of cubic feet of ore per long ton. The experiments afford no direct data as to the porosity of the ore, but they do afford, by comparison with calculated specific gravities, a constant factor of difference which is due to the effects of porosity and moisture. This ore, it must be remembered, is a very hard, compact material as mined, and in its normal condition underground carries very little moisture. As shown in the analyses by Doctor Harris the moisture present ranges generally between 0.5 and 0.6 per cent, and it rarely rises above 2 per cent. By using the average factor of difference obtained as suggested above, a consistent specific gravity for any sample of hard ore of this district can be calculated, if the content of metallic iron be given.

On applying the formula outlined on page 129 to the area contained in Division A of the Birmingham district, the data and results shown in the following tables are obtained.

Estimated available red-ore reserves in Red Mountain and Shades Valley.[a]

Subdivision.[b]	L.	D.	T.	t.	$\frac{T+t}{2}$.	R.	Fe.	N.	Quantity of ore.
	Feet.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Per cent.*	*Per cent.*		*Long tons.*
1	11,000	3,400	4.25	4	4.12	90	36	10.5	13,207,500
2	15,000	3,500	4.5	4	4.25	90	33.7	10.7	18,724,500
3	18,200	3,100	4	4	4	90	35.8	10.5	19,333,800
4	6,800	3,700	3.5	3	3.25	90	36	10.5	7,008,700
5	15,000	3,500	7	5	6	85	35.8	10.5	25,500,000
6	18,200	3,100	8	5	6.5	85	34.7	10.6	29,404,900
7	6,800	3,700	10	6.5	8.25	85	32	10.8	15,969,900
8	14,500	5,300	10	6.5	8.25	85	35	10.6	50,840,000
9	5,000	5,300	12	7	9.5	85	36	10.5	20,855,500
10	11,700	6,000	9.5	7	8.25	85	35	10.6	46,441,000
11	14,200	6,000	9	5.5	7.25	90	36.9	10.4	53,455,000
12	15,500	5,200	10.75	7	8.87	90	35	10.6	60,698,500
13	10,000	5,800	8.5	4.7	6.6	90	35.4	10.5	32,810,700
14	5,200	3,400	5.5	4	4.75	80	33	10.8	6,220,700
Total									400,470,700
Production of Birmingham district, 1880 to 1908, inclusive									42,000,000
Total red ore at present available									358,470,700

[a] For explanation of column headings, see p. 129.

[b] Irondale seam:
1. Morrow Gap to Bald Eagle.
2. Bald Eagle to Red Gap.
3. Red Gap to Helen-Bess.
4. Helen-Bess to Hedona.

Big seam, upper bench:
5. Bald Eagle to Red Gap.
6. Red Gap to Helen-Bess.
7. Helen-Bess to Hedona.

Big seam, upper bench—Continued.
8. Hedona to Walker Gap.
9. Walker Gap to Graces Gap.
10. Graces Gap to Spring Gap.
11. Spring Gap to Woodward No. 2.
12. Woodward No. 2 to Readers Gap.
13. Readers Gap to Potter.
14. Potter to Sparks Gap.

Estimated red-ore reserves in lower bench of Big seam in Red Mountain and Shades Valley.

Subdivision.[a]	L.	D.	T.	t.	$\frac{T+t}{2}$.	R.	Fe.	N.	Quantity of ore.
	Feet.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Per cent.*	*Per cent.*		*Long tons.*
8	14,500	5,300	6	5	5	85	30	11.1	29,412,800
9	5,000	5,300	8	5	6.5	85	34	10.7	13,673,500
10	11,700	6,000	8	5	6.5	85	36	10.5	36,938,300
11	14,200	6,000	7.6	4	5.8	85	37	10.4	40,389,000
12	15,500	5,200	5	3	4	85	34	10.7	25,611,100
Total									146,024,700

[a] The subdivisions correspond to the areas similarly numbered in the preceding table.

Estimated red-ore reserves, not at present available, in eastern part of Shades Valley.

Subdivision.[a]	L.	D.	T.	t.	$\frac{T+t}{2}$.	R.	N (average).	Quantity of ore.
	Feet.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Per cent.*		*Long tons.*
1	11,000	3,500	4	2.5	3.25	85	10.5	10,131,400
2	15,000	3,500	4	2.5	3.25	85	10.5	13,812,500
3	18,200	3,000	4	2.5	3.25	85	10.5	14,367,100
4	6,800	5,300	3	2	2.5	80	10.5	6,865,000
5	15,000	3,500	5	3	4	85	10.5	17,000,000
6	18,200	3,000	5	3	4	85	10.5	17,680,000
7	6,800	5,300	6.5	4	5.25	80	10.5	14,416,100
8	14,500	4,800	6.5	4	5.25	85	10.5	29,580,000
9	5,000	5,000	7	4	5.5	80	10.5	10,476,100
10	11,700	5,000	7	4	5.5	80	10.5	24,514,400
11	14,200	9,800	5.5	3	4.25	75	10.0	44,624,400
12	15,500	20,000	7	3	5	65	10.5	71,963,300
13	10,000	6,600	4.7	2.5	3.6	75	10.5	16,971,100
Total								292,401,400

[a] The subdivisions correspond to areas lying between lines extended southeastward from the points specified in the table above. (See fig. 15.) Subdivisions 1 to 4 represent the Irondale seam, and 5 to 13 the upper bench of the Big seam.

There is thus indicated a total of 358,470,700 long tons of ore at present available in the main portion of the Birmingham district, and it is probable that one-half billion tons would be reached by any estimate that considered carefully the reserves in the other divisions of the district not included within the present estimate. The estimates show also a reserve of 146,024,700 long tons of ore in the lower bench of the Big seam, and of 292,401,400 long tons in the main part of the Big seam in the eastern part of Shades Valley—a total of 438,426,100 long tons of red ore not available under present conditions.

When it is considered that the annual production of red ore in Alabama has not yet exceeded 3,200,000 long tons, and that the production has not increased rapidly in recent years and does not promise to increase rapidly in the near future, the results of the estimate indicate that the iron ore at present available in this district promises to last more than one hundred years longer at the present rate of output. The foregoing estimate, which gives a grand total of 796,896,800 long tons of red ore in the Birmingham district, as compared with the preliminary estimate of 1,000,000,000 long tons of red ore in Alabama, previously published by E. C. Eckel,[a] appears fairly conservative, when it is recalled that the Birmingham district probably contains 80 per cent of the red ore of the State that can be regarded as possibly workable. On the other hand, the preliminary estimate made by Eckel of 1,000,000,000 long tons of red ore in Alabama, including as it did much ore probably carrying 25 to 30 per cent metallic iron, and occurring in seams at present regarded as too thin to be profitably worked, but of possible future value, appears to be consistently supported by the present estimate of ore reserves in the Birmingham district.

It should be repeated, in conclusion, that the present estimate is based on the belief that the hard-ore beds are the result of a single concentration of iron-oxide sediments that took place when the beds were deposited, that they occur as fragments of what were originally rather uniform lens-shaped bodies; that, as a consequence of their supposed method of origin, the content of metallic iron does not greatly diminish from the point where the hard ore is first encountered in the mine slopes to the point where the bed has thinned to a minimum workable thickness; and finally, that the structure remains fairly constant as indicated in the foregoing discussions. This last element it should be remembered is one of the most uncertain with which the miner has to deal and can be rendered more certain only by thorough and systematic prospecting with the core drill in places where no definite mine data or reliable geologic indications are available. Unknown structural complications, "horses" of barren rock, and unexpected thinning of the ore beds may of course greatly reduce the quantity of recoverable ore counted on in this estimate.

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[a] Eckel, E. C., A review of conditions in the American iron industry. Eng. Mag., vol. 30, 1906, pp. 518–527.

MINING METHODS.

STAGES OF DEVELOPMENT.

There have been three stages in the development of the red-ore mines in the Birmingham district. The first stage consists of trenching the ore beds along the outcrop on the crest or on the northwest face of Red Mountain, and of mining the ore from open cuts on the crest or sides of the mountain. The ore obtained in this way is mostly soft. This method of mining has been practicable only where the overlying beds do not exceed a thickness that can be profitably stripped—usually not more than 20 feet, but reaching twice that thickness in some old workings. Most of the mines have passed beyond this stage, but at the Helen-Bess and the Green Spring workings this type of mining may still be seen. (See Pl. IX, *A*.) The cost of equipment for open-cut mining is very much less than for underground work, but where the stripping is heavy there is not much saved in the cost of ore.

The second stage of development combines the open cut and outside incline with underground work. Three mines, the Ruffner, Helen-Bess, and Valley View, are good examples of workings at present in this stage of development. A very fortunate relation between the Big and Irondale seams and the topography of Red Mountain exists in many places, particularly in the northern half of the district, wherever the dip of the Clinton strata is approximately the same as the southeast slope of the mountain. This slope is cut by narrow V-shaped ravines at intervals of one-fourth to one-half mile, and on both sides of many of these hollows the two seams are exposed from the crest nearly to the foot of the ridge. (See Pls. VIII and IX, *B*.) Inclined tramways are built on the flanks of the ravines and when the outcrop ore has been worked out entries are driven on the strike of the ore beds from each side of the ravines and the ore is mined from the upper side of the entry. The cable tramway may be operated by gravity or by power, according to the side of the mountain on which the ore is to be delivered. At the Sloss-Sheffield Ruffner mine No. 1 the tracks of the railway to which the ore is delivered are on the southeast side of the mountain, making it possible for cars loaded with ore going down the mountain to pull up the empties, but at the Valley View mine of the Birmingham Ore and Mining Company the ore is hauled up over the mountain and loaded into railroad cars on the opposite side. At mines of this type soft, semihard, and hard ores are obtained, depending on the thickness and character of the cover of the bed.

The third stage of mining, the one to which the majority of the workings in the Birmingham district have now attained, involves systematic underground work entirely. The general plan is very simple, comprising a main or central slope, driven on the dip, or in the direction of one of the vertical joints of the ore bed, from which right and left headings, or entries,[a] are turned off at regular intervals of 50 to 65 feet. About 30 feet of ore is mined from the upper side of the heading and about 30 feet is left as a wall or pillar to protect the workings entry until robbing is begun. Mules haul the trams to the main slope, up which the ore is moved by a cable to a tipple, below which it is crushed and loaded directly into railroad cars bound for the furnace. (See Pl. X, *B*.) A manway is usually provided at one side of the slope for safe passage of men and mules. Excessive water has been encountered in few of the workings of this type, except where the rocks are faulted, so that a 3 to 4 inch pump usually suffices to drain a mine.

Operation by vertical shafts is a fourth stage, which some of the mines in the basin east of Red Mountain may reach in the near future. The working face of the ore bed can be reached more directly by a vertical shaft 700 to 1,000 feet in depth than by a slope three or four times that length. The initial expense of such a shaft as would be required would be far greater than that of a slope, but a much greater quantity of ore can be handled, and eventually the cost per ton may fall below that of slope mining.

UNDERGROUND WORKINGS.

General types.—The underground workings are of two types, the partially closed, such as belong to the second stage of mine development, and the complete or closed workings, such as belong to the third stage of mining. The closed workings are of two forms: (1) The main slope or haulage way is driven on the ore seam from the outcrop or from the face of the open cut (fig. 16), and (2) the ore seam is reached by a crosscut tunnel and opened by a slope (fig. 17). In either case the slope may descend directly with the dip, or at a slight angle to it, following the direction of the system of vertical joints in the ore, which in places cut the ore bed sharply into blocks 10 to 30 feet wide. The distinction between these forms is shown in the plans, figures 18 and 19. As the closed workings constitute nine-tenths of the active mines of the district, a few additional notes on the details of their character and methods of operations are added. For still greater detail in this subject the reader is referred to recent articles by Crane [b] and Higgins.[c]

System of mining.—The room-and-pillar system of mining is employed, with final robbing of the pillars (figs. 18 and 19). From

[a] The term in general use in the Birmingham district for the openings driven to the right and left of the main slope is "heading."

[b] Crane, W. R., Iron mining in the Birmingham district, Alabama: Eng. and Min. Jour., February 9, 1905, pp. 274-277.

[c] Higgins, Edwin, Iron operations of the Birmingham district: Eng. and Min. Jour., November 28, 1908, pp. 1043-1049.

both sides of the main slope entries or headings are driven in the ore at regular intervals of 50 to 65 feet, thus dividing the mine into levels or stopes which are worked independently. The distance between the centers of the headings is determined by twice the length to which it is desired to drive the rooms. For instance, if it is desired to drive rooms 30 feet in length up the dip from the heading the headings are driven 60 feet apart. The size of the rooms depends on the character of the roof and thickness of the ore seam. The grade of the main slope varies with the dip of the beds, whether it is driven directly down the dip or with the jointing of the ore. The dips range from 15° to 45° as observed in the various slopes of the district, but they range mostly between 18° and 30°. The direction of the set of vertical joints followed by certain slopes makes a small angle with the direction of the dip, and therefore such slopes are less steep than the dip. This feature is not regarded as of much advantage, however, for on account of folds in the strata the dip becomes in places so low that gravity does not readily carry the cars down the slope. To facilitate haulage and drainage the headings are given a grade of about 3 per cent toward the main slope. Where a slope follows the jointing diagonal to the dip of the ore bed the headings turn off

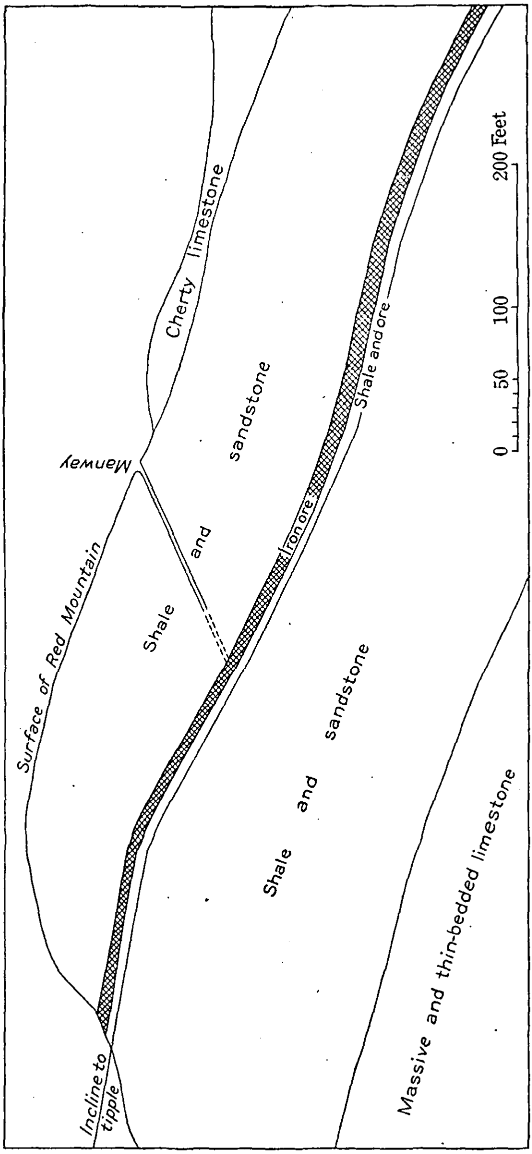


FIGURE 16.—Typical profile of slope on Red Mountain, starting on outcrop.

from the slope at acute angles on one side and obtuse angles on the other.

Two methods of haulage are in use in the ore mines. Under the older method the trams of ore in trains of 5 to 8 cars each are hauled up the slope by cable. The floor of the slope corresponds with the bottom of the ore that is mined. With tram haulage the headings are sometimes offset 15 to 25 feet in order that the switches on opposite sides may not come at the same point on the main slope track. The later method of haulage employs the skip, or steel slope car, which carries ore from the mouths of the headings up to the tipple. With skip haulage the right and left headings are generally opened directly opposite each other and the main slope is depressed about 8 feet below the bottom of the worked ore bed, enough to give headway for dumping the pit cars into the skip. The tracks in the headings are laid on the floor of the workable bench of ore. The main slope is therefore 16 to 20 feet high, while the headings are the height of the workable portion of the ore bed, unless this is less than enough to

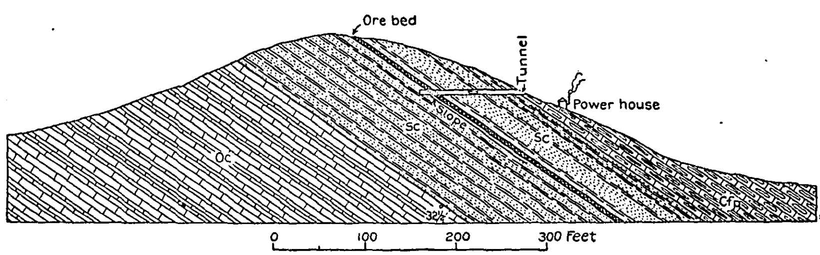


FIGURE 17.—Profile showing slope reached by tunnel. Sc, Clinton (Rockwood) formation; Oc, Chickamauga (Pelham) limestone; Cfp, Fort Payne chert.

provide head room for miners and mules. The width of headings is about 15 feet for 60 to 100 feet from the main slope, beyond which it is increased to 25 or 30 feet, the width of the rooms. The portions of ore remaining after driving the headings, cutting out rooms and connecting the headings by "break throughs" or air ways about 100 feet apart, are called pillars. The pillars are finally taken out or robbed after the mine workings have been extended below as far as is advisable.

Manways are usually driven about 75 feet from the main slope and parallel to it. The manways are sometimes driven on the ore bed from the outcrop, but at many mines the manway entrance is at the top of the mountain. They are about 5 feet wide and 5 to 7 feet high, are usually timbered, and the floor is cut into steps to facilitate the passage of men and mules. Where drainage is necessary in the upper parts of the mine sumps may be provided in the headings, and there is usually a sump at the bottom of the slope. Slopes are now situated at intervals of one-fourth to one-half mile apart along the

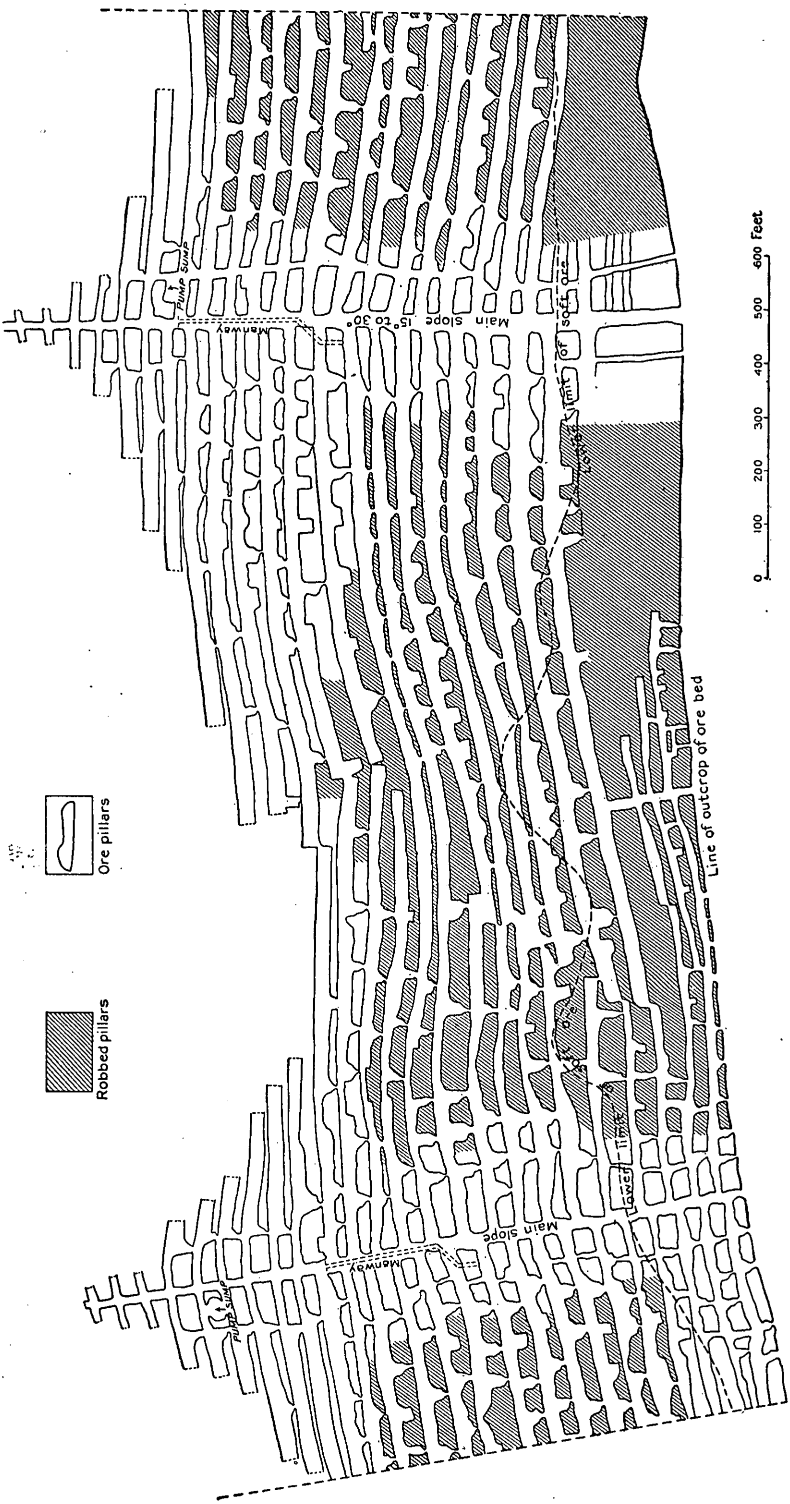


FIGURE 18.—Typical plan of two adjacent slopes on Red Mountain driven directly on dip of beds.

FIGURE 19.—Typical plan of two adjacent slopes on Red Mountain driven in direction of vertical jointing of beds.

productive part of Red Mountain, between Graces Gap and Potter, and the ore is all worked out to the driving line or property line between slopes, so that in many instances the headings from one slope connect with those of adjoining slopes. (See figs. 18 and 19.)

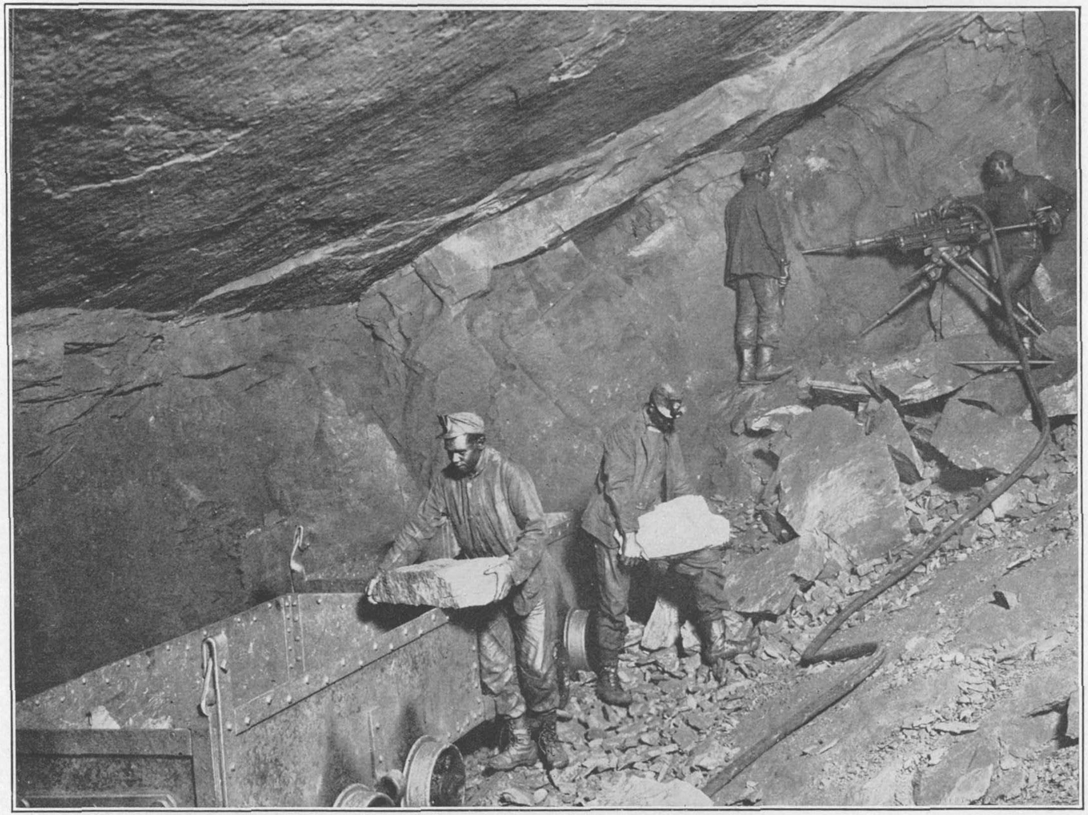
Equipment and methods.—Owing to the shaly nature of the rocks overlying the ore beds and to their flatness, the roof must in many places be supported when the ore is removed. This is especiaally true where there are "bells" or "pots" in the overlying shale, such as are often observed in connection with coal seams. Square sets and lagging are provided in the slopes and manways. The working headings are timbered first with posts, or, where the ground is very loose, square sets and lagging may be used, although seldom necessary.

Since the presence of water in a mine is due to fractures in the rocks, mines in localities of slight folding or faulting usually encounter more or less water, while those in undisturbed strata may be practically dry. The water which collects in the sumps is pumped out by air or by steam, principally by air, since air has also to be employed extensively for drilling.

The ventilation of these iron-ore mines is much more easily effected than that of a coal mine, since there are no suffocating or inflammable gases and no combustible dust. In dry mines there is some ore dust and, of course, considerable powder smoke from blasting. The currents of air entering the mine slope naturally pass downward and are divided and drawn laterally into the headings, and the air supply is further augmented by the exhaust from the air drills, which also stimulates the circulation. The mines are still illuminated largely by torches and miners' lamps, but in the best-equipped mines incandescent electric lamps have been installed in slopes and manways. Electrical apparatus is employed for signaling, and in some mines telephones are installed at stations underground.

Drills are operated by air under a pressure of 75 to 80 pounds, and the ore is shot down by dynamite fired usually by fuse, but in some mines by electricity. The ore face is worked upward from the heading, so that gravity aids in moving the broken ore to the tram car. The tram cars are gathered into small trains and hauled by a mule to the slope, or else they are moved singly by gravity to the slope and hauled back to the face by mule. (See Pl. XI.)

Robbing.—Robbing of the pillars, or final extraction of the ore, is begun first in the upper headings and farthest from the main slope. Robbing in the hard ore can usually be accomplished by cutting off transverse slices from the pillars, working slopeward. The directions of vertical jointing which divide the ore beds into diamond-shaped blocks that are deflected slightly from the directions of strike and dip aid to a certain extent all the operations of mining, but most of all the robbing or removal of the last blocks of ore. After the pillars are removed the roof is allowed to cave in and fill the workings.



TYPICAL UNDERGROUND MINING OPERATIONS.

Upper bench of Big seam in Red Mountain; face of right-hand heading. Photograph furnished by courtesy of Tennessee Coal, Iron, and Railroad Company.

Therefore the new slope and heading work is kept far ahead of the portion of the mines being robbed. Where the old workings on the upper bench of the Big seam have been allowed to cave in it is very doubtful whether the lower bench of this seam can ever be utilized, even where it carries sufficient ore to be worked independently.

Haulage and power.—Raising ore to the surface is, as previously stated, accomplished either by dumping it from the tram car into a skip which is hauled up the slope by winding engine and cable or by hauling the mine cars themselves out by the cable. Steel cables used in the slopes are generally 1⅛ to 1½ inches in diameter.

Skip haulage has supplanted train haulage in all the slopes of the Tennessee Company and at some of the Republic slopes, because it requires fewer hands, is safer, tends to increase the output, simplifies the mine arrangement, and reduces cost of repairs, all of which render it the more economical method. Mine cars, where train haulage is employed, are of wood, bound by strap iron, and carry about 2 tons of ore. Where skip haulage is in vogue, the tram car used in the heading is of metal and carries about 2 tons of ore. It is lower and wider than the mine car, and is more easily filled and dumped. The mine cars run on a track of 36-inch gage; the tram car requires a 42-inch track, while the steel skip, which has a capacity of 8 to 15 tons, runs on a track of 60-inch gage. The skip is open at the top and the front is provided with a gate which opens automatically when the skip is emptied. For dumping waste material the skip may be switched off before reaching the tipple.

When the skip reaches the surface it continues in the same plane to the tipple. Where train haulage is employed the cars run out on a level trestle to the tipple. Here the ore is dumped into a pocket feeding into a gyratory crusher which breaks the lumps to 6 inches or less in length and discharges into railroad cars on the siding. Modern ore cars used on the railroads are gondola shaped, built of steel, and have capacities of 30 to 50 short tons each.

Power plants for the mines along Red Mountain are built near the west of the mountain, many of them beyond the railroad and at considerable distance from the slopes with which they are connected. Where three or more slopes, one-fourth to one-third of a mile apart, are operated by the same company, steam and compressed air may be generated at a central station and piped to each slope in the group.

PROSPECTING.

In connection with mine development the importance of diamond-drill prospecting has been more fully recognized within the last three years than previous to 1907. When mine slopes were first begun on Red Mountain the ore supply was considered inexhaustible and but little thought was given to ore reserves southeast of the mountain, in Shades Valley. Likewise there was little apprehension of faults through which the ore might be lost. Both of these considerations are now receiving their proper share of attention from the larger mining companies and from persons who are interested in securing ore lands. Core drilling at distances of 1,000 to 3,000 feet from the outcrop has been the means of locating faults in the strata, the dip of the beds, and of determining the character and thickness of the ore beyond the slopes. From the information thus obtained it has been possible to anticipate a fault and to plan the modifications necessary in a slope in order that the ore may be reached beyond the fault with no loss of time. The nature of much ore underlying Shades Valley has been determined by the use of the core drill and the value of the land adjusted correspondingly, but there is still a vast acreage absolutely unexplored, particularly from the line of Readers Gap and Parkwood northeastward almost to Irondale. While much of this country is rough and surface conditions are not suggestive, the geological conditions suggest that Clinton ore of excellent quality and of workable thickness underlies practically the whole of the territory thus defined, at depths that will not be considered prohibitive to mining twenty-five years hence. Unfortunately much money has in the past been wasted in ill-considered methods of drilling. Attempts have been made to drill deep holes with apparatus that was inadequate, and such holes have mostly been abandoned without reaching ore. Holes have also been drilled with the churn drill, which at the best yields very uncertain results. A core is absolutely necessary if the quality of the ore is to be determined. Many holes have been drilled with both the churn drill and the core drill the logs of which are preserved only in the memory of the driller, and the washings and cores from the ore beds were scattered to the winds without chemical analyses of the material.

The importance of efficient drilling apparatus, thorough and intelligent supervision of work, and careful, accurate recording of the logs can not be urged too strongly here. The valley rocks above the ore consist of shale, sandstone, limestone, cherty limestone, and chert. Much of the sandstone is calcareous. All of these rocks except the shale are hard to drill, the chert and cherty limestone being most refractory. Both the diamond-bitted drill and the steel bit with crushed steel are proving successful in bringing up cores. The cores most satisfactory are those with diameters not less than $1\frac{1}{4}$ inches. A core $5\frac{3}{4}$ inches in diameter was being obtained from a hole drilled in January, 1909, but this seems an unnecessarily large diameter. The present costs of drilling in these valley rocks approximate $3 per foot for 1-inch to $1\frac{1}{8}$ inch cores, if the hole does not exceed 1,000 feet in depth. Larger cores and deeper holes are both more expensive, and costs may run as high as $5 per foot. Drilling is mostly done by contract.

PRODUCTION AND CONSUMPTION OF IRON ORE.

Since 1894 Alabama has held third place among the iron-producing States. In 1907, a normal year in the iron industry, her total production of iron ore amounted to 4,039,453 long tons, composed of 3,144,011 tons of red hematite and 895,442 tons of brown hematite.

The Birmingham district in 1907 produced 2,742,860 tons of red hematite, or 87.2 per cent of the total tonnage of red ore in Alabama. The series of mines known as the Red Mountain group of the Tennessee Coal, Iron and Railroad Company are classed among the prominent iron-ore mines of the United States. Together, this group, including the Potter slopes, formerly leased by the same corporation, in 1907 produced 1,403,745 long tons, or more than 51 per cent of the total red ore for the district.

In 1908 there was a slight decrease in the tonnage of ore mined, due to the closing of several slopes belonging to the smaller companies.

The following table shows the quantity and value of red and of brown ore produced in Alabama and in the Birmingham district in 1907 and 1908, compiled from returns made to the United States Geological Survey:

Production of iron ore in Alabama and Birmingham district, 1907–8.

	Alabama.			Birmingham district.			
	Long tons.	Value.	Average value per ton.	Long tons.	Value.	Average value per ton.	Percentage of state production.
1907.							
Red ore	3,144,011	$3,451,677	$1.10	2,742,860	$2,876,167	$1.05	87.2
Brown ore	895,442	1,411,452	1.58	313,636	476,023	1.52	35
1908.							
Red ore	2,775,903	3,046,217	1.09	2,597,651	2,799,633	1.08	93.2
Brown ore	958,535	1,312,685	1.37	387,265	527,068	1.36	40.4

It will be noticed that in a year of industrial depression, such as 1908, the production from the Birmingham district did not suffer as did other districts in the State. The production of brown ore in the Birmingham district actually showed a large increase in 1908, due in part to the reopening of the mines at Champion. The average value for red ore per ton is between $1.05 and $1.10, and has not suffered much change in the last three years. The average value for brown ore per long ton in 1908 was about $1.36, as compared with $1.55 for 1907.

Practically all the ore produced in the district is manufactured into pig iron in the vicinity of Birmingham. The ore is handled by 29 coke furnaces distributed as follows: In Birmingham, 8 furnaces, four of which belong to the Sloss-Sheffield Steel and Iron Company

(Pl. XVII, *B*), one to the Tennessee Coal, Iron and Railroad Company, two to the Birmingham Coal and Iron Company, and one to the Williamson Iron Company. At Ensley there are 6 stacks and at Bessemer 5 stacks of the Tennessee Coal, Iron and Railroad Company; at Thomas, 3 stacks of the Republic Iron and Steel Company; at Woodward, 3 stacks of the Woodward Iron Company; and at Oxmoor, 2 stacks of the Tennessee Coal, Iron and Railroad Company. On the outskirts of the district are the furnace of the Southern Steel Company, at Trussville, and that of the Central Iron and Coal Company at Holt, near Tuscaloosa.

In general the furnaces run on a burden of coke, red ore, brown ore, and dolomite or limestone, though certain of them at times use only a self-fluxing red ore. The ores of the district contain too much phosphorus to be converted into steel by the Bessemer process, but pig iron from it is being very successfully used for basic open-hearth steel making. The basic open-hearth process is employed by the Tennessee Coal, Iron and Railroad Company at the Ensley rail mill which, including improvements now under way, consists of two 20 gross ton acid Bessemer converters and 6 new 100 gross ton basic open-hearth tilting furnaces, together with one coal-reheating furnace, soaking pits, blooming mill, rail mill, and finishing department, shops, and auxiliaries. The entire output of the company's six coke furnaces is transferred as hot metal to the steel mill, where it is made into billets and rails. The Ensley mills are adjacent to the Pratt coal field and thus occupy a peculiarly advantageous location since most of the ore and fluxing materials are mined within a distance of 3 to 10 miles.

Besides the Ensley plant this company operates at Bessemer rolling mills having a capacity of 60,000 tons annually of bars, plates, and light rails. The Southern Steel Company also operates rolling mills at Ensley.

BROWN ORES.

ORIGIN.

By Edwin C. Eckel.

GENERAL STATEMENT.

The Appalachian Valley throughout its entire extent from Vermont to Alabama presents almost ideal opportunities for the formation of brown-ore deposits. Flanked on the east by iron-bearing crystalline rocks, a continuous supply of ferriferous waters has been afforded for ages. The rocks of the valley itself, consisting chiefly of limestone with interbedded shales and sandstones, all containing iron in small amounts, are more immediate sources of supply. These valley rocks, varied in composition, solubility, and hardness, and often dipping steeply, offer excellent locations for brown-ore deposition.

In the southern portion of the valley, from Philadelphia to Alabama, the lack of glacial action has permitted the accumulation of thick deposits of residual material, and this deep residual is accompanied by an extensive and interesting series of brown-ore deposits.

North of the glacial limit conditions are different, and the present ore deposits of the northern part of the valley are to be regarded as merely the basal portions of more extensive original deposits. There the residual ores are largely or entirely lacking and most of the deposits are partly or entirely inclosed in solid rock. By far the majority of these deposits are found to be alteration products from iron carbonate, which in turn originated through the replacement of a limestone bed.

The Birmingham district, which is geologically a portion of the great Appalachian Valley, contains a series of brown-ore deposits that are important as regards both their actual size and their relations to the iron industry of the district. These deposits are located some distance southwest of Birmingham, near Woodstock, in that portion of the valley lying west of the tracks of the Alabama Great Southern Railroad.

CONSTITUTION OF BROWN ORES.

The hematite or sesquioxide group of iron ores contains a number of closely related mineral species, all agreeing in containing their iron in the ferric form, as the sesquioxide (Fe_2O_3). The species of the group differ in their degree of hydration. Hematite proper, usually distinguished as red or specular hematite, is entirely anhydrous, carrying no combined water. The other members of the group are more or less hydrous, and differ in the amount of water which is chemically combined with their iron oxide.

The relation between these various iron-oxide minerals is best brought out if their formulas be so arranged as to give a constant iron factor. This has accordingly been done in the table below:

Chemical character of different iron-oxide minerals.

Name of mineral.	Chemical formula.	Composition.	
		Iron oxide.	Water.
		Per cent.	*Per cent.*
Hematite	$2Fe_2O_3, 0H_2O$	100	0
Turgite	$2Fe_2O_3, 1H_2O$	94.7	5.3
Goethite	$2Fe_2O_3, 2H_2O$	89.9	10.1
Limonite	$2Fe_2O_3, 3H_2O$	85.5	14.5
Xanthosiderite	$2Fe_2O_3, 4H_2O$	81.6	18.4

From this table it will be seen that the five minerals in question make up a perfect series with respect to their percentages of combined water, beginning with the anhydrous hematite oxide, and showing gradually increased hydration to the other end of the series. In fact, the series can be carried still further if the doubtful mineral limnite ($Fe_2O_3, 3H_2O$) be included.

Hematite proper, the anhydrous sesquioxide, is usually distinguished from the others as red hematite, specular hematite, fossil ore, etc., according to the characteristics of the particular specimen in hand. The four hydrous oxides, turgite, goethite, limonite, and xanthosiderite, are commonly grouped under the names of brown-iron ores, brown hematite or limonite. It is probable that if the product from any particular brown-ore deposit be carefully examined, it will be found that much of the ore is limonite proper, with much goethite, and smaller proportions of the other two hydrous oxides. In the present report the term limonite will be used, if at all, in its proper and restricted sense, referring to the mineral of the formula $2Fe_2O_3, 3H_2O$. When, on the contrary, hydrous iron oxides in general are referred to, they will be called simply brown ores or brown iron ores.

TYPES OF BROWN-ORE DEPOSITS.

The principal difficulty that seems to arise in discussing the origin of brown-ore deposits is the tendency to regard them all as of one type. It has often happened that a limited group of such deposits has been carefully studied; that a satisfactory explanation of the origin of this particular group has been reached; and that then this explanation has been extended to cover all or most of the brown-ore deposits of the Appalachian region. More extended studies would have shown that the most striking characteristic of brown-ore deposits is their variety in form and origin.

The brown-ore deposits of the Woodstock district are of a type extremely common in the southeastern United States, characterized by the occurrence of masses and fragments of brown ore associated with residual clays, the ore-clay mixture being underlain by limestone and overlain by relatively recent sands and gravels. Deposits of this type are not bog ores, for they show no evidence whatever of having been deposited in water basins. They differ, on the other hand, from the type of deposit common in the Oriskany ore region (Virginia) and the Salisbury region (Connecticut) in certain important particulars. The most striking of these differences is that iron carbonate is rare or absent in the deposits of the Woodstock district, while it forms the usual bottom of the deposits in the other two districts.

In discussing the origin of these deposits it must be premised that the shaly limestones on which they now rest once outcropped at elevations high above the present valley level and that these limestones have been reduced to their present level largely by simple decay. Water has dissolved and carried off the lime carbonate, leaving behind the clayey matter once contained in the limestones. This residual clayey matter now appears as the sticky white and gray clay with which the ores are so closely associated and in which they are often actually embedded.

The following analyses of the Conasauga limestone associated with brown ore from this district are of service in the present connection:

Analyses of limestone and residual clay below brown ore at Houston mine.

[Analyst, R. S. Hodges, Alabama Geological Survey.]

	SiO_2.	Al_2O_3.	Fe_2O_3.	FeO.	TiO_2.	CaO.	MgO.	Na_2O.	K_2O.	CO_2.	H_2O.
Unweathered limestone	12.34	1.34	0.77	......	0.11	44.34	2.54	0.24	0.76	35.20	1.87
Weathered limestone	27.75	6.57	1.62	0.27	.39	29.69	3.02	.23	3.53	22.84	4.19
Residual clay	55.92	25.24	5.10	.30	1.21	.10	1.61	.43	2.48	....	9.00

An average analysis of the whole series of limestones composing the Conasauga formation, if one could be obtained, would undoubtedly show that the "average rock" is a very impure limestone. Such a rock, when subjected to weathering agencies, would give rise to the formation of thick deposits of residual material, this residual representing the insoluble portions of the original mass. As it is often assumed that this action would of itself give rise to the formation of brown-ore deposits, it is worth while to determine just what would happen in such a case.

Assume a limestone of the following composition:

Insoluble residuum:	
SiO_2	2.5
Al_2O_3	1.0
Fe_2O_3	.5
	4.0
Soluble carbonate:	
$CaCO_3$	94.0
$MgCO_3$	2.0
	96.0

A horizontal bed 100 feet thick of this limestone, if the carbonates are removed by solution, would evidently yield a 4-foot bed of insoluble residual material. But this would in all probability be a 4-foot bed of clay of about the following composition:

SiO_2	56.25
Al_2O_3	22.50
Fe_2O_3	11.25
Water, etc	10.00
	100.00

The point to be kept in mind is that this residual will be a clay, and that the iron of the original limestone will be present in this clay largely in the form of minute particles of iron-silicate minerals or as fine scattered particles of iron oxide. It will not be present as a distinct mass or bed of brown ore. The matter hardly seems to require much discussion, but many theories of the origin of brown ores tacitly assume that the iron of the original limestone appears in the residual mass as brown ore. A theory of this type would of course imply that 100 feet of the limestone above discussed would by its decay give rise to a bed one-half foot thick of brown ore.

It can therefore be set down as an axiom that the decay of a limestone carrying slight percentages of disseminated iron materials can never of itself yield a deposit of brown ore. The decay of the limestone may be a very important step in the formation of such a deposit, but it can never be the only step. There must also be some process by which the iron is concentrated, either in the original limestone or in the residual material. In the opinion of the writer this concentration usually takes place in the limestone before its decay, though in some cases it evidently has occurred in the residual. In the Woodstock district, for example, the bulk of the deposits appear to have been formed by the solution of a limestone in which seams and stringers of brown ore had been deposited prior to its weathering. In the Russellville and middle Tennessee deposits the evidence is still more conclusive, for in those areas such primary deposits of iron carbonate and brown ore have been found in the unaltered limestone.

Geologic age of brown-ore deposits.—It is a common practice to refer to some of our eastern and southern brown ores as "Cambro-Silurian ores," to others as "Oriskany ores," "Subcarboniferous ores," etc. It should be clearly understood, however, that the geological terms used in this way do not refer to the age of the ores, but to the age of the rocks with which the ores are now associated, or in which they are now embedded. As a matter of fact, the bulk of our brown-ore deposits appear to have been formed rather recently, the majority probably during Tertiary time, and the fact that some of the ores now happen to be associated with Cambro-Ordovician limestones and others with later rocks has nothing whatever to do with the age of the ore deposits themselves.

Over half a century ago Edward Hitchcock, noting the occurrence of Tertiary fossils in connection with the brown-ore deposits near Brandon, Vt., was led to express the view that all brown-ore deposits were of Tertiary age. This has been treated by later geologists as hasty and unfounded generalization, and it is true that his results were deduced from a narrow basis of observation. Nevertheless, it must now be admitted that his conclusion seems to be supported by strong evidence, and that to-day it must be accepted as at least highly probable that the bulk of our brown-ore deposits were formed during the Tertiary.

Three lines of evidence are available which enable us to place this relatively narrow limit on the main period of brown-ore formation. They are:

1. It is readily demonstrable, with respect to the majority of the deposits, that they were formed after all the folding of the region had been accomplished, and at a period when the topography was substantially similar to that now existing.

2. Many brown-ore deposits can be proved, and most others may be inferred, to have existed at the beginning of the glacial period in the north, and at the commencement of the Lafayette deposition in the south.

3. Direct evidence as to the age of a very few ore deposits is afforded by the inclusion or association of Tertiary fossils with them.

In the Russellville district, Alabama, there is, fortunately, rather definite proof that the brown-ore deposits were in existence, in substantially their present location, form, and size, during late Tertiary time. This proof is afforded by the relation which the Lafayette formation (late Tertiary) of the region bears to the underlying and adjacent brown-ore deposits.

This is best brought out on examination of some of the older workings, about midway between the present Sloss-Sheffield openings and Russellville. In these workings the red loams of Lafayette age are seen to overlie directly the brown ores and their associated clays.

The bulk of the Lafayette, here as everywhere, is made up of a reddish loam, but near its base a pebble bed occurs. This varies in thickness from a few inches to several feet. Most of the pebbles are the usual rounded quartz and chert which are so common everywhere at the base of the Lafayette. Along with these, however, are many smooth-surfaced but more angular fragments of brown iron ore. These have evidently been derived directly from the near-by beds of brown ore, and consequently these brown-ore beds must have been in existence, in practically their present form, during the deposition of the basal Lafayette beds.

It may be added that where the Lafayette overlies a clay bed so that its own basal beds have been pathways for subsurface waters, the iron has been gradually leached out from the upper portions of the Lafayette and redeposited as a cement around the pebbles of the basal bed. In places we have therefore three ferriferous types in view in the same section:

1. The original deposits of brown ore;
2. The derived brown-ore pebbles in the Lafayette;
3. A ferruginous conglomerate at the base of the Lafayette, consisting of pebbles of quartz, chert, and brown ore enveloped in a limonitic matrix.

It is probable that this series is repeated at many points, both in the Russellville and in other southern brown-ore districts, but the evidence happens to be clearest at the points noted. In the Woodstock district, for example, the evidence as to age is less direct, but even there it is possible to say quite definitely that most of the ores were formed prior to the Lafayette deposition and later than the Cretaceous.

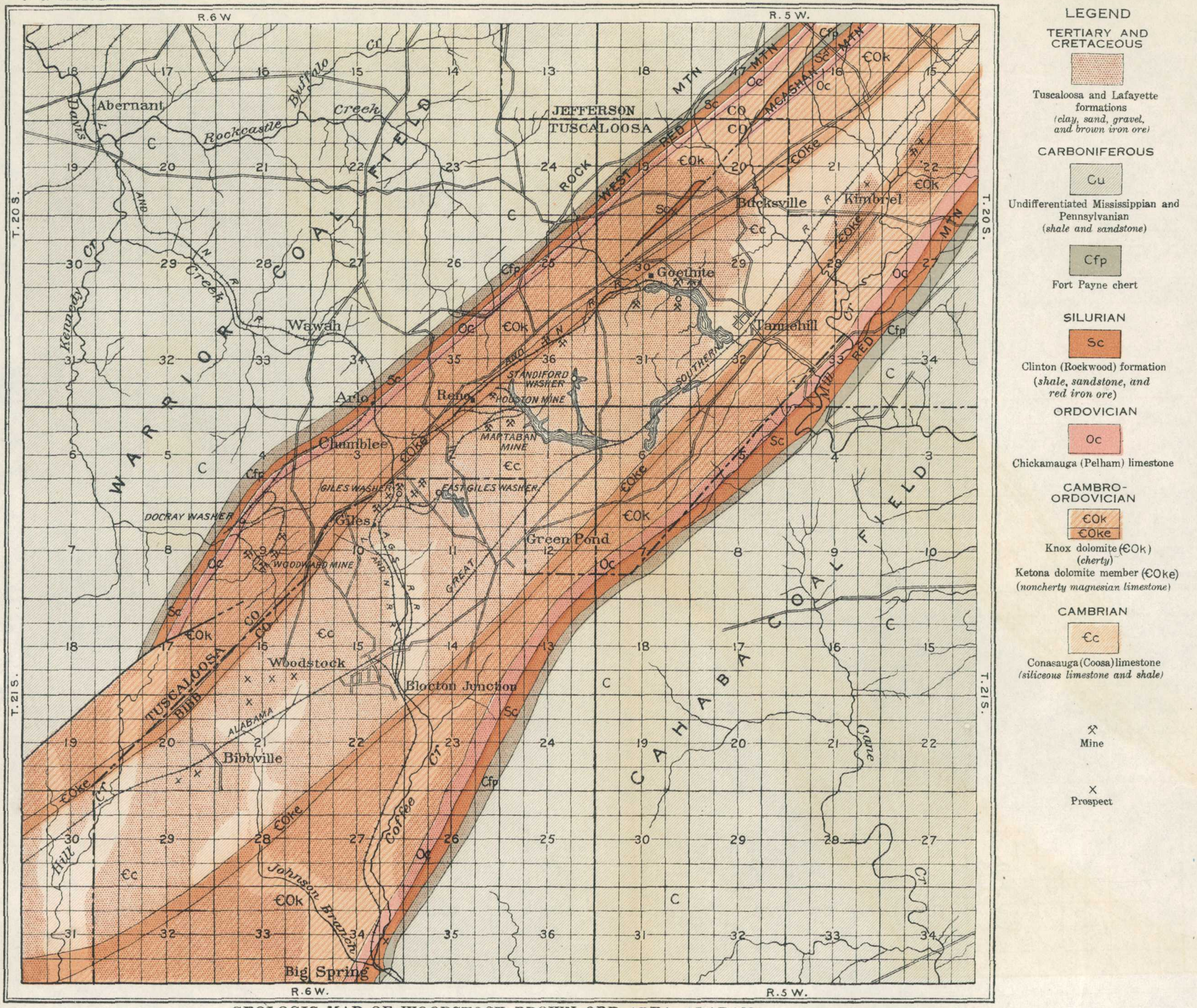
GEOLOGY AND DEVELOPMENT.

By Ernest F. Burchard.

WOODSTOCK AREA.

LOCATION AND EXTENT.

Although all the brown ore used in the Birmingham district is not produced within the district as defined in this paper, a large proportion of it is mined within Birmingham Valley, principally in the vicinity of Woodstock. This district produces about 37.5 per cent of the brown-ore tonnage of the State. It lies between Red Mountain on the southeast and the Warrior coal field on the northwest. Its length from northeast to southwest is nearly 12 miles and its width ranges from 2 to 3½ miles, so that its area is between 30 and 35 square miles. The present known limit of the ore northeast of Kimbrel is in sec. 21, T. 20 S., R. 5 W., along the east side of the Alabama Great Southern Railroad, but the limit of the ore field southwest of Bibbville has not been determined. The map (Pl. XII) shows the general geology of the area, its relations to Red Mountain and West



Base taken from Tennessee Coal Iron and Railroad Co. land maps

GEOLOGIC MAP OF WOODSTOCK BROWN ORE AREA, ALABAMA

1 0 1 2 Miles

1908

Geology by Charles Butts, Ernest F. Burchard, and Hoyt S. Gale
Surveyed in 1904

Red Mountain, the red-ore bearing ridges, and the relations of the brown-ore field to portions of the Warrior and Cahaba coal fields. The area mapped is within the Brookwood quadrangle, of which a reconnaissance topographic map was made by the survey in 1895. The Alabama Great Southern main line passes along one side of the district; the Blocton Branch of the Louisville and Nashville Railroad crosses nearly the middle of the district, and both roads send out spurs to the working mines.

TOPOGRAPHY.

The old surface features of Birmingham Valley southwest of Bucksville have been somewhat modified by the Coastal Plain deposits of clay, sand, gravel, and loam that attain an important thickness here. The margins of the valley are not so well defined as farther northeast, since Red and West Red mountains have been worn down lower and their rocks are for the most part covered by the Coastal Plain sediments, so that only the most resistant sandstones standing vertical at the base of the Pennsylvanian series now rise noticeably above the general level. Rock Mountain, northwest of Goethite, and Sand Mountain and Red Ridge to the southeast mark, respectively, the outer limits of the valley in those directions. The Coastal Plain sediments have overlapped the old peneplain surface, but they are now undergoing erosion by streams that are working back into courses of former streams, so that the surface is more hilly and dissected than it is in the valley farther northeast where there are no coastal deposits. The speed of erosion is controlled by the rate at which the streams are able to cut through bed rock, on which they are now working in the gaps where they flow out of the valley. Davis Creek flows northward into the Warrior coal field and has cut in Rock Mountain a wide gap, through which the Louisville and Nashville Railroad is built. The same road passes through Sand Mountain in a gap cut by Johnson Branch at Big Spring. Rock Mountain is cut also by Rockcastle Creek, and Red Ridge is severed from Sand Mountain by Mill Creek, the headwater branches of which drain the northeast end of the brown-ore district.

It is of interest that here, where the Birmingham Valley formerly was almost completely buried by Coastal Plain deposits, the new drainage originating in the valley should flow directly across and outward from it rather than along its major axis, so that the topographic conditions in this respect do not vary from those farther northeast beyond the limit of Coastal Plain deposits. This condition of drainage is controlled by three factors. First, the relatively greater altitude of the valley than the neighboring regions, by which it becomes in fact a divide between the basins of Warrior and Cahaba rivers; second, by the rock dips which in general are toward the bordering coal fields; and, third, by the old drainage which had cut gaps in the bordering ridges and dissected the peneplain before the coastal deposits were laid down over the submerged surface. The present actual divide is well toward the northwest edge of the valley. Giles is situated between the headwaters of Davis and Caffeys creeks. The headwaters of Cooley Creek extend back to Rock Mountain, as do those of Mill Creek. The extreme relief does not much exceed 200 feet and most of the hills are not more than 100 feet high. The old or pre-Cretaceous topography was also somewhat uneven, as is indicated by the discovery of buried ridges of Cambrian limestone in the ore cuts and test pits. (See Pl. XIII.) In places these ancient ridges seem to bear some relation to the present hills, but not everywhere.

RELATION OF ORE TO TOPOGRAPHY.

The ore masses are mostly above drainage level, some of them being well toward the hilltops, as at Goethite. The most important exception is the deposit at Giles, which extends so low that it has to be pumped to keep down the water which enters from springs in the cut. Ore at the Woodward property, 2 miles southwest of Giles, also extends below water level. The hilly topography facilitates the construction of settling ponds in the hollows, several of which have been utilized in this way, but is not too rugged to permit the construction of wagon roads with easy grades, and railroad spurs where needed.

STRATIGRAPHY.

The rocks that underlie the valley, so far as could be ascertained, have relations, structure, and distribution similar to those farther northeast in the valley, where they are more readily observed. There are, above the Paleozoic formations, sediments of Cretaceous and Tertiary age, besides more recent soils. Since this brown-ore district is practically an economic unit the following table of the formations associated with the ores is given here for ready reference. The Carboniferous formations do not underlie the valley at all, and, so far as the brown ore is concerned, probably no Paleozoic rocks above the Knox are concerned, at least in the vicinity of Woodstock. Southwest of Dudley, however, a deposit of brown ore was noted in sediments overlying Chickamauga limestone. (See p. 164.)

Rock formations in Woodstock brown-ore district.

System.	Formation and character.	Thickness.
		Feet.
Quaternary	Soil	1- 5
Tertiary	Lafayette formation (loam, sand, and gravel)	1- 50
Cretaceous	Tuscaloosa formation (clay and sand)	1- 200
Ordovician	Chickamauga limestone	300- 500
Cambro-Ordovician	Knox dolomite	500-2,000
	Ketona dolomite member (base)	100- 200
Cambrian	Conasauga (limestone and shale)	[a] 1,000+

[a] Base not exposed.

The thickness of the rocks below the Cretaceous can not be determined with certainty in this area, as the exposures are very few and far between. The Conasauga and Knox formations have the most extensive distribution of the Paleozoic rocks, and these formations are covered in many places by Cretaceous and Tertiary sediments, as shown by the map. (Pl. XII.) In general the Lafayette is so thin as to make its differentiation from the Tuscaloosa impracticable on a map of this scale, but it is also true that the Lafayette is very generally present on top of the Tuscaloosa.

GEOLOGIC RELATIONS AND CHARACTER OF THE BROWN ORE.

If it should be attempted to give a general rule for the distribution of workable deposits of brown ore in the Woodstock district, it might be said that nearly all such deposits have been found directly associated with two groups of rocks: (a) Cambrian limestone and Cambro-Ordovician dolomite, and (b) Cretaceous clays and Tertiary loam and gravel. The ore occurs in irregular masses or banks in clay, sand, loam, and gravel, at or near the contact of this unconsolidated material with the underlying limestone or dolomite beds. Most of the ore-bearing materials are apparently of Cretaceous age, although some are later. The ore may therefore be divided into two types: (a) The main ore masses, which occur with the Cretaceous clays and sands, and (b) the later ore, which occurs in Tertiary loam and gravel. The Tertiary ore is not extensive nor important, and is mined only in connection with the older ore in a very few places. It consists of ferruginous sandstone, conglomerate with iron-oxide matrix, and sand or loam that may be largely iron oxide. These materials are fairly rich in iron and lie close enough above the main ore beds at one place in the Goethite mine to be mined with the lower ore by a steam shovel, and the mixture is found to wash a satisfactory quantity and grade of ore. The ore of type (b) is seldom more than 10 feet thick. The masses of ore of type (a) associated with Cretaceous materials occur in varying degrees of richness, mixed with clay, sand, and gravel, and are separated by areas of barren material. These deposits in places reach a thickness of 75 feet or more. As has been stated, the surface of the Paleozoic rocks is irregular, and many of the ore deposits seem to have been segregated at places where the surface is most uneven. Hollows or depressions in the limestone appear to have been favorable places either for the deposition of ore or for the collection and concentration of ore débris.

Associated with the ore masses are beds of variegated clay—white, pink, and yellow in color. A black clay-like material is also present, which belongs rather with the ore than with the group of variegated clays. The variegated clays are interbedded with the ore and also overlie it. In this variegated character they strongly resemble the clays that, elsewhere in the State, Dr. E. A. Smith, state geologist, has shown to be of Cretaceous age, and has designated as Tuscaloosa. Pockets of the ore contain yellow to red finely divided material, which may be slimy, putty-like, or a dry ochery powder, depending on the quantity of moisture present. The composition of a sample of this clay-like material, analyzed on a dry basis, is as follows:

Analysis of clay from tight pocket in brown ore, Houston mine.

[Analyst, R. S. Hodges, Alabama Geological Survey, 1907.]

Silica (SiO_2)	48.77
Alumina (Al_2O_3)	27.52
Ferric oxide (Fe_2O_3)	7.54
Ferrous oxide (FeO)	.21
Titanium dioxide (TiO_2)	1.52
Lime (CaO)	.11
Magnesia (MgO)	1.68
Sodium oxide (Na_2O)	.41
Potassium oxide (K_2O)	3.55
Water (H_2O)	9.24

The black claylike material, where it is present at all, is usually most closely associated with the ore. At the Giles mine this material is of a dead black color when moist, is faintly laminated in places, is firm enough to be cut with a knife, and is not gritty. When dry the clay looks grayish-black; when burned it becomes much lighter in color. It may entirely surround a mass of ore, a bed of it may lie above or below a mass of ore or at one side of it, and it may rarely fill cavities in a honeycombed mass of ore. Generally, however, the black clay is found below the ore. In many places this black clay is below a heavy cover of ore, variegated clay, sand, and loam, so that it could hardly be an infiltration of surface mold. The Conasauga limestone is in places dark and carbonaceous, but it is seldom directly connected with this dark "clay." In the analyses of the black "clay" which follow the presence of organic matter, manganese, and iron pyrites may be significant.

Sample 1 contained pyrolusite of a fibrous structure, possibly pseudomorphous, very soft and disintegrated. Apparently it occurred in a pocket containing an unusually large quantity of manganiferous ore. Sample 2 contained a considerable quantity of ferrous sulphate ($FeSO_4$) and manganous sulphate ($MnSO_4$), soluble in water.

Analyses of black "clay" from brown-ore pits.

	1.	2.	3.
Silica (SiO_2)	23.26	63.00	66.86
Alumina (Al_2O_3)	7.45	13.11	15.51
Ferric oxide (Fe_2O_3) / Ferrous oxide (FeO)	4.97	3.04	.05
Ferric disulphide (FeS_2) (iron pyrites)	....	....	2.69
Manganese dioxide (MnO_2)	38.55	....	....
Manganous oxide (MnO)	16.84	1.10	....
Titanium dioxide (TiO_2)	.40	.44	.83
Cobaltous oxide (CoO)	.03	....	....
Calcium oxide (CaO)	.58	.23	.20
Magnesium oxide (MgO)	.29	.18	.70
Potassium oxide (K_2O)	1.27	7.46	5.53
Sodium oxide (Na_2O)	.28	.31	.18
Sulphur trioxide (SO_3)	Trace.	3.81	....
Carbon dioxide (CO_2)	None.	None.	....
Phosphorus pentoxide (P_2O_5)	.20	None.	....
Water (H_2O) (below 100° C.)	1.13	2.95	....
Water (H_2O) above 100° C.)	4.75	3.91	8.39
Organic matter	....	Trace.	....
	100.00	99.54	100.94

1. From Houston mine. Analyst, R. C. Wells, U. S. Geol. Survey, 1909.
2. From East Giles mine. Analyst, R. C. Wells, U. S. Geol. Survey, 1909.
3. From Giles mine. Analyst, R. S. Hodges, Alabama Geol. Survey, 1907.

Separating the ore masses and the other unconsolidated deposits from the unaltered limestone and shale of the Conasauga is a cream-colored residual clay, termed "white horse" by the miners, ranging in thickness from a few inches to 35 feet. This maximum thickness has been measured in test wells, and, owing to the steep inclination of the beds, it represents a less thickness measured at right angles to the bedding planes. There is no likelihood that this clay is of Cretaceous material, for the following reasons: The Conasauga beds consist of thin-bedded, platy limestone, interbedded with shale. They are inclined steeply to the southeast for the most part, and are contorted and sharply folded to a considerable extent. In only a few places the strata lie nearly flat. The residual clay invariably shows the same bedding and sharp, contorted folding that the limestone shows, and moreover, these folded beds of clay can be traced continuously, layer for layer, into the original limestone, with apparently little or no loss in volume, since the layers are of the same thickness whether of clay or of solid rock. (See Pl. XIII, *B*.) While the shale layers of the Conasauga can reasonably be expected to disintegrate into a clay, it is not at first so clear how the limestone layers can weather to a clay with so little loss in volume. When it is considered, however, that the limestone, as shown by the following analyses, is decidedly siliceous, it is apparent that a considerable residue would remain after the lime was dissolved out; and it is also probable that the loss of soluble constituents is compensated for in large part by the hydration of the clay. Furthermore, the beds stand so nearly on edge that the clay would not become so compact as if the beds lay flat. There has doubtless been some shrinkage, but the rate of subterranean decay has probably been rapid, because it has taken place on the edges of the strata and along the bedding rather than perpendicular to it. The following three analyses show gradations from unweathered limestone through weathered limestone to residual clay, all of which occur below the brown ore at the Houston mine. The relative increase of silica, alumina, and iron from limestone to clay are noteworthy.

Analyses of Cambrian limestone and residual clay, below brown ore.

[Analyst, R. S. Hodges, Alabama Geological Survey, 1907.]

	SiO_2.	Al_2O_3.	Fe_2O_3.	FeO.	TiO_2.	CaO.	MgO.	Na_2O.	K_2O.	CO_2.	H_2O.
Unweathered limestone	12.34	1.34	0.77	......	0.11	44.34	2.54	0.24	0.76	35.20	1.87
Weathered limestone	27.75	6.57	1.62	0.27	.39	29.69	3.02	.23	3.53	22.84	4.19
Residual clay	55.92	25.24	5.10	.30	1.21	.10	1.61	.43	2.48	....	9.00

The proper identification of these cream-colored clays is of consequence in prospecting and mining, for they represent the lower limit to which the ore extends, and where the ore rests against a reef or knob of clay-covered limestone the clay represents a wall in that direction. In prospecting and mining this clay is frequently mistaken for the Cretaceous clay, or vice versa, and the ability to recognize each is of practical value for several reasons. In the first case, the removal of the residual clay would result only in reaching barren limestone beyond, while to abandon work in the Cretaceous clay might mean missing the discovery of a valuable mass of ore. The best criteria for differentiating the two types of clay are (*a*) the thin laminations and the variegated bright colors that are usually characteristic of the Cretaceous clay, and (*b*) the yellowish color and the folded, contorted structure of the original limestone that persists in most of the Cambrian residual clay.

These general conditions are found at all the workings in the district, and further details will be given in the following local descriptions.

When washed, picked, and screened, ready for the blast furnace, the brown ore in the Woodstock area carries in carload lots, according to present standards, 39 to 50 per cent metallic iron, 10 to 20 per cent silica, 3.25 to 5 per cent alumina, and 5 to 7 per cent of water. The manganese and phosphorus run irregularly. The manganese ranges between 0.25 and 1.2 per cent, and the phosphorus may run less than 0.20 per cent in one mass of ore while on the opposite side of the hill it may be more than 1 per cent. By determining the high and low phosphorus portions of a deposit through careful prospecting and sampling it is sometimes possible so to control shipments that they may carry a more nearly uniform quantity of this element.

Working analyses of the ores from the several mines and data regarding the proportions of ore to gravel will be found on page 169.

DEVELOPMENTS.

Brown ore is being mined on a large scale in the Woodstock district by the Tennessee Coal, Iron and Railroad Company, the Republic Iron and Steel Company, and the Central Iron and Coal Company, while the Woodward Iron Company had completed development of a tract of 400 acres and was erecting a washer and shipping dry-screened ore in January, 1909. The ore mined by these companies is used in their several furnaces at Bessemer, Ensley, Thomas, Holt, and Woodward, Ala. Besides these companies there are several smaller operators in the district, who work out ore by hand and haul it by wagon to the railroad. Under favorable conditions brown ore may still be mined profitably in this way, since the material is always salable. Formerly there were two furnaces within the district, the old Edwards furnace, just north of Woodstock, and the old Tannehill furnace, on Mill Creek, southeast of Tannehill, but both of these have been dismantled.

The clay industry has developed on a small scale incidental to the mining of brown ore. At West Giles clays belonging to the Coastal Plain deposits are worked. These clays are of variegated colors and are interbedded with layers of sand. They strongly resemble the clays of the Tuscaloosa formation. They are used for making fire brick by the Bessemer Fire Brick Company. Three grades of clay are taken; No. 1 is a pink, almost pure clay; No. 2 is pink and white; and the third grade is scrap clay mixed with an equal quantity of sand. Pottery clays are reported to have been quarried here formerly, but the material is not now used for pottery.

There were in 1909 seven large brown-ore mines in active operation, besides several minor workings, and there are several localities now abandoned, but once famous producers, at which the richest or most readily accessible ore has been worked out, although much ore has recently been discovered in test pits sunk below the level of former workings.

MINES.

TANNEHILL (GOETHITE).

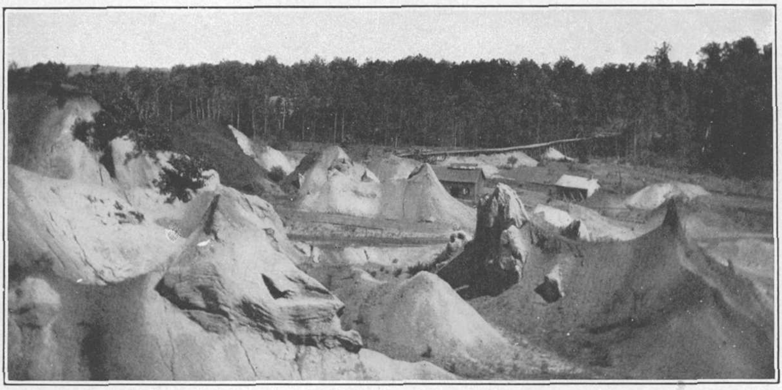
The mines at Tannehill were opened in 1887 and have produced ore continuously since then. They are now operated by the Republic Iron and Steel Company. The ore deposit lies in an east-west ridge extending partly across secs. 29 and 30, T. 20 S., R. 5 W., north of Mill Creek, and ore occurs also in the hills on the south side of the creek. The workings comprised in 1906 on the north side of the valley three worked-out cuts of several acres each, and a fourth cut, then active, adjacent to which, on the north, ore was still accessible in masses scattered through an area one-fourth by one-eighth mile, as proved by systematic test wells. South of Mill Creek ore was also being mined. The main washer and crusher was supplied by cut No. 4, in the northeast portion of the tract.

The ore occurs high in the hills, is capped with a few feet of red loam, and rests on or against masses of Conasauga limestone, which are decomposed to clay at the contact. Where the underlying limestone rises high in the hill the contour of the ore deposits does likewise. Toward the bottom of the valley the ore thins and finally disappears.

The worked-out area of the three western cuts is so extensive that a good exposure of the old limestone surface is afforded. (See Pl. XIII, *A*.) The ore and gravel have been cleanly removed from this surface, which consists of sharp ridges and pinnacles of bluish-white limestone or cream-white residual clay. The ore is distinctly of two types here: (a) The main deposit, which appears to be associated with Cretaceous sediments, and (b) the surface ore, which is mixed with loam of the Lafayette formation. The main ore body (type a) is overlain in places by variegated clays that are characteristic of the Tuscaloosa formation. This ore is in places interstratified with yellowish clay, which is distinct from the residual clay of the Conasauga formation. For the most part the ore is in large bowlders and coarse to fine gravel. The bowlders are porous, honeycombed masses with powdered chert and ferruginous powder in the cavities. Fragments of chert are also embedded in the ore. The large bowlders are called "dornicks" and must be crushed before washing. The worked-out deposits probably reached a thickness of 40 to 50 feet in places. In one of the old cuts a comparatively even limestone floor underlay several acres, with only a few reefs rising 15 to 25 feet above its surface, and a few pits reaching to a similar depth below. Residual clay mantled the limestone, and the ore overlay this, banked against the reefs and filling the pits. Where the reefs and pinnacles of clay-covered limestone are close together the ore is often found to fill solidly the intervening spaces. The ore and limestone drop off abruptly from the hills toward the surrounding valleys. The ancient topography may have resembled in general that of the present, but the old limestone surface was very much serrated, and faces of isolated crags, now revealed by stripping, show evidences of stream erosion which resulted in the formation of cliffs. It is of course possible that some of the irregularity of the top surface of the limestone has been produced by solution since the Coastal Plain deposits were laid down, but the evidences of stream erosion and overhanging cliffs are not to be attributed to subterranean decay. These Cambrian limestones have been sharply folded and contorted throughout the district, as shown in the illustration (Pl. XIII, *B*). Overlying the main ore and variegated clays is a massive blanket deposit of Lafayette loam, with a little quartz, chert, and ore gravel. The loam itself is red, and in places is so largely composed of iron oxide in the form of fine sand and loose gravel that it is mined and washed as ore. There are also scattered masses of sandy ore in it close to the surface. The Lafayette is unconformable on the underlying deposits, and its thickness ranges from a few inches to about 15 feet. In places it has been entirely removed by erosion.

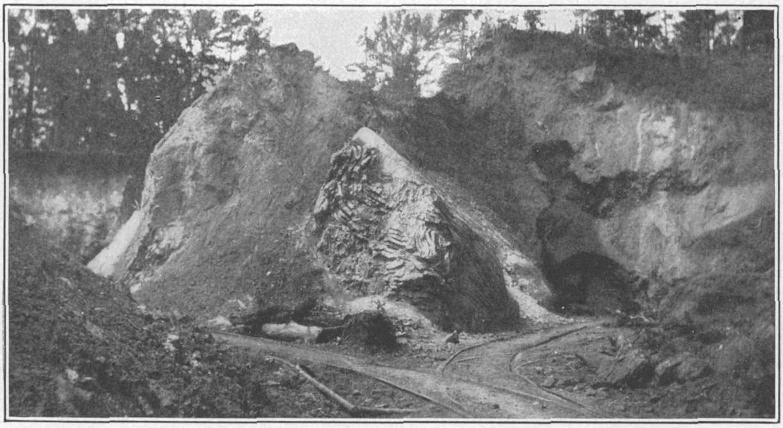
Ore is mined here by steam shovel from open cuts that require little but stripping, and it is also loosened by pick and shoveled by hand into tram cars. The ore is high enough to be trammed by gravity from most of the cuts to the crusher and washer. The mine is connected with the Birmingham Mineral Division of the Louisville and Nashville Railroad.

Prospecting has shown that ore and gravel extend northward from the present workings in an area about one-fourth by one-eighth mile in extent. Within a mile northeastward from the Goethite workings, in the middle part of the valley, the Coastal Plain deposits thin out and practically disappear. Northeast of the Goethite area they may occur in patches, as for instance east of the Alabama Great Southern Railroad, northeast of Kimbrel, and ore is being dry-screened and shipped from these deposits. It is of interest in this connection that no important brown-ore deposits



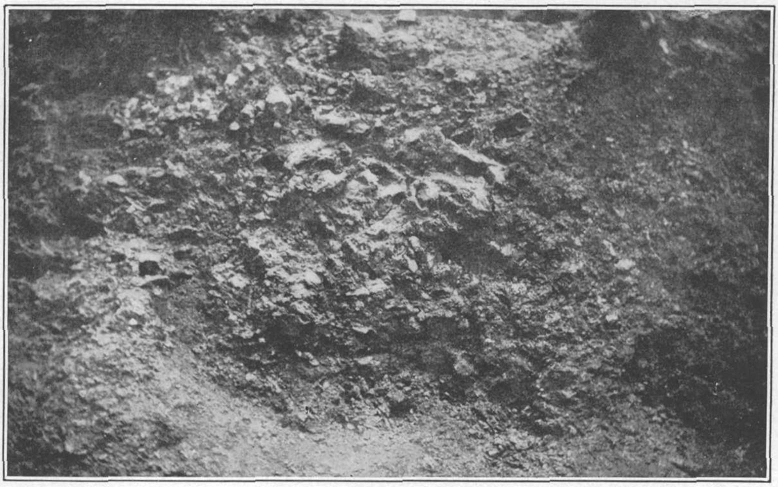
A. ABANDONED OPEN CUTS AT TANNEHILL BROWN-ORE MINE.

Showing pinnacles of Conasauga limestone and residual clay, from which ore has been stripped.



B. FACE OF CUT AT HOUSTON BROWN-ORE MINE.

Showing reef of folded Conasauga limestone; residual clay to left, ore to right.



C. SOLID MASS OF ORE AT HOUSTON BROWN-ORE MINE.

have been noted in this valley between the northeastern limit of the main Coastal Plain deposit and the Champion district, 60 miles farther northeast, where traces of sand and gravel, possibly remnants of Coastal Plain material, are associated with the rown ore.

M'MATH AND GREELEY.

he McMath and Greeley workings are about 1 mile southwest of Goethite, on the ınch of the Louisville and Nashville Railroad that runs there. The ore deposit ociated with Cretaceous material here is very similar to that at Goethite, but the vering of red loam of the Lafayette formation, 10 to 15 feet thick, does not appear o carry much ore. Six double washers were in operation at this place in 1895, but have since been removed and the workings closed. Recent prospecting has revealed large quantities of ore below the levels of the old workings, and it is expected that operations will be resumed in the near future by the Tennessee Coal, Iron, and Railroad Company.

HOUSTON.

The Houston mines, operated by the Republic Iron and Steel Company, in the SE. ¼ sec. 35, T. 20 S., R. 6 W., consist of four or more large cuts, which afford the finest kind of illustrations of Conasauga limestone reefs with brown-ore deposits against them. (See Pl. XIII, *B*.) Only one type of ore appears to be important here, viz, the type (a) or pre-Lafayette material. The Conasauga limestone reefs have a trend N. 35° E. Their strata range from a fraction of an inch to 3 or 4 inches thick and dip in general steeply southeast, but are overturned in many small sharp folds. The vertical relief in the old limestone surface, as indicated by the open cuts, is at least 75 feet. The old limestone surface is nearly everywhere covered by residual clay, in places showing the shaly structure of the original limestone, even to the folds. On steep sides of the reefs the residual clay may be but a few inches to a foot or two thick, but in the hollows between the reefs it may be 20 feet or more thick. On this residual clay the brown ore rests in cellular masses, interbedded with some yellow clay, and a few small pockets of black clay. In a few places the ore lies directly on the limestone without any residual clay between. The masses of brown ore contain but little foreign matter, and they are almost continuous in the pits. (See Pl. XIII, *C*.) Over an irregular surface of brown ore lies the red loam of the Lafayette, reaching a thickness of 25 feet in places. Over the high points of the limestone reefs the ore extends higher than otherwise and outcrops at the grass roots in several places. While affected somewhat by the undulations of the surface of the limestone, the brown ore may be said to fill out the inequalities in that surface rather than to form a blanket with a parallel surface. Experience has shown that the heaviest ore deposits lie banked on the southeast sides of the limestone reefs. In the largest cut the ore extends down to a point more than 80 feet below the top of the hill. Test pits east of this cut show limestone within 20 feet of the surface, and thus indicate the presence of a buried limestone ridge in that direction. The ore is worked by steam shovel from two levels. The character of the workings and the relations of ore and limestone are shown in Plate XIII, *B* and *C*.

STANDIFORD.

The Tennessee Coal, Iron, and Railroad Company operates the workings at Standiford. The ore mined appears to be of the two types described at Goethite. The clay and sand of the Tuscaloosa formation are present, associated with and apparently overlying the ore in places. Loam of the Lafayette caps the hills and is 3 or 4 feet to more than 30 feet thick. On the northwest side of the largest cut Conasauga limestone is exposed, weathered to clay and shale on the outer edges. One "horse" of residual clay with a thick deposit of ore on it occurs in the southwest part of the main cut, but otherwise there is little evidence here of the rock floor below the ore deposits. The deepest cut is still in ore, and evidently most of the workings have yet to reach the limestone.

A bowlder of marcasite weathered on the surface to ferrous sulphate was observed in this cut, and black clay is another accessory mineral that is present in abundance. The ore is loaded by steam shovel into tram cars, which are hauled from the cuts to the main track by mules. Dinkey locomotives then gather up the ore trains and haul them to the washer. Analyses of the ore from this locality are given on page 169.

MARTABAN.

The Martaban mine, operated by the Tennessee Company, about one-half mile south of the Houston mine, is a cut with a maximum depth of about 60 feet. Ore of type (a) only is present here, with a thickness reaching 25 feet in places. The ore is uncomformable upon Conasauga limestone, with a surface of residual clay at the contact. This clay grades within a few feet into the limestone, which has a platy structure that can be traced to the surface of the clay where it has not been disturbed. A few ferruginous bands occur in this clay. The ore itself is in mammillary, dense lumps, and also in honeycombed masses that in places simulate strata. Associated with the ore there are locally beds of yellow and blue laminated clay that, except for close inspection, might be mistaken for the beds of residual clay of the Conasauga. In places over the ore lie the laminated white and pink clays of the Tuscaloosa formation, and in others the red loam lies directly on the ore. There is a small amount of black clay associated with the ore near its contact with the residual clay. The red loam is 3 to 20 feet thick and it overlies the ore and the variegated clay unconformably. It involves stripping to a thickness of 20 feet in places. The ore is mined by steam shovel.

EAST GILES.

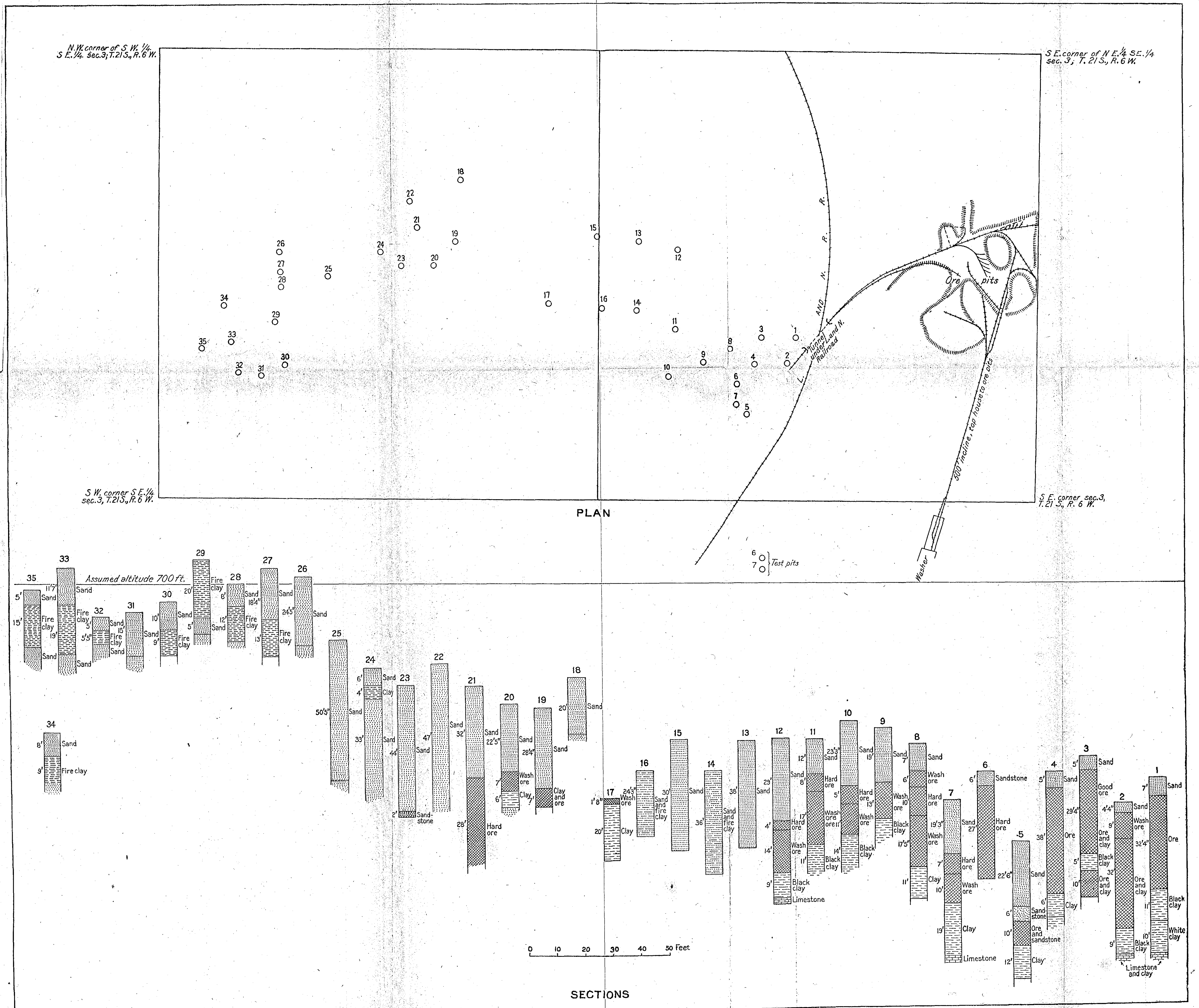
The Tennessee Company also has property at East Giles. It joins on the east the Giles mine of the Central Iron and Coal Company, and the charcteristics of its deposits are similar to those at that mine, which is described below. Although a certain section probably would not be repeated anywhere within 100 feet in the quarry, the following section is fairly representative of the beds exposed there:

General section at East Giles mine.

	Feet.
Loam, red (Lafayette) with a few streaks of light shaly clay and sandy ore (stripped in mining)	6–10
Clay, laminated, white to pink (Tuscaloosa?), with a few bands of loam and sandy ore	10–20
Sand, white, coarse, micaceous, with bands one-fourth to one-half inch thick of ferruginous sandstone and conglomerate	5–6
Brown ore, sand, gravel, and laminated clay that becomes black toward the bottom	25–40
Clay, residual, light-colored (Conasauga)	1–10
Limestone (Conasauga), shaly, thin-bedded, and contorted.	

There is a sharp separation between the beds regarded as Tuscaloosa and the Lafayette, their contact being unconformable, yet they bear a slight resemblance to each other near the contact, since the Lafayette may contain some reworked Tuscaloosa in its lowest part. The top of the brown ore is also irregular. In places it rises nearly to the top of the laminated clay and seems to be associated with it.

Although this is a new opening, a comparatively large production is maintained from it. Before the East Giles and Martaban mines of the Tennessee Company were opened systematic prospecting had blocked out the deposit that was to be worked, extensive stripping laid bare the ore beds, settling ponds were constructed, and railways and washers were built. In a word, the mine was fitted to produce large quantities of ore from the start. The ore runs a trifle higher in iron than that from the other washers of the Tennessee Company in this district.



PLAN OF BROWN-ORE WORKINGS AND SECTIONS OF TEST PITS, CENTRAL IRON AND COAL COMPANY, GILES, ALA., 1906.

GILES.

The present active workings of the Central Iron and Coal Company are east of the Louisville and Nashville Railroad at Giles. (See Pl. XIV.) Formerly extensive mining was carried on west of the railroad and southwest of the present pits, but the deposits there have been nearly cleaned out and the workings abandoned. In the pits at Giles the ore worked is of type (a), associated with Cretaceous clays. It is overlain directly by Lafayette materials consisting of deep red loam at the top and white clayey sand at the bottom. The red loam reaches a thickness of 30 feet in the hill at the north end of the quarry. The brown ore is in brittle honeycombed masses and also in loose bowlders, concretions, and gravel. It has a vertical range probably of 100 feet, due to the irregularity in its floor, but the actual thickness is probably less than half as great. The ore is underlain in the whole open cut by thin-bedded to shaly Conasauga limestone with a very uneven surface. The surface of the limestone varies 50 feet or more in altitude within the pits. Several knobs of limestone rise high into the ore masses which surround them. Between the ore and the limestone, or over the decomposed surface of the limestone, is everywhere a residual clay, with the banded structure of the limestone and its shaly layers well preserved. This residual clay ranges from 1 to 10 feet thick. Where the limestone lies flat the clay may represent a greater thickness of limestone beds, but usually the limestone is highly tilted and the clay is in the same position, representing the weathered edges of the rock, into which it can be traced, layer for layer. The brown ore lies directly against this lime-leached residual clay, filling the hollows in the old surface and forming rich ore banks against the buried ridges and pinnacles. In a few places thin bands of iron oxide were observed within the clay, following its bedding planes. Such bands are not present in the original limestone and are thought to be secondary in the clay. The iron formerly disseminated through the limestone may have been concentrated into the clay. Intimately associated with the ore is a black "clay." This "clay" entirely surrounds masses of ore, beds of it lie above or below masses of ore or at one side of it, and the "clay" may even fill cavities in the ore. In many places this "clay" is below a heavy cover of ore and Tertiary sand and conglomerate, and thus is evidently not an infiltration of organic surface mold. Analyses of samples of it from this pit, given on page 155, show no organic matter, but do show the presence of iron sulphide. Tight cavities in the ore are found partly filled with a finely divided material which when moist is white, yellow, or red ooze, but when dry is a thin film of powder within the cavity. Besides the black "clay" there are, accompanying the ore, and perhaps contemporaneous with it, some masses of light-colored clay and sand.

At the clay pits in West Giles there are several sandy brown-ore bands above the variegated Tuscaloosa(?) clays. These ore bands lie in cross-bedded sands, and probably represent the Lafayette or type (b) ore.

WEST PANOKA.

Southward from Giles, west of the Louisville and Nashville track, mining has been carried on in former years in a thin deposit of brown ore that underlies 5 to 15 feet of red loam. The ore was mixed with sand and clay and lay not far above cherty shale of Cambrian age. This cut is now abandoned and the washer removed.

WOODSTOCK.

Near Woodstock, in the S. ½ sec. 16, and the NW. ¼ sec. 21, T. 21 S., R. 16 W., are some recently opened brown-ore cuts and pits on property belonging to Robert Hayes, of Woodstock. The cuts are in the side of a low hill composed of unconsolidated deposits. Twelve to 15 feet of beds are exposed, consisting of brown ore in curving bands within clay. The ore becomes richer with depth. The opening is cut down to a level where considerable water seeps in and does not reach the bottom of the ore-bearing material nor disclose any limestone. In a ditch dug to drain the property brown ore has been disclosed in a solid bed several hundred feet long. The clay associated with the upper part of the ore is light yellow to pinkish, and is smooth and nearly free from grit. In this clay are thin plates of white, brown, and black chert. Some of the chert is highly ferruginous and grades into ore. In a few test pits recently sunk 12 to 17 feet or ore were found, interbedded with clay. The ore mined here is reported to carry from 42 to 50 per cent iron. The ore is hauled to a siding on the Alabama Great Southern Railroad, about one-half mile distant.

WOODWARD IRON COMPANY.

Near the middle of sec. 9, T. 21 S., R. 6 W., the Woodward Iron Company has done some very systematic prospecting, and an ore body trending northeast-southwest, 300 to 1,500 feet wide and more than 4,000 feet long, ranging from 1 to 32 feet thick, but in general from 4 to 15 feet thick, has been proved. The cover is composed in part of loam of the Lafayette formation and possibly some Tuscaloosa materials, the total thickness being in general between a few inches and 20 feet, but running in one place to 47 feet. A few holes struck no ore at all, and several encountered very hard ore at water level and were driven no deeper, so that it is not known just how thick the ore may be at those places. Limestone, probably Knox, and residual clay were found below the ore in several pits. Clays of the Tuscaloosa formation are found in abundance just northwest of the ore-bearing ground. A few sections of typical prospect pits are given herewith.

Sections in SW. ¼ NE. ¼ sec. 9, T. 21 S., R. 6 W.

(1.)	Feet.
Sandstone	6
Sand	24
Clay	5
Ore	2
Water.	

(2.)	
Loam	20
Sand	18
Ore (bottom not reached)	12

(3.)	
Loam	12
Ore	3
Clay	16
Limestone.	

(4.)	Feet.
Loam	5
Ore	24
Clay	15
Limestone.	

(5.)	
Ore	6
Clay	34
Limestone.	

(6.)	
Clay	30
Water.	

Sections in NE. ¼ SW. ¼ sec. 9, T. 21 S., R. 6 W.

(1.)	Feet.
Loam	20
Ore (bottom not exposed)	10

(2.)	Feet.
Loam	16
Ore	20½
Ore and water.	

Sections in NW. ¼ SE. ¼ sec. 9, T. 21 S., R. 6 W.

(1.)	Feet.
Loam	28
Ore	2½
Clay	9¾

(2.)	Feet.
Loam	30
Ore	5
Clay	13

In one prospect the ore was found to be highly manganiferous. Below 43 feet of loam was found 3 feet of brown ore, then 5½ feet of clay, then 4 feet of manganese ore and brown ore mixed, and the pit stopped in ore and water. Analysis showed the material in the lower bed to carry 45.8 per cent insoluble matter, 15.2 per cent iron, and 18.2 per cent manganese.

In connection with the prospecting of this property, a detailed topographic map on a scale of 100 feet to 1 inch, with 5 to 10 foot contour intervals, was prepared. By means of this map it has been possible to select the best sites for a storage dam, pump house, washer, and to lay out pipe line, railway tracks, settling pond, etc., besides plotting the location of the test pits at their relative altitudes.

This property is connected with the mineral division of the Louisville and Nashville Railroad at Chamblee by a spur about 2 miles in length.

In January, 1909, the Woodward brown-ore workings consisted of several open cuts in the hillsides at or above the level of the private railroad line. The ore is exposed in places to a depth of 15 feet. No ore is exposed to the underlying limestone or its residual clay. Little or no stripping is required in places, while in others 10 feet of stripping is necessary. The cover normally consists of a reddish residual clay, mixed with surface débris. Some red loam of the Lafayette is present. The ore consists of (*a*) "wash ore"—that is, of loose, small-sized fragments, and loose irregular-shaped masses, all imbedded in reddish clay or reddish to light-yellow sand and clay—and (*b*) masses of hard, compact ore that are continuous for some distance. Associated with and inclosed by these large masses of ore are pockets of tough yellow clay, showing faint laminations in places. This clay and the beds of laminated Cretaceous clay that are also found near the ore in several railroad cuts are indiscriminately termed "white horse" by the miners. No true "white horse" or clay bottom was observed in these workings.

The massive ore is so compact and hard that it can be worked only very slowly and with great difficulty by pick and shovel, and blasting is therefore employed. Within masses of this ore were noted cavities in which redeposition of limonite had taken place through the action of percolating water, and some of the cavities contained fine-grained yellow sand.

The ore that was produced from here at the beginning of 1909 was worked out by hand in connection with blasting, and was screened by hand over an inclined, stationary screen of coarse mesh. Steam shovels will be used when the washer is ready to handle ore.

The washer at this place, nearing completion in January, 1909, is of a very substantial character. It is described on pages 167–168. It is expected to wash 500 short tons per ten-hour day.

PROSPECTS AND ORE RESERVES.

In addition to the mining operations and prospecting just described, prospecting has been carried on actively in many other parts of the district, especially in areas adjacent to known deposits of ore. The ore is extremely variable as to size and location of workable masses, and it is also characteristic of the deposits that the appearance of the surface, which is generally covered by a forest of pine and oaks, rarely affords reliable indications of the extent or value of the ore, if any be present. Test pits or wells, 3 to 4 feet in diameter, must therefore be sunk; but when the residual clay that overlies the Conasauga limestone is reached no pit need be dug deeper, for no more ore will be found.

At the Giles locality, where active operations cover a total of, perhaps, 10 acres, the ore does not reach the surface, except, possibly, in a deep gully here and there. West of the present openings, beyond the Louisville and Nashville Railroad track, nearly 40 small test pits or wells were sunk, ranging from 15 to 65 feet deep, grouped so that the individual pits are 50 to 100 feet apart. In this manner the value of a given area, such as the S. ½ SE. ¼ sec. 3, was definitely determined. The general plan of open-cut mining as it existed in 1906, and the distribution of prospect holes and their character on this property, are illustrated in Plate XIV.

Portions of secs. 28 and 29, T. 21 S., R. 6 W., south of Bibbville, are reported to carry brown ore, and, as previously stated, some ore is reported in the SE. ¼ sec. 21, T. 20 S., R. 5 W. near Kimbrel.

Southwestward, beyond the area of the Woodstock district as mapped in Plate XII, there is an area of 30 square miles or more that has not been thoroughly prospected. Geologic conditions are similar to those in the Woodstock district, except that the Coastal Plain sediments become thicker toward the southwest. Judging from the associations of the ore where it is worked, there is reason to believe that deposits of brown ore may be found near the contact of the Coastal Plain sediments and the Conasauga limestone and Knox dolomite. It is not probable, however, that such deposits could be worked where the Coastal Plain deposits are several hundred feet deep, but where the cover of clay, sand, and loam is 20 to 50 feet deep prospecting can be carried on with reasonable hope of ultimate success.

During the present survey considerable brown-ore débris was noted over the hills that are covered by loam of Lafayette age, several miles south of Dudley. In sec. 24, T. 22 S., R. 8 W., the Chickamauga limestone is exposed along Reedy Branch, and on its upturned edges sand and loam of the Lafayette appear to carry considerable ferruginous material, judging from surface indications. An average sample of this loose material was collected from the M. C. Pierson place, and on analysis by R. C. Hodges, of the Alabama Geological Survey, was found to carry 47.6 per cent iron and 15.62 per cent silica.

Experienced miners of brown ore have found that it is good economy to test thoroughly a piece of ground before any development work is undertaken, and that it is likewise advisable to push prospecting for some distance beyond the point where an ore body terminates, provided limestone underlies clays, sands, and loam, such as those in which the ores are usually found. The cost of prospect pits 30 to 36 inches in diameter, not exceeding 50 feet in depth, ranges from 35 to 50 cents per foot. The value of a detailed topographic map in connection with prospecting of brown ore, as well as in later development work, can not be overestimated. It is an expensive form of mapping, but it has been found to be a true economy where large developments are planned. The Woodward Iron Company and the Tennessee Coal, Iron and Railroad Company have undertaken much of this detailed mapping in the Woodstock and Champion districts. A step farther in the right direction would be the careful geologic mapping of the boundaries of the formations associated with the ores.

The probable northwest and southeast limits of deposits of value in this district are indicated on the map (Pl. XII) by the outer boundaries of the Chickamauga limestone, although probably very little ore will be found beyond the boundaries of the Knox area. For outlines of the area possibly carrying brown ore southwest of the Woodstock district, see the general map (Pl. II). The same geologic boundaries will define the possibly productive field.

CHAMPION AREA.

LOCATION.

The Champion brown-ore mines are in Murphrees Valley, 5 miles northeast of Chepultepec, which is the nearest point shown on the geologic map (Pl. II) accompanying this bulletin. The present active workings are in secs. 32 and 33, T. 12 S., R. 2 E., and secs. 4 and 5, T. 13 S., R. 2 E. They comprise a strip about 1½ miles northeast-southwest and one-third mile northwest-southeast.

GEOLOGIC RELATIONS.

Only brief notes can be given here regarding this deposit, since it is beyond the area properly included within this report, and consequently was not studied in detail. The brown-ore deposit at Champion lies along a northeast-southwest ridge. The ore overlies Cambro-Ordovician siliceous and cherty magnesian limestone. The ore is imbedded in tough red clay, mixed with much chert, and in certain test pits along the northwest margin of the deposit white quartz sand and waterworn gravel, characteristic of Lafayette deposits, have been found. On the southwest margin of the brown ore Clinton strata are faulted against the Cambro-Ordovician limestone. This limestone is seamed with minute fractures, and where weathered the noncherty portion decomposes to a light-colored, friable, sandy material rather than to a clay. The residual material in contact with the limestone is thus easily broken down and worked into the overlying clay, and therefore less of this residuum or "white horse" underlies the ore here than at Woodstock. The masses of ore-bearing clay lie in depressions on the limestone surface and are banked up against reefs and bowlders of the limestone. The ore-bearing material seems partly to overlie the Clinton formation, which forms a low ridge adjoining the siliceous limestone on the southeast.

The age of the red clay carrying the ore was not determined. This clay carries much nonfossiliferous chert, evidently residual from the Cambro-Ordovician limestone, and the most natural inference would be that the clay is itself residual from the cherty limestone. The fact, however, that white sands and gravels resembling Lafayette materials have been found in or below this red clay suggests that the clay may not be wholly residual from the older rocks. In its broader features the whole deposit suggests the concentration by stream action of these materials in an ancient channel, now completely obscured. The position of the fault scarp may have influenced the location of the deposits.

CHARACTER OF THE ORE.

The ore occurs in fine fragments, gravel, dornicks, and in some large masses. It is embedded in clay and chert, with a little sand and gravel. The ore outcrops on top of the ridge in many places and lies scattered loosely over the surface. Thicknesses of 40 to 50 feet of ore-bearing material have been mined in places, and test pits in the bottoms of old levels show the presence of ore still lower. The surface of the underlying siliceous limestone is irregular, with reefs and bowlders rising between pockets of ore-bearing dirt. The mantle of unconsolidated material above the limestone is not all ore bearing. There is considerable barren chert and clay, and in places the white sand and gravel mentioned above occurs in the old open cuts. The wash ore in this deposit is comparatively rich, and the workings have been recently reopened after an idleness of many years.

The ore after concentration carries from 43 to 52 per cent metallic iron, 5 to 18 per cent silica, 2 to 4 per cent alumina, 0.6 to 0.85 per cent manganese, 0.18 to 0.3 per cent phosphorus, and 6 to 7 per cent water.

As at present handled, 1 cubic yard of dirt appears to yield generally from 0.60 to 0.75 ton of ore. There is practically no stripping.

DEVELOPMENTS.

The brown-ore property at Champion is owned jointly by the Sloss-Sheffield Steel and Iron Company and the Tennessee Coal, Iron and Railroad Company, and is now operated by the latter company. A new log washer has been built with a capacity of 500 to 600 long tons per day, and two steam shovels are operated to mine the ore. The ore is hauled by locomotive and tram cars to the washer flume. In the washing process the ore passes by gravity from the top of the flume until it is loaded into cars on a siding of the Louisville and Nashville Railroad.

MINING AND CONCENTRATION METHODS.

In both the Woodstock and the Champion areas the brown ore is mined from open cuts. The cuts are usually begun in a hillside, but if the ore extends below the valley level the openings are deepened, and thus some of them, for instance at Giles, are deep pits which have to be drained by pumping. A little mining is done by hand where the ore is rich and there is little or no cover. In mining by hand the material is loosened by pick and shovel, or by blasting, and milled down into tram cars, or, if no washer is operated, the ore may be first screened through a stationary sand and gravel screen before loading. Most of the ore, however, is mined by steam shovel. The steam shovel is economical and efficient in stripping and for mining ore except where the bottom is very irregular. In the Woodstock area the bottom is irregular in many places, owing to the projecting reefs and masses of the underlying limestone.

The steam shovels used in brown-ore mining range from 20 to 60 tons in weight, and handle from 1¼ to 2½ cubic yards per dipper.

The brown ore is separated from the impurities that are mined with it, such as loam, sand, gravel, and clay, by a system of breaking, washing, picking, and screening. Complete separation of impurities is not effected by this process, for the washers and screens are essentially sizers rather than concentrators. Hand picking succeeds in eliminating some of the coarse impurities that are retained by the screens, but there is no way of saving the fine ore that is lost by the screens. In the Woodstock district only a small proportion of fine ore is wasted, however, and analyses of such waste material have shown that it generally runs lower in iron and higher in silica than the ore recovered.

A description of the latest washer to be installed in the Woodstock district, that of the Woodward Iron Company, at Docray, will serve to illustrate the standard method and equipment employed for cleaning and concentrating the brown ore. Gravity carries both ore and water through the whole process from the top deck of the washer until the cleaned ore is delivered to the railroad cars and the water to the settling pond. The washer is built in two sections on a hillside above the Louisville and Nashville Railroad track. Ore is brought from the cuts in steel, bottom-dump cars. The tracks of the mine road terminate on the top deck of the washer. Three cars may be dumped at once on this deck. The ore falls through to a steel-shod incline below, 80 by 20 feet, pitching 30°. The ore slides down the incline over a bar screen 12 feet wide, pitching at the same angle as the incline. The bar screen is constructed of steel rails, 4 inches by 12 feet, spaced 3 inches apart.

The screenings fall into a trough or flume of water. The rejects fall on a conveyor belt, 36 inches by 80 feet. This belt may serve as a picking belt if necessary. The belt discharges into a No. 7½ Gates gyratory crusher, which discharges into the same flume that received the screenings. This flume is lined with a U-shaped chilled-iron channel, 27 inches wide at the top and 13½ inches high inside. The flume is 96 feet long, pitches about 2¼ feet in 12 feet, and is fed by a 6-inch stream of water under about a 50-foot head. This flume discharges its ore into a revolving conical screen 12 feet long by 3 and 3½ feet diameters. The axis of the screen is horizontal with the small end toward the flume. Inside the screen is a spiral retarder, and the ore that passes the perforations, which are 1½ inches in diameter, is divided between two sets of washers below. The rejects from the screen fall on a conveyor belt and are carried to a chute which divides the material between two revolving sand screens below. Each of the two log washers consists of two logs 29 feet long, octagonal in section, 18½ inches between faces. The ore after passing through the log washers goes also to the sand screens. These two screens are of wire, with ⅛-inch mesh. They are 6 feet long, conical in shape, 31 and 37 inches in diameter at the ends. The ore from each of the sand screens passes on to a picking belt, 36 inches by 30 feet. From these belts the lumps of foreign material, such as clay, chert gravel, sandstone, etc., are removed by hand. The picking belts discharge into a storage bin built directly over the Louisville and Nashville Railroad track. This bin holds 2 carloads of ore, and dumps into cars below. The muddy waste water passes to a mud flume beyond the railroad track. This mud flume carries the waste 1,500 feet up a small valley to the head of the settling pond, which is about one-half mile in length. Water is supplied from a storage reservoir above a dam on Kennedy Creek, about three-fourths mile below the washer, and the clear water from the lower end of the settling pond will be collected also by this storage reservoir. Two pumps with 6-inch suction and 5-inch discharge will be employed, and the water will be pumped to two 25,000-gallon tanks on the hill about 50 feet above the washer. This washer is designed to handle 500 short tons of ore in ten hours.

At most of the other washers in the Birmingham district the ore is first delivered to a horizontal grizzly or bar screen, similar to the inclined screen described above. The ore is then sledged so that it all passes the openings in the grizzly and it is not subsequently crushed.

Owing to the variation in thickness of stripping, the quantity of clay and gravel in the ore, and the extent of barren material between pockets of ore, there is necessarily a wide range in the ratios between cubic yards of dirt moved to tons of ore washed. Careful records have been kept by the several operators and monthly averages often show great variations. Including stripping, the high and low ratios for dirt moved to ore washed during certain months in 1908, considering the Woodstock and Champion areas as a whole, are as follows: High ratio (for poor ore), 6 cubic yards of ore-bearing material and stripping to 1 long ton of ore washed; low ratio (for rich ore), 1.29 cubic yards of ore-bearing material and stripping to 1 long ton of ore washed. The present average appears to be about 3.5 yards to 1 ton. If the stripping be removed, 1 cubic yard of dirt will yield from 0.3 to 1.6 tons of washed ore.

Climatic conditions in Alabama are particularly favorable to the mining of brown ore throughout the year. Ice seldom accumulates so as to interfere with steady operation of washers in the winter time.

Analyses of washed brown iron ore, Woodstock and Champion areas, Birmingham district, Alabama.

Description of sample.	Authority.[a]	Fe.	SiO_2.	Al_2O_3.	Mn.	P.	H_2O.
Tannehill, average, December, 1907	R	45.57	12.37	4.13	......	......	......
Tannehill, average, December, 1908	R	43.31	17.75	5.02	......	......	......
Houston, average, December, 1907	R	44.63	15.92	4.69	......	......	......
Houston, average, December, 1908	R	47.47	12.90	4.45	......	......	......
Standiford, average, June, 1906	T	46.06	14.85	3.47	0.92	0.57	2.29
Standiford, average, December, 1908	T	41.92	15.67	3.98	.64	.59	6.60
Standiford, high shipment, 1908	T	44.45	14.00	3.55	.48	.64	6.40
Standiford, low shipment, 1908	T	39.10	19.58	3.68	1.08	.51	5.50
Martaban, average, May, 1906	T	42.14	19.46	5.38	.59	.21	2.36
Martaban, average, December, 1908	T	44.47	12.38	4.22	1.19	.93	6.91
Martaban, high shipment, 1908	T	47.31	10.26	4.41	.26	.53	4.49
Martaban, low shipment, 1908	T	42.13	17.98	5.01	.94	.40	6.0[illegible]
East Giles, average, June, 1906	T	49.62	11.22	3.75	.71	.57	1.42
East Giles, average, December, 1908	T	45.90	11.20	4.10	.59	.46	6.20
East Giles, high shipment, 1908	T	48.29	9.75	3.26	.74	.32	5.50
East Giles, low shipment, 1908	T	43.09	15.67	4.45	.59	.49	6.45
Greeley, stock house, sample	M	43.08	21.04	....	......	.45	12.60
Giles, working analysis, 1906	C	44.47	14.05	4.20	.98	.56	3.20
Giles, working analysis, 1906	C	40.95	19.22	4.07	......	......	.95
Woodward Iron Company, analysis,[b] 1908	W	49.00	14.60	4.80	......	.63	......
Champion, average, December, 1908	T	47.19	12.50	2.44	.72	.26	7.10
Champion, high shipment, 1908	T	52.04	5.18	2.13	.84	.24	6.05
Champion, low shipment, 1908	T	42.76	18.13	3.72	.60	.18	7.20

[a] Authorities: C, Central Iron and Coal Company; M, McCalley, Henry, Report on the valley regions of Alabama, pt. 2, 1897, p. 462; R, Republic Iron and Steel Company; T, Tennessee Coal, Iron and Railroad Company; W, Woodward Iron Company.

[b] Dry-screened ore.

FUEL AND FLUXES.

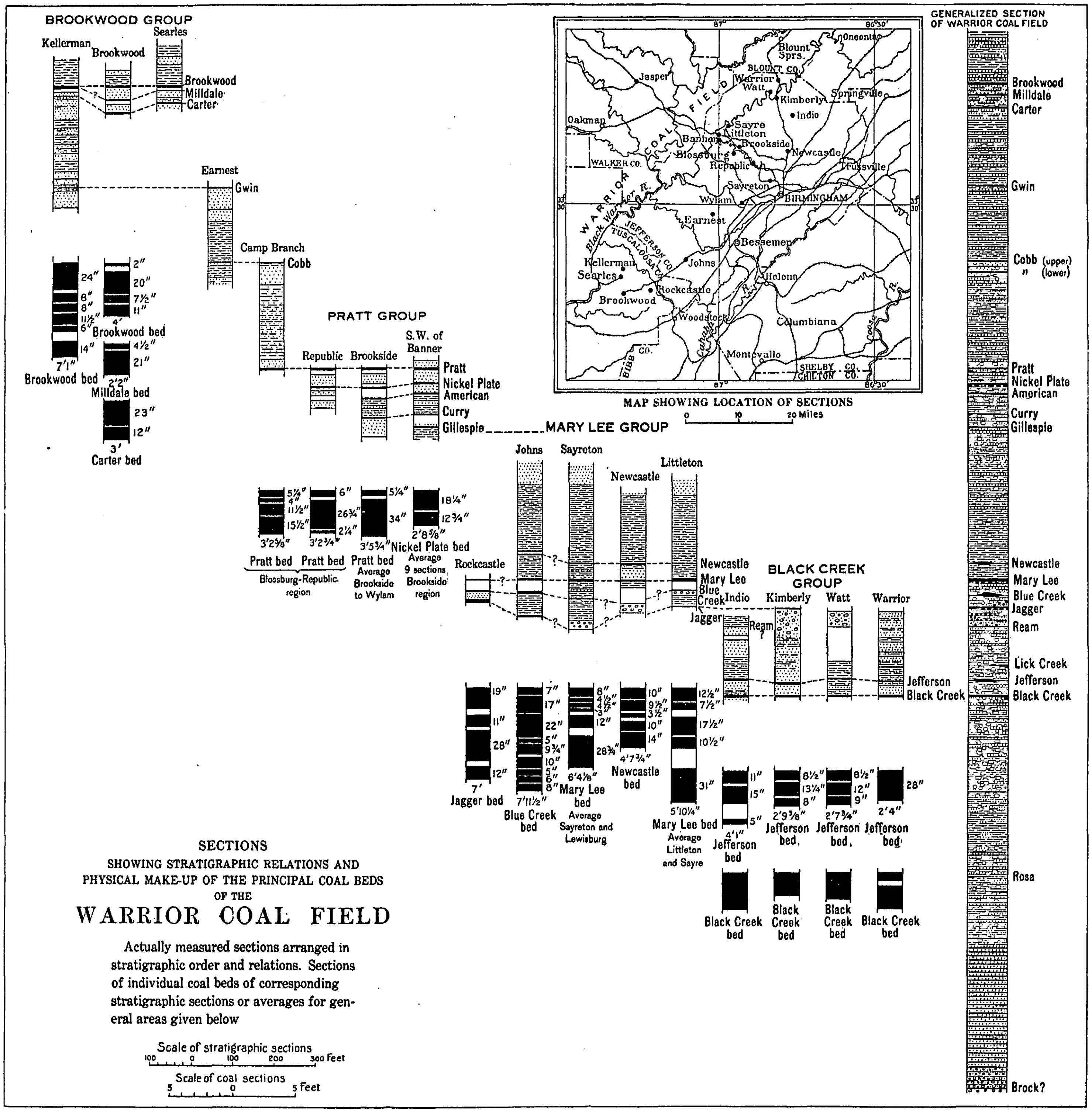
By Charles Butts.

FUEL.

THE COKING-COAL BEDS.

LOCATION AND LIMITS.

The fuel used in the blast furnaces of Alabama is coke, at present made exclusively from coal mined in the Warrior coal field, the southeast boundary of which is shown on the map (Pl. II). Most of the coke is made from the coal of the Pratt and Mary Lee beds. The last-mentioned bed is commonly known in the region as the "Big seam." Under this designation may be conveniently included the Blue Creek bed of the Little Basin and the Jagger bed mined from Yolande to Rock Castle. Whether the Mary Lee, Blue Creek, and Jagger beds, as the names are used by mining men at the different localities where these supposedly different beds are mined, are really the same or not is a question that can not be definitely answered, but it is certain that they lie at nearly the same geologic horizon, and for the present purpose may be treated as the same, since there is only one "big seam" known at any one locality. (See sections, Pl. XV.) A smaller amount of coke is made from the three beds of the Brookwood group of coals mined in the vicinity of Brookwood. The Newcastle bed, of limited extent near Newcastle, is also a good coking coal. Coal from a number of the beds of the Cahaba coal field outlined on the map (Pl. I) also yields good coke. In fact the first coke made in the Birmingham district was made from the coals of this basin. Owing, however, to the generally higher amount of volatile matter in the coals of the Cahaba basin than in those of the Warrior basin, the yield of coke from the coals of the Cahaba was less, and the coke therefore more expensive, than that from the coals of the Warrior field, so that coking the Cahaba coals has been nearly, if not quite, discontinued. In this discussion therefore only the coke from the coals of the Warrior field will be considered.



SECTIONS
SHOWING STRATIGRAPHIC RELATIONS AND PHYSICAL MAKE-UP OF THE PRINCIPAL COAL BEDS OF THE

WARRIOR COAL FIELD

Actually measured sections arranged in stratigraphic order and relations. Sections of individual coal beds of corresponding stratigraphic sections or averages for general areas given below

GEOLOGY.

The stratigraphic relations of these coals is shown by the following very generalized section:

Section showing the stratigraphic relations of coking-coal beds, Warrior field, Alabama.

	Feet.
Brookwood coal	5
Sandstone	35
Milldale coal	2½
Sandstone	40
Carter coal	2½
Shale and sandstone with thin coals	700
Pratt coal	3½
Shale and sandstone	400–700
Mary Lee coal (possibly same as Jagger and Blue Creek at Adger, Yolande, etc.)	6
	1, 190–1. 490

Over most of the Warrior field the rocks lie nearly flat. (See fig. 1 and description on p. 25.) Along the southeast margin, however, they vary in dip along the outcrop from 15° to 80° NW. The zone of highly inclined rocks rarely exceeds one-half mile in width. From the neighborhood of Birmingham southwestward the Warrior field is affected by normal faults running at right angles to the southwest margin. These faults are the most serious obstacles to mining. The roof and floor of the coal beds of this field are almost everywhere strong.

The physical make-up of the several coal beds differs greatly. The Pratt bed and the Milldale and Carter beds of the Brookwood coal group are comparatively free from impurities in the form of clay partings, etc., while the Brookwood bed and the various beds of the Mary Lee group are very dirty, the coal being separated into many bands by partings of clay and shale. The following sections are intended to illustrate these features, as well as show the variations in the beds at different places:

Section of the Mary Lee bed near northern outcrop in center of sec. 13, T. 15 S., R. 4 W.

	Ft.	in.
Shale.		
Coal	1	½
Clay		3
Coal		6
Clay	1	6
Coal (bottom not seen)	1+	
	4	3½

Section of Mary Lee bed at Thomas mine at Littleton.

	Ft.	in.
Sandstone.		
Shale	1	
Coal	1	
Parting		1
Coal		6
Clay (average 5 inches)		1–7
Coal	1	7
Parting		¾
Coal		5½
Clay	1	7
Coal	2	2½
Shale		1½
Coal		8½
	9	10¾

Section of Mary Lee seam at Sayreton mine.

	Ft.	in.
Shale.		
Coal	1	2
Bone		¼
Coal		4½
Rash		¾
Coal		3
Rash		¼
Coal		2
Clay		1
Coal		4
Bone		¼
Rash		1
Coal	2	10½
Shale.		
	5	5½

Section of Mary Lee seam, Sleepy Hollow, near Blossburg.[a]

	Ft.	in.
Shale.		
Coal	1	10½
Shale		2½
Coal		2
Shale		2
Coal		2
Shale	1	7
Coal	2	4½
Shale		8
Coal		2
Shale	2	10½
Coal	3	
Shale		6
Coal		5½
Shale and clay.		
	14	2½

Section of Blue Creek bed at Adger mine.

	Ft.	in.
Shale.		
Coal	1	4
Clay	1	½
Coal	1	5½
Clay		10½
Coal	2	
Shale		¾
Coal	1	3½
Slate		½
Coal		5½
Clay		2
Coal		6
	8	2¾

Section of Jagger seam at Davis Creek mine, Rock Castle.

	Ft.	in.
Shale.		
Coal	1	7
Clay		6½
Coal		11
Rash		3
Coal	2	4
Clay		4½
Coal	1	
	7	

The last section shows the make-up of the "big seam" of the Mary Lee group at the most southern point at which it is well known. The number of such sections as those above might be indefinitely increased and they would all emphasize the fact that the thick bed of coking coal in the Mary Lee group, whether everywhere at the same horizon or at different horizons at different places, is in all places of the same dirty make-up.

The following sections show the physical composition of the Pratt bed:

[a] Bore hole reported.

Section of Pratt bed at Warner mine, Republic.

	Ft.	in.
Shale.		
Coal		6
Bone		3
Coal	2	4
Clay		¾
Coal		10
Clay		5
Coal		10
Clay.		
	5	2¾

Section of Pratt bed at Pratt No. 1 mine, Sandusky shaft.

	Ft.	in.
Sandstone.		
Coal		1¼
Bone		1
Coal	4	5
Rash		4
Shale.		
	4	11¼

Section of Pratt bed at Woodward No. 2 mine, Dolomite.

	Ft.	in.
Coal		10
Parting (slate or bone)		2
Coal	3	9
Parting (slate or bone)		3
Coal	1	8
	6	8

Section of Pratt (?) bed one-half mile west of Adger.

	Ft.	in.
Coal		8
Clay	1	
Coal	2	
Clay	1	8
Coal	1	6
	6	10

The foregoing sections show the Pratt coal to be not only thinner than the coking bed of the Mary Lee group, but also to be much less broken by partings of a deleterious nature.

Below are a few sections of coal beds of the Brookwood group:

Section of the Carter or Johnson bed at mine No. 10, Brookwood.

	Ft.	in.
Sandstone.		
Shale	4	
Coal	1	7
Slate		1
Coal	1	1½
Coal bed	2	9½

Section of Milldale bed at mine No. 7, Brookwood.

	Ft.	in.
Sandstone.		
Shale	4	
Coal		4½
Bone		½
Coal	1	9
Coal bed	2	2

Section of Brookwood bed at central mine, Kellerman.

	Ft.	in.
Shale.		
Coal	2	
Bone		3
Coal		8
Bone		1
Coal		8
Bone		1½
Coal		11½
Parting		½
Coal		6
Shale		9
Coal	1	2
	7	2½

Besides the grosser and more abundant impurities shown in the sections given above, considerable sulphur in the form of iron pyrite is disseminated through the coal as well as occurring abundantly in some of the thin partings. The pyrite in the coal is in the form of thin flakes and laminæ or, elsewhere, in the form of thicker and more irregular bunches or stringers. All these impurities are very deleterious to coke, and it it is absolutely necessary to remove them from the dirtier coals before they will make coke fit for blast-furnace use at all, and necessary in the cleaner beds before the coal will make the best grade of coke.

QUANTITY OF COKING COAL.

Having exhibited the make-up of the different coking-coal beds, it is now possible to compute the average thickness of the coal in each bed. These thicknesses are as follows, considering the coals of the Mary Lee as one bed and those of the Brookwood group as one bed:

Average thickness of coal beds in Warrior field, Alabama.

	Ft.	in.
Average of 24 measurements of coal in the Mary Lee bed	4	10
Average of 31 measurements of coal in the Pratt bed	3	6
Average of 9 measurements of coal in the Brookwood group	3	

The areas in which the different coal beds or group of beds will probably yield good coke are indicated on the map (Pl. I). The Mary Lee coal makes good coke as far west as Horse Creek, where the yield of coke begins to diminish. It is assumed, therefore, that an area about 20 miles wide, extending parallel to the southeastern margin of the Warrior field, from the northern outcrop of the Mary Lee bed to Yellow and Hurricane creeks on the southwest, is everywhere underlain by a thick bed of good coking coal, whether that bed is everywhere the Mary Lee or in some localities, as at Yolande and vicinity, another bed of the same group as the Mary Lee but at a different horizon.[a] This area would include approximately 580 square miles. The Pratt bed yields good coke everywhere. Its extent as a workable bed east of the Sequatchie anticline or Democrat Ridge will probably not exceed 180 square miles, while its known area west of the Sequatchie anticline is bounded on the west by Mulberry Fork of Black Warrior River and Lost Creek, and is about 50 square miles, making in all 230 square miles. The area of the Brookwood group is very hard to estimate, but it may be as much as 50 square miles. It thus appears that the importance of the Mary Lee coal or group of coals far exceeds that of all the other coking coals taken together.

[a] Recent developments have shown that the "big seam" is not so thick as was supposed over a large area extending from Dolomite to Scrap.

Taking the areas and thicknesses given above, together with the fact that a bed of coal 1 foot thick and an acre in extent, or an acre-foot of density 1.35, contains approximately 1,800 short tons of coal, there is obtained the following tonnage in the ground for each of the beds or groups discussed above:

Estimated tonnage of coking coals, Warrior field, Alabama.

	Short tons.
Mary Lee group	3,207,168,000
Pratt bed	827,360,000
Brookwood group	160,800,000
	4,195,328,000

In this computation it is assumed that approximately 100,000,000 tons of Pratt coal have been worked out, leaving a remainder of 827,360,000 tons as given above. No allowance has been made for the amount worked out in the Mary Lee and Brookwood groups. Assuming that 80 per cent of the total coal in the ground will be mined, the yield would be 3,366,262,400 short tons. Assuming further that the coal will yield 60 per cent of coke, the total amount of coke that could be made from this coal would be 2,019,757,240 short tons. On the basis of 1.8 tons of coke to a ton of pig iron, which is derived from a statement of furnace operations of a single company for April, 1906, this quantity of coke would produce 1,122,087,355 short tons of pig iron. To produce this amount of iron at the present rate of production would take six hundred and twenty-five years, but if the production should be doubled every twenty years it would take only eighty-seven years. This result of course can be varied by making different assumptions as to the rate of increase of production. It seems improbable that the production will be doubled every twenty years, so that the duration of iron smelting in the district, so far as dependent upon the local supply of coke, may be regarded as between eighty-seven and six hundred and twenty-five years. As shown on pages 132–133, the estimated total tonnage of iron ore falls considerably below the iron-ore equivalent that might be smelted by the coal estimated to be present here.

The value of the above calculation of the quantity of coke that will be produced in the district must be considered in this connection. It is certain that coal from other beds and from other areas than those involved in the calculation will supply good coke. There are large quantities of good coking coal in the Cahaba basin, in the plateau regions, and in the Warrior basin outside of the areas included in the above calculation. Against the coking coal that can be supplied from these sources must be offset the quantity of coal from the areas of coking coals outlined above that will be used for other purposes than coke. Probably over one-third of the coal mined from the coking coal beds described in the preceding pages is used for steaming and domestic purposes, and this use is likely to be continued. Furthermore, the assumption that the coal of the Mary Lee group, for instance, maintains its thickness and coking qualities in the deeper part of the Warrior basin, where it is entirely unknown, may be erroneous, and the coal may be much thinner and poorer, or worthless altogether, in part of the area. This consideration is offset, however, by the possibility that other beds of the area may thicken with depth and afford a large supply of good coal. It thus appears that there are so many factors of uncertain value entering into the question of the total supply of coking coal and duration of the iron-smelting industry of the district as to render any calculation of that duration of little value. In the writer's opinion, however, the quantity of coking coal obtained in the foregoing calculation is considerably below the true figure. A corresponding factor of the problem is the supply of iron ore, a question that has been treated in this bulletin on pages 132–133.

COMPOSITION OF COKING COALS.

The chemical composition of the Alabama coking coals is shown by the following table of analyses. The samples analyzed were collected in the manner described below and are believed to be fairly representative of the coal. A channel was cut in a fresh face of the coal from top to bottom of the bed, throwing out such impurities as are rejected in mining. In this way 25 to 50 pounds of coal was obtained, which was pulverized and quartered down to a quart sample, sealed in a galvanized-iron can, and sent to St. Louis, Mo., for analysis at the laboratory of the fuel-testing plant of the United States Geological Survey. The analyses given are those of the sample as received at the laboratory, the samples having suffered no loss of moisture by air-drying.

Analyses of samples of coking coals from Alabama.

[Analyses made at the fuel-testing plant of the United States Geological Survey at St. Louis, Mo.]

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
Moisture	3.35	2.49	2.16	2.88	2.91	2.63	3.37	2.20	4.46	3.21
Volatile matter	26.92	27.34	27.11	25.98	24.08	26.49	25.77	24.62	22.30	23.20
Fixed carbon	59.01	57.14	55.47	60.96	53.21	59.63	61.21	60.51	47.98	64.09
Ash	10.72	13.03	15.26	10.18	19.80	11.25	9.65	12.67	25.26	9.50
Sulphur	.67	1.37	.93	.94	.70	.97	.94	.54	1.32	.79

1. Mary Lee seam, Thomas mine, Littleton, Ala.
2. Mary Lee seam, Mary Lee mine, Lewisburg, Ala.
3. Mary Lee seam, Mary Lee mine, Lewisburg, Ala.
4. Blue Creek seam, Adger mine, Adger, Ala.
5. Blue Creek seam, Adger mine, Adger, Ala.
6. Blue Creek seam, Johns mine, Johns, Ala.
7. Blue Creek seam, Johns mine, Johns, Ala.
8. Blue Creek seam, Belle Sumpter mine, Belle Sumpter, Ala.
9. Blue Creek seam, Belle Sumpter mine, Belle Sumpter, Ala.
10. Jagger seam, Yolande mine, Yolande, Ala.

Analyses of samples of coking coals from Alabama—Continued.

	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.
Moisture	4.00	1.60	1.73	2.51	2.68	2.07	2.27	1.83	2.88	2.27
Volatile matter	24.42	24.98	26.37	27.10	25.17	26.80	27.00	29.28	29.56	26.86
Fixed carbon	64.44	68.55	64.96	59.96	61.82	61.28	57.70	57.53	56.91	55.82
Ash	7.14	4.87	6.94	10.43	10.33	9.85	13.03	11.36	10.65	15.02
Sulphur	.76	.51	.89	1.68	1.86	2.13	1.79	4.24	2.04	2.45

	21.	22.	23.	24.	25.	26.	27.	28.	29.	30.
Moisture	2.66	1.63	1.86	3.08	3.16	3.85	1.96	2.35	3.81	2.04
Volatile matter	29.93	30.81	28.52	26.86	25.40	30.80	31.55	32.36	30.19	34.68
Fixed carbon	59.04	64.03	64.73	66.31	67.75	59.70	60.96	58.15	55.99	51.68
Ash	8.37	3.53	4.89	3.75	3.69	5.65	5.53	7.14	10.01	11.56
Sulphur	1.71	.57	2.27	.55	.56	.78	1.11	1.37	1.49	1.57

11. Jagger seam, Abernant mine, Abernant, Ala.
12. Jagger seam, Abernant mine, Abernant, Ala.
13. Jagger seam, Davis Creek mine, Rock Castle, Ala.
14. Pratt seam, Warner mine, Republic, Ala.
15. Pratt seam, Warner mine, Republic, Ala.
16. Pratt seam, Tutweiler No. 4 mine, Pinckney, Ala.
17. Pratt seam, Tutweiler No. 4 mine, Pinckney, Ala.
18. Pratt seam, Pratt No. 16, mine, Cardiff, Ala.
19. Pratt seam, Pratt No. 16 mine, Cardiff, Ala.
20. Pratt seam, Kosmo mine, Mineral Springs, Ala.
21. Pratt seam, Clift mine, Clift, Ala.
22. Pratt seam, Pratt No. 4 mine, Wylam, Ala.
23. Pratt seam, Pratt No. 4 mine, Wylam, Ala.
24. Pratt seam, Woodward No. 2 mine, Dolomite, Ala.
25. Pratt seam, Woodward No. 2 mine, Dolomite, Ala.
26. Carter seam, No. 10 mine, Brookwood, Ala.
27. Milldale seam, No. 7 mine, Brookwood, Ala.
28. Brookwood seam, Searles mine, Searles, Ala.
29. Brookwood seam, Central mine, Kellerman, Ala.
30. Brookwood seam, Tidewater mine, Tidewater, Ala.

Of these analyses No. 9 manifestly is not representative of the Blue Creek bed. No. 30 is of a coal from a mine out of the coking coal district, and might well be disregarded. The best coal of the Mary Lee group comes from the Jagger bed, the best coal of the Pratt bed is mined from Wylam southward, while the best coal of the Brookwood group is obtained from the Milldale and Carter beds. The last fact is important because one of these beds has a greater extent than the Brookwood bed and probably contains a larger amount of coal.

Average analyses of these coals are given below, omitting analysis No. 9 from the Mary Lee group:

Average analyses of coals from the table above.

	1.	2.	3.
Moisture	2.71	2.41	2.80
Volatile matter	25.61	27.77	31.92
Fixed carbon	60.77	61.07	57.29
Ash	10.92	8.74	8.00
Sulphur	.87	1.82	1.27

1. Average of 12 samples from the Mary Lee group.
2. Average of 12 samples from the Pratt bed.
3. Average of 5 samples from the Brookwood group.

It is of interest to compare the Alabama coals with the important coking coals of West Virginia and Pennsylvania. The following are average analyses of coal from the Sewall bed of West Virginia:

Average analyses of coals from Sewall bed, West Virginia.[a]

	1.	2.
Moisture	0.69	1.83
Volatile matter	23.95	27.114
Fixed carbon	72.040	66.617
Ash	3.320	3.615
Sulphur	.740	.801
Phosphorus	.008	.007

[a] West Virginia Geol. Survey, vol. 11, 1903: Coal report.

1. Average of 34 samples.
2. Average of 47 samples.

These two sets of samples were taken from regions separated by a considerable distance, and the differences in composition of the coal are mainly regional. These averages are representative of the principal West Virginia coking coals, since coal from the Quinnimont and Pocahontas beds, which, with the Sewall, supply most of the coking coal of the State, is substantially like that of the Sewall. They are much purer coals than those of Alabama.

The following is an average of standard Connellsville coking coal:

Average of standard Connellsville coking coal.

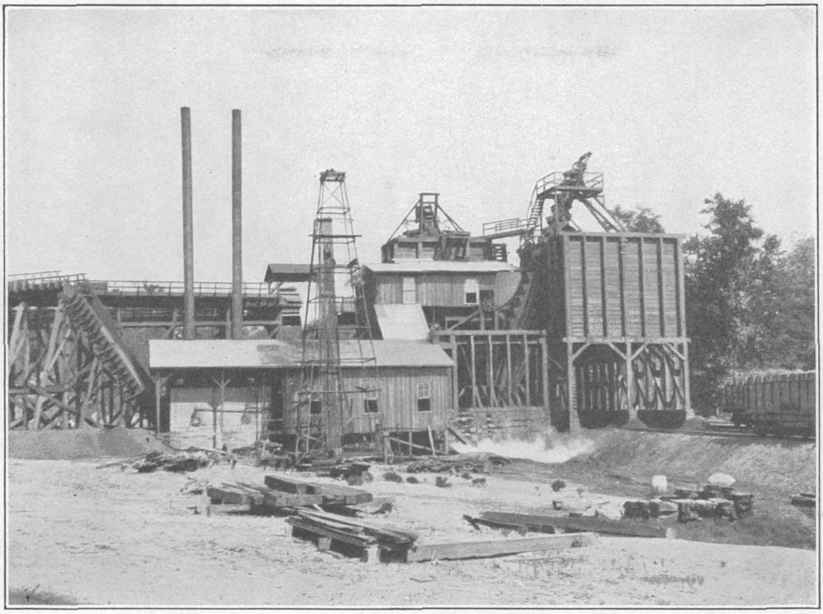
Moisture	1.260
Volatile matter	31.800
Fixed carbon	59.790
Ash	7.160
Sulphur	.530

This analysis agrees closely with the analyses of the Mary Lee coals and the Pratt coal of Alabama. The principal differences are in the content of ash and volatile matter, the former being greater and the latter less in the Connellsville coal. Connellsville coal is also much lower in sulphur than Pratt coal.

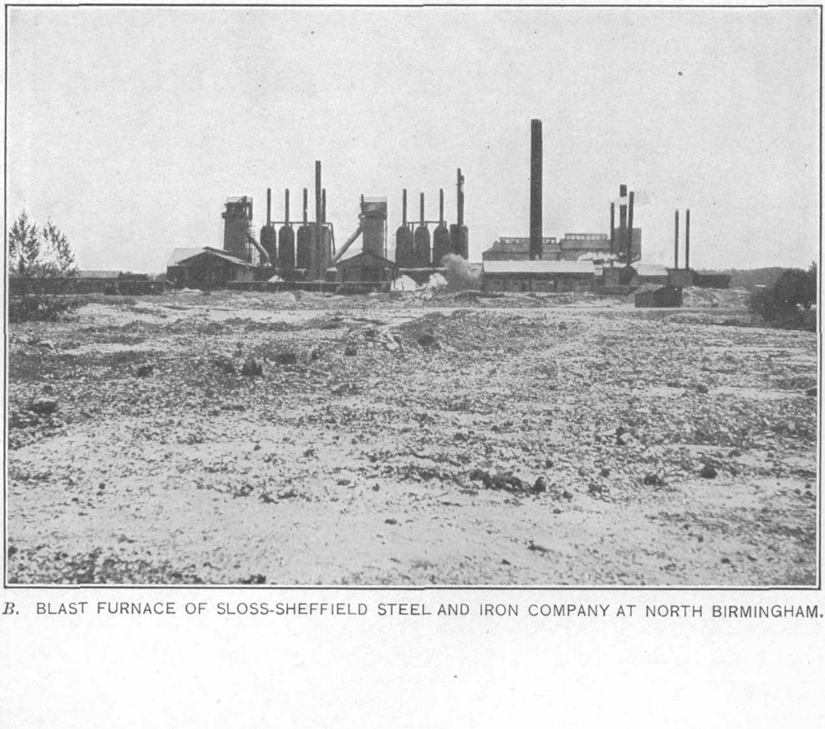
MINING AND PREPARATION OF COAL.

MINING METHODS.

The pillar and stall method of laying out mines is followed altogether in Alabama. The workings follow the faces and butts of the coal, the main entries and rooms being driven as nearly as possible in the direction of the face, and the side entries or cross headings approximately in the direction of the butts of the coal. Endless rope, tail-rope, end-rope, electric, and mule haulage are in vogue, the tendency being to supplant other methods by electric haulage in the larger mines. Mining machines of various types are largely used and in the more important mines will probably supersede pick mining altogether at no distant date.



A. STEWART WASHER OF CENTRAL IRON AND COAL COMPANY AT KELLERMAN, ALA.



B. BLAST FURNACE OF SLOSS-SHEFFIELD STEEL AND IRON COMPANY AT NORTH BIRMINGHAM.

COAL WASHING.

IMPORTANCE OF PROCESS.

As shown in the detailed sections of the various coal beds given on pages 171–173, most of the coking coal mined in the Birmingham district contains too much bone, rash, clay, shale, and sulphur to make good coke. Sulphur is the most injurious impurity, since it enters the iron and seriously impairs its quality. The other impurities impair the quality of the coke both by reducing its calorific power and by weakening it so that it will not sustain the furnace burden that it otherwise would, and at the same time cause the production of a great deal of fine coke, or breeze, which is of little or no value. Large pieces of bone, shale, etc., especially, cause the coke to break up, while the same impurities in a fine state are more deleterious chemically. In addition to their injurious effect upon the quality of the coke, these impurities require the consumption of considerable coke and flux for their removal with the blast-furnace slag.

The removal of these impurities becomes therefore a very important matter, and is more or less perfectly accomplished by washing the coal.

DESCRIPTION OF WASHERS.

Two types of washers are in use, the Stewart and the Robinson-Ramsay. The essential part of the Stewart washer is the jig (Pl. XVI, *A*). This is a rectangular tank with a perforated iron bottom. The jig works up and down within a fixed tank which is kept full of water and in which it fits closely. The downward movement of the jig causes the water to rise through the perforated bottom and carry the lighter coal to the top, where it spills over the edge of the jig, while the heavier impurities settle to the bottom of the jig and pass off through a slot. In the Robinson-Ramsay washer there is a fixed conical tank with the broader end upward. In this tank is a revolving framework to keep the water and coal agitated. Into the bottom of this tank water is forced by a pulsometer and a constant upward flow is maintained. The coal, being lighter, is carried to the top and runs out with the water, while the impurities, being heavier, settle and are drawn off at the bottom. Some of the lighter impurities, especially fine flakes of sulphur, pass off with the water and coal, but are mostly carried away by the water, from which they are separated in a sludge tank, where they settle to the bottom, leaving the water comparatively free from fine impurities, so that it can be used over and over.

Before passing through the washer, the run-of-mine coal is screened. The screenings or slack coal go directly to the washer, but the lump is first crushed to about 1¼-inch size before washing.

RESULTS OF WASHING.

The results of washing operations have been carefully investigated by Mr. David Hancock for the Republic Iron and Steel Company, and by Mr. H. R. De Hall, for the Tennessee Coal, Iron, and Railroad Company. The following is from Mr. Hancock's report upon the operations of the Stewart washer at Sayreton:[a]

Our run-of-mine coal, as shown by the average of 49 samples taken in the mine, is made up as follows:

	Per cent.
Coal	82. 6
Bone coal	11. 4
Shale	4. 5
Slate (from partings)	1. 5

The average specific gravity of these portions I give below, showing the extent of variations in parentheses:

Coal	1. 33 (1. 29–1. 37)
Bone	1. 45 (1. 38–1. 56)
Shale	1. 60 (1. 40–2. 04)
Slate	1. 95 (1. 70–3. 40)

The next table shows the results of ten days' washing, and is the average of 11 samples:

Washed product:	Per cent.	Tailings:	Per cent.
Coal	87. 9	Coal	3. 8
Bone	10. 3	Bone	18. 2
Shale	1. 8	Slate and shale	78. 9
Slate	. 0		

The work is even better than here shown, for the reason that it is the lighter varieties of bone and shale that remain in washed coal and the heavier varieties that go to the slate dump. This point is well shown by the following analysis:

Washed product:	Per cent of ash.	Tailings:	Per cent of ash.
Coal	7. 50	Coal	11. 90
Bone	18. 00	Bone	27. 90
Shale	33. 40	Shale	55. 00

I give finally two representative analyses of our coke, one before the washer was installed and one showing the coke as it now is:

	Unwashed.	Washed.
	Per cent.	*Per cent.*
Volatile	3. 65	2. 75
Fixed carbon	76. 71	82. 55
Ash	18. 85	14. 10
Sulphur	. 79	. 65

I have inspected hundreds of cars of Sayreton washed coal and have never yet found a piece of slate of higher than 1.70 specific gravity, although Sayreton run-of-mine carries an average of 40 pounds per ton of heavy slate of this character.

[a] Fulton, John, Treatise on coke, 1905, p. 120.

It may be added that the ash in the washed product taken as a whole was found by Mr. Hancock to be 8.46 per cent, while the ash of the unwashed run-of-mine coal, calculated from the 18.85 per cent ash in the coke from such coal, is 11.15 per cent, showing a reduction by washing of 2.69 per cent of the ash in the coal as it goes to the coke ovens, with the consequent reduction of the ash in the coke by 4.75 per cent.

The following is an average of the results of seven washing tests made by Mr. De Hall, of the Tennessee Company. The bed is not named, but is said by Mr. De Hall to be one of the dirtiest in Alabama.

Average of seven washing tests of dirty Alabama coal.

Washed product (6,457 tons):	P. ct.	Refuse (698 tons, or 9.8 per cent):	P. ct.
Coal (specific gravity 1.37 and less)	77.2	Coal (specific gravity 1.37 and less)	5.4
Bone (specific gravity 1.37 to 1.56)	16.07	Bone (specific gravity 1.37 to 1.56)	3.7
Slate (specific gravity 1.56 and over)	6.1	Slate (specific gravity 1.56 and over)	91.2

The bone in the unwashed product is really about one-third good coal, so that the actual bone, probably having, like the bone in Mr. Hancock's test, about 18 per cent of ash, really amounts to only a little over 10 per cent of the washed product. It is calculated from the figures above that 14.4 per cent, or 1,030.45 tons, of the coal as it goes to the washer is slate of over 1.56 specific gravity. Of this amount 61.8 per cent is removed in the refuse, leaving 38.2 per cent in the washed product.

INJURIOUS EFFECT OF IMPURITIES.

The benefit derived from the removal of this material will be better appreciated upon consideration of the fact that with the exception of sulphur the slate (shale) is the most deleterious element in the coke, not only because it decreases its calorific power and demands more coke and flux to convert it into slag, but because it is mostly or very largely composed of pieces of considerable size, which, more than any other form of impurities, impairs the strength of the coke, causing it to break up into small pieces, with a consequent production of a large quantity of breeze.

In order to show the effect of shale fragments on the strength and quality of coke, the following private letter, by Mr. A. E. Barton, superintendent of furnaces at Ensley, is published here:

Ten cars of coke made from washed slack coal from Pratt mines were weighed on arrival at the furnace, and weighed after they had been unloaded in the stock house. The braize was then shoveled out of the cars, and they were weighed again. The amount of braize thus obtained was 0.49 per cent of the whole, this being less than the half of 1 per cent.

In ten cars containing coke made from unwashed slack and run of mines treated in the same way the braize was 4.61 per cent. This comparison does not usually show the relative amount of braize in each, as the men who unload the cars into buggies are instructed, in case of unwashed coke, to shake their forks and unload as little braize as possible, whereas in the case of washed coke they are told to slide their forks when charging up a car. The reason for this is that the braize from the washed coke consists largely of pieces of good coke about the size of a hickory nut, and a certain proportion of this braize charged into the furnace along with the larger coke does not appear to have any bad effect on the working of the furnace. The braize from the unwashed coke, on the other hand, is made up chiefly of pieces of slate and fine coke dust, and we think it policy in practice to throw this away.

We have, therefore, in a car of washed coke 99.51 per cent of coke suitable for blast-furnace use, and in a car of unwashed coke 95.39 per cent.

It is somewhat difficult to tell exactly the saving in coke per ton of iron brought about by the use of washed coke.

We find, however, in practice that when we have to use unwashed coke made from slack and run of mines in place of washed coke it is necessary to reduce the burden 600 pounds, and even then the furnace is more apt to make hard iron than get too hot. If the coke was all made from unwashed slack, with no run of mines with it, the burden would have to be decreased still lower.

A reduction of 600 pounds of ore in our burdens insures an increase of about 160 pounds of coke per ton of iron made, and I think we can safely say that the use of washed coke lessens our fuel consumption per ton of iron from 150 to 200 pounds, thus effecting a saving of from 18 to 25 cents to the furnace. This is based on the actual amount of coke charged into the furnace, and does not take into account the saving in braize or the benefits derived from the more regular working of the furnace and increased output.

The saving in braize at the furnace alone, based on our present coke consumption of, say, 1.35 tons of coke per ton of iron made, would be 15 cents on the ton of iron, or an actual total saving to the furnace of, say, 35 cents, barring out all uncertainties, such as increased make, etc.

REDUCTION OF ASH CONTENT.

The quantity of coal lost in the refuse is a matter of consequence. In the tests made by Mr. De Hall, an average of 5.4 per cent of the refuse is classed as coal. This amounts to 37.7 tons, or one-half of 1 per cent of the raw coal, an insignificant amount. Furthermore, the coal in the refuse has been shown to be higher in ash, and therefore of poorer grade, than the coal of the washed product.

It would be interesting to know to what extent the ash in the coke was reduced in the case cited above from Mr. De Hall, but no data were furnished on that point. The ash can be computed, however, by using the ash percentage of the different constituents—coal, bone, and slate—as determined by Mr. Hancock for the Mary Lee coal washed at Sayreton, viz:

Percentage of ash in constituents of Mary Lee coal.

Washed product:		Refuse:	
Coal	7.50	Coal	11.90
Bone	18.00	Bone	27.90
Slate	33.40	Slate	55.00

This composition of constituents will undoubtedly hold for the coal of Mr. De Hall's investigations. The percentage of ash in the washed product obtained by this method is 9.44 and in the unwashed coal 13.6, giving a reduction of the ash by washing of 4.16 per cent. Assuming a 60 per cent yield of coke, the ash in the coke made from the unwashed coal would be 22.6 per cent, while the ash in the coke made from the washed product would be 15.73 per cent, showing a reduction of ash in the coke of 6.87 per cent. It will be seen that these results obtained by Mr. De Hall agree closely with those obtained by Mr. Hancock, and probably indicate approximately the average results of washing the dirtier coal throughout the district.

POSSIBLE IMPROVEMENTS.

It is believed that these results are as good as can be obtained by primary washing—that is, a system of washing where the coal of all sizes is washed together in a single operation. Further improvement is to be looked for only by a more elaborate system in which the coal is separated into different sizes and each size washed by itself in a jig that in construction and speed of running is especially adapted to that size. It is pretty certain that a much more nearly complete elimination of impurities could be obtained by such a washer, but whether profitably so or not is not known.

That washing by the present system pays is indicated by the fact that since 1900 practically all the slack coal has been washed before coking, while in 1905 of 4,409,854 tons of coal of all classes coked 3,112,478 tons was washed.

COKE AND COKING METHODS.

PRODUCTION OF COKE IN ALABAMA.

Most of the coke made in Alabama is made in bee-hive ovens of usual size and method of construction. There are in operation 280 by-product ovens of the Semet-Solvay type—240 at Ensley and 40 at Holt, in Tuscaloosa County—and a battery of Thomas ovens at Coalburg, operated by the Sloss-Sheffield Iron and Steel Company. There is also in use at Pratt No. 5 mine, at Ensley, a battery of bee-hive ovens modified so that the gas given off in coking can be collected. This gas is used in firing the boilers furnishing power for the mine.

The charge of coal is 5 tons and the time of burning is usually forty-eight hours, though some coke is burned seventy-two hours. This charge, roughly speaking, will yield 3 tons, or 60 per cent of coke, though statistics show that the actual yield, taking all the coal coked in the State, is somewhat less than that figure. According to statistics,[a] the average yield for the six years 1900 to 1905 was 58.6 per

[a] Mineral Resources U. S. for 1905, U. S. Geol. Survey, 1906, p. 738.

cent, or, rejecting the yield in 1901, which was abnormally low, being 55.8 per cent, the average was 59.2 per cent. The average yield of coke from the coal of the different beds is indicated by the following figures compiled from returns to the United States Geological Survey. The tonnage of coal given as from the different beds was not all the coal made into coke from those beds, but is the sum of such coal as could be identified as from the beds named:

Yield of coke from Alabama coals.

	Coal.	Coke.	Yield.
	Short tons.	*Short tons.*	*Per cent.*
Mary Lee beds	605,857	331,883	54.7
Pratt beds	751,088	429,837	57.2
Brookwood beds:			
Bee-hive ovens	320,654	192,195	59
Semet-Solvay ovens	....	....	68.4
Black Creek beds	....	....	53

The minimum yield of bee-hive coke at any of the plants coking coal of the Mary Lee group was 46 per cent and the maximum yield was 62.4 per cent. The minimum yield from Pratt coal was 52 per cent and the maximum 59.2 per cent. The minimum of Brookwood coal was 58.8 per cent and the maximum 63.5 per cent. One operation in Black Creek coal yielded 53 per cent coke. Considering the three important coking coal beds, these figures show the highest yield of coke from the Brookwood bed, the next highest from the Pratt bed, and the lowest from the Mary Lee or equivalent bed. Averaging the percentages given above, the result is 58.4 per cent, which is almost exactly the average yield of all the coal coked in the State, so that the relative yield of the different beds shown in the table appears to be nearly correct.

The yield of coke from Alabama coals is generally lower than that from the coal of other regions in the Appalachian field. The Kanawha district of West Virginia comes nearest to Alabama in yield, viz, an average of 58.7 per cent for the six years 1900–1905. In the New River district, West Virginia, the yield was 60 per cent, and in the Flat Top district, West Virginia, Pocahontas coal, 63 per cent for the same time. In the Connellsville district, Pennsylyania, the average yield for the years 1900–1905 was 67.2 per cent and the average yield from the other Pennsylvania districts, with the exception of the Reynoldsville district, will not vary greatly from this.

COMPOSITION AND PHYSICAL CHARACTER OF COKE.

REPRESENTATIVE ANALYSES.

The composition of some of the Alabama cokes is shown by the following average analyses for four-week periods, which are believed to be representative of the cokes named:

Average analyses of Alabama cokes, for four-week periods.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
Volatile matter	0.69	0.56	1.11	1.04	1.03	1.10	1.57	0.91	1.45	1.24
Fixed carbon	83.51	85.01	87.23	89.24	87.58	88.02	83.11	86.45	81.58	81.77
Ash	13.95	13.91	11.17	9.23	10.88	10.32	14.00	12.44	16.09	16.14
Sulphur	1.33	1.16	1.43	1.21	1.19	1.20	.75	1.33	.94	.73

1. Pratt two-thirds washed, one-third unwashed. Average daily product, 1,163.7 tons.
2. Pratt one-third washed, two-thirds unwashed. Average daily product, 472.8 tons.
3. Pratt unwashed. Average daily product, 213 tons.
4. Pratt washed. Average daily product, 208.4 tons.
5. Pratt unwashed. Average daily product 171.2 tons.
6. Pratt unwashed. Average daily product, 91.8 tons.
7. Blue Creek unwashed. Average daily product, 184.6 tons.
8. Pratt one-third washed, two thirds unwashed. Average daily product, 233.4 tons.
9. Blue Creek two-thirds washed, one-third unwashed. Average daily product, ——.
10. Blue Creek two-thirds washed, one-third unwashed. Average daily product, 776.8 tons.

These analyses agree substantially with the following average analyses of the cokes used in the State, taken from Phillips:[a]

Average analyses of Alabama cokes.

	1.	2.	3.
Moisture	0.76	0.75	0.75
Volatile matter	.75	.75	.75
Fixed carbon	84.50	88.50	87.00
Ash	14.00	10.00	11.50
Sulphur	0.90-1.60	0.80-1.10	1.00-1.30

1. Coke from run-of-mine coal.
2. Coke from washed slack.
3. Coke from lump coal.

For the sake of comparison the following analyses of some of the West Virginia cokes and of Connellsville standard coke and Stonega coke are presented:

Analyses of West Virginia cokes, Connellsville standard coke, and Stonega coke.

	1.	2.	3.	4.	5.	6.	7.
Moisture	0.19	0.16	0.14	0.13	0.09	0.79	2.90
Volatile matter	1.35	1.14	1.06	.98	.98	1.31	1.32
Fixed carbon	87.21	85.60	91.26	91.71	90.99	86.88	92.05
Ash	11.25	13.12	7.54	7.18	7.94	11.54	5.60
Sulphur	.96	.89	.75	.64	.58	.70	.74

1. Kanawha district, Campbells Creek bed. West Virginia Geol. Survey, vol. 2, p. 574.
2. Kanawha district, Eagle bed. West Virginia Geol. Survey, vol. 2, p. 590.
3. New River district, Sewall bed. West Virginia Geol. Survey, vol. 2, p. 664.
4. New River district, Quinnimont bed. West Virginia Geol. Survey, vol. 2, p. 671.
5. Flat Top district, Pocahontas No. 3 bed. West Virginia Geol. Survey, vol. 2, p. 700.
6. Connellsville standard coke. Fulton, Treatise on coke, p. 334.
7. Stonega coke. Fulton, Treatise on coke, p. 334.

So far as calorific power of coke depends upon composition, Pratt coke is equal to Kanawha and Connellsville coke, but a little lower than New River and Pocahontas coke, while Blue Creek coke is lower than all the other cokes of the last table.

[a] Iron making in Alabama, Alabama Geol. Survey, 1898, pp. 86, 87.

PHYSICAL PROPERTIES.

The physical properties of coke which appear to be of the greatest importance are cell space, hardness, and crushing strength. The cellular character of coke permits the rapid combustion upon which the heat of the blast furnace depends. The rapid combustion is due to the larger surface of coke exposed, because of the cells, to the oxidizing blast of the furnace. The most favorable ratio of cell space or volume to the coke substance is stated by Fulton[a] to be 56 to 44, though he does not state how this conclusion was reached.

The hardness of the coke substance is believed to affect the absorption of the coke by the heated furnace gases; the harder the coke the less the absorption. Such absorption is thought by some to be a matter of importance; by others, however, it is regarded as a question of rather theoretical and speculative nature, since the reactions in a blast furnace are difficult to investigate and not all of them are well known.

The crushing strength of coke, or its power to sustain the pressure of a great weight, is one of its most important properties. Upon that power largely depends the height and size of the blast furnace, and consequently in a measure the economy of furnace operations.

A quality of coke of equal or greater importance, compared with those just described, is uniformity in chemical and physical character. A furnace man who can depend upon having coke of uniform character can regulate his practice to that character and then proceed with his operations with a reasonable certainty of getting uniform results.

In order to exhibit the comparative physical properties of Alabama cokes and cokes from other fields, the following table is given. The figures for Alabama cokes are taken from Phillips[b] who appears to have made the only tests of Alabama cokes. The figures for the other localities are taken from Fulton[c]. No. 14 is a test of Jagger coke made from coal mined at Abernant, Ala. This test also was made by Fulton and is taken from his report to the mining company.

Physical properties of Alabama and other cokes.

	1.	2.	3.	4.	5.	6.	7.
Specific gravity	1.764	1.839	1.838	1.513	2.567	1.784	1.836
Percentage of cell space	52.18	42.96	44.48	44.27	47.38	46.62	42.90
Compressive strain (pounds per square inch)	474.00	464.00	558.00	362.00	568.00	589.00	750.00

1. Blue Creek, 48-hour coke from washed slack; average of 7 determinations.
2. Pratt, 48-hour coke from washed slack; average of 10 determinations.
3. Pratt, 72-hour coke from washed slack; average of 13 determinations.
4. Pratt, 48-hour coke from disintegrated nut, not washed; average of 2 determinations.
5. Pratt, 72-hour coke from disintegrated nut, not washed; average of 2 determinations.
6. Pratt, 48-hour coke from washed and disintegrated slack; average of 8 determinations.
7. Pratt, 72-hour coke from washed and disintegrated slack; average of 2 determinations.

[a] Fulton, John, Treatise on coke, 1905.
[b] Iron making in Alabama, Alabama Geol. Survey, 1898.
[c] Fulton, John, Treatise on coke, p. 334.

Physical properties of Alabama and other cokes—Continued.

	8.	9.	10.	11.	12.	13.	14.
Specific gravity	1.84	1.88	1.67	1.79	1.83	1.80	1.81
Percentage of cell space	46.20	47.00	56.66	57.32	47.93	56.07	46.61
Compressive strain (pounds per square inch)	400.00	545.00	245.00	296.00	236.00	290.00	431.00

8. Black Creek, 48-hour coke, 1 determination.
9. Milldale, 72-hour coke, 1 determination.
10. Stonega, Va., 48-hour coke. Fulton, Treatise on coke, p. 334.
11. Coal gas seams, W. Va. Idem, p. 334.
12. Pocahontas coke. Idem, p. 334.
13. Connellsville coke. Idem, p. 334.
14. Jagger coke, Abernant, Ala. Report to company.

The tests of crushing strength were made with a Reihle testing machine on 1-inch cubes of coke. There are so many conditions, however, affecting the structure and strength of coke, such as the state of the weather, whether rainy or dry, variations in the size and purity of the coal, time of coking, amount of water used in quenching, and whether inside or oustide quenching is used, that there is much doubt as to the value of such crushing tests. It is found that coke from different parts of the same oven, and even different samples from the same part, show great differences in strength. Hence the necessity of long-continued tests to reach a correct conclusion as to the average strength of the coke. So it may be questioned whether the figures given in the table as representing the crushing strains of the different cokes really represent the relative burden-bearing powers of those cokes in the furnace.

Apparently no determinations of the relative hardness of Alabama cokes have been made.

Constancy in character is said to be one of the prime merits of Connellsville coke. This permits a furnace manager to proceed with his operations with the certainty of securing the results he wants to obtain in the metallic product. There is no reason to suspect that, under ordinary conditions, Alabama cokes are not fairly good in this respect. Circumstances sometimes interfere, however, with securing a uniform coke. Among them are heavy rains, which cool the ovens and prevent thorough coking, the demand for coke on the part of the furnace men, or the temporary disablement of a washer, both of which lead to charging the ovens with unwashed coal and the production of an inferior grade of coke.

CONSUMPTION OF COKE PER TON OF IRON.

The amount of coke consumed per ton of iron smelted depends upon a number of variable factors, among the most important of which are the quality of the coke, the composition of the flux, the composition of the ores, and the working of the furnace. It would require a full knowledge of all these conditions to understand the significance of any statement of coke consumed per ton of iron.

Below is given a statement of average consumption of coke per ton of iron, based upon data furnished by various iron companies. These averages probably represent closely the results obtained in actual practice in the district. The statements are given in the following form in order not to reveal the identity of the companies furnishing the data:

Average consumption of coke per ton of iron.

STATEMENT FOR APRIL, 1906.

Blast furnace.	Proportion of kinds of ore (approximate).[a]			Coke per ton of iron.
	Hard.	Soft.	Brown.	
	Per cent.	*Per cent.*	*Per cent.*	*Tons.*
1	67	31		1.66
2	69	31		1.73
3	70	27		1.78
4	65	30		2.06
5	59		38	1.17
6	100			1.68
7	100			1.69
8	[b] 100			1.54
9	72	17	10	1.60
10	88	11		1.65
Average				1.8

STATEMENT FOR TWELVE MONTHS, 1905.

Blast furnace.	Hard.	Soft.	Brown.	Coke per ton of iron.
1	84.6	11.4	2.6	1.77
2	83	14	2.5	1.79
Average				1.78

STATEMENT FOR THREE CONSECUTIVE MONTHS, 1906.

Blast furnace.	Hard.	Soft.	Brown.	Coke per ton of iron.
1	(c)		(d)	1.85
2	(c)		(d)	1.89
3	(c)		(d)	1.93
4	(c)		(d)	1.63
5	(c)		(d)	1.60
6	(c)		(d)	1.56
Average				1.74

[a] In most cases a little mill cinder and scrap was used which are not taken into account in this table. In such cases the total percentage falls a little below 100.
[b] Nearly.
[c] Nearly all.
[d] A little.

These statements show a consumption of 794,862 tons of ore of all kinds, 551,630 tons of coke, and the production of 309,948 tons of pig iron. The average consumption of coke per ton of iron was 1.78 tons. Considering the length of time covered by the above statements, the quantities of raw materials, and the amount of production, this result ought to be representative for the district as well as for the companies reporting. These figures show a considerably greater consumption of coke per ton of iron made than those given by Phillips,[a] the averages of which are stated in the following table:

[a] Iron making in Alabama, Alabama Geol. Survey, 1898.

Average consumption of coke per ton of iron, as given by Phillips.

	Proportion of kinds of ore (approximate).		Coke per ton of iron.
	Hard.	Soft.	
	Per cent.	*Per cent.*	*Tons.*
Furnace, three consecutive months, 1895	51.3	48.6	1.35
Furnace, four consecutive months, 1895	50.6	49.4	1.52
Furnace, three consecutive months, 1890	65.9	34.1	1.57
Furnace, three consecutive months, 1893	90.7	9.3	1.61

Phillips states that the average consumption of coke per ton of iron was, in 1898, 1.41 tons, while in 1906, as shown above, it required on the average 1.78 tons of coke per ton of iron made. Whether this difference is due to incorrect statements, difference in furnace management, difference in the ores, difference in the coke, or partly to all these circumstances, is not definitely known.

FLUXES.

GENERAL STATEMENT.

Both limestone and dolomite are used for flux in this district, though dolomite is much more extensively used than limestone. The geologic relations of the limestone and dolomite formations are described on pages 14–17. A detailed description of the character and distribution of these formations follows:

BANGOR LIMESTONE.

The Bangor limestone is of Carboniferous age and is named from Bangor, Ala., where it has been quarried. It is generally a semicrystalline, rather light gray limestone, varying from a few feet to 300 feet or more in thickness.

This limestone outcrops along both sides of Blount Valley, from Reids station to Bangor and farther north. It forms most of the valley walls, its outcrop extending from their base upward nearly to the bottom of the sandstone that caps the sand ridges or mountains overlooking the valley. It dips into the hills at angles of 5° to 15°.

The limestone is thus favorably situated for quarrying, and it has been worked on a considerable scale at Blount Springs and Bangor. Two quarries between these two places are now in operation. They are open workings, and in one the face is almost 80 feet high, extending nearly to the top of the outcrop on the escarpment. The following is a section of the rock quarried:

Section of Bangor limestone between Blount Springs and Bangor.

	Feet.
Gray semicrystalline limestone	28
Dark semicrystalline limestone	12
Gray semicrystalline limestone	40

The limestone beds are separated by thin partings of shale. Limestone from this quarry is used for flux in the furnaces at Birmingham and Bessemer.

Other quarries have been operated along the outcrop at both Bangor and Blount Springs. The one at Blount Springs was operated by the Sloss-Sheffield Steel Company. The composition of the limestone from this quarry, which includes a thickness of 100 feet or more, is as follows:

Average of eight analyses of Bangor limestone from Blount Springs and Compton quarries.[a]

Silica (SiO_2)	1.05
Iron oxide and alumina ($Fe_2O_3+Al_2O_3$)	.82
Lime carbonate ($CaCO_3$)	96.74
Magnesium carbonate ($MgCO_3$)	.71
	99.32

On the west side of Murphrees Valley and its southward continuation, Opossum Valley, the Bangor limestone outcrops from the north boundary of the area under discussion southward nearly to Sayreton Gap. As far south as Village Springs or Dale its outcrop extends high up on the valley side, as in Blount Valley. South of Dale the outcrop of the limestone lies along a narrow valley. The limestone thins southward, being about 100 feet thick at Boyles Gap, south of which it has never been found. From Dale northward the dip is about 15° W. Southward from that place the dip increases, and the limestone is vertical or overturned from Mount Pinson to its southern limit. It probably is not workable far south of Dale. On the east side of Murphrees Valley the Bangor limestone is not well known. A thickness of about 50 feet was seen in a ravine about 2 miles northeast of Swansea, and a thickness of 100 feet is possible there. Topographic features indicate a greater thickness northward, while south of the above-mentioned ravine to Remlap no limestone appears, though it is probably present but concealed. The limestone north of Swansea is vertical and not workable. In Wildcat Cove, due east of Village Springs, the Bangor limestone outcrops from the valley bottom high up on Pine Mountain and is 300 feet thick or more. This is typical Bangor limestone, and the probable extent and position of its outcrop with respect to the surface features are shown on the geologic map (Pl. II). The limestone dips east at a low angle and is very favorably situated for quarrying. East of Blount Mountain the limestone outcrops along the valley of Canoe Creek, dipping probably at a low angle to the northwest. The Bangor limestone has been quarried extensively from Dale northward.

[a] Analyzed by Henry McCalley, J. L. Beeson, and J. R. Harris. McCalley, Henry, Report on the valley regions of Alabama, pt. 1, p. 410.

Section of Bangor limestone at Dale quarry.

	Feet.
Limestone	20
Red shale	5
Green shale	5
Gray crystalline limestone	25
Dark limestone	30
White limestone	5
Shale	1
Clay	2
Gray limestone	60
	163

At Dale nearly the full face of the outcrop on the valley wall is quarried, the stone being used for flux. The limestone has been extensively worked along this outcrop for some distance north of Dale, but all the quarries except the one at Dale have been abandoned. These abandoned workings suggest that it has been the practice to continue operations until it became necessary to remove too much cover, and then to open a new quarry at another place. Below are analyses of limestone from this region.

Analyses of Bangor limestone from Compton quarry, north of Dale.[a]

	1.	2.	3.
Silica (SiO_2)	2.05	4.45	2.80
Iron oxide and alumina ($Fe_2O_3+Al_2O_3$)	.76	3.30	.70
Lime carbonate ($CaCO_3$)	89.64	86.35	94.59
Magnesium carbonate ($MgCO_3$)	8.15	....	....

[a] Alabama Geol. Survey, Report on valley regions of Alabama, pt. 1, p. 142.

1. Average sample of 150 feet of rock used as flux. J. L. Beeson, analyst.
2 and 3. Stockhouse samples. W. B. Phillips, analyst.

These analyses show considerably more silica and magnesia in the limestone in this region than at Blount Springs. Analysis 2, however, is the only one that shows an excessive amount of insoluble constituents, with a corresponding low amount of lime carbonate.

In Shades Valley the Bangor limestone does not appear to be worth considering as a source of flux. A short distance south of Trussville there is a small exposure of limestone near the top of the Bangor. This limestone has been quarried on a small scale, but is not quarried now. This limestone was once quarried near Graces Gap for use as flux at the Oxmoor furnace.

It may be noted that at Vanns's quarry, about 2 miles north of Trussville, a coarsely crystalline gray limestone just above the Fort Payne chert has been quarried to some extent for flux.

CHICKAMAUGA (PELHAM) LIMESTONE.

The Chickamauga limestone has been used to some extent as flux. Its stratigraphic position is below the Clinton formation, which carries the red ores of the region, and above the Knox dolomite. In Birmingham Valley this limestone outcrops along the west escarpment of Red Mountain almost the entire distance from a point west of Blocton nearly to Springville. There are several gaps in this outcrop that are due either to faults or to nondeposition of the limestone. One of these is on the west side of Red Mountain, 1 mile south of Sadlers Gap; another extends northward from Clay for 2 miles, and another about 3 miles in length is northeast of Ayres. It outcrops also along the west side of Birmingham Valley in strips and patches, being faulted out in places, from Big Sandy Creek (see p. 105), southwest of Vance, to west of Bessemer. From the latter point it is faulted out nearly to Cunningham Gap, whence northward it forms the east face of West Red Mountain in Murphrees Valley to Chepultepec and beyond. Along the east side of Murphrees Valley it is cut out by a fault as far south as Village Springs. Around the south end of Blount Mountain it outcrops in a broad belt extending from Village Springs to Springville, and thence northward parallel to the east side of Blount Mountain. A belt of Chickamauga limestone also extends down the east side of Red Mountain from Canoe Creek nearly to Trussville.

Along all the outcrops described above the limestone is generally rather thin-bedded and light or dark gray in color. In places, as at Dale and west of Swansea, there is a thick-bedded buff limestone near the base, and around the south end of the Blount Mountain syncline purple-mottled layers occur through the lower 25 feet or more. In this region a varying thickness up to 100 feet or more above the bottom contains a large proportion of impure limestone, at the top of which is a bed of conglomerate or fine chert breccia 10 feet thick or so. Crystalline limestone also occurs in the formation, mainly toward the top. The Chickamauga limestone appears to range from 300 to 700 feet in thickness, except where affected by faults, as described above. Its thickness at Gate City is about 300 feet; on Blackburn Fork, west of Swansea, 500 feet; at Chepultepec, 600 to 800 feet; and on Butler Mountain, at the south end of Blount Mountain, 500 to 600 feet. The limestone dips into the hills on either side of the valleys, generally at angles of 15° to 20°, though higher dips may occur locally. In some localities, as in the region of Butler and Foster mountains, it lies nearly flat.

Below is a section of the limestone exposed in the quarry of the Cheney Marble White Lime Company, near Chepultepec, in Murphrees Valley:

Section of Chickamauga limestone at Chepultepec quarry.

	Feet.
Dark-gray crystalline limestone	40
Darker crystalline limestone	20
Blue limestone	5
Gray limestone	2
Blue limestone	5
Shaly, impure limestone	6
Dark amorphous (lithographic?) limestone	2
Gray limestone	10
	90

The section of the Chickamauga limestone on Foster Mountain is as follows:

Section of Chickamauga limestone on the west side of Foster Mountain.

Top of Foster Mountain.	Feet.
1. Gray, very granular, thick-bedded limestone, weathering into thin layers	25
2. Gray granular limestone like 1	30
3. Dove-colored limestone	70
4. Dove-colored limestone, amorphous	30
5. Mostly gray and bluish crystalline limestone	30
6. Gray crystalline limestone	10
7. Concealed	20
8. Thick-bedded, finely granular, bluish limestone	20
9. Thick-bedded, gray, crystalline limestone; beds weather into thin (1-inch) layers	100
10. Concealed, débris of granular limestone	25
11. Bluish limestone	5
12. Concealed, débris blue and bluish limestone	30
13. Bluish, thick-bedded, somewhat granular limestone	5
14. Concealed	20
15. Bluish and grayish limestone	5
16. Concealed, débris of bluish and dove-colored limestone	50
17. Thick-bedded limestone	20
18. Concealed	20
19. Gray and blue brittle limestone	40
20. Conglomerate, mainly siliceous	5
21. Impure and variegated limestone, conglomerate layers	40
West base of Foster Mountain.	
	600

With respect to natural conditions this is the most favorable locality for quarrying the Chickamauga limestone in the region. From 400 to 500 feet of rock is here available, entirely above drainage and exposed on all sides. This locality could easily be reached from the Louisville and Nashville Railroad by a spur 3 miles long, leaving the main track 2 miles north of Mount Pinson and extending up Dry Creek to Foster Mountain.

The Chickamauga limestone has been quarried at Gate City by the Sloss-Sheffield Steel and Iron Company for use as flux, but it is no longer used in this region for that purpose to any extent. The subjoined analyses show the composition of the limestone at this quarry:

Analyses of Chickamauga limestone at Gate City quarry.[a]

	1	2
Silica (SiO_2)	5.70	3.30
Iron oxide (Fe_2O_3)	1.87	2.14
Lime carbonate ($CaCO_3$)	91.16	91.33

[a] McCalley, Henry, Report on the Valley Regions of Alabama, pt. 2, Alabama Geol. Survey, 1897, pp. 338, 339.

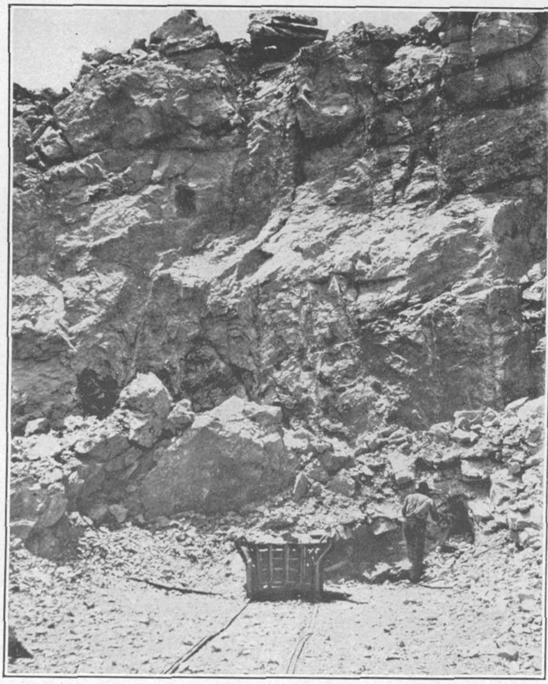
1. Average sample from crusher. Henry McCalley, analyst.
2. Average of four samples. J. W. Miller, analyst.

The high percentage of silica shown by these analyses probably indicates why the use of this limestone as flux has been discontinued. Much purer rock can be obtained in the region, as is shown below. An analysis of the Chickamauga limestone south of Dudley, on Big Sandy Creek, is given on page 110.

KETONA DOLOMITE MEMBER.

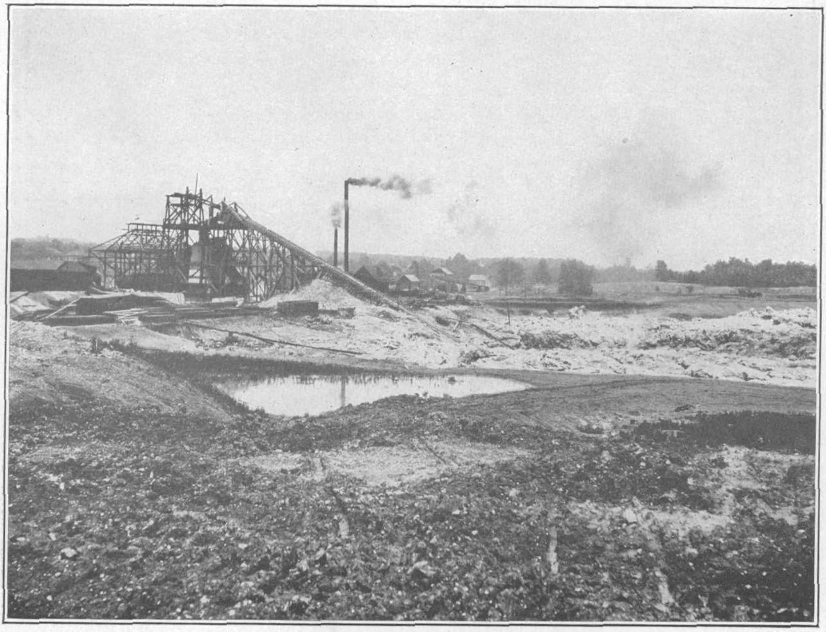
LOCATION AND CHARACTER.

As stated on page 14, the Ketona dolomite member includes the lower 500 or 600 feet of the rocks included in the Knox dolomite, as the term has been used hitherto. This member outcrops from Vance northward along the west side of Jones Valley to Bessemer, and around the north end of the Salem Hills. It outcrops around the south end of Flint Ridge and northward along the east side of Opossum Valley to Mount Pinson. The outcrop around the north end of the Salem Hills and that around the south end of Flint Ridge are separated by a gap 1½ miles wide, from which the dolomite has been eroded. Along the Opossum Valley strip are located the quarries of the Republic Iron and Steel Company, at Thomas (Pl. XVII, *B*); the Sloss-Sheffield Company, at North Birmingham (Pl. XVII, *A*); the Lacy-Buek Company, near Lardona; the Birmingham Realty Company, at Dolcito; and the Tennessee Company, at Ketona. At Vance is the quarry of the Central Iron and Coal Company. In Jones Valley the dolomite outcrop extends from Birmingham nearly to Chalkville. South of Birmingham along the west flank of Red Mountain the dolomite is not exposed, and there are reasons for thinking that it may thin out or change to a more or less magnesian limestone. In Murphrees Valley the dolomite outcrops along the east side of Gravelly Ridge from Chepultepec to Remlap.



A. DOLOMITE QUARRY OF SLOSS-SHEFFIELD STEEL AND IRON COMPANY, NORTH BIRMINGHAM, ALA.

Looking south. Shows massive bedding and eastward dip of dolomite.



B. DOLOMITE QUARRY OF REPUBLIC IRON AND STEEL COMPANY, THOMAS, ALA.

Looking north. Shows topography and method of raising stone.

The Ketona dolomite member is generally gray and more or less crystalline. As shown by the following analyses, it is nearly free from silica, though thin plates of chert or silica in some other form are said to occur in the rock at various points. At the top it begins to show more or less abundant chert inclusions, such as nodules, stringers, and thin irregular sheets. This transition may be observed in the vicinity of the abandoned Dolcito quarry, where the overlying cherty beds of the Knox dolomite are fairly well exposed, and shows the transition from the noncherty phase (Ketona member) to the cherty phase of the Knox. The rock is in most places thick bedded. The dip along the western belt, where the quarries mentioned above are located, is from 10° to 15° E. (See Pl. XVII, *A*.) In weathering, much of the surface becomes granular, simulating closely a coarse-grained sandstone. As stated above, the thickness of this dolomite seems to be about 500 feet. It was measured in Opossum Valley, west of Birmingham, and along the section from the Spencer quarry through Lardona, where the top and bottom can be determined within reasonably close limits. There may be considerable variation from this thickness, however, in different parts of the region.

The dolomite outcrop is nearly everywhere confined to the valley flats, and with the exception of the Spencer quarry of the Lacy-Buek Company at Lardona all the quarries extend below drainage level. This circumstance involves the expense of constant pumping to keep the quarries dry and that of raising the rock to a high tipple from which it can be dumped into a crusher and thence loaded into the cars. Plate XVII, *B*, illustrates the conditions described above.

QUARRY METHODS.

The conditions for quarrying are most favorable in Murphrees Valley between Remlap and Chepultepec, where the dolomite outcrops well up on the east side of Gravelly Ridge, and, though the rock dips to the west at a considerable angle, large bodies could be quarried in such a way as to be self-draining. Moreover, the expense of raising the rock from a deep quarry on level ground would be avoided.

All the quarries are open workings except the one at Vance, in which underground mining has recently been substituted for the open quarry. About 10 feet of stripping is necessary in the valley to remove the soil from the rock before quarrying it. In quarrying, holes are drilled around the margin of the quarry to a depth of 20 feet, or to a bedding plane, and the rock is blasted from the face, the bigger masses being again broken by blasting. The broken rock is then loaded into cars, which run by gravity on converging tracks to the foot of the incline. These cars are dumped into a car running on the incline and are raised to the tipple, where the rock is dumped into the crusher. After crushing, the rock is in some cases screened and in others not. When screened, the larger pieces, about 4 inches in the smallest diameter, are used for flux, while the smaller sizes are used for concrete work or for surfacing roads or walks.

While it is somewhat more expensive to quarry the dolomite than it would be to quarry the limestone of the region in a hillside quarry, where hoisting and pumping would be unnecessary, yet the dolomite is said to be softer than limestone, and this, since the dolomite is therefore easier to break and crush, offsets, in part at least, the greater expense of quarrying it.

From this dolomite is obtained all the flux used in the vicinity of Birmingham except that obtained from the Bangor limestone.

ANALYSES.

At the quarries of the Tennessee-Republic Company, at Ketona, and of the Sloss Company, at North Birmingham, this rock is a nearly pure dolomite, as shown by the following analyses:

Analyses of dolomite from Ketona and North Birmingham quarries.

	1	2
Silica (SiO_2)	1.31	0.70
Alumina (Al_2O_3)	.96	.63
Lime carbonate ($CaCO_3$)	55.80	56.41
Magnesium carbonate ($MgCO_3$)	42.47	43.00

1. Average of 4 analyses of average sample from Ketona quarry, August to October, 1903. Analyses furnished by Tennessee-Republic Company.
2. Average of 10 analyses of car-load lots from North Birmingham quarry, August, 1903, to June, 1905. Analyses furnished by Sloss Company.

These analyses indicate that the lime and magnesia in this rock are nearly in the proportions of the mineral dolomite and that it is properly called dolomite. W. B. Phillips [a] has made a number of silica determinations from the dolomite in the vicinity of Dolcito. At the south end of the Dolcito quarry, which had a face of 17 feet at the time of sampling, samples taken from every foot of the face showed a range of 0.48 to 0.88 per cent of silica, with an average of 0.64 per cent. At the northeast end of the same quarry, presumably from the same beds as at the southwest end, though not so stated, the silica, in samples taken in the same way, ranged from 0.48 to 4.58 per cent, with an average of 1.69 per cent. This shows a considerable variation within a short distance. Two miles northeast of Dolcito, on Fivemile Creek, 29 samples taken at intervals from top to bottom of 116 feet of dolomite gave silica ranging from 0.96 per cent to 7.28 per cent, with an average of 3.26 per cent.

[a] McCalley, Henry, Report on the valley regions of Alabama, pt. 2, Alabama Geol. Survey, 1897, pp. 323-326.

ADVANTAGES OF DOLOMITE FLUX.

Dolomite flux has at least three distinct advantages over limestone flux in this district. These advantages are succinctly stated in the following quotation from a letter to the writer by Mr. H. R. De Hall, the chief chemist of the Tennessee Coal, Iron, and Railroad Company:

There are several reasons why, in furnace practice here, dolomite should be preferred above limestone, which reasons I will try to state and explain as briefly as possible.

The fluxing power of dolomite is greater than that of limestone; an equivalent of carbonate of magnesia weighs 84, while an equivalent of carbonate of lime weighs 100; in fluxing power these equivalents are equal because the power of a base to combine with an acid does not depend upon its atomic weight, but upon its chemical affinity. So the fluxing power of the two carbonates are to each other as 84 to 100.

The dolomite of this district is a good deal purer than the limestone. The foreign matter of the former does not exceed 2 per cent, while of the latter an average is at least 4 per cent. To determine the values of a stone as a flux we must deduct the impurities it contains, plus as much of the base as is necessary to flux those impurities. Taking the limestone at 96 per cent lime carbonate, and deducting 8 per cent to take care of its own impurities, we have left 88 per cent of lime carbonate as available flux. Taking the dolomite to contain 2 per cent of impurities and 43 per cent carbonate of magnesia, with 55 per cent of carbonate of lime, we have left, after deducting 4 per cent from the carbonate of lime to take care of the impurities, 43 per cent magnesia carbonate and 51 per cent lime carbonate. The fluxing power of the two carbonates are to each other as 84 to 100, so reducing the magnesia carbonate to its equivalent in fluxing power of lime carbonate, we have

$$\frac{43 \times 100}{84} + 51 = 102.19.$$

Therefore the relative value of the two fluxing materials of this district are to each other as 88 is to 102.19.

It is claimed that magnesia has less affinity for sulphur than calcium, and that therefore dolomite is not as efficient a desulphurizer as limestone. Admitting this to be a fact, the objection is insignificant in comparison with the advantages its use affords in this district. Our ores are practically free from sulphur, and as our burdens for a large proportion consist of hard red ore, which is a physical combination of ferric oxide and lime carbonate, there is always enough lime in the mixture to take care of the sulphur in the coke.

Besides the above economical reasons, there is another one which the southern furnace practice has fully demonstrated. We have to carry an enormous amount of slag in our furnaces. Wherever the burden largely consists of red ore and limestone as flux the furnace tends to "hang" and make "slips," causing irregular working of the furnace, resulting in "running off" and bad iron. Magnesia makes the slag more fluid and when, in similar case as above, dolomite is used to such extent that the slag contains from 8 to 10 per cent magnesia, the furnace works smooth and regularly.

Aside from all questions of a theoretical nature the furnace practice of the district for the last ten years has amply demonstrated the excellence of dolomite flux, and its use is firmly established. Only a few furnaces run on limestone flux, and it is said that in some furnaces the reason for this is that the slag is used for cement manufacture, for which it would be unsuitable if it contained magnesia.

The quantity of good dolomite in the district to be had under present quarrying conditions is practically inexhaustible.

CONASAUGA (COOSA) LIMESTONE.

The Conasauga limestone underlies the Knox dolomite and generally makes most of the flat lands of the valleys from Birmingham southward. It may be seen outcropping at many points in the streets of Birmingham, in the vicinity of Bessemer, and along the valley between the two places, as, for example, along the Alabama Great Southern Railroad. Most of the limestone outcropping in Opossum Valley between North Birmingham and Thomas is the Conasauga.

The Conasauga limestone can be readily distinguished from the overlying dolomite by the following differences: The limestone is thin-bedded, blue or dark gray, without granular texture, and effervesces freely when treated with cold dilute acid; the dolomite is thick-bedded, generally light gray with distinct granular texture, and effervesces in cold dilute acid very feebly or not at all.

It is probable that the Conasauga in this region is not all limestone, but is composed of alternating layers of limestone and shale. No use has been made of this limestone so far as known to the writer.

Below is the average of two analyses by William E. Janes of the limestone from an old quarry near Wheeling, northeast of Bessemer. It was kindly furnished by Mr. A. Lodge, of the Woodward Iron Company:

Average analysis of Conasauga limestone from Wheeling quarry.

Silica (SiO_2)	1.20
Iron oxide and alumina ($Fe_2O_3+Al_2O_3$)	.49
Lime carbonate ($CaCO_3$)	89.03
Magnesium carbonate ($MgCO_3$)	8.04
Sulphur dioxide (SO_2)	.115

This rock is suitable for flux. It would, however, manifestly be unsafe to draw any conclusions as to the general composition of this limestone from these two analyses.

The outcrop of the formation is always on low ground, little above drainage, and the dips are high, so that conditions for quarrying there are very unfavorable. Since there is abundant material in the region of as good or even better quality, and better situated for quarrying, there is little likelihood that this limestone will be utilized to any great extent.

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